Impacts of circular economy policies on the labour market

Final report and Annexes

Cambridge Econometrics, Trinomics, and ICF
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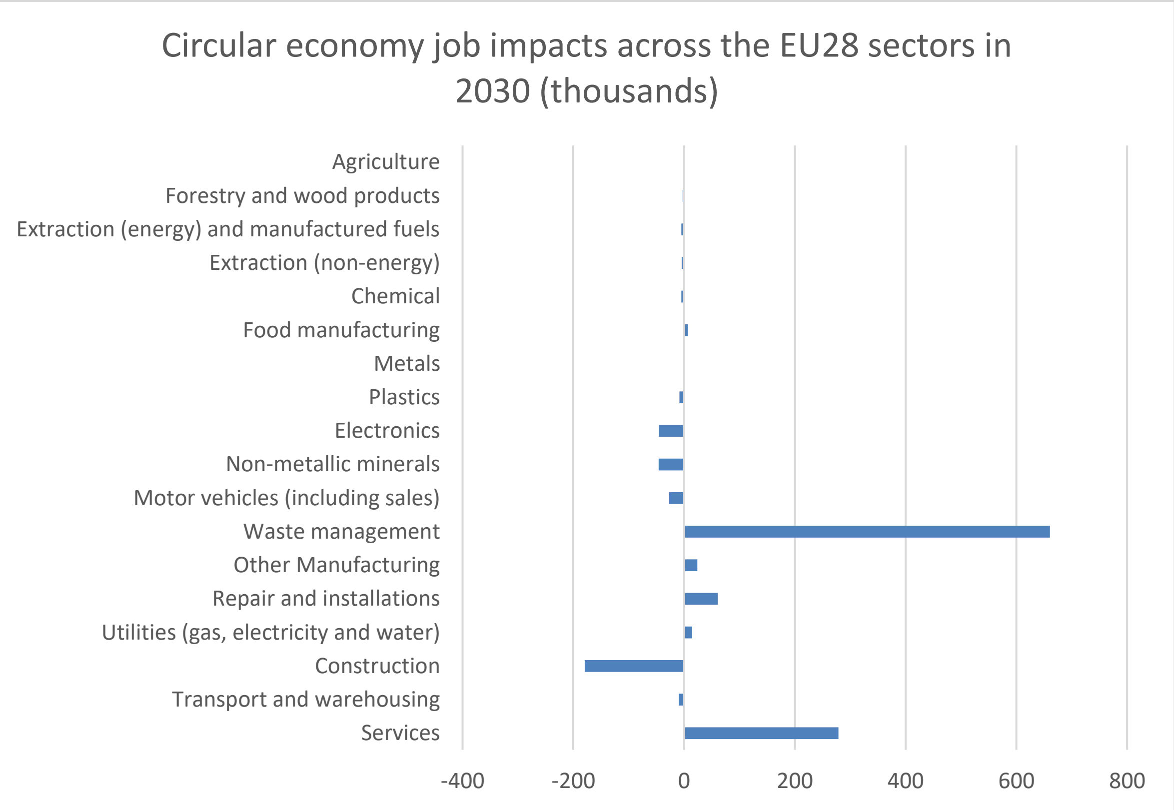
Table of Contents

How does a transition to a more circular economy affect jobs and skills demand in Europe?

This report provides detailed answers to this question. The study looked at trends of circular economy activities across different sectors and quantified these activities as modelling inputs to provide employment changes for different sectors. Furthermore, the analysis provide estimates of the occupational shifts and skills requirements that a shift to a more circular economy could entail.

The aim of this report is to develop an understanding of how a transition towards a more circular and resource efficient economy in Europe will affect labour markets across the Member States. Our analysis is the most comprehensive quantification of the EU jobs impacts from the circular economy to date. By using a fully integrated energy-environment-economy model (E3ME), our analysis considers both direct job losses and job creations that result from a shift to a more circular economy. It also captures indirect, induced and rebound impacts from interactions between sectors, Member States, and between economic, environment, material, energy and labour market indicators.

Our findings suggest that the EU is on the right track by making the circular economy a policy priority as circular economy policies will contribute to reducing negative environmental impacts, while simultaneously contributing to higher employment levels. By moving towards a more circular economy, GDP in the EU increases by almost 0.5% by 2030 compared to the baseline case. The net increase in jobs is approximately 700,000 compared to the baseline through additional labour demand from recycling plants, repair services and rebounds in consumer demand from savings generated through collaborative actions Although the magnitude of job creation is driven by our assumption of the rate of circular economy uptake in the scenarios, our analysis confirms that it is



possible to become more resource efficient and increase employment at the same time.

Source(s): E3ME, Cambridge Econometrics.

While the net impacts on EU employment are positive, the sectoral composition of employment will change. Sectors that produce and process raw materials will decline in size while the recycling and repair sectors will experience additional growth. We have also identified other sectors that will potentially benefit from transition toward a circular economy, including services sectors and electricity. Sectors that could lose out include those that produce durable goods such as electronics, machinery, cars and accommodation. Construction sector employment is expected to fall from productivity gains as a result of new building techniques. Our scope excludes energy efficiency improvement to existing properties which could well compensate this loss.

Among Member States, the GDP and employment results are positive but are generally higher in the Central and Eastern European countries, primarily due to larger reductions in oil imports in these countries as a result of more circular economy activities in the motor vehicles sector. Countries in western Europe are more affected by a decline in production of electronics and cars. In Eastern Europe, these durable goods are mostly imported and so the reduction in demand improves the trade balance and GDP.

In terms of skills needs across the various sectors and occupations, the additional impacts of circular economy take-up are relatively small-scale in comparison with other drivers of change, such as the impact of technological change on jobs and the shift to high-skilled jobs in some sectors. This finding suggests that take-up of circular economy activities does not in itself have a transformative effect on labour markets with regards to skills needs, even under the ambitious scenario; the jobs and skills implications of the circular economy should be seen in this inter-connected context. The general trend is towards increased demand for cross-cutting competences, such as problem solving and communications. Transition to the circular economy therefore provides evidence of the importance of transversal skills, not least because jobs will evolve and workers will need to be adaptable.

There are several ways in which policy tools could address the circular economy transition while promoting jobs and adequate skills – through circular economy policies as well as through education and training policies. Policies should also address employment impacts in affected sectors and areas to support the job transitions.

It should also be mentioned that there are large uncertainties surrounding the future labour intensities in the waste sector due to increased automation, product material enhancement (to ease recycling) and technology. Our employment results for the waste sector could be overestimates if there was a sustained drive to increase mechanisation in the sector. Policies should therefore promote new skills to support the implementation of new technologies in the sector.

Finally, our study highlighted the importance of rebound effects. Rebounds in consumer spending occur as a result of efficiency gains and cost savings from circular economy activities. They can only be captured in a full modelling framework, as was used in this analysis. Although rebound effects are good for the economy, they also mean that there is an increase in material consumption associated with additional consumer spending. Additional policies may therefore be needed if Europe is to meet ambitious targets to reduce overall material use.

1. Study Introduction

1.1. Circular economy activities and impacts on the labour market

The linear economy relies on a "take-make-waste" model of production. Under this model, raw materials for production are used to produce goods and these goods move along the consumption chain from consumers to landfill sites. In contrast, a circular economy emphasises the utilisation of recycled inputs and ensures that the inputs to production can be recycled and reused while preserving or enhancing their economic value (Aldersgate Group, 2012).

In a more circular economy there is lower employment demand in extractive industries (given a decreased demand for raw materials) and it is expected that, as economies become more circular, employment in reuse and recycling industries increases.

According to existing studies, new jobs in the circular economy do not just substitute for declining employment in extractive industries (such as in fossil fuels, or mining and quarrying)[1]. According to the Ellen MacArthur Foundation, employment opportunities in the circular economy extend to small and medium-sized enterprises via the development of reverse logistics, increased innovation and entrepreneurship and increased development of the service-based economy (Ellen MacArthur Foundation, SUN and McKinsey, 2015). Another 2015 report by the Green Alliance suggests that employment in the circular economy can generate jobs for a range of skill types and has the potential to boost employment in areas with among the highest unemployment rates (WRAP and Green Alliance, 2015).

Jobs gains due to a transition to a circular economy have the potential to be significant. A study by the European Remanufacturing Network suggests that in Europe remanufacturing alone has the potential to deliver 34,000 to 65,000 new jobs (Circulate News, 2016). WRAP suggests that a transition to a circular economy could create up to 1.2 to 3 million jobs across Europe (WRAP, 2015).

According to a 2015 analysis; "Growth Within: A Circular Economy Vision for a Competitive Europe", positive employment effects due to a transition to a more circular economy are estimated to be largely driven by the impacts of increased consumer spending. If industries can source a larger share of their inputs from less expensive recycled materials, then prices for consumers would be anticipated to be lower.

Although it is generally agreed that a transition to a circular economy would have positive economic effects, not all sectors would benefit evenly from such a transition. Some industries would likely be negatively impacted (e.g. extractive industries, or the traditional carbon-based power sector). Benefits from a transition to a more circular economy are not expected to be evenly distributed and would likely involve considerable transition costs. However, if well managed, such a transition has the potential to generate considerable economic growth.

1.2. Study objectives

The aim of this report is to develop an understanding of how a transition towards a more circular and resource efficient economy in Europe will affect labour markets across the Member States. More specifically:

- How do changes deriving from EU circular economy policies impact on the economy; how this is reflected in different economic sectors; what effects does this have on the labour force, including changes in sectoral (i.e. reallocation of labour across sectors) and occupational composition?
- Who are winners and losers in the labour market and, in so far as possible, what is the size of the net employment impacts, where possible split by skill group and age?
- What are direct labour markets within circular economy activities; what are the indirect labour market impacts related to the supply of intermediate goods and services from other

[1] Green Alliance (2015), suggests that as the UK is becoming more efficient at utilising resources and transitioning to a circular economy, employment is estimated to grow larger than the estimated decline in extractive industries like oil and gas. WRAP (2015) explored several scenarios for a transition to a circular economy and found potential job creation of between 250,000 and 520,000 jobs and an overall decrease in the unemployment rate. In summary, although employment decreased in some sectors, employment is estimated to increase overall.

sectors; what are the induced labour impacts related to changes in household expenditure patterns?

- Are there differences between the short-term and medium-term perspectives?
- What are the underlying drivers of employment, including ecologically-driven structural change (e.g. of resource productivity increases); technological change and innovation; public green investment, etc.?
- Under what conditions can the circular economy boost employment in the EU?
- How can EU policy support this process, including in skills development, and could how can the EU mitigate possible negative impacts

1.3. Objective outcomes

In order to answer the above questions, it is necessary to both identify key features and sectors within the circular economy and also to understand the wider economic impacts of moving to a circular economy.

By using a large scale macro-econometric model, E3ME (see Annex A), our analysis covers impacts across the whole economy (i.e. both direct, indirect and induced), including for example supply chain effects or developments in wages across different economic sectors and labour crowding out effects. The modelling results are supplemented with additional analysis on occupational levels, while also considering as much as possible impacts on different skills groups.

Finally, this study was carried out in the context of relevant policy – both in the circular economy sphere, resource efficiency and more general labour market policy (e.g. life-long learning, etc.). Where possible, the impacts are linked to potential European policy, covering both the medium-term outcomes but also the transition path to get there (which may show potential social disruption).

Table 1.1 provides a summary of how we answer the project research questions. Specific tasks and their outputs are discussed in the following chapters.

Table 1.1 Answering the key research questions

Research questions	Answers
How do changes deriving from EU circular economy policies impact on the economy? How is this reflected across economic sectors? What effects does a circular economy transition have on the labour force, including changes in sectoral and occupational composition?	5 Impacts on the EU Economy and Jobs 6 Changes in Occupations and Skills Needs
Who are winners and losers in the labour market and, in so far as possible, what is the size of the net employment impacts, split where possible by skill group and age?	5 Impacts on the EU Economy and Jobs 6 Changes in Occupations and Skills Needs 2 Summary of Recent Literature
What are direct, indirect and induced labour market impacts?	5 Impacts on the EU Economy and Jobs
Are there differences between the short-term and medium-term perspectives?	5 Impacts on the EU Economy and Jobs Annex B Literature Review
What are the underlying drivers of employment, including ecologically-driven structural change (for instance of resource productivity increases); technological change and innovation; public green investment, etc.?	2 Summary of Recent Literature 7 Policy Implications
Under what conditions can the circular economy boost employment in the EU?	5 Impacts on the EU Economy and Jobs 7 Policy Implications

How can EU policy support this process, including in skills development, and could how the EU mitigate possible negative impacts?	5 Impacts on the EU Economy and Jobs 7 Policy Implications

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1.4. Other study deliverables

A separate document contains three annexes is provided with this report: a non-technical description of the model used in this study, E3ME (Annex A), a detailed literature review (Annex B) and a set of sectoral profiles (Annex C). A summary of the literature review is provided in Chapter 2 and Chapter 4 includes a description of the degree of circular economy activity at sectoral level.

2. SUMMARY OF RECENT LITERATURE

We have used the relevant issues from the project's research questions to help structure our summary of the literature. The full literature review is provided in Annex B.

Who are winners and losers in the labour market and what are the size of the net employment impacts, split by skill group and age?

The following sub questions and findings relate to these research questions:

What is the circular economy?

Various definitions and interpretations of the Circular Economy exist, but the definition from the Ellen MacArthur Foundation (2014) is the most commonly cited and is used as the circular economy definition in this study. In essence, the circular economy aims to keep products, components and materials in the economy for as long as possible and thus tries to reduce or eliminate waste. The two main strategies to increase the circularity of the economy are: (1) Regeneration of biotic materials[2] and (2) maintaining the value of abiotic materials[3] for as long as possible through various feedback loops and recovery schemes.

Which sectors are most likely to be affected by the circular economy?

Circular economy activities are often cross-sectoral and also involve new kinds of activities that are not yet captured by traditional classifications of economic sectors. Though some specific sectors can create circular business models largely within their own activities (e.g. the food industry or the construction sector), other (horizontal) circular economy business actions such as design for re-use and recyclability, repair, reuse or waste management, can involve a variety of economic sectors. Such cross-sectoral activity complicates the analysis of circular economy labour impacts.

The literature points to evidence that the sectors that offer virgin materials and those providing durable goods will suffer from lower demand for their products if the degree of circularity in the economy increases. On the contrary, sectors engaging in recycling, maintenance and repair activities will grow rapidly and create new jobs. Companies that offer know-how and technology to enable material-efficiency will also benefit from the transition to a circular economy.

What impacts on employment might the circular economy have?

When analysing the labour market impacts of the circular economy it is important to look at the net job creation or loss and not at the gross impact. The transition to a more circular economy may imply job losses in some sectors and increased employment in others. Therefore, an accurate picture of employment implications can only be obtained when sector-specific impacts are not studied in isolation but put into the context of the changes occurring in the wider economy.

How are the employment impacts of a more circular economy distributed across skill levels?

Several studies have found that increasing the circularity of the economy would have a positive net employment impact and could create jobs across all skill levels. However, most of the studies that we identified and reviewed focused primarily on increasing resource efficiency and increasing recycling rates. The level of ambition envisaged for the circular economy strongly influences the type and extent of labour market impacts that will occur. There is a lack of literature that considers the employment effects of the inner loops of the circular economy (i.e. reuse, remanufacturing, etc.).

Circular economy activities will require both high and low-skilled jobs. For example, there should be more design and technology related jobs, which requires highly-skilled workers, while the increased recovery and reuse of waste would create the need for new lower-skilled jobs. Overall, the

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[2] Biotic material refers to any natural material that originates from living organisms, such as wood.
[3] Abiotic material refers to non-biological or non-renewable materials.

transition to a circular economy will entail new and more specialised skills, and reskilling strategies will be needed to enable workers to move from high to low-carbon sectors.

What are the underlying drivers of employment, including ecologically-driven structural change (e.g. resource productivity increases); technological change and innovation; public green investment, etc.?

The following sub questions and findings relate to these research questions:

What can be expected regarding substitution between capital, use of materials and labour?

The transition to a circular economy might change production processes by substitution of some capital inputs with labour inputs. The expected impact on the overall capital-labour ratio in the economy is likely to be driven by two main effects:

- Circulating materials for as long as possible will result in a shift in focus from the primary economic sectors (agriculture, mining & quarrying, etc.) to the secondary and tertiary sectors.
- Within sectors, the share of labour-intensive activities like repairing or refurbishing might increase compared to the manufacture of new products. Even though this could lead to a higher labour-to-capital ratio, it does not automatically increase net employment.

This shows that the impact of the circular economy on the overall capital-labour ratio is very complex. The nature of the employment effects also depends on the indirect and induced effects of the circular economy, which can be net negative for manufacturing sectors (despite servitisation and an increase in refurbishing and repairing activities), but strongly positive overall due to the rebound effect of increased consumption. In addition, the circular economy relies to a large extent on further digitalisation and automation of the economy, and technological development which further affects the labour-to-capital ratio.

How can EU policy support this process, including new skills development, and how could the EU mitigate possible negative impacts?

At the EU and Member State levels, there are a number of policies that are targeted at the transition towards the circular economy, including training programmes that are of relevance to the circular economy. However, at both levels, there are no real skills-related policies specifically designed to foster the transition to a more circular economy.

3. Labour Market Impacts of Circular Economy Activities – Methodology

3.1. Overview of our approach

This part of the report describes the approach that we used to estimate the scale of impacts from circular economy activities. Our analytical approach is primarily model based and draws on the macroeconomic framework offered by the E3ME model. However, prior to any modelling being carried out, it was necessary to carry out an in-depth analysis of the key sectors that this study assesses.

The modelling information for each of the sectors chosen is taken directly from our own analysis of sector profiles (see Chapter 4). The E3ME model results provide estimates of the economic and labour market impacts by Member State and sectors, based on the level of circular economy activities we assumed in the scenarios. These results are further disaggregated to provide occupation and skills impacts (see Chapter 6) which allow us to draw policy recommendations (Chapter 7).

3.1.1. *The E3ME model*

The E3ME model includes 43 consumer spending categories, 70 economic sectors, 23 fuel users of 12 fuels and 15 users of 7 raw materials. E3ME also covers each Member State individually (and 31 other world regions). The model captures indirect and rebound effects through its linkages between sectors, labour, energy and materials.

The E3ME model contains a relatively detailed treatment of labour market and is used to feed into the EU's annual skills projections (CEDEFOP, 2018). Its close linkages between physical and economic activities make it suitable for providing labour market impacts of circular economy activities. A full model description is provided in Appendix A.

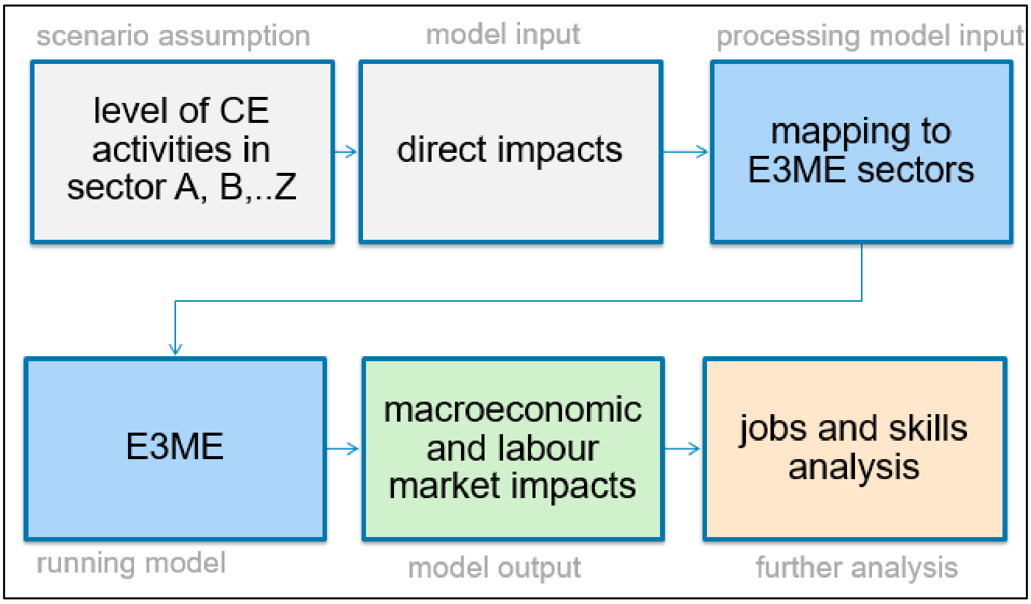
3.1.2. *'Activities' approach*

The scenarios are modelled using an 'activities' approach rather than a 'policies' approach. The scenarios are defined by scaling up or down the level of circular economy activity in each of the five focus sectors. Each sector has different circular economy activities, which are described in detail in the sector profiles in Annex C. No explicit assumptions have been made about whether these changes are driven by policies, behavioural change or new technology. A narrative of these three potential drivers of change and why we have chosen the activities approach has been provided as part of the sector profiles (see Chapter 4).

Flows of work

The diagram below demonstrates the flows of work undertaken. The first task was to identify the circular economy activities within sectors and to estimate direct impacts. After this, the next task was to translate the direct impacts to E3ME modelling inputs by mapping the sectors to E3ME's classifications. E3ME then provided the indirect and wider macroeconomic and labour market impacts of different rates of circular economy activities in the EU. Finally, the modelling results were used to provide further analysis of impacts across occupational groups and skills levels.

Figure 3.1 Flows of work under the circular economy activities approach



3.1.3. *Five key focus sectors*

We have chosen five key focus sectors, which are broad enough to represent the most important circular economy sectors and activities in the EU. These sectors are:

- Food
- Construction
- Motor vehicles
- Waste management
- Electronics and electrical equipment

Chapter 4 provides further details on how the sectors are selected.

3.1.4. *Circular economy activity scenarios*

Two different scenarios were constructed based on different levels of circular economy activities in the focus sectors (moderate and ambitious). These are the scenarios that were modelled to assess labour market impacts.

Table 3.1 provides an overview of the scenarios.

Table 3.1 Overview of the circular economy scenarios

	Food	Construction	Waste Management	Electronics	Motor Vehicles	All
Baseline	**Business as usual** (continuation of historical trends; legislation adopted by Member States until December 2014 included in forecasts)					
Moderate	**Moderate uptake of the circular economy** (measures in Circular Economy package & moderate sectoral transformation)					
Ambitious	**Ambitious uptake of the circular economy** (moderate + extensive sectoral transformation)					

3.1.5. *Circular economy activities in the baseline*

So as to allow comparison with other model-based studies, a baseline was constructed based on official published economic and energy-sector projections. The standard E3ME baseline was used, which is consistent with the Reference Scenario published by the European Commission (DG ENER, 2016).

The modelling baseline does not explicitly assume a certain level of circular economy activities. The baseline consists of the latest historical data (up to 2016) and projections that include policies that were adopted by December 2014 (plus amendments to three directives in the beginning of 2015). We have not assumed a certain rate of 'greening' activities in the baseline in addition.

According to the documentation that accompanies the projections:

"… the Reference Scenario does not assume implemented the most recent initiatives promoting a circular economy, which would otherwise be expected to have noticeable effects on overall efficiency."

and

"The Reference Scenario includes policies and measures adopted at EU level and in the Member States by December 2014. In addition, amendments to three Directives only agreed in the beginning of 2015 were also considered."

"… the European Commission's Circular Economy Package, adopted on December 2, 2015, and therefore after the cut-off date for the policies to be reflected in the Reference Scenario."

The scenarios that we assess look at additional circular economy activities (moderate and ambitious) on top the level embedded in the baseline.

In order to ensure consistency, the sector profiles (see Chapter 4) assume that there is the same level of circular economy activity as in the baseline (continuation of historical trends; legislation adopted by Member State until December 2014), to which the moderate and ambitious scenarios were compared qualitatively. The modelling inputs were formed as differences from the baseline.

3.2. Estimating the impacts of a more circular economy on jobs

The process of estimating the jobs impacts of different levels of circular economy activities was carried out using the E3ME model. The model determines first the impacts on economic production levels and prices. The demand for labour (which is derived from product demand) follows. The E3ME model is able to capture further indirect, induced and rebound impacts from the initial changes in circular economy activities.

Table 3.2 summarises circular economy activities as types of modelling inputs and how changes are modelled in E3ME.

Table 3.2 E3ME modelling inputs

Type of modelling inputs	Modelling method in E3ME
Increase in alternative materials and energy sources, e.g. recycled materials and biofuels	Changing input-output structure of the relevant sectors
Reduction in the consumption of virgin materials, e.g. metals, plastic and petrol	Changing input-output structure of the relevant sectors
Increase in repairing activities	Changing input-output structure of the relevant sectors (assuming that repairs occur within the same sector)
Collaborative economy	Reduction in demand for traditional business products (less buying), increase in demand within the household sectors (sharing), small increases in demand for collaborative economy platforms
Investment in recycling facilities	Exogenous additional investment by the recycling sector

Changes in the labour intensity of recycling activities compared to traditional waste management	Exogenous increase in employment in the waste management & recycling sector (same sector)
Cost reductions from the more efficient use of resources or production methods (e.g. modular design)	Exogenous reduction to industry costs

3.2.1. *IO coefficients*

The majority of circular economy activities identified in the five focus sectors (see Chapter 4) require adjustment to the existing input-output structure of the model. This reflects the changes to the supply chain of a sector as a result of higher circular economic activities. For example, if the construction sector uses less timber and instead uses recycled wood, this change is entered to E3ME as an adjustment to the input-output coefficients of the construction sector's purchases less from wood manufacturing (lower) and from the recycling sector (higher).

3.2.2. *Investment*

For the waste management sector, we have introduced additional investment to reflect demand for new recycling plants as a result of higher circular economic activities. The additional investment is entered to E3ME exogenously and is assumed to be fully funded through higher recycling sector costs. The model estimates the indirect effects from the investment as well as its induced impacts (from higher employment).

3.2.3. *Collaborative activities*

A big part of the circular economy comes from higher rates of collaborative activities. The fundamental difference between the collaborative economy and the traditional economy is the way that consumers purchase goods and services. In a traditional economy, consumers pay businesses to produce goods and services. This consumer spending generates demand for industry output, resulting in additional demand through a sector's supply chain. This process also generates employment demand.

In a collaborative economy, consumers no longer make these purchases from traditional businesses. Instead, they pay other households to 'borrow' the goods or services that they provide. In the modelling, we do not distinguish between households that are 'buyers' and households that provide the goods and services. Instead the money that would otherwise get spent and transferred to traditional businesses stays within the household sector.

It is assumed that the additional money received by the households that provide goods and services is spent. It is not an unrealistic assumption to assume that households (e.g. an Airbnb host) will spend this money in the same way as his or her income from traditional employment. This assumption generates additional income that gets spent elsewhere in the economy. The additional spending causes a 'rebound effect' from higher consumer demand.

3.2.4. *Productivity and labour intensity*

In some sectors, we have assumed that productivity and labour intensity will change as a result of higher circular economy activities. For example, waste landfill and recycling have different labour intensities. Waste management is a highly mechanized process that requires a small level of labour input. Recycling, on the other hand, can be much more labour-intensive (collecting, sorting, processing, reselling, etc). We therefore introduced a change to the sector's labour intensity to reflect more recycling activities and less waste landfill management.

3.2.5. *Costs*

Reductions in costs arising from modular design in the construction sector are entered exogenously to the E3ME model to provide further impacts. This reduction in cost reflects efficiency gains that are not related to higher labour productivity from modular design.

3.2.6. *Main linkages in E3ME*

Figure 3.2 summarises the main linkages in E3ME, and shows the importance of the economic input-output system (purchases between different economic sectors) in determining overall impacts[4]. Despite being a highly stylised representation of the complex linkages within the model, it is still possible to determine two loops within the diagram.

Multiplier effect

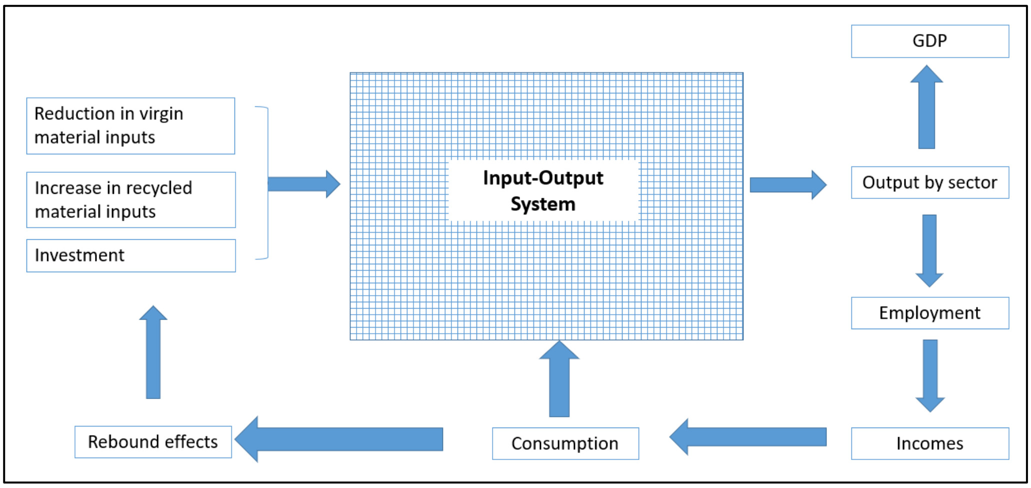
The first of these loops is a standard multiplier effect; if the circular economy measures create additional output and employment then the extra income that goes with that employment may be used to purchase other goods and services. While this can boost economic outcomes further (loop in the bottom right of the diagram) it may also lead to rebound effects in physical consumption (loop round the bottom of the diagram).

Rebound effects

These rebound effects mean that some of the initial reductions in resource consumption are eroded due to additional spending elsewhere in the economy.

Although very little research has been carried out into the potential scale of possible rebound effects in non-energy resource consumption[5], it is likely that the scale of impacts is smaller than that for energy, at least when talking about the circular economy. The reason is that the benefits of circular economy policies are likely to be economic sectors (e.g. recycling) rather than final consumers, although this could vary according to the particular sectors targeted.

Figure 3.2 Modelling circular economy measures via IO adjustment in E3ME



3.3. Linking jobs to occupations and skills

The task of extending E3ME results to provide impacts by occupation and skill group is very important for identifying skills gaps that could occur if ambitious policies to move to a circular economy are implemented.

3.3.1. *Methodology*

The E3ME modelling provides estimates of circular economy impacts on total employment levels within each economic sector. The next task is to explore the implications for the shape of jobs and the skills required. By understanding occupational shifts in employment it is possible to assess how the skills required within the economy may evolve, both within sectors and between sectors. This

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[4] Although policies relating to final consumption (e.g. by households) can also be considered with a similar approach.
[5] Cambridge Econometrics is currently carrying out some internal research on the topic but this is still at a relatively early stage.

analysis is largely qualitative in nature, although it draws on the model data and classifications where relevant.

Using the E3ME output as the starting point, the following two steps have been undertaken:

Step 1 - Occupation

Further disaggregating the employment shifts shown by the model (as necessary) to map potential shifts at a more detailed occupational level:

- The occupational composition of employment at 2-digit level within the priority sectors has been mapped as part of the scoping that underpinned the sector profiles (based on CEDEFOP's 41-industry classification).
- It is possible to apply judgements based on the literature review material and on other sources of labour market data (e.g. some national data; sector studies) to identify which of the most detailed occupational groupings are likely to be impacted by the modelling outputs.
- Key occupations are those within the priority sectors shown either by the modelling or the literature review / sector profile evidence to be substantially impacted by the circular economy.

Step 2 –Skills

Profiling these 'key' occupations in terms of required skills based on the ESCO database at a detailed occupational level (up to four-digit level):

- By mapping the required skills, knowledge and competence associated with detailed occupations in the ESCO classification and combining this with the qualitative evidence about the impact of a more circular economy on jobs (from the literature review), priority skills associated with the shift to the circular economy have been identified.
- By analysing how similar profiles of skills (as captured by occupational groupings) are distributed across the economy, it is possible to form judgements about the potential for cross-sector redeployment; either supporting growth or to mitigate anticipated reductions in workforce size. This analysis can also be supported by looking at occupational distribution across sectors (how the occupational group maps across sectors, i.e. where the jobs are found across sectors and what therefore is the potential for a transition of skills).

4. Circular Economy Activities in Different Sectors

4.1. Introduction

4.1.1. *The activities approach*

For this study, we have chosen to take an approach based on 'activities' rather than one based on a 'policy' approach. The choice of approach means that the study is not assessing potential impacts of specific policies but is instead looking directly at the links between circular economy activities and the labour market. The scenarios show an increase in the size of the circular economy, without linking the change to particular policies. This approach has also been suggested by the Ellen MacArthur Foundation as the preferable method in 'A Toolkit for Policymakers' (2015). The reason behind it is that the practical implications of a more circular economy will vary between sectors, as sectors differ in the way in which resource flows and relationships with the consumer are organised. Furthermore, for some sectors the major negative resource impacts are related to the production phase, whereas for other products the impacts during the use phase are most significant.

The activities approach implies generating modelling inputs that are bottom-up from a sectoral perspective. The inputs are formed by studying the plausible circular economy activities that will take place in the selected key sectors and their supply chains. This information is derived from the in-depth sector profiles.

4.1.2. *Five key focus sectors*

We have chosen five key focus sectors, which are broad enough to represent the most important circular economy sectors and activities in the EU and their potential impacts on employment and the labour market. Contrary to existing studies, we do not only study the effects of the circular economy on these sectors in isolation, but also account for the indirect impacts on related sectors through their supply chains. The analysis therefore covers goods both before and after production (material sourcing, using the product and its end-of-life phase), meaning that the degree of circularity can be assessed over a product's lifetime.

In order to ensure that the largest part of the impacts of the circular economy are covered by this study, we developed a systematic approach to select the five sectors, further explained in the sections below.

4.2. Sector selection

4.2.1. *Selection criteria*

In order to cover the bulk of the impacts that will be brought about by the circular economy in Europe, sectors have to meet a number of conditions. Ideally, this means that together, the selected sectors:

- Jointly capture a large share of the total potential that the circular economy could deliver to the EU economy by 2030 (the timeframe of this study);
- Represent the sectors and supply chains in the EU economy that are likely to be most significantly transformed by the circular economy towards 2030;
- Represent a variety of potential changes that the circular economy could bring about to the EU economy (in terms of which circular loops and business models are likely to be applied), including both the technological and biological cycles of the circular economy;
- Represent an adequate mix of the different types of labour classes and categories that could be affected by the circular economy in the EU.

In order to arrive at a representative and balanced set of focus sectors that meet the above conditions, we have developed three selection criteria against which all NACE 2-digit sectors of the EU's economy are scored. The five focus sectors that scored highest on these three criteria were selected for the in-depth assessment. The selection criteria were the following:

Table 4.1 Sector selection criteria

Criterion	Description
Circular economy sector potential	The potential that circular economy activities have in the sector (thus representing the extent to which the sector might be transformed by the circular economy from a business perspective)
Circular economy policy importance	Whether the sector is a priority in terms of circular economy policy action and/or whether the sector was identified by previous literature on this topic as a priority sector in terms of its potential for the circular economy
Economic significance	Importance of the sector to the EU economy in terms of value added generation and employment

Selection criterion 1: Potential for the circular economy in the sector

Due to differences in their current linearity and circularity, the extent to which the circular economy will transform a sector varies across different economic activities. In order to select the sectors that will be most significantly affected by the circular economy, we scored the sectors on their circular economy potential, as defined by the Ellen MacArthur Foundation in Growth Within: a circular economy vision for a competitive Europe (2015). This report develops six RESOLVE circular economy levers (different strategies for increasing implementation of circular principles, see box IV-1) and indicates what is the potential for bringing about change in each sector. We assigned a "1" for low potential, "2" for medium potential and "3" for high potential and derived the average score for each sector. In our selection of focus sectors, we have taken into account that the selected focus sectors jointly cover many of the different RESOLVE levers.

Box 4-1 RESOLVE: Activities that can make a product's lifecycle more circular

REgenerate – Use of renewable energy and materials (biological materials)
Share – Reduce the need for new goods through sharing/renting and the use of second-hand products
Optimise – Reduce resource use, improve durability, reduce wasting of materials during production and optimise operation, e.g. through automation
Loop – Remanufacturing, recycling and recovery of useful materials and components
Virtualise – Replace physical products with virtual services
Exchange – Replace materials and processes by others with less impact on resource use and the environment

Source: Ellen MacArthur Foundation (2015) Growth within: a circular economy vision for a competitive Europe

Selection criterion 2: Policy priority area and other literature

The second selection criterion covers the extent to which a sector is covered by policy action or expected to be covered by future circular economy policy actions, as those sectors are more likely to undergo a circular transition (holding everything else equal). We take the priority actions indicated in the EC Circular Economy Action Plan and its Annex(European Commission, 2015), as indicative for future EU policy action per sector. In addition, previous literature on the topic that reviewed the potential of the circular economy for European sectors – particularly in relation to jobs – has also indicated a number of sectors that are most likely to be impacted by a circular economy in the future(IEEP, 2014). We have also considered those findings and scored sectors on the extent to which they were identified by previous literature or current policy as priority sectors or likely impacted sectors.

Selection criterion 3: Importance of the sector in the economy

In order to select sectors that are likely to experience significant changes in their economic structure and employment effects due to the transition to a circular economy, it is important to select sectors that are currently producing significant value added and employ a significant share of the EU workforce. Merely due to their size, the changes to the sector due to the transition to the circular economy will affect many workers and/or have a significant impact on economic output.

We use data from Eurostat's Structural Business Statistics and National Accounts for the year 2013 on number of people employed in the sector and value added at factor cost at the NACE 2-digit sector aggregation level to score each sector for its role in the EU economy.

As the ultimate aim of the in-depth sector analysis is to develop modelling inputs for the E3ME model, we use the NACE sector classification to define the scope of our sectors as it is consistent with E3ME. For each NACE 2-digit sector, we gathered the data and information for the three selection criteria as described in the previous section.

4.2.2. *Results from applying the selection criteria*

Selection criterion 1: Potential of the circular economy in the sector

The results from scoring all economic sectors on criterion 1 indicate:

- The highest potential for circular actions can be found in the manufacturing sectors (NACE Section C), the construction sector (Section F) and the wholesale and retail sector (Section G).
- The electricity sector (Section D) also shows a high potential for transition on the basis of circular economy principles. This is likely to stem largely from its role in providing renewable energy to circular production processes, however, and therefore plays largely an enabling function to circular initiatives in other sectors.
- Most of the services sectors (Sections J-N, P, Q and R) score low on circular economy transformation potential.

Selection criterion 2: Expected circular policy action and existing literature findings

The findings from applying selection criterion 2 indicate that:

- Agriculture, forestry and fishing, food and beverages, rubber and plastics products and construction activities are mentioned as important sectors in the Circular Economy Action plan, but also in the wider literature.
- The Circular Economy Action Plan also indicates that critical raw materials and bio-based materials are likely to be subject to circular policy action in the future, but these material flows are do not correspond to a single NACE sector.
- The WRAP (2015) study states that the waste treatment & recycling sector will be strongly affected by circular economy policies.

Selection criterion 3: Importance of the sector in total EU value added creation and employment

The summary results for selection criterion 3 indicate:

- High employment in the services sectors: NACE sections M-U jointly account for ~37% of employment in the EU. Employment in the primary sector (A) equalled 4% of the total labour force in the EU in 2013. The manufacturing sector, due to its material intensity an important circular economy sector, accounted for 12% of EU employment in 2013. Around 22% of the EU workforce works in the wholesale and retail trade sectors (G-I).
- Significant value added is created in the services sectors (29% of total EU value added in 2013 in sectors M-U). A large share of value added is generated by the real estate sector (including imputed rents; 10% of the total) for which value added measurement errors are common. Contrary to the relatively large share of employment in the agricultural sectors (4%), relatively little value added is created in agricultural activities (1%).

4.2.3. *Final selection of focus sectors*

Based on the results presented, five focus sectors were selected for the modelling exercise:

1. Food products & beverages (NACE A, C10 & 11)
2. Motor vehicles (NACE 29)
3. Construction (NACE F 41&43)

4. Electronics and Electrical equipment (NACE 26 & 27)
5. Waste collection and treatment (NACE 38 & 39)

Even though waste collection and treatment is considered in all sector profiles due to the life-cycle approach to the sector assessments (including the end-of-life stage of products), the waste treatment sector is also chosen as a separate economic sector to be assessed in isolation, due to its important role in closing material loops for all other sectors of the economy. As a result, the assessments of sectors 1-4 mainly focus on the potential of circular actions that prevent the generation of waste, thereby affecting the *volume of waste* going to the waste treatment sector. Sector profile 5 assesses, *how this waste can be treated* in such a way that the circular economy is promoted.

The results from the in-depth sector assessments are included in full in Annex C. The remaining sections of this chapter summarise the outcomes of these analyses based on the following structure:

1. Presenting a short introduction of the sector;
2. Summarising the potential of the circular economy in the sector;
3. Outlining the details of the most important circular activities and transforming these to inputs for the E3ME model.

4.3. Food sector

4.3.1. *Overview of the sector*

The food production chain is composed of several economic sectors, which together form the extended 'food sector'. At the beginning of the chain are agriculture and fisheries, providing the unprocessed foodstuffs, which are subsequently processed into final products by the food and drinks industry. Finally, those food products are sold via wholesale and retail companies or restaurants and other food services to the final consumer. Within this study, the agriculture & fisheries (NACE A) and the food & drinks industry (NACE C10 & 11) are seen as the core of the food sector. Agriculture and fisheries represents a mere 1.6% of the EU's gross value added (GVA), but the sector provides employment to around 5% of the EU's workforce. The food & drinks industry's employment accounts for approximately 1.8% of the total employment in the EU and creates 1.8% of the EU's GVA. Wholesale and retail is a substantial employer in the EU, as around 4% of the European workforce is employed by these sectors, and they account for 2.2% of the EU's GVA. Lastly, food & drinks services (e.g. catering services, restaurants & bars) provide employment to 1.1% of the EU's workforce and generate 1.2% of the EU's GVA.

4.3.2. *Potential of the circular economy in the food sector*

Food production and consumption from a biological and nutrient perspective are inherently circular as the nutrients and carbon consumed by animals and humans would normally be cycled back into the food chain as plants. However, intensive agriculture has disrupted the natural balance between nutrient extraction and deposition. As a result, the food value chain is currently very linear as waste is created at several points. For example, agriculture uses almost 17 million tonnes of nutrients (from fertilizers) on an annual basis, of which only one fifth is recycled to the soil after food production and consumption. This enormous amount of nutrient losses leads to depletion of finite resources such as phosphorus, but also to negative environmental impacts such as eutrophication and N_2O and NOx emissions.

Another inefficient aspect of the current food production system is that around 70% of agricultural land is used to produce meat and dairy products. As the production of animal-derived products requires much more energy and resource inputs than the production of vegetable-based products, the high level of meat and dairy consumption leads to very high requirements for nutrients and arable land. From a circular economy perspective, this is a suboptimal use of the available resources. The increasing demand for agricultural land also promotes the conversion of natural areas to agricultural land, leading to deforestation and biodiversity loss, not only inside Europe but also in countries from which Europe imports animal feed.

The last major issue in the food sector today is that it is still very wasteful during production and consumption. It is estimated that around 20% of all the food that is produced ends up as food waste. Furthermore, a lot of residues and organic waste are generated throughout the production chain; these resources could be reused more efficiently.

4.3.3. *Circular strategies for the food sector*

The aforementioned linear aspects of the food sector can be addressed through the implementation of three main circular strategies.

Improving nutrient use efficiency and recovery

The first strategy is improving nutrient use efficiency and recovery, which corresponds to the Regenerate lever of the RESOLVE framework. Overall, demand for fertilizers can be decreased by using innovative farming practices. The fertilizers that are used can be preferentially produced through the processing of organic waste and manure. In summary, the following aspects were modelled:

- Reduction in overall fertilizer use;
- Substitution of inorganic fertilizers with organic fertilizers, which will come from 1) better nutrient recovery from manure and 2) increased nutrient recovery from sewage sludge.

Optimal food use

The second strategy is optimal food use, which means first that food waste will be reduced. It also relates to a shift from the consumption of meat and dairy products to vegetable oils, fats and proteins. This strategy aims to achieve a more efficient use of resources and corresponds to the optimise lever of the RESOLVE framework. Optimisation of food use will be modelled as follows:

- Food waste will be reduced throughout the value chain:
  - A reduction in waste generation in the food & drinks industry;
  - A reduced demand for packaging materials by the food & drinks industry;
  - A reduction in demand for food products by food wholesale, retail and food services;
- A reduced demand for food at the level of the final consumer
- A reduction in the demand for animal-derived food products.

Optimise the use of agricultural residues and waste streams

The third strategy is to optimise the use of agricultural residues and waste streams, which is related to the regenerate lever of the RESOLVE framework. Although waste reduction and prevention are always the first priority, the generation of waste or by-products is hard to avoid in some processes. In such cases, it is important to try to loop the materials back into the value chain or at least to recover as much of the embedded energy and resources as possible. For this strategy, two main activities were modelled:

Conversion of organic waste and former foodstuffs to animal feed (Optimised use of residue streams and by-products)

Biogas production from manure in agriculture

4.3.4. *Translating circular economy activities to modelling inputs*

The three aforementioned circular strategies and the corresponding activities have been translated into modelling inputs for E3ME. Table 4.2 summarises how this translation has been done. An elaborate explanation on how we arrived at the assumptions and quantitative model inputs can be found in the food sector's full sector profile in Annex C. Table 4.3 summarises the precise magnitude and directions for each of the modelling parameters defined Table 4.2. The precise modelling inputs can also be found in the full sector profile of the food sector.

One should note that dietary changes were not modelled, despite the fact that such shifts hold significant circular economy potential and can have substantial economic and environmental impacts. However, the current version of the E3ME model does not make a distinction between different kinds of agricultural and food products and therefore the model is not fit for modelling the effects of such dietary shifts[6].

Table 4.2 Translation of circular activities in the food sector into E3ME modelling inputs

Circular economy activity	Implications for E3ME modelling
Reduction in overall fertilizer use	• Reduction in chemical demand (fertilizers) from agriculture through adjusting input-output (IO) coefficients
Substitution of inorganic fertilizers with organic fertilizers	• As above, plus increased input within agriculture (purchasing organic fertilizer)
Reduction of food waste (assuming less food is bought, avoiding waste, and one unit of input produces more output than in the Baseline)	• Reduction in household spending on food • Reduction in hotel and catering intermediate demand from agriculture and food manufacturing (IO) • Reduction in retail intermediate demand from agriculture and food manufacturing (IO) • Reduction in food manufacturing intermediate demand from agriculture (IO) • Reduction in rubber and plastic products (representing packaging) intermediate demand from food manufacturing sector (IO)
Use of organic waste and former foodstuffs as animal feed	• Increased demand from agriculture (buying feed directly) of food manufacturing (waste from its production) (IO)
Biogas production from manure in agriculture	• Utility supply sector purchase (intermediate demand) from agriculture (manure) (IO)

Table 4.3 Scenario inputs for the food sector

E3ME model input	Moderate scenario	Ambitious scenario
Reduction in chemical demand (fertilizers) from agriculture through adjusting IO coefficients	28% reduction in mineral fertilizer input (12 bn EUR cost saving)	46% reduction in mineral fertilizer input (20 bn EUR cost saving)
Increased input within agriculture (purchasing organic fertilizer)	8% of total fertilizer demand (3.2 bn EUR)	13% of total fertilizer demand (4.4bn EUR)
Reduction in household spending on food	12.3 bn EUR of savings	24.5bn EUR of cost savings
Reduction in hotel and catering intermediate demand from agriculture and food manufacturing (IO)	3 bn EUR	6 bn EUR

[6] The model is currently being expanded to include equations for 17 types of foodstuff, which will be linked to a land allocation module.

Reduction in retail intermediate demand from agriculture and food manufacturing (IO)	1.5 bn EUR	3 bn EUR
Reduction in food manufacturing intermediate demand from agriculture	1.95 bn EUR	3.9 bn EUR
Reduction in rubber and plastic products intermediate demand from food manufacturing sector	2.2% reduction	11.1% reduction
Increased demand from agriculture (buying feed directly) of food manufacturing (waste from production) (IO)	0.4% of the expenditure of agriculture on animal feed is shifted to inputs from food manufacturing	1% of the expenditure of agriculture on animal feed is shifted to inputs from food manufacturing
Utility supply sector purchase (intermediate demand) from agriculture (manure)	145 PJ additional biogas from manure added to baseline	290 PJ additional biogas from manure added to baseline

4.4. Construction sector

4.4.1. *Overview of the sector*

The construction sector is a key sector for the EU economy and represents a major source of employment. It accounts for 9% of the EU's GDP and provides 18 million direct jobs[7]. In terms of number of companies, the sector is composed 99.9% of SMEs (employing fewer than 250 people) which are responsible for 80% of the construction output. In the EU, the average size of construction enterprises is four workers. Small enterprises (less than 50 employees) are responsible for 60% of production and employ 70% of the sector's working population[8]. The construction sector is the most material-intensive economic sector in the EU. In the EU, of all materials extracted from the earth each year, more than half (by weight) are used in construction (Bio Intelligence Services, 2013). Construction, therefore, has a high potential for increasing the circularity of the economy. In its EU action plan for a Circular Economy, the European Commission singled out construction as a priority sector (European Commission, 2015).

For all these reasons, the construction sector has been selected as a focus sector in this report. In this chapter of the report, we only consider the activities related to the construction of buildings, which accounts for 78% of the sector's value added. Civil engineering activities are excluded. However, the possible circular economy implications for construction-related, high-skilled occupations such as civil engineering are considered in Chapter 6.

4.4.2. *Potential of the circular economy in the construction sector*

Even though circular economy activities are already happening in the built environment (e.g. the use of digital construction tools for a smart design of buildings, recycling of construction and demolition waste, and the use of more circular construction materials), most work so far has focused on improving the energy efficiency of buildings. However, increasing circularity in the built environment means reducing the amount of resources used, as well as the amount of waste created, during the entire construction life cycle, through reuse, recycling or remanufacturing.

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[7] European Commission website. Accessed at: https://ec.europa.eu/growth/sectors/construction_en
[8] European Builders Association website. Accessed at: http://www.ebc-construction.eu/index.php?id=3

Around 10-15% of building materials are wasted during construction, and around 60% of office buildings in the EU are not used even during working hours)(Ellen MacArthur Foundation, 2015). It is estimated that 20-40% of energy in buildings could be saved and a large amount of demolition waste is landfilled (6-54% depending on the EU country) (Ellen MacArthur Foundation, 2015).

These figures show that a large untapped circular economy potential exists in the sector, in particular for minimising resource use during (1) the production of construction products and (2) the use-phase of buildings, the two lifecycle stages with the biggest environmental impacts. The construction of new buildings requires large quantities of new raw materials. The majority of the materials used in the construction of buildings are new materials, although accurate figures on the use of recycled materials are lacking (European Commission, 2014). Further, many buildings are not yet built in such a way that resource use during the use-phase is minimised. This needs to be addressed if the circular economy potential of the sector is to be realised.

4.4.3. *Circular strategies for the construction sector*

There are several circular economy strategies that can be applied along the lifecycle of a building, with measures affecting the design phase, the extraction of resources, the actual construction, maintenance of buildings, retrofitting and renovation, and the end-of-life stage. In the design phase, it is important that buildings are made in such a way that they can easily be remodelled, retrofitted, expanded or disassembled. In the construction process it is important to use sustainable materials, preferentially recycled materials and, where suitable, bio-based materials. Prefabrication can prevent wastage of materials at the construction site and modular design will enable easy remodelling of buildings when they need to be renovated, or easier disassembly at a building's end-of-life. Buildings should be designed and constructed in such a way that energy use and the need for maintenance are minimised. At the same time, regular maintenance is often very important to maintain optimal resource efficient operation of buildings. At the end-of-life stage, deconstruction is preferred over demolition as this enables the reuse of materials in the construction of new buildings.

Although all the aforementioned strategies should be employed to make the construction sector more circular, we have focused on the following activities for modelling the circular economy in the sector.

Recycling, reuse and recovery of construction and demolition waste

Recycling, reuse and recovery of construction and demolition waste is an activity with a high potential. Currently around 50% of construction and demolition waste is recycled (own assumption based on Bio Intelligence Service, 2011), although this should increase to 70% by 2020 according to the Waste Framework Directive. We assume this rate will apply in 2030 without further policy action, and that the rate will increase in the moderate and ambitious scenarios. The main impact of this activity would be increased demand for recycled construction materials. This is reflected in the model as a reduction in virgin material purchases, e.g. from the mining and quarrying sector, and as an increase in purchases from the waste treatment sector.

Higher utilisation of buildings

Higher utilisation of buildings through sharing and efficient use of empty buildings has been identified as a high potential measure by the Ellen MacArthur Foundation (2015). European offices occupy 1.4 billion m^2 of space. Tele-working and office-sharing, enabled by digitalisation, would likely continue to grow but would not fully solve the underutilisation issue (Ellen MacArthur, 2015). Peer-to-peer renting/sharing could increase the utilisation of residential buildings. In the model we assume that demand for traditional accommodation will be reduced, as more people engage in peer-to-peer renting/sharing of homes. This development is reflected in the model as a shift of income from the hotels industry to households. It also slightly increases the revenues for the online platforms that are managing such transactions. The estimates behind these shifts are taken from Trinomics (2017).

Modular design

Modular design involves industrial production, prefabrication and 3D printing. Moving construction towards factory-based industrial processes is already helping companies cut costs as much as 30% and shorten delivery time by 50% or more. Modular design typically reuses and refurbishes some 80% of the components; up to 30% of new buildings could use industrial approaches by 2020 (versus 20% today), 50% by 2030, and 80% by 2050, and these approaches could reduce construction cost by 10-30% per m^{2}(Ellen MacArthur, 2015). The main impacts modelled are decreased construction costs per unit of output for new buildings and increased labour productivity due to these changes.

4.4.4. *Translating circular economy activities to modelling inputs*

The three aforementioned circular strategies and the corresponding activities have been translated into modelling inputs for E3ME. Table 4.4 summarises how this translation has been done. An elaborate explanation on how we arrived at the assumptions and quantitative model inputs can be found in the full sector profile in Annex C.

Table 4.5 summarises the magnitude and directions for each of the modelling parameters. The precise modelling inputs can also be found in the full sector profile on the construction sector.

Table 4.4 Translation of circular activities in the construction sector into E3ME modelling inputs.

Circular economy activity	Implications for E3ME modelling
Recycling, reuse, waste reduction, and recycling of Construction and Demolition waste (C&D)	• Increase in construction demand from recycling (buying more recycled materials) (IO) • Reduction in construction minerals demand (cement, sands, glass, ceramics etc.) from construction (IO)
Sharing, efficient use of empty buildings	• Households letting out spare rooms resulting in reduction on demand for traditional accommodation (e.g. hotels) (exogenous reduction in consumer spending on traditional hotels and accommodations) • Small payment to collaborative platforms such as AirBnB (exogenous increase in consumer spending on miscellaneous services) • Assume households spend money from P2P (peer-to-peer) activities on other goods and services (reallocation of consumer spending)
Modular design	• Lower construction sector costs per unit of output from non-labour related efficiency gains (exogenous reduction of unit cost in the construction sector) • Increase in labour productivity of new construction per unit of output (exogenous reduction in construction labour demand)

Table 4.5 Scenario inputs for the construction sector

E3ME model input	Moderate scenario	Ambitious scenario
Increase in construction demand from recycling (buying more recycled materials)	5% additional purchases from the waste & recycling sector compared to the baseline	15% additional purchases from the waste & recycling sector compared to the baseline

Reduction in construction minerals demand (cement, sands, glass, ceramics etc.) from construction (IO)	* -5% compared to the baseline	* -15% compared to the baseline
Households letting out spare rooms resulting in reduction on demand for traditional accommodation (exogenous reduction in consumer spending on traditional hotels and accommodations)	Consumer spending on traditional models of accommodation reduced by €6.4bn compared to the baseline	Consumer spending on traditional models of accommodation reduced by €18.4bn compared to the baseline
Small payment to collaborative platform such as AirBnB (exogenous increase in consumer spending on miscellaneous services)	€1.05bn compared to the baseline	€3.03bn compared to the baseline
Lower construction sector costs per unit of output from non-labour related efficiency gains (exogenous reduction of unit cost in the construction sector)	3% lower cost for new buildings in 2030 compared to the baseline	9% lower cost for new buildings in 2030 compared to the baseline
Increase in labour productivity of new construction per unit of output (exogenous reduction in construction labour demand)	*-5% of labour requirement for newbuilds compared to the baseline	*-10% of labour requirement for newbuilds compared to the baseline

Note(s) * own estimation.

4.5. Motor vehicles sector

4.5.1. *Overview of the sector*

The production of motor vehicles (NACE code 29) includes a range of products including passenger cars, large commercial vehicles (trucks) and motorcycles. The production of passenger cars accounts for the largest share (87%) of the production of motor vehicles in Europe (ACEA, 2015). Passenger cars make up an important part of the life of an average European citizen as many of us depend on cars to provide the mobility we seek for private and professional reasons. Car ownership in the EU is also high. The average European citizen owned 0.49 cars in 2014 (i.e. almost one car for every two citizens). Due to the importance of the passenger cars in the motor vehicles sector (and in society), we have focused on the potential of the circular economy in relation to passenger cars in this sector profile.

As in other sectors, the passenger car sector is analysed from a lifecycle perspective (the car from a cradle to grave perspective) and taking into account supply chain linkages. The production of motor vehicles involves a complex and varied chain of suppliers of various materials and parts, which are assembled together by Original Equipment Manufacturers (OEMs), run by the large automotive brands. Rubber and plastic products, metals and chemicals form the three most important material-based inputs to the motor vehicle sector. The automotive sector in turn is an important client for them: 13% of the total rubber and plastics output in Europe serves as input for the passenger car industry, 11% for the EU metal sector's output and 2% of the chemicals sector's total output. In these three sectors, 3.2% (or 7 million) people were employed in 2014 in the EU.

The production of parts and assembly of cars accounted for 2% of total EU employment (2.4 million people) in 2014. In the retail and distribution stage (the end of the supply chain and the beginning of the life cycle 'use' phase), jobs such as selling (parts and accessories of) cars and the maintenance and repair of cars represented 2.5% of all EU employment in 2014 (almost 3 million people). Altogether, the motor vehicle supply chain accounted for 8% of total employment in the EU in 2014.

More information on the detailed economic structure of the EU motor vehicles sector can be found in the full sector profile in Annex C.

4.5.2. *Potential of the circular economy in the motor vehicles sector*

According to our analysis of recent literature and data, the potential of the circular economy in the automotive sector differs per life cycle phase. The production of motor vehicles and sourcing of materials has been a competitive market for decades where margins are slim. Under the influence of increasingly stringent regulation, the sector has been innovating strongly to reduce material use and increase efficiency of its production process. In addition, the End of Life (EOL) phase of cars has, under the influence of regulation, developed into more circular outcomes over time: only 9% of the waste generated by passenger cars is disposed of. Overall, 82% of the waste from cars is already recovered (recycled) and 9% is directly reused (without being recycled first). In contrast, the 'use' phase in the car's life cycle is much less optimised and still inherent to significant efficiency losses:

- The EU car is not in use for 92% of the time (parked)
- When in use, on average 1.6 seats in the car are occupied, and
- Engine losses and idling amount to 86% of fuel consumption (Ellen MacArthur Foundation, 2013).

As a result, a large share of the potential of the circular economy in the automotive sector is based on increasing utilisation and efficiency in the 'use' phase of the life cycle of cars. It is also in the use phase that most of the environmental damage is created. Notably, the use phase accounts for 75 to 80% of total GHG emissions in the life cycle of regular diesel/petrol cars.

It is important to consider, however, that even without (additional) circular economy policy efforts, the sector is already undergoing dramatic structural changes by switching to electric drivetrains and autonomous vehicles. In 2016, 1.3% of light duty vehicle sales were of plug-in hybrids (PHEVs). The share of fully electric battery electric vehicles (BEVs) in total EV sales is still relatively small but is growing. There are predictions that within a decade the complete market for new passenger cars will shift to EVs. ING expects that the price for ICEs and BEVs will break even between 2023 and 2028 and that, by 2035, 100% of new car sales will be battery electric vehicles. Other organisations, however, expect that ICEs will remain dominant until 2035 if the international community does not implement ambitious climate policies(McKinsey & Amsterdam Round Table, 2014). Either way, there is an ongoing transition towards electric and autonomous vehicles that is likely to capture a large share of the overall circular potential of the sector, through increased efficiency and a lower environment impact of car driving. However, as argued in the next section, additional policy and industry efforts towards a circular transformation could increase the speed of the transformation.

4.5.3. *Circular strategies for the motor vehicles sector*

A fully circular automotive sector would reduce resource use in the production of cars as much as possible, optimise the utilisation of cars in terms of number of persons in a car and the amount of time the car is driving, and reuse and recycle materials at the end of a life that has been prolonged as much as possible. In the sections below, the three changes to the sector that would contribute most significantly to realising this circular vision for the motor vehicle sector are outlined. These three changes are also introduced as inputs to the E3ME model. In this way the model can be 'shocked' with the changes that resemble a circular transformation of the automotive sector and thus simulate what would happen to employment and other socio-economic parameters. It is important to note that progress on all three actions is to different extents already ongoing in the sector. The scenario design shows that in order to realise the circular vision of the car sector, future actions 'only' have to focus on supporting ongoing transformation rather than initiating new and radical actions.

Car sharing

Car sharing refers to either more individuals using the same car at different occasions or more individuals using the same car at the same time. In both cases, the utilisation rate of cars would increase (up from the current 8%) and productive assets would be used more efficiently so that less resources and assets are needed in total. The transition towards autonomous vehicles could reinforce the effects of car sharing as autonomous vehicles are better suited for car sharing than regular cars (autonomous vehicles are not a circular action on their own). Car sharing is considered a circular action as it reduces the resource use and GHG emissions per person per kilometre while leading to economic efficiency gains along the supply chain. Car sharing would result in the following circular economy implications:

1. The average car would be used more often and/or more seats would be occupied. Thus, all else equal, fewer individuals would need a personal car which would reduce the overall demand per person. In the E3ME model, this is modelled by:

- Reducing the demand for new cars as less individuals require an individual car

2. Transferring the same amount of people (while using fewer cars) would require less petrol/diesel or electricity. In the E3ME model, this is modelled by:

- Reducing the demand for petrol/diesel/electricity as less cars will be on the road because more seats are occupied in a single car

3. The demand for products which serve to maintain the car operational would shrink. In the E3ME model, this is modelled by:

- Reducing the spending on car operations as less individuals will own a car, which will lead to an absolute decline in the demand for additional components and services

4. Online platforms will be used more intensively as most car sharing platforms use online platforms or mobile applications to match car owners and renters. Most of the platforms charge a user fee. Thus, an increase in car sharing would lead to higher expenditures on online platforms that facilitate car sharing. In the E3ME model, this is modelled by:

- Increasing the spending on online platforms as they are often used for car sharing purposes

Electrification

The electrification of cars is the transition from internal combustion engines (ICEs) towards electric vehicles (EVs). Further electrification of the vehicle fleet would restore the impact on ecosystems as the demand for petrol and diesel would reduce drastically. However, as the new cars require electricity in the use phase, the demand for electricity would increase. Electrification is considered a circular action as it reduces the environmental pressures caused in the use phase of the motor vehicle sector and it leads to economic efficiency gains. The efficiency gains have been proven in practise in the last decade as the business case for EVs has strongly improved. The way in which this action will be modelled using E3ME is:

- Increasing the demand for electricity for the use of cars and reducing demand for fossil fuels (increasing the share of electricity used by cars compared to fossil fuels)

Evolution in materials

The evolution in materials refers to innovations in the materials that are used in the production phase of the car. The evolution of materials is considered a circular action as it reduces the amount of disposed waste, resource use and the GHG emissions per person kilometre. Moreover, as lighter and fewer materials can also achieve cost reductions on the long run, it would also lead to economic efficiency gains. In the motor vehicles sector, there are two effects related to the evolution of materials that would generate substantial changes in the sector. First, the amount of ferrous metals in the production phase of the automotive sector decreases. This would decrease the demand for virgin materials and would make vehicles lighter. The reduced weight would lower GHG emissions per person kilometre. Second, the actions in remanufacturing and the reuse of parts and materials are increased. This would further increase the demand from the recycling sector. In the E3ME model, this is modelled by:

- Decreasing the demand for ferrous metals by car manufacturers as new cars require less and lighter materials and increasingly use recycled materials.

- Increasing the demand for recycled materials as they will substitute the raw materials.

4.5.4. *Translating circular economy activities to modelling inputs*

The three aforementioned circular strategies and the corresponding activities have been translated into modelling inputs for E3ME. Table 4.6 summarises the identified circular actions and their implications on the sector. An elaborate explanation on how we arrived at the assumptions and quantitative model inputs can be found in the full sector profile in Annex C. Table 4.7 summarises the precise magnitude and directions for each of the modelling parameters defined. The precise modelling inputs can also be found in the full sector profile.

Table 4.6 Circular economy activities in the motor vehicles sector

Circular economy activity	Implications for E3ME modelling
Car sharing & autonomous vehicles	• Reduction in demand for cars • Additional reduction in petrol & diesel demand (over and above the reduction in petrol & diesel demand from reduction in demand for cars due to the increased utilization of cars) • Reduction on car operations spending (other than fuels) • Increase in spending to sharing platform (e.g. Zipcars)
Electric vehicles	• Increase in electricity demand from cars, shifting away from oil-based products (exogenous change)
Evolution in materials	• Reduction in demand for ferrous metals from car manufacturing (IO change) • Increase demand from recycling sector by car manufacturing (IO change)

Table 4.7 Scenario inputs for the motor vehicles sector

E3ME model input	Moderate scenario	Ambitious scenario
Reduction in car demand	-7.5% reduction in household spending on 'purchase of cars' in 2030 compared to baseline	-15% reduction in household spending on 'purchase of cars' in 2030, compared to baseline
Reduction in petrol & diesel demand (exogenous change)	-6.5% change in petrol & diesel demanded by the EU vehicle fleet by 2030, compared to baseline	-8.4% change in petrol & diesel demanded by EU vehicle fleet in 2030, compared to baseline
Reduction on car operations spending (other than fuels)	25% reduction in household spending on 'operation and maintenance of cars' in 2030, compared to baseline	40% reduction in household spending on 'operation and maintenance of cars' in 2030, compared to baseline
Increase in spending to sharing platform	5,370 m euro	16,401 m euro

Increase in electricity demand from cars, shifting away from oil (exogenous change)	3% (half of the reduction of petrol/diesel)	4% (half of the reduction of petrol/diesel)
Reduction in demand for ferrous metals from car manufacturing (IO)	-2.5% change in demand for ferrous metals by production of motor vehicles sector	-5% change in demand for ferrous metals by production of motor vehicles sector
Increased demand from recycling sector by car manufacturing (IO)	5% increase in use of remanufactured/reused materials	10% increase in use of remanufactured/reused materials

4.6. Waste management sector

4.6.1. *Overview of the sector*

The waste management sector (NACE37-39) differs from the other four sectors that are covered in this report (as well as virtually every other sector), as its 'raw materials' derive from all other sectors. After waste is collected it is sorted and sent to specific facilities according to the treatment type. These treatment types are disposal or incineration, re-use, recovery or recycling, thereby entering into the loop once again as secondary raw materials. This recycling can continue until the material no longer possesses any value for the supply chain. The treatment methods for each waste category vary across the EU. Overall, the majority of waste is landfilled and one third is recycled. The three main sub sectors of the waste sector are collection, treatment and disposal and material recovery/sorting. In 2015, the EU had:

- 20,000 waste collection enterprises, employing 527,000 people.
- 7,000 waste treatment and disposal enterprises employing 203,000 people.
- 20,222 materials recovery enterprises, employing 189,204 people.

The total amount of waste treated in 2014 in the EU was 2.5 billion tonnes. Three quarters of this derives from soils, construction and demolition waste. About 10% consists of 'mixed ordinary waste', which mainly consists of household waste and other similar waste types, while the 'other' category is 15% and includes wastes like metals, animal and vegetable wastes, etc. Although the waste sector fulfils an essential function in the economy it only accounts for 0.4% of the EU's employment and GDP.

4.6.2. *Potential for circular activities*

Recycling, reuse and recovery are essential parts of the circular economy. Waste management therefore plays a central role in the circular economy and could help prevent future economic losses and depletion of natural capital, as well as offering opportunities for the creation of new jobs. If the waste sector is to become more circular, the principles it needs to follow are generally captured by the well-known waste management hierarchy. The hierarchy runs down through reduction, reuse, recycling, other recovery (e.g. energy recovery) to disposal. The circular approach involves maximising options at the top of the hierarchy and reducing those at the bottom.

There are potentially large gains in terms of circularity to be made by moving up the waste hierarchy. Most of the potential that can be tapped into is outside the waste sector itself. For many products, there is the potential to minimise waste generation throughout the entire value chain, from product design to packaging. This can be done through redesign with waste prevention as a priority. More accurate manufacturing approaches, such as 3-D printing also offer the opportunity to reduce waste. In order to achieve the maximum benefits, there is a need for a joint effort from consumers, producers, policymakers, local authorities and waste treatment facilities.

There is potential to reduce the costs associated with sorting mixed waste to extract valuable materials through the increased use of technology. One example of this potential is the creation of NIR spectroscopy for waste, which is a technology that has been developed to be able to sort waste, such as plastics, more efficiently. There is also a great potential to extract biochemicals or recover energy and nutrients from various waste streams. For example, mixed ordinary waste accounts for 10% of total waste arisings but, due to its varying contents, this waste stream is hard to recycle. However, if the contents were better sorted, mixed ordinary waste would become a smaller waste stream, but would also contribute to waste streams with better recycling rates. For this to happen, consumers need to be willing and able to sort their waste to enable recycling, and the required recycling infrastructure should be in place.

An important issue in enabling waste to be used and seen as a resource is when material stops being legally classified as a waste; this is known as the 'end of waste' criteria. The issue is important because, when a material is classified as a waste, its shipment and use are constrained, making its reuse or recycling more difficult or impossible. Clarifying the definition of waste and waste-related materials is an important step in reducing waste and encouraging circularity; for this reason, an amendment to the Waste Framework Directive as part of the Circular Economy Package in 2015 has been proposed. If the waste market in the EU functioned in a more efficient manner, the waste sector could improve performance.

It is important to note that the largest impacts of the circular economy on the waste sector will originate from circular economy activities in other sectors. Other sectors' activities will lead to changes in demand for the waste management sector. The most significant changes will relate to waste prevention due to the design of more durable products or products with increased reparability. Secondly, product design needs to be changed in such a way that recycling of materials is made easier.

These changes affecting the volume and quality of the waste that is created will not be modelled as changes in the waste sector, but in the sectors upstream that create the waste. The changes in the interlinkages between the waste sector and sectors upstream will lead to endogenous responses for the waste sector in E3ME when we model circular activities in other sectors. The responses include changes in the waste sector's supply-chain, employment and its investment impacts.

4.6.3. *Strategies for making the waste sector more circular*

Taking the aforementioned considerations into account, there are two main strategies through which the waste sector can contribute to a more circular economy in the EU, namely:

1. Reduce the amount of waste that is landfilled or incinerated without energy recovery. For this subsector a stagnation in activity is expected first, followed by a decline.
2. Increased recycling rates and higher-quality recycling.

These two strategies will have several implications for levels of production and employment in the waste sector. Waste management is a highly mechanised process that requires a small level of labour input. Recycling is much more labour-intensive (due to collecting, sorting, processing, reselling, etc). Therefore, increased recycling is expected to lead to output and employment growth in the waste sector. In the short to medium term it appears that this growth will be labour intensive, but in the medium to long term it may become more mechanised, as automated sorting and dismantling becomes more affordable. In order to model the aforementioned strategies, we introduce a change to the sector's labour intensity to reflect more recycling activities and less waste management. We also expect the non-labour related operational costs of the sector to increase because recycling is a more expensive process than other common waste treatment processes such as landfilling or incineration.

4.6.4. *Translating circular economy activities to modelling inputs*

A summary of the implications of the two circular economy strategies in the waste sector for E3ME modelling are shown in Table 4.8 and

Table 4.9.

Table 4.8 Circular economy activities in the waste sector

Circular economy activity	Implications for E3ME modelling
Increased recycling rate, leading to:	
- Higher demand for labour	• Increase in labour intensity coefficient
- A need for more recycling stations	• Increase in investments into the waste sector
- Higher operational costs	• Increase in non-labour costs in the waste sector

It is expected that many of the impacts within the total waste sector will be close to zero as waste and recycling fall under the same sector classification in E3ME (NACE 37-39). Positive impacts associated with higher recycling are likely to be offset by reductions in landfill and waste management demand.

Table 4.9 Scenario inputs for the waste sector

E3ME model input	Moderate scenario	Ambitious scenario
Labour intensity per 10,000 tonnes of waste	Around four times higher in recycling compared to landfill(Scottish Government, 2017) - same assumption for both ambitions	
Additional investment	*20% of existing sector investment	*40% of existing sector investment
Additional costs	*20% of existing sector costs	*40% of existing sector costs

Note(s) * own estimation.

4.7. Electronics and electrical equipment sector

4.7.1. *Overview of the sector*

The electronics (NACE code 26) and electrical equipment (NACE code 27) sectors cover a broad set of products which all consume electricity to use and/or store information, or as a source of power[9]. The sector includes among others, computers, consumer electronics, optical instruments, transformers, electrical lighting equipment and electric household appliances. In order to focus on the sector's most important components in the light of the circular economy, the sector assessment targets types of products and equipment that are part of the EU circular economy debate.

Currently, the regular supply chain in the sector is characterised by a linear process from raw material extraction to use-phase to end-of-life phase(Antea Group, 2016). Concerning economic importance, the sector is responsible for around 10% of the European manufacturing sector's turnover (approximately €0.6 billion out of €6 billion for total manufacturing), value added and number of employees according to Eurostat. This implies that it is of less economic importance than the food, construction and motor vehicles sector. Yet, taking into account the growing importance of electronics, the political priority assigned to this sector, the existing inefficiencies and the substantial environmental impacts, the sector is considered a key sector for the circular economy. The full sector analysis can be found in Annex C.

4.7.2. *Potential of the circular economy in the electronics sector*

Currently, the trend in the sector is to focus on energy efficiency improvements in the design phase, reverse logistics during use-phase, and the end-of-life phase of products (recycling) as the

[9] On definition of electrical and electronics goods, see http://www.europe-economics.com/publications/the_economic_impact_of_the_domestic_appliances_industry_in_europe_finaol_report.pdf

main actions to improve circularity. One other rising activity is sharing and leasing business models, where companies experiment with peer-to-peer renting of electronics and electrical products. However, the markets for these are very low scale and immature.

Concerning the use-phase, moderate improvements by circular actions seem feasible. Possible actions include renting/sharing of electronic products and equipment, extending the durability of a product, but much of this depends on consumer behaviour. Currently, this phase accounts for the largest environmental impacts (through GHG emissions). In addition, devices are only used for 50% of their potential lifetime which indicates that the products are underutilised (Ellen McArthur Foundation, Growth Within, 2015). This implies that the potential of reusing electronics which have not yet reached their end-of-life stage, could be improved.

Regarding the end-of-life phase, improvements are possible. According to stakeholders, 38% of end-of-life products are shipped outside Europe illegally (Arcadis & Trinomics, 2016). As there is no control over the recycling process of this waste, valuable materials and components are lost. Moreover, the waste generated by the sector is expected to grow significantly over the coming years (by 12 million tonnes by 2020). On the other hand, the economic value of the materials in waste electrical and electronic equipment is relatively low, which hinders the development of a strong business case.

Improving circularity of the product design is another area of potential that still needs to be further explored and developed. There are several circular economy trends in the sector but some of them have opposing impacts. For example, more complex product design decreases the amount of needed materials and increases functionality, while at the same time decreasing the ability to recycle and repair parts that are glued together and integrated (EEA, 2017). Another trend is modular design. Modularity increases the lifetime of products as parts can be repaired and remanufactured. However, relevant services and parts need to be available (EEA, 2017).

4.7.3. *Circular strategies for the electronics sector*

Despite several challenges, there is the potential to improve the electronic sector’s circularity. The following actions are expected to have the largest impacts and are therefore used as model inputs.

Reverse logistics, better use of materials and recycling

Reverse logistics is an overarching term that refers to all actions concerning the reuse and recovery of materials, remanufacturing etc. It is considered a circular action as all actions contribute to closing the loop in the electronics sector. Moreover, due to the size of the current inefficiencies in the processes (e.g. large illegal leakages of end-of-life products outside the European loop), it is the key circular action in this sector and could cause a large reduction in the demand for raw materials and significant economic efficiency gains.

To model reverse logistics in the electronics sector, we estimate the reduction in metal and plastics demand from electronics as key impacts using the WEEE Directive reuse, recovery and recycling targets. Metals and plastics are two of the three main materials arising from the WEEE, besides glass, where ferrous metals account for approximately 50%, non-ferrous metals for 5% and plastics for 20-25% of the WEEE arising(SEC, 2008). Unfortunately, we did not find estimates for the proportion of glass in WEEE. The pressure to extract new metals and plastics would be lower as the recycled materials can substitute new metals and plastics. Thus, the incentive to extract more raw materials as input for the electronics sector will decrease and the demand for recycled products will increase. Moreover, if electronics are increasingly reused, the demand for new products will shrink. This pattern will reinforce the decrease in demand for new metals and plastics.

The demand for repair services will also increase. Due to the reverse logistics, electronics can be more often reused. However, in many cases products need to be repaired or modified before they can be reused. If the lifetime of devices is extended, the probability that products need to be repaired increases as older products require more repair services. Finally, if modular electronics (i.e. phones in which parts can be easily replaced or repaired) became more important, it will become easier and cheaper to replace or repair broken components instead of replacing the entire device. This would also increase the demand for repair services.

Optimising utilisation

Optimising utilisation refers to making better use of existing electronics over their complete lifetime. Moderate increases in the utilisation rate of electronic and electrical products are expected. Increasing the utilisation rate is considered a circular action as it would lower the demand for new products and thus decrease the environmental damage caused by the input of raw materials. There are also several examples that show that actions to increase the utilisation rate can also be profitable to businesses (as economic efficiency gains are still not fully exploited). Existing business models that enhance the utilisation rate of products include peer 2 peer (P2P) platforms. On these online platforms, individuals can rent devices that are generally underutilised (such as a drilling machine). This sort of service can potentially increase the utilisation rate of products substantially. To model the sharing of electronic goods, we base our modelling inputs developed as part of another study for DG Environment on the "Environmental potential of the collaborative economy"(Trinomics, 2017).

4.7.4. *Translating circular economy activities to modelling inputs*

The aforementioned circular strategies and corresponding activities have been translated into modelling inputs for E3ME. Table 4.10 summarises how this translation has been done. An elaborate explanation on how we arrived at the assumptions and quantitative model inputs can be found in the full sector profile in Annex C. Table 4.11 summarises the magnitude of the modelling parameters. The precise modelling inputs can also be found in the full sector profile.

Table 4.10 Circular economy activities in the electronics sector

Circular economy activity	Implications for E3ME modelling
Reuse, recovery, remanufacture, better use of materials, and recycling	• reduction in metal demand from electronics (IO) • reduction in plastic demand from electronics (IO) • increase in demand from recycled materials (IO) • increase to the repair sector (IO – within sector)
Optimising use – P2P sharing, extending the lifetime of products	• reduction in electronics demand from consumers • payment to sharing platform e.g. Peerby

Table 4.11 Scenario inputs for the electronics sector

E3ME model input	Moderate scenario	Ambitious scenario
reduction in metal demand from electronics (IO)	Share of ferrous metals in EEE[10] reduced by 2-4 percentage points compared to the baseline Share of non-ferrous metals in EEE reduced by 0-1 percentage points compared to the baseline	Share of ferrous metals in EEE reduced by 4-6 percentage points compared to the baseline Share of non-ferrous metals in EEE reduced by 0-1 percentage points compared to the baseline
reduction in plastic demand from electronics (IO)	Share of plastic in EEE reduced by 1-2 percentage points compared to the baseline	Share of plastic in EEE reduced by 2-3 percentage points compared to the baseline
increase in demand from recycled materials (IO)	Similar amount to replace raw materials	
increase to the repair sector (IO within sector)	20%*	50%*

[10] EEE Electrical and Electronics Equipment.

reduction in electronics demand from consumers	Numbers are potential savings compared to Baseline. • Household appliances 2.5% • Audio-visual, photographic and information processing equipment 1.75%	Numbers are potential savings compared to Baseline. • Household appliances 5% • Audio-visual, photographic and information processing equipment 3.5%
payment to sharing platform e.g. Peerby	25% fee of the above spending	25% fee of the above spending

Note(s) * own estimation.

5. IMPACTS ON THE EU ECONOMY AND JOBS

5.1. Introduction

This part of the report presents the results from the E3ME modelling of the circular economy activities. The next section describes macro impacts for all the scenarios while the subsequent sections present detailed results for the combined scenarios only.

5.2. Impacts on the EU economy and jobs

5.2.1. *GDP*

The overall impacts of increased circular economy activity on EU GDP are positive (see Figure 5.1). In the Ambitious-Combined circular activities scenario, GDP increases by almost 0.5% by 2030 compared to the baseline. The individual sector scenarios each contribute up to 0.15% of the GDP increases. In the moderate scenario, GDP impacts remain positive but smaller at 0.3% by 2030.

Waste recycling sector

The GDP results suggest that circular economy activities in the waste sectors, due to higher demand from other sectors, produce the most beneficial impacts on GDP. The benefits are due to higher investment required for the recycling plants, as well as additional labour demand to process recycled materials.

Motor vehicles sector

Circular economy activities in the motor vehicles sector produce the second largest boost to GDP. Although there is a reduction in car sales due to collaborative actions in this sector, the benefits of reducing oil and metal imports, as well as rebounds in consumer spending from car-sharing, outweigh any negative economic impacts.

Electronics sector

In case of the electronics sector, the positive impacts are driven by increased demand for repair services, reduction in raw material imports, increase in recycled materials demand and the rebounds in consumer spending from collaborative activities. However, these impacts are slightly dampened by the reduction in sales of new electronics products.

Food sector

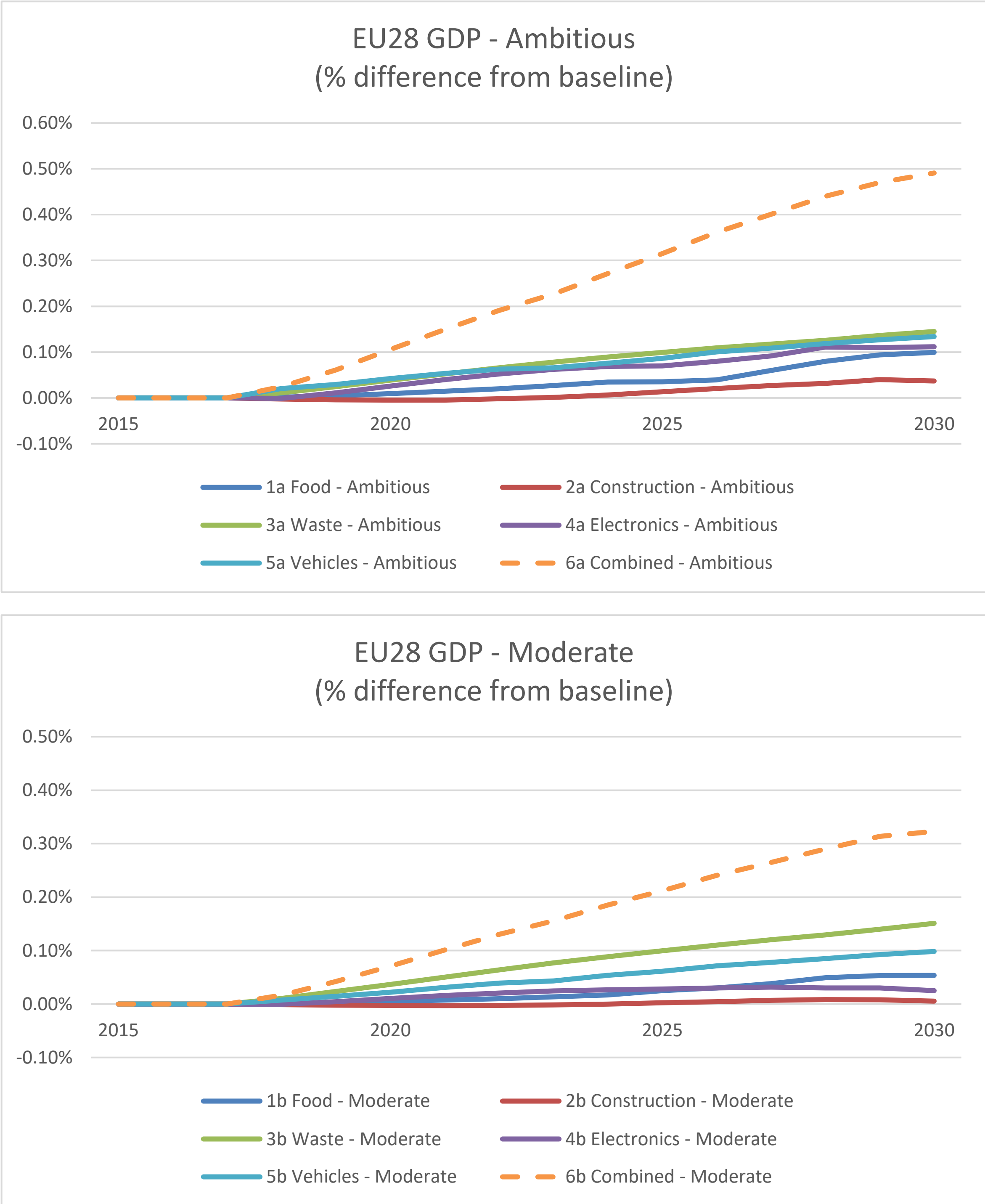
In the food sector, a reduction in food waste reduces domestic demand for agriculture and food manufacturing but the rebounds in consumer spending and trends for organic materials makes the overall impact positive.

Construction sector

Increased circularity in the construction sector produces the smallest impacts on GDP. Although the circular economy activities are similar in this sector, there is a reduction in construction employment demand due to improvements in productivity.

It should be noted, however, that renewable energy (e.g. solar panels) and refurbishment to make buildings more energy efficient do not fall under the scope of the circular economy in this project. The macroeconomic and labour market impacts of improving buildings' energy efficiency in the EU has already been extensively analysed with E3ME for the European Commission. According to the analysis, EU GDP and employment are expected to increase by 0.6% and 0.25%, respectively, by 2030 in a scenario with higher energy efficiency rates in buildings (European Commission, 2016).

Figure 5.1 EU GDP impacts in the circular economy scenarios (% from baseline)



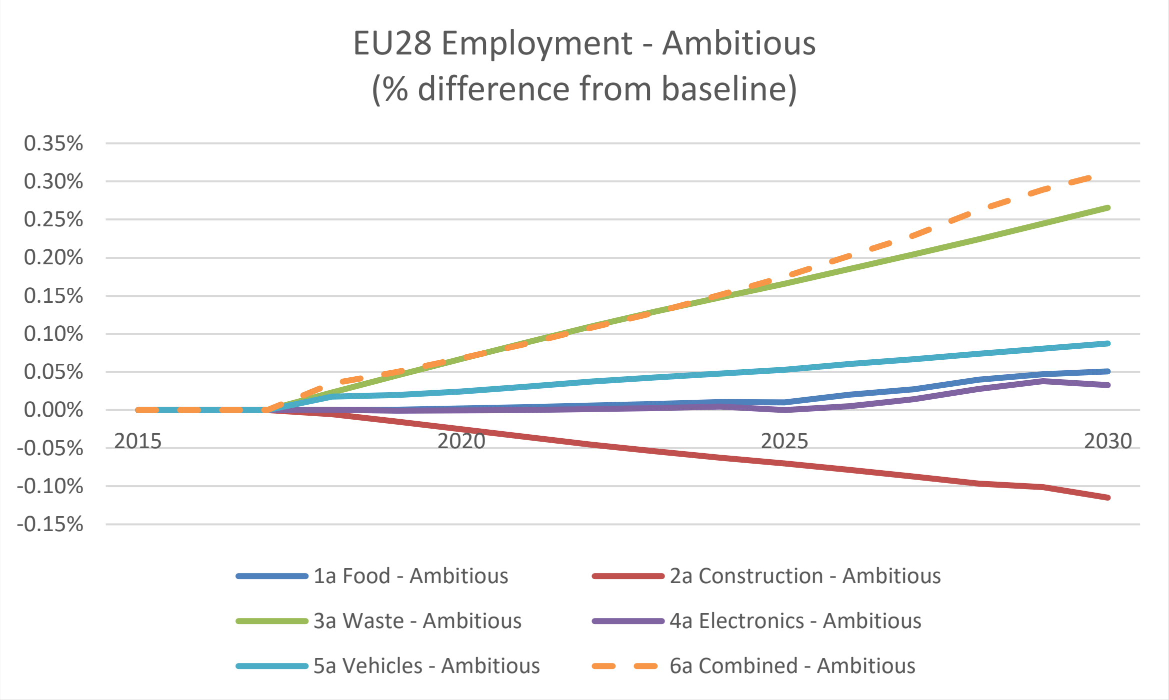
Source(s): E3ME, Cambridge Econometrics.

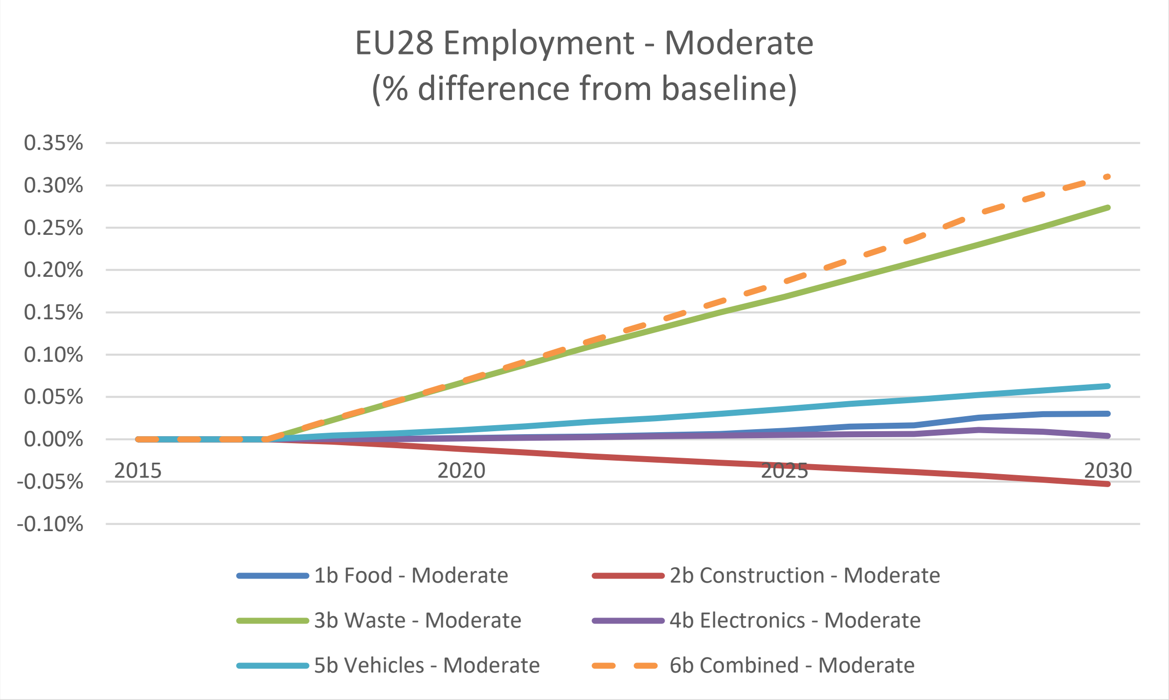
5.2.2. *Employment*

The employment results generally follow the same trends as GDP because rates of economic production are a key driver for employment demand. In both of the combined scenarios, employment increases by almost 0.3% (around 650,000 – 700,000 jobs). These results are mainly driven by employment demand in the waste management sectors to cope with higher demand for recycled materials.

The only sector that shows a substantive reduction in employment is construction. In this sector there is a strong improvement in labour productivity from new modular construction techniques (built into the scenario as an assumption), which reduces total labour demand.

Figure 5.2 EU employment impacts in the circular economy scenarios (% from base)





Source(s): E3ME, Cambridge Econometrics.

Although the overall GDP and employment impacts are positive, it is important to consider the complex interactions that underlie the aggregate outcomes. Impacts may not be positive throughout the European economy. The scenarios include a range of different inputs; some result in positive impacts on the economy and jobs (e.g. increased demand for recycling), while others may result in negative impacts (e.g. reduction in raw virgin materials). Table 5.1 provides a summary of the key economic impacts in the scenarios.

Table 5.1 Summary of key economic impacts in the scenarios

Type of modelling inputs	Initial impacts	Indirect and induced impacts
Increase in alternative materials and energy sources, e.g. recycled materials and biofuels	Different supply chains, different costs	Employment, investment, industry prices, trade, income and consumption
Reduction in the consumption of virgin materials, e.g. metals, plastic and petrol	Supply-chain impacts	Employment, investment, income and consumption
Increase in repairing activities	Supply-chain impacts	Employment, investment, income and consumption
Collaborative economy	Supply-chain impacts for traditional businesses, increased income within households	Employment, income and consumptions (knock-on effects from additional incomes from collaborative actions)
Investment in recycling facilities	Boost to economy and sector receiving the investment	Employment and further knock-on effects
Change in labour intensity of recycling activities compared to traditional waste management	Higher income and consumption	Further knock-on effects – mostly related to consumer goods and services
Cost reductions from more efficient use of resources or production methods (e.g. modular design)	Industry prices	Industry demand, trade, employment and further knock-on effects

The overall net impacts from the modelling exercise represent a combination of these positive and negative impacts. The modelling results at sectoral level in the next section give further insights to these complex interactions.

5.2.3. *Other macro- indicators*

Table 5.2 provides a summary of key macroeconomic indicators in 2030 in the two combined scenarios. Consumer spending increases from higher employment levels, rebounds from other savings, and lower inflation. Demand for recycling plants and from higher rates of economic activity drives up demand for investment. In terms of trade, there is a net reduction in imports due to lower levels of fossil fuel and raw material imports. This reduction is larger than the increase in imports that result from higher levels of economic activity. There is very little change in the level of EU exports, indicating limited impacts on competitiveness.

Table 5.2 Summary of Indicators in 2030, EU (% difference from baseline)

	6a Combined - Ambitious	6b Combined - Moderate
GDP	0.5	0.3
Employment	0.3	0.3
Consumer spending	0.4	0.3
Investment	0.4	0.3
Exports	0.0	0.0
Imports	-0.8	-0.3
Consumer prices	-0.1	-0.1
Labour force	0.1	0.1

Source(s): E3ME, Cambridge Econometrics.

5.2.4. *Results by Member State*

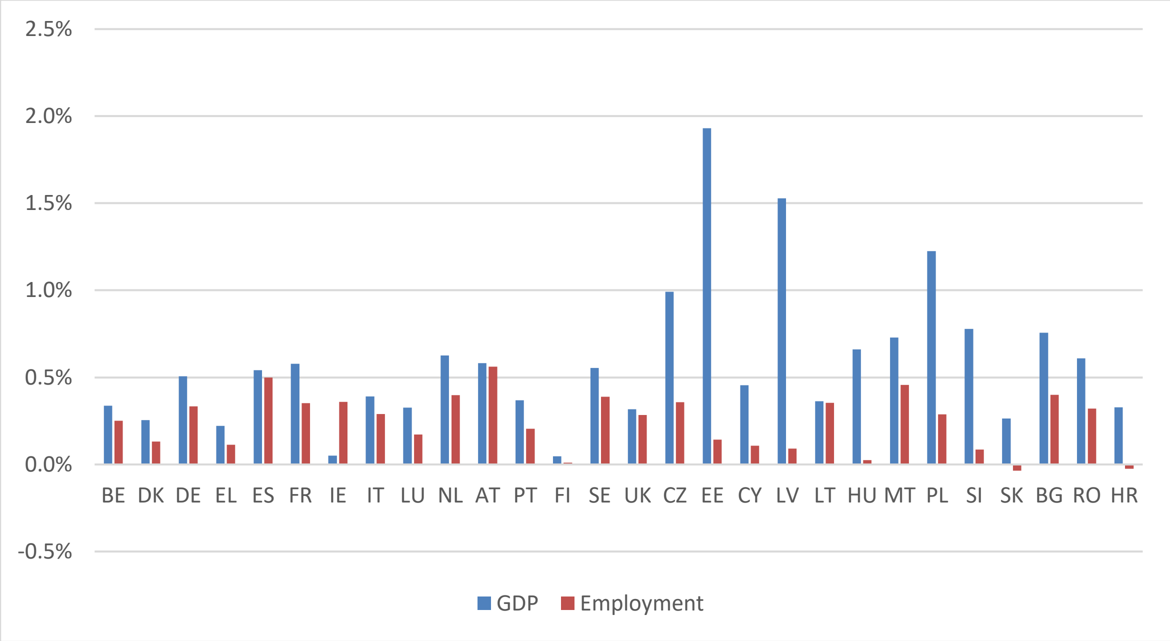
Figure 5.3 presents results for the scenarios disaggregated by Member State. The GDP impacts are positive in all Member States and the employment impacts are positive in most Member States. The variation in the employment results among Member States reflects the different economic structures and labour intensities of the main circular economy activities across the EU.

The GDP results from the modelling are generally higher in the Central and Eastern European countries, primarily due to larger reductions in oil imports in these countries in the scenarios. Despite progress, CEE countries remain relatively more energy-intensive than countries in Western Europe and, as a result, circular economy activities in the motor vehicles sector are more beneficial to them.

Countries in western Europe are more affected by the increase in the share of circular economy activities in the electronics sector. Production of electronics is more concentrated in these countries and so changes to the sector has a proportionally larger impact. In Eastern Europe, electronic devices are mostly imported and so the reduction in demand improves the trade balance and GDP.

Estonia, Latvia, Poland and the Czech Republic see particularly large improvements in GDP from the improved trade balance driven by both the reduction in electronics and oil imports. On the other hand, the GDP impact in Finland is limited. Although the circular economy drives up demand for recycling, there is a reduction in Finland’s main exports such as oil, steel, timbers, chemicals and electronics.

Figure 5.3 Results by Member State in the Combined-Ambitious scenario (% from base)



Source(s): E3ME, Cambridge Econometrics.

5.3. Employment impacts at sectoral level

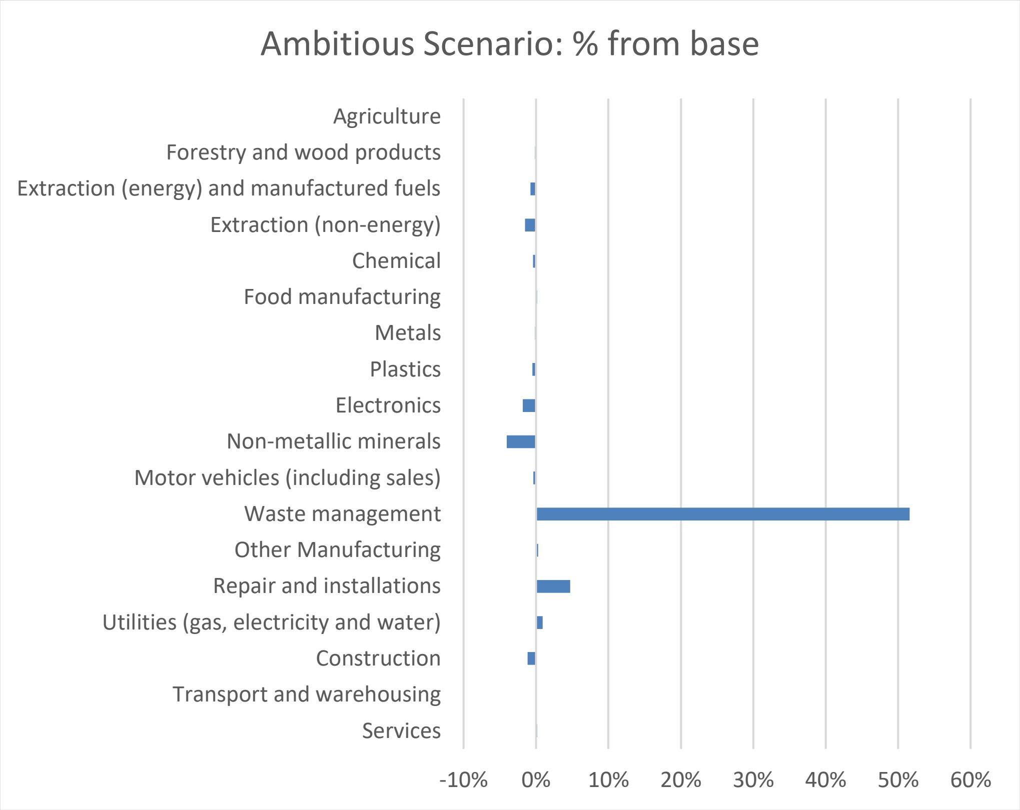
It is estimated that around 700,000 net additional jobs will be created in the Ambitious-Combined circular economy activity scenario. This figure includes both the job losses and gains within and across all sectors of the economy. For example, there is a reduction in agriculture employment demand, as a result of reduction in food waste, but higher demand for organic materials and additional consumer spending compensate the job losses in the sector. Our modelling results show the net impact on agriculture employment to be small but positive.

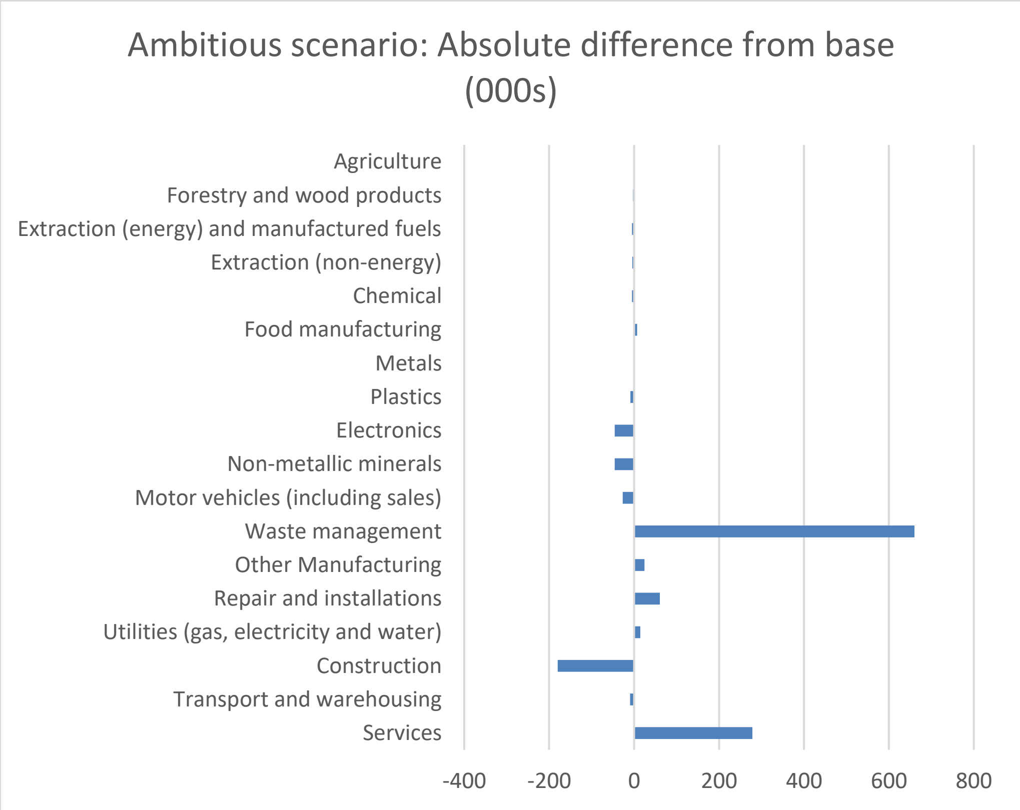
The most obvious shift in employment patterns is between job losses in sectors that extract and process raw materials, and job increases in sectors that offer recycling and repairing services (see

Figure 5.4). It should be noted that the number of jobs in extracting and processing raw materials in Europe has declined continuously over recent history and now makes up only a small share of total employment (which is only apparent in the lower half of the figure). In 2015, the share of the mining and quarrying sector in total EU employment was less than 0.1%. This trend of declining employment minimises the negative employment impacts from the transition to a more circular economy in the EU.

Other sectors are also affected by a shift to more circular economy. Table 5.3 summarises the likely impacts, based on the modelling exercise and the key relationships between the main sectors of the economy.

Figure 5.4 EU28 employment impacts by sector by 2030





Source(s): E3ME, Cambridge Econometrics.

Table 5.3 Summary of EU employment impacts in the Combined-Ambitious scenario by sector by 2030 (differences compared to the baseline)

Sector	Impacts 000s	Impacts %	Key explanations	Baseline 2015-30 (% change in employ-ment)
Agriculture	1.0	0.0%	Increase in demand for organic materials (feed), fertilizers and bioenergy; compensated by the loss in demand from cutting food waste	-18%
Forestry and wood products	-2.8	-0.1%	Reduction in demand from construction	-6%
Extraction (energy) and manufactured fuels	-4.8	-0.7%	Reduction in demand from transport sector	-26%
Extraction (non-energy)	-4.3	-1.5%	Reduction in demand from construction	-20%
Chemicals	-4.7	-0.4%	Reduction in demand from the agriculture sector	-5%
Food manufacturing	5.2	0.1%	Increase due to rebounds in consumer spending and demand for food waste in production which, compensates the loss in demand from cutting food waste	-17%
Metals	-1.2	-0.1%	Reduction in demand from construction, motor vehicles and electronics, although impacts are small as lower demand reduces import volumes	-12%
Plastics	-8.6	-0.5%	Reduction in demand in single-use plastic and from electronics	5%
Electronics	-50.6	-2.1%	Reduction in demand due to fewer purchases (because of more sharing and longer product lifetimes)	-14%
Non-metallic minerals	-45.8	-4.0%	Reduction in demand from construction	-11%
Motor vehicles (including sales)	-26.7	-0.4%	Reduction in demand due to fewer purchases and more sharing	4%
Waste management	660.4	51.6%	Big increase in demand for recycling activity and recycled materials (more labour intensive activity), which offsets decreases in demand for traditional landfill (less labour intensive)	0%
Other Manufacturing	24.4	0.3%	Increase due to rebounds in spending and from recycling plants' investment; outweighs the reduction in demand from other sectors (through supply chains)	-10%
Repair and installation	60.6	4.7%	Increase due to more repair activities	0%
Utilities (gas, electricity and water)	14.5	0.9%	Increase due to higher electricity demand from electric cars (shifting from oil)	-6%

Sector	Impacts 000s	Impacts %	Key explanations	Baseline 2015-30 (% change in employ-ment)
Construction	-179.4	-1.2%	Reduction in employment due to new construction techniques such as modular design which requires less time to build. Also, reduction in demand from collaborative activities in the accommodation sector	5%
Transport and warehousing	-9.2	-0.1%	Reduction due to collaborative action in the road transport sector and less distribution and storage demand for new products (offsets increased demand for recycled materials)	-2%
Services	267.6	0.2%	Increase due to rebounds in spending and increasing demand for technology platform providers and R&D	7%
Total	**695.5**	**0.3%**		3%

Source(s): E3ME, Cambridge Econometrics and CEDEFOP employment projections

5.4. Winners and losers in the scenarios

The objective of this report is to provide a comprehensive quantification of the jobs impacts of circular economy activities. The model-based analysis that was carried out captures both potential job creation due to increased rates of recycling and job losses in extraction and other activities that will see a decline as Europe moves towards a more circular economy. Moreover, the analysis captures employment impacts from indirect and rebound effects on top of the direct changes that we have introduced. We can therefore identify the sectors that are expected to gain and those that are expected to lose out.

Sectors facing reductions in employment

The employment results in the previous section show that the sectors that will see reductions in employment are the mining and extraction sectors. Sectors that process raw materials including wood, non-metallic minerals, chemicals, plastic and metals could also see reductions in employment. By extending product lifetimes and undertaking more collaborative actions (more sharing, less buying), the EU will also see a reduction in demand for sectors that produce durable goods such as cars, accommodation and electronics.

Despite reductions in car purchases, the negative impact on employment in the European car manufacturing sector is limited. There two explanations for this. First, some of the reductions in demand are met through reductions in car imports to the EU. Second, exports of cars remains strong (we do not assume circular economy activities outside the EU in this analysis). The model results show that most of the employment reduction comes from domestic car sales activity rather than production of cars.

Contrary to some of the results from previous studies, construction employment is expected to fall due to the introduction of more efficient building techniques and a reduction in demand for housing from better using existing housing stocks. However, as noted previously, our study excludes energy efficiency in buildings. Construction employment would likely increase if there was a substantial programme of energy efficient investment (European Commission, 2016).

Sectors with increases in employment

The highest levels of job creation will be in the waste management sector. This sector includes both recycling activities and landfill management. The latter will see a decline but a higher demand for recycled materials will drive up demand for the overall sector. The results for job creation also reflect how recycling activities are much more labour-intensive (collecting, sorting, processing, reselling, etc). Landfill management, in contrast, is a highly mechanised process that requires only a small level of labour input.

Another sector that benefits in terms of job creation is the repair sector. Services and some manufacturing sectors also benefit from rebounds in consumer spending and stimulus from recycling demand. Although the agriculture and food sectors will see a reduction in demand if Europe tackles food waste, demand for organic materials and by-products from food production will compensate this loss, resulting in a net small increase in employment.

We have not included renewable energy technologies in our analysis. A push for renewables could lead to further demand for bio-crops, but at the same time generate demand for raw materials (notably metals) to build wind turbines or glass to build solar panels. An increase in these activities could offset the trend of circular economy activities and requires careful management of materials.

5.5. Linking job impacts to occupation and skills

In the modelling, it is in general assumed that workers can easily transfer existing skills between sectors. However, in reality, a worker who loses a job in extraction may not be able to get a new job in the repair sector. Our analysis in the next chapter provides further insights as to what the transition to circular economy means in terms of occupations and skills needs.

6. Changes in Occupations and Skills Needs

6.1. Approach to understanding the impact on occupations and skills

The E3ME modelling quantifies shifts in sector employment under the moderate and ambitious scenarios for the Circular Economy. The baseline scenario indicates how the pattern of employment is estimated to evolve to 2030, independent of the take-up of circular economy activities, reflecting wider drivers of change. The moderate and ambitious scenarios highlight the additional impact of circular economy take-up on employment.

Key sources

The modelling results provide an entry point for assessing the implications for jobs and skills. In order to assess what the projected employment shifts related to circular economy take-up means for jobs and skills, it is important to look at the occupational composition of the most affected sectors. Occupations provide the key for understanding how the skills mix may evolve as a consequence of the sectoral shifts in employment. This analysis is based on modelling results for the disaggregated E3ME sectors. These sectors map to the NACE classification and are generally more detailed than the five priority sectors used to inform the modelling, which intended to capture the lifecycle of products and services. There are two important sources of evidence/information that support such an analysis:

CEDEFOP

- Cedefop’s skills and employment forecast breaks down the occupational composition of sectoral employment at a detailed level to 2030. Looked at alongside the E3ME modelling results on circular economy impact, this provides intelligence on the current distribution of jobs, and therefore skills, within sectors. It also quantifies the distribution of high-, medium- and low-skilled jobs within each occupational group based on the proxy measure of qualification levels, although skill needs in any particular context are obviously much more nuanced in practice.

ESCO

- The ESCO classification of occupations, skills and competences has been developed by the European Commission over a number of years to set out job/skill/knowledge requirements at a highly-granular level. The first full version of ESCO was published in 2017. Its occupational map provides an overview of the skills, competences and knowledge associated with key occupations (as signalled by the Cedefop forecast occupational profile) for the sectors most impacted by circular economy take-up (as indicated by the E3ME modelling).

Sector impacts

in Chapter 5 summarised the employment impacts of the circular economy on key sectors. It showed that the most substantial net employment impacts from the circular economy are concentrated in a small number of sectors. Looking at the disaggregated E3ME sectors, only four sectors are forecast to have a net employment impact of over +/-50,000 jobs across the EU28 by 2030 under the combined/ambitious scenario:

- The sewerage and waste sector is the key area for employment growth linked to the circular economy.
- The repair and installation of machinery sector also shows employment growth related to the additional impact of the circular economy.
- The construction sector shows a significant decline in employment as a consequence of circular economy take-up.
- The electronics sector also shows a net decline in employment linked to the circular economy.

Below we explore the occupation and skills implications of the circular economy for the four sectors anticipated to have a substantial employment impact. For each sector, the potential occupational implications of the E3ME modelling (combined scenario) are described, before looking at the skills associated with key occupations in each sector. The occupational analysis is also broadened out to consider how the sectoral distribution of occupations may figure in an overall understanding of the impact of the circular economy on jobs and skills.

Below we explore the occupation and skills implications of the circular economy for these four sectors. For each sector, the potential occupational implications of the E3ME modelling (combined scenario) are described, before looking at the skills associated with key occupations in each sector. The occupational analysis is also broadened out to consider how the sectoral distribution of occupations may figure in an overall understanding of the impact of the circular economy on jobs and skills.

6.2. Sewerage and waste: The key area for employment growth

By far the most significant circular economy-related impact is on employment in the sewerage and waste sector. The sector is forecast to gain 650,000 jobs (+50.77%) under the combined moderate scenario and 660,000 jobs under the combined ambitious scenario (+51.59%). This is notable because the Cedefop forecast (excluding additional circular economy-related impacts on employment) indicates a small decline in employment in this sector in the period to 2030. Take up of circular economy activities could therefore be transformative for employment in the sewerage and waste sector.

The changing occupational profile

Table 6.1 shows the occupational distribution of the sewerage and waste sector, based on the Cedefop forecast. The current occupational profile is somewhat weighted towards elementary and semi-skilled occupations. Overall, though, the sector comprises a wide range of occupations and no single sub-major occupational group dominates the profile.

The Cedefop forecast highlights a long-term (non-circular economy) shift towards more highly-skilled occupations, such as science and engineering professionals and administrative and commercial managers. However, the scale of change implied by the circular economy modelling suggests that new jobs will be distributed across a range of occupations.

Table 6.1 Sewerage and waste – Distribution of highest-volume occupations, EU28

Sub-major occupational group	Employment		Share		Net change 2018 to 2030
	2018	2030	2018	2030	
Refuse workers and other elementary workers (ISCO 96)	198,989	199,210	16.1%	16.3%	220
Drivers and mobile plant operators (83)	171,316	161,865	13.8%	13.3%	-9,451
Science and engineering associate professionals (31)	159,130	156,055	12.9%	12.8%	-3,076
Science and engineering professionals (21)	76,154	79,871	6.2%	6.5%	3,716
Business and administration associate professionals (33)	65,745	64,694	5.3%	5.3%	-1,051
General and keyboard clerks (41)	49,135	36,873	4.0%	3.0%	-12,262
Numerical and material recording clerks (43)	45,138	35,109	3.6%	2.9%	-10,029
Labourers in mining, construction, manufacturing and transport (93)	44,708	45,764	3.6%	3.8%	1,056
Building and related trades workers, excluding electricians (71)	39,822	34,527	3.2%	2.8%	-5,295
Production and specialised services managers (13)	37,981	38,464	3.1%	3.2%	482

Business and administration professionals (24)	37,580	39,587	3.0%	3.2%	2,007
Stationary plant and machine operators (81)	36,412	39,699	2.9%	3.3%	3,287
Administrative and commercial managers (12)	36,255	44,803	2.9%	3.7%	8,548
Customer services clerks (42)	31,922	40,695	2.6%	3.3%	8,772
Metal, machinery and related trades workers (72)	31,311	17,868	2.5%	1.5%	-13,444
Grand total	*1,237,797*	*1,219,455*	*100%*	*100%*	*-18,342*

Source: Cedefop (2018)

6.2.1. *Priority skills (selected occupations)*

Refuse workers and other elementary workers

The refuse workers and other elementary workers sub-major occupation is the largest group of workers in this most heavily-impacted circular economy-related sector and, as such, may superficially be expected to be an area in which the labour market and skills impact of circular economy take-up is clearest. Table 6.2 shows that these workers are widely distributed across sectors. It also shows that they are concentrated in sectors where circular economy take-up is expected to have a positive impact on employment. As such, the refuse workers and other elementary workers group may embody the kind of skills requirements at elementary level where there is increased demand as a consequence of the circular economy.

Table 6.2 Sectoral distribution of refuse workers and other elementary workers, EU28

Sector	Share of occupational employment in the sector	circular economy impact on sector employment to 2030*
1 Public administration and defence	12.3%	→
2 Education	8.4%	↑
3 Security and office administrative	7.7%	↑
4 Sewerage and waste	**7.7%**	↑
5 Real estate activities	7.1%	→

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

From a skills perspective, slightly over half of refuse workers and other elementary workers in the sewerage and waste sector have medium-level qualifications (53.8%) according to Cedefop data and most of the rest have lower-level qualifications (39.7%). This profile is expected to remain fairly consistent to 2030, with a small shift towards medium- and high-level qualifications. There is a more pronounced shift towards higher-level qualifications for this occupational group in other sectors. As such, there is, in theory, a high potential availability of new entrants to meet any increased demand, even if the impact of circular economy take-up is to increase the demand for these roles across multiple sectors.

The refuse workers and other elementary workers category can be split into different groups of jobs, only some of which are likely to benefit from the circular economy (distinguishing refuse workers from other elementary workers):

- The most relevant roles in the refuse worker minor occupational group are garbage and recycling collectors and refuse sorters. The other category of jobs in this minor group (sweepers and related labourers) is less relevant from a circular economy skills and jobs perspective. It is logical to think that garbage and recycling collectors and refuse sorters will be the elementary waste-related jobs most substantially impacted by the circular economy.
- The other elementary worker minor occupational group includes a group of jobs that also involve collection/delivery (e.g. odd job persons; water and firewood collectors; messengers/package deliverers), some of which are impacted by drivers of change outside

of the circular economy. They are therefore less relevant from the perspective of the circular economy. However, the group also includes meter readers, a job impacted by wider technological/environmental developments.

Table 6.3 shows the essential skills/competences and knowledge associated with the most relevant occupational unit groups based on the ESCO mapping. There is a relatively high degree of commonality in skills and knowledge requirements across the different job roles.

Table 6.3 Skills, competences and knowledge for refuse and recycling workers

	Refuse collector	Recycling worker	Sorter labourer
Essential skills and competences	• assess waste type • collect domestic waste • collect industrial waste • maintain refuse collection equipment • maintain waste collection records • manage waste	• assess waste type • collect broken appliances • dismantle broken appliances • dispose waste • ensure compliance with waste legislative regulations • handle chemical cleaning agents • manage waste • operate recycling processing equipment • troubleshoot • use personal protection equipment	• assess waste type • communicate with waste collectors • dispose waste • handle chemical cleaning agents • operate recycling processing equipment • sort waste • store sorted waste
Essential Knowledge	• health, safety and hygiene legislation • waste and scrap products • waste management	• health, safety and hygiene legislation • waste and scrap products • waste management	• health, safety and hygiene legislation • waste and scrap products • waste management

Source: ESCO v1.0.2

The circular economy is likely to bring new knowledge requirements, but these requirements are likely to be in scope of what is currently required by these roles. The impact of circular economy take-up on these elementary roles is therefore likely to be an upskilling requirement rather than anything that is transformative to jobs.

The optional skills and competences associated with these roles encompass more generic elements, such as the waste/recycling process, monitoring/compliance and maintaining records, alongside technical competence in areas such as dealing with contamination and handling hazardous waste. Optional knowledge brings in areas with wider applicability such as electricity, electronics principles and pollution prevention.

This provides reasonable scope for transferability into these roles in the sewerage and waste sector, with lack of knowledge likely to be the main barrier. However, the cross-cutting nature of these requirements perhaps indicates areas of knowledge with wider applicability for supporting the growth of the circular economy (i.e. health, safety and hygiene legislation; waste management; pollution prevention etc).

Drivers and mobile plant operators

The drivers and mobile plant operators sub-major occupation is the second largest group in the sewerage and waste sector, although it is not clear that circular economy take-up will substantially impact on these jobs or associated skill requirements. Table 6.4 highlights that only a very small share of these jobs are in the sewerage and waste sector. They are primarily concentrated in the land transport sector, where circular economy take-up (even under the ambitious scenario) is anticipated to have a neutral effect on employment.

Table 6.4 Sectoral distribution of drivers and mobile plant operators, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1 Land transport	43.3%	→
2 Construction	7.6%	↓
3 Other retail trade	7.1%	→
4 Warehousing	4.8%	→
5 Other wholesale trade	3.6%	→
6 Agriculture	3.4%	→
7 Food, Drink & Tobacco	2.9%	→
8 Postal and courier activities	2.9%	→
9 Sewerage and waste	**1.8%**	↑

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

The occupational group encompasses a set of jobs that share skills in areas such as machine/vehicle operation, but deploy these skills in quite different contexts and in combination with sector-specific skills and knowledge. Excluding minor occupational groups related to maritime, rail and passenger transport (e.g. taxi and motorcycle drivers), as well as agriculture and construction-related mobile plant operation roles, the key jobs within the sewerage and waste sector that may be impacted by the circular economy are within the heavy truck and lorry driver minor group, namely, refuse vehicle drivers (see Table 6.5).

There is no evidence of changing skill requirements that are circular economy-related for this group and the impact of the circular economy in this context may be about the overall number of jobs. However, the Cedefop forecast suggests a small decline in the number of driver and mobile plant operator jobs in the sewerage and waste sector to 2030 before circular economy-related impacts are taken into account. Substantial circular economy growth could create additional demand for drivers that mitigates this forecast decline, but this may just mean that employment levels are steady rather than growing.

Table 6.5 Skills, competences and knowledge for refuse vehicle drivers

	Essential	Optional
Skills and competences	• adhere to transportation work schedule • drive waste collection vehicle • maintain waste collection records • park vehicles in depot • use personal protection equipment	• assess waste type • collect domestic waste • collect industrial waste • dispose of hazardous waste • dispose of non-hazardous waste • empty community waste collection bins • establish waste collection routes • maintain refuse collection equipment • maintain septic tanks • operate GPS systems • read maps
Knowledge	• types of waste collection vehicles • waste and scrap products • waste management • waste transport legislation	• hazardous materials transportation • hazardous waste storage • road transport legislation

Source: ESCO v1.0.2

Science and engineering associate professionals

Science and engineering associate professional roles are an important component of a number of the sectors impacted by the circular economy:

- They represent the third largest occupational group in both the sewerage and waste sector and the repair and installation sector – which are sectors forecast to see an increase in employment as a consequence of circular economy take-up.

- Yet they are also the second largest group in the construction sector and the third largest group in the electronics sector, both of which will have circular economy-related decline in employment.
- Table 6.6 shows that relatively few science and engineering associate professionals currently work in the sectors anticipated to experience circular economy-related employment growth; while the negatively-impacted construction sector has the highest concentration of these jobs across the entire economy.

Table 6.6 Sectoral distribution of science and engineering associate professionals, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1 Construction	15.8%	↓
2 Architectural & engineering	9.5%	↑
3 Other machinery & equipment	4.9%	→
4 Public administration and defence	4.5%	→
5 Metal products	4.4%	→
6 Other retail trade	4.3%	→
7 Food, Drink & Tobacco	3.8%	→
8 Motor Vehicles	3.6%	→
15 Sewerage and waste	**2.0%**	↑
19. Optical & electronic equipment	**1.5%**	↓
20. Repair/installation of machinery	**1.4%**	↑

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

It is not, therefore, straightforward to describe the impact of the circular economy on science and engineering associate professional jobs and skills in linear terms. However, the ESCO occupational map provides a way to understand the extent to which the specific occupations most closely associated with key circular economy sectors share common skills and knowledge:

- The minor occupational group most closely associated with the sewerage and waste sector is process control technicians. Most process control jobs relate to energy and manufacturing sectors (power production plants, chemicals, gas processing and chemical plants), which are not forecast to be substantially impacted overall by circular economy take-up. The most relevant occupational unit group is incinerator and water treatment plant operators, which encompasses a variety of technician and operator process control roles where circular economy take-up may transform processes and knowledge requirements (rather than overall employment levels).
- Looking beyond jobs in the sewerage and waste sector specifically, it is possible that circular economy take-up will impact on the physical and engineering science technician minor occupational group. Even in sectors where circular economy take-up has a marginal employment effect, technological innovations driven by the needs of the circular economy could evolve technician processes and knowledge requirements across some electrical, mechanical and chemical engineering roles (and perhaps even more so for electronics engineering technicians specifically). The group also includes civil engineering technician roles found in the construction sector. However, it is not clear from the literature that any decline in construction employment associated with circular economy take-up would specifically affect these jobs. Indeed, some of these civil engineering roles are specifically associated with circular economy-related matters and could experience increased demand (e.g. energy conservation officers; energy consultants).
- The minor occupational group of mining, manufacturing and construction supervisors is likely to be affected differently by sector. At a micro-level, there may be some offsetting from lower demand for mining supervisors to increased demand for waste-related supervisors, but the overall number of jobs concerned is likely to be incredibly small. The wide range of construction-related supervisory roles could feel the impact on circular economy-related decline in employment, although, given that these roles combine a general supervisory competence

with technical/trades-related skills, this is likely to be inconsequential to the sector meeting future skills-related challenges, which depend on effective supply of specialist skills.

Irrespective of sector, the Cedefop forecast describes a split between medium- and high-level qualifications required for the vast majority of these roles. Across all relevant sectors, there is anticipated to be a shift from medium to high-level jobs up to 2030, suggesting a more general upskilling requirement.

While civil engineering associate roles tend to have a more distinctive skill set within this sub-major occupational group, Table 6.7 shows the degree of alignment in skill/competence requirements across other science and engineering associate professional minor occupational groups. While there is clearly sector-specialist skills and knowledge requirements that are role-related, there is also a requirement for more transversal skills related to design, monitoring, operations and communications activities at the associate professional level.

For this important occupational group, this finding may indicate something about the overarching skills and knowledge that could be associated with circular economy take-up. It also shows that, even for sectors expected to be negatively impacted in terms of employment overall, the picture at the level of specific job roles might be more complex.

Table 6.7 Skills, competences and knowledge for selected science and engineering associate professional workers

	Solid waste operator (Process control technician)	**Electronics engineering technician (Physical and engineering science technicians)**	**Waste management supervisor (Mining, manufacturing and construction supervisors)**
Essential skills and competences	• assess waste type • communicate with waste collectors • control delivered waste • dispose of non-hazardous waste • ensure compliance with environmental legislation • ensure compliance with waste legislative regulations • ensure equipment availability • maintain recycling records • monitor waste treatment equipment • operate recycling processing equipment • test samples for pollutants • troubleshoot	• adjust engineering designs • align components • apply soldering techniques • assemble electronic units • assist scientific research • conduct performance tests • configure electronic equipment • ensure finished product meet requirements • fasten components • inspect quality of products • interpret electronic design specifications • liaise with engineers • meet deadlines • prepare production prototypes • read assembly drawings • read engineering drawings • record test data • solder electronics • test electronic units • use testing equipment	• design plant waste procedures • ensure compliance with policies • ensure compliance with waste legislative regulations • establish waste collection routes • liaise with managers • manage recycling program budget • manage staff • perform planning • supervise staff • supervise waste disposal • supervise work • supervise worker safety
Essential Knowledge	• waste and scrap products • waste management	• circuit diagrams • design drawings • electronic components • electronic equipment standards	• health, safety and hygiene legislation • waste management

		• electronic test procedures • electronics • integrated circuits • printed circuit boards • types of electronics	

Source: ESCO v1.0.2

Science and engineering professionals

Science and engineering professionals are one of the few relatively large groups in the sewerage and waste sector anticipated to grow based on the Cedefop forecast – i.e. even before the additional impact of take-up of circular economy activities is considered. They are a significant component of most of the sectors anticipated to be impacted by the circular economy. As well as being the fourth largest group in the sewerage and waste sector, they are the second largest group in the electronics sector.

However, as Table 6.8 shows, only a small proportion of science and engineering professionals work in these sectors. While only being the seventh largest group in the construction sector, the number of science and engineering professionals working in construction is more than double the combined number working in the sewerage and waste and electronics sectors.

While circular economy take-up affects the various sectors where science and engineering professionals are concentrated in various ways (as Table 6.8 shows), the number jobs is expected to increase to 2030 in all relevant sectors based on the Cedefop forecasts, irrespective of the overall sectoral employment trends. This indicates that any negative employment impacts directly related to circular economy take-up are less likely to impact on science and engineering professionals specifically. The skills challenge, such that it is, may relate to lack of supply to meet future demand; something that is relevant to, but not driven by, the labour market impact of the circular economy.

Table 6.8 Sectoral distribution of science and engineering professionals, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1 Architectural & engineering	17.2%	↑
2 Construction	7.5%	↓
3 Public administration and defence	6.0%	→
4 Research & Development	5.8%	↓
5 Education	3.8%	↑
6 Motor Vehicles	3.8%	→
7 Other machinery & equipment	3.5%	→
12. Optical & electronic equipment	2.3%	↓
25 Sewerage and waste	1.2%	↑

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

Science and engineering professional jobs in the sewerage and waste sector are almost exclusively the preserve of people with higher-level qualifications (94.7% in 2018, compared with 82.0% of science and engineering professionals across all sectors). The qualifications profile of these workers in both the construction and electronics sector is closer to the average position.

Unlike science and engineering associate professional roles, there is little scope for, or expectation of, further substantial shifts towards higher-level qualifications to 2030 based on the Cedefop forecast. This reflects the highly-skilled, technically specialist nature of existing jobs across physical sciences, mathematics, life sciences, engineering, electro-technology and architecture/planning.

The higher-skilled nature of the workforce, combined with the level of technical specificity within sectors, inhibits the potential for skills transfer and creates ongoing skills challenge in terms of the time required to train these professionals. It necessarily limits pools of labour supply that employers can draw on. None of these issues are specific to the circular economy and, indeed, in terms of supply, the anticipated circular economy-related net increase in employment in some sectors is inconsequential in the context of wider factors driving up demand for science and engineering professionals.

While it is possible, based on the literature, to identify jobs that may be boosted by circular economy-related matters, such as industrial designers within the architects, planners, surveyors and designers minor occupational group and environmental protection professionals within the life sciences professionals minor occupational group, the E3ME modelling puts in context that the number of these jobs is relatively small in the context of the overall labour market.

The labour market implications of the circular economy in this context therefore align with challenges faced by policy makers more widely in terms of ensuring future skills supply (the STEM skills agenda) and upskilling to maintain skills and knowledge where technological advances continue to evolve the working environment. The circular economy is extremely pertinent in this context, but its additional effect is marginal.

Business and administration associate professionals

The fifth largest occupational group in the sewerage and waste sector, business and administration associate professionals, is also concentrated in sectors in which the circular economy is expected to increase employment. Only a small share of these jobs is currently found in the sewerage and waste sector (see Table 6.9). This indicates that there is a much larger labour pool to draw on, but it may suggest that the real issue for attracting people into new sewerage and waste jobs is that current routes into the sector are ad hoc and small-scale. There could be a need to support pathways into the sector (careers advice, sector-specific training) to effectively meet future skill needs.

Table 6.9 Sectoral distribution of business and administration associate professionals, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1 Legal and accounting	15.7%	↑
2 Public administration and defence	14.1%	→
3 Financial services	6.8%	↑
4 Other retail trade	6.5%	→
5 Security and office administrative	5.5%	↑
44 Sewerage and waste	**0.4%**	↑

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

6.3. Repair and installation of machinery: Substantial growth

The literature indicates that repair and remanufacture activities are a likely growth area as a result of circular economy take-up. However, the jobs associated with this kind of activity are widely dispersed across the economy. The E3ME model suggests that circular economy-related employment growth is focused on the repair and installation of machinery sector and is driven by the circular economy impact on the electronics lifecycle sector.

The sector is forecast to gain 25,000 jobs across the EU28 (+2.0%) under the moderate scenario and 64,000 jobs (+4.7%) by 2030 under the ambitious scenario as a consequence of circular economy take-up. In terms of scale, this is a much more modest increase than that related to the sewerage and waste sector. As the second largest beneficiary of a circular economy-related employment boost, this highlights that the overall impact on employment levels is relatively small-scale. The Cedefop forecast (before circular economy-related take-up is accounted for) indicates only a marginal increase in employment in the repair and installation of machinery sector up to 2030, albeit with some substantial occupational shifts.

The scope of the sector, based on the NACE definition, includes 'the specialised repair of goods produced in the manufacturing sector with the aim to restore machinery[11]'. This encompasses routine repair, but does not include the rebuilding or remanufacture of machinery and equipment, which is considered a manufacturing category. The sector classification and the E3ME modelling separates out the repair of computers and personal and household goods, for which the forecast suggests that circular economy-take-up will have a minimal net employment impact (and which includes the repair of: consumer electronics; household appliances; footwear and leather goods; watches, clocks and jewellery; furniture and home furnishings).

The changing occupational profile

The repair and installation of machinery sector includes a diverse occupational profile with a preponderance of associate professional and craft and related trades jobs.

Table 6.10 lists the largest occupational groups in the sector. It shows an anticipated decline in craft and related trades employment based on the Cedefop forecast. The occupational profile also reflects the wide array of equipment in scope of the sector, which ranges from metal products and machinery, through electronic and optical equipment (including medical equipment), to electrical equipment and a range of transport equipment (excluding motor vehicles).

There is no evidence that circular economy take-up will reverse the forecast decline in craft and trades roles in this sector specifically and, if it does, this is likely to protect jobs rather than lead to skills shortages (all other things being equal). The literature indicates potential circular economy-related growth in remanufacture as an activity, which is anticipated to create a mix of high and low skilled jobs. However, this trend tends not be related to equipment and machinery so much as other goods and services (it could be both, of course).

As the E3ME modelling suggests little overall employment impact from circular economy take-up in the repair of computers and personal and household goods sector, this perhaps indicates that the 'remanufacture agenda', while potentially leading to the new development of new services, only creates a small number of jobs overall. The relevant activities are only a small component of the household goods repair sector. In contrast with the crafts-focused repair and installation of machinery sector, the occupational profile of the repair of computers and personal and household goods sector is much more geared towards service workers - with the largest groups being personal service workers (31.2%), cleaners and helpers (17.0%) and personal care workers (6.8%).

Table 6.10 Repair and installation – Distribution of highest-volume occupations, EU28

Sub-major occupational group	Employment		Share		Net change 2018 to 2030
	2018	2030	2018	2030	
Metal, machinery and related trades workers (ISCO 72)	189,402	168,760	14.7%	13.1%	-20,643
Food processing, wood working, garment and other craft and related trades (75)	186,326	143,113	14.5%	11.1%	-43,213
Science and engineering associate professionals (31)	114,146	126,752	8.9%	9.9%	12,606
Labourers in mining, construction, manufacturing and transport (93)	63,287	64,418	4.9%	5.0%	1,131
Health associate professionals (32)	61,529	66,597	4.8%	5.2%	5,068
Electrical and electronic trades workers (74)	61,436	57,225	4.8%	4.5%	-4,211

[11] Eurostat (2008), NACE Rev. 2 - Statistical classification of economic activities in the European Community

Business and administration associate professionals (33)	56,796	60,430	4.4%	4.7%	3,634
Handicraft and printing workers (73)	53,378	45,109	4.2%	3.5%	-8,269
Building and related trades workers, excluding electricians (71)	48,482	54,039	3.8%	4.2%	5,557
Science and engineering professionals (21)	48,174	64,405	3.8%	5.0%	16,232
Stationary plant and machine operators (81)	47,884	47,763	3.7%	3.7%	-121
Assemblers (82)	45,447	45,622	3.5%	3.5%	175
Numerical and material recording clerks (43)	43,259	36,770	3.4%	2.9%	-6,489
Production and specialised services managers (13)	37,468	40,683	2.9%	3.2%	3,215
General and keyboard clerks (41)	34,367	29,847	2.7%	2.3%	-4,520
Drivers and mobile plant operators (83)	31,477	36,262	2.5%	2.8%	4,786
Grand total	*1,284,521*	*1,285,575*	*100%*	*100%*	*1,054*

Source: Cedefop (2018)

6.3.1. *Priority skills (Selected occupations)*

Metal, machinery and related trades workers

Although the largest occupational group in the repair and installation sector, the vast majority of metal, machinery and related trades workers operate in other sectors (see Table 6.11). This situation partly reflects the fact that many sub-occupational groups are more closely associated with installation rather than repair (e.g. container equipment assemblers within the sheet metal workers occupational unit group, as well as a range of job roles within the category of structural-metal preparers and erectors).

The most relevant minor occupational group is machinery mechanics and repairers, which covers transport, agricultural and industrial machinery technicians and mechanics. There is little evidence that these roles would see a circular economy-related growth. However, essential skills for these roles include handling and disposal of goods and waste (hazardous and non-hazardous), the requirements for which could evolve as a consequence of the circular economy. These skills are relatively transferable in the context of job requirements that generally centre on the use of tools. The findings suggest that, irrespective of the circular economy impact on these occupations (which is expected to be minor in scale), it is likely that these jobs will evolve though skills updating activities.

Table 6.11 Sectoral distribution of metal, machinery and related trades workers, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1. Other retail trade	17.7%	→
2. Metal products	17.2%	→
3. Other machinery & equipment	9.2%	→
4. Other wholesale trade	9.1%	→
5. Construction	5.9%	↓
10. Repair/installation of machinery	**2.3%**	↑

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

Food processing, wood working, garment and other craft and related trades

The second largest occupational group in the repair and installation sector is food processing, wood working, garment and other craft and related trades workers. The Cedefop forecast anticipates that this occupation will experience the largest absolute decline in sector employment before the impact of circular economy take-up is taken into account.

The specific occupational areas in this diverse group that relate to the repair and installation of machinery are marginal to the group itself. Fewer than 5% of these jobs are in the repair sector (see Table 6.12). This share includes niche workers 'not elsewhere classified' such as optical lens finishers and moulders.

However, it is notable that food processing, wood working, garment and other craft and related trades workers are predominantly found in sectors for which circular economy take-up under the ambitious scenario is expected to be positive or neutral. While the overall impact of circular economy take-up on employment in those sectors is marginal, this may hint at a group of jobs that will be in greater demand across the economy as a result of the circular economy.

One of the challenges is that the literature related to circular economy growth in these areas (e.g. remanufacture) alludes to potential jobs that do not map well to the current occupational landscape. Looking beyond the repair and installation of machinery, the relevant minor occupations that most closely map to circular economy activities are various furniture-related roles. These may provide insight into the types of skills and knowledge that some future remanufacture jobs could require (see Table 6.13).

Table 6.12 Sectoral distribution of Food processing, wood working, garment and other craft and related trades workers, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1. Food, Drink & Tobacco	23.9%	→
2. Textiles, Clothing & Leather	13.5%	↑
3. Manufacturing nes	8.3%	↑
4. Other retail trade	7.4%	→
5. Construction	6.6%	↓
6. Repair/installation of machinery	**4.6%**	↑

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

Table 6.13 Skills, competences and knowledge for selected food processing, wood working, garment and other craft and related trades workers

	Furniture upholsterer (Garment and related trades workers)	Furniture restorer (Wood treaters, cabinet-makers and related trades workers)
Essential skills and competences	• clean furniture • create patterns for textile products • cut textiles • decorate furniture • fasten components • install spring suspension • perform upholstery repair • provide customized upholstery • sew pieces of fabric • sew textile-based articles • use manual sewing techniques	• apply a protective layer • apply restoration techniques • assess conservation needs • create smooth wood surface • create wood joints • do historical research • document restoration • estimate restoration costs • evaluate restoration procedures • join wood elements • operate wood sawing equipment • provide conservation advice • sand wood • select restoration activities

Essential Knowledge	• furniture industry • furniture trends • textile materials • upholstery fillings • upholstery tools	• art history • conservation techniques • technical drawings • types of wood

Source: ESCO v1.0.2

6.4. Construction: Decline masking growth opportunities

The E3ME modelling indicates that the largest negative employment effect resulting from circular economy take-up relates to the construction sector. Under the ambitious scenario, the sector is forecast to lose 182,000 jobs by 2030 (or 84,000 jobs under moderate scenario). These are large numbers but, given the overall size of the sector, this only relates to a 0.5-1.2% decline in employment as a consequence of circular economy take-up.

The Cedefop forecast anticipates an increase in employment of over 600,000 across the EU28 in the construction sector from 2018 to 2030. The additional impact of circular economy take-up is therefore relatively marginal, although forecasting construction sector employment levels is particularly challenging given its volatility in relation to the economic cycle.

The changing occupational profile

The Cedefop forecast indicates that future growth in construction employment will be concentrated on managerial, professional and associate professional roles (see Table 6.14). It is likely that the occupational impact of the circular economy will follow this lead, with higher-skilled roles replacing some lower-skilled and trades-related roles.

These trends could translate into circular economy-related growth in science and engineering associate professional roles (and some upskilling of those roles), as described in Section 2 of this chapter. The other high-skilled sub major occupational group expected to grow based on the Cedefop forecast is production and specialised services managers (i.e. construction managers). While it is not clear from the literature that circular economy take-up will create jobs in this area, the overall pattern suggests that the picture is not uniformly negative.

Table 6.14 Construction – Distribution of highest-volume occupations, EU28

Sub major occupational group	Employment		Share		Net change 2018 to 2030
	2018	2030	2018	2030	
Building and related trades workers, excluding electricians (ISCO 71)	6,239,233	6,123,562	42.9%	40.3%	-115,672
Science and engineering associate professionals (31)	1,251,619	1,450,184	8.6%	9.6%	198,565
Electrical and electronic trades workers (74)	1,188,582	1,189,109	8.2%	7.8%	527
Labourers in mining, construction, manufacturing and transport (93)	957,192	954,963	6.6%	6.3%	-2,229
Drivers and mobile plant operators (83)	716,325	670,103	4.9%	4.4%	-46,222
Production and specialised services managers (13)	664,845	804,091	4.6%	5.3%	139,246
Science and engineering professionals (21)	495,025	516,237	3.4%	3.4%	21,213
Metal, machinery and related trades workers (72)	480,243	444,280	3.3%	2.9%	-35,963
Business and administration associate professionals (33)	370,606	428,248	2.5%	2.8%	57,642
General and keyboard clerks (41)	363,716	357,176	2.5%	2.4%	-6,541

Numerical and material recording clerks (43)	272,671	264,261	1.9%	1.7%	-8,410
Food processing, wood working, garment and other craft and related trades (75)	267,662	353,611	1.8%	2.3%	85,949
Business and administration professionals (24)	155,143	213,741	1.1%	1.4%	58,597
Administrative and commercial managers (12)	145,028	213,220	1.0%	1.4%	68,192
Grand total	*14,546,909*	*15,180,308*	*100%*	*100%*	*633,399*

Source: Cedefop (2018)

6.4.1. *Priority skills (selected occupations)*

Building and related trades workers

Building and related trades workers represent more than two in five construction jobs. It is a sub major occupational group that is primarily concentrated in the construction sector (see Table 6.15). The Cedefop forecast estimates that, even though construction sector employment is anticipated to grow by over 600,000 across the EU28 from 2018 to 2030, the number of building and related trades workers is anticipated to fall by over 100,000. This decline is likely to be mirrored in terms of circular economy-related impact.

The occupational group can be segmented into building frame and related trades workers, building finishers and related trades workers and painters, building structure cleaners and related trades workers. There is no evidence that any particular specialist group within these categories is likely to be specifically negatively affected by circular economy take-up. Any circular economy-related decline in employment may be experienced across the full range of specialist building trades, reflecting changes in the volume of building activity and maintenance requirements. However, much more significant from a policy perspective will be the probable upskilling requirement across the board related to new materials and design driven by circular economy needs.

Table 6.15 Sectoral distribution of building and related trades workers, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1. Construction	**71.2%**	↓
2. Security and office administrative	2.8%	↑
3. Real estate activities	2.0%	→
4. Other retail trade	1.9%	→
5. Public administration and defence	1.6%	→
6. Rubber and plastic products	1.4%	↓

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

The cyclical nature of construction sector employment means that meeting skills demand during growth periods is a general challenge faced by the sector. It is not clear that the effects of the circular economy will do anything to change these patterns and the overall effect of the circular economy on employment is dwarfed by other drivers. The evidence suggests a substantial shift in the occupational mix within the sector over the next decade that could in itself create a skills challenge. The impact of circular economy take-up in this context is likely to amplify existing challenges that are primarily driven by other factors (such as the use of new technologies within the construction process).

Labourers in mining, construction, manufacturing and transport

The fourth largest sub major occupational group in the construction sector is labourers. These elementary roles are fairly widely distributed across the economy, ranging from freight handlers, to shelf fillers and factory hands. They are more concentrated in sectors anticipated to be negatively or neutrally affected by circular economy take-up (see Table 6.16).

The relevant occupational unit groups in a construction context are building construction labourers and civil engineering labourers. While new processes associated with increased resource efficiency may reduce demand for labour, this is likely to be connected to other, non-circular economy drivers of change.

Of more significance from a labour market perspective is forecast changes to qualification levels of labourers in construction. The Cedefop forecast anticipates a decline in the share of these workers with low-level qualifications from 43.4% in 2018 to 33.3% in 2030, which suggests that there will be fewer opportunities, even among elementary jobs, for people below the medium-qualified level.

Table 6.16 Sectoral distribution of Labourers in mining, construction, manufacturing and transport, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1. Other retail trade	16.9%	→
2. Construction	**14.3%**	↓
3. Other wholesale trade	8.8%	→
4. Food, Drink & Tobacco	5.6%	→
5 Warehousing	4.9%	↓
24. Repair/installation of machinery	**0.9%**	↑

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

6.5. Electronics

The electronics sector is forecast to lose fewer jobs as a consequence of circular economy take-up than the construction sector, but to lose a larger share of its current employment base. Employment is anticipated to decline by 25,000 (-1.9%) under the moderate scenario and 64,000 under the ambitious scenario (-4.9%) within the combined scenario by 2030. To put this in context, the Cedefop forecast (excluding additional circular economy impact) indicates a net increase in employment of 74,660 from 2018 to 2030. The negative employment impact of circular economy take-up (under the ambitious scenario) is therefore roughly equivalent to the expected level of employment growth over the next decade.

The changing occupational profile

Table 6.17 sets out the occupational mix of the electronics sector, and highlights forecast growth for both lower- and higher-skilled occupations before the impact of circular economy take-up is taken into account. Given that the circular economy-related decline in employment driver is a function of lower consumer demand as a consequence of increased collaborative use and longer product lifespans, it might be expected that the impact is focused on occupations such as assemblers and electrical and electronic trades workers. The former is expected to grow, while the latter is expected to decline under the non-circular economy forecast.

Table 6.17 Electronics – Distribution of highest-volume occupations, EU28

Sub major occupational group	Employment		Share		Net change 2018 to 2030
	2018	2030	2018	2030	
Assemblers (ISCO 82)	171,970	189,163	13.6%	14.1%	17,193
Science and engineering professionals (21)	152,246	157,327	12.0%	11.7%	5,081
Science and engineering associate professionals (31)	121,562	109,206	9.6%	8.1%	-12,356
Electrical and electronic trades workers (74)	93,708	82,769	7.4%	6.2%	-10,939
Information and communications technology professionals (25)	88,352	104,183	7.0%	7.8%	15,831
Business and administration associate professionals (33)	72,781	76,019	5.7%	5.7%	3,239
Business and administration professionals (24)	61,565	71,202	4.9%	5.3%	9,637
Numerical and material recording clerks (43)	61,367	53,570	4.8%	4.0%	-7,797
Metal, machinery and related trades workers (72)	48,954	40,429	3.9%	3.0%	-8,525
Production and specialised services managers (13)	46,836	52,420	3.7%	3.9%	5,584
Administrative and commercial managers (12)	45,915	58,793	3.6%	4.4%	12,879
Stationary plant and machine operators (81)	41,809	58,003	3.3%	4.3%	16,195
Labourers in mining, construction, manufacturing and transport (93)	41,406	50,402	3.3%	3.8%	8,996
Information and communications technicians (35)	37,217	35,254	2.9%	2.6%	-1,963
Grand total	*1,267,867*	*1,342,527*	*100%*	*100%*	*74,660*

Source: Cedefop (2018)

Other workers, especially those in professional roles, may be positively impacted by circular economy-related drivers to the extent that consumer demand drives product design or manufacturing processes. Table 6.18 shows that the small, but growing, ICT professionals sub major group is concentrated in sectors in which circular economy take-up is anticipated to boost employment. While not to a scale that would in itself likely lead to skills shortages, this highlights how difficult-to-measure granular shifts in employment associated with the circular economy could contribute to future skills shortages.

Table 6.18 Sectoral distribution of Information and communications technology professionals, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
1. Computer programming, info serv	43.2%	↑
2. Public administration and defence	4.9%	→
3. Financial services	4.1%	↑
4. Legal and accounting	3.5%	↑
8. Optical & electronic equipment	**2.5%**	↓

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

6.5.1. *Priority skills (selected occupations)*

Assemblers & Electrical and electronic trades workers

Assemblers and electrical and electronic trades workers are two of the largest sub major occupational groups in the electronics sector (alongside the science and engineering professional/associate professional roles discussed in Section 2 of this Chapter). While these roles sit within different major occupational groups, it is useful to consider them in parallel when looking at potential skills implications of circular economy take-up. Table 6.19 shows that these two groups of workers are concentrated in similar sectors (as well as electronics, this includes construction, electrical equipment manufacture and the other machinery and equipment sector) and the employment effect of circular economy take-up is generally neutral.

While the non-circular economy forecast predicts growth in the assembler group and decline in the electrical and electronics trade group, this is one area where the circular economy might indicate the opposite trend occurring. Increased re-use and extension of product lifecycles could create demand for repair technicians at the expense of product manufacturing roles. Table 6.20 compares the essential skills/competence and knowledge requirements of an example assembler role and a trades role working in electronics. While acknowledging that job roles will themselves evolve as a consequence of circular economy take-up and wider drivers of change, it is notable that repair and maintenance roles have simpler knowledge requirements and broader (more cross-cutting) competence requirements than assembler roles.

Table 6.19 Sectoral distribution of assemblers and electrical and electronic trades workers, EU28

Sector	Share of occupational employment in the sector	Circular economy impact on sector employment to 2030
Assemblers		
1. Motor Vehicles	18.6%	→
2. Electrical equipment	13.1%	→
3. Optical & electronic equipment	10.0%	↓
4. Other machinery & equipment	8.3%	→
5. Manufacturing nes	4.3%	↑
6. Construction	3.9%	↓
Electrical and electronic trades workers		
1. Construction	35.0%	↓
2. Other retail trade	5.3%	→
3. Electrical equipment	4.5%	→
4. Other machinery & equipment	3.6%	→
8. Optical & electronic equipment	2.8%	↓

Source: Occupational employment – Cedefop (2018); circular economy impact – E3ME modelling
Circular economy impact based on combined ambitious scenario (+/- 0.2%)

Table 6.20 Skills, competences and knowledge for selected assembler and electrical and electronic trades workers

	Printed circuit board assembler (Electrical and electronic equipment assemblers)	Consumer electronics repair technician (Electronics mechanics and servicers)
Essential skills and competences	• apply through-hole technology manually • assemble printed circuit boards • coat printed circuit board • ensure conformity to specifications • ensure public safety and security • meet deadlines • operate insertion mount machine • prepare board for soldering • read assembly drawings • solder components onto electronic board	• apply company policies • create solutions to problems • maintain customer service • maintain equipment • provide customer follow-up services • provide customer information related to repairs • repair equipment on site • replace defect components • set up consumer electronics • troubleshoot • use repair manuals
Essential Knowledge	• circuit diagrams • electronics • integrated circuits • printed circuit boards • semiconductors • through-hole technology	• consumer electronics • electronics

Source: ESCO v1.0.2

The Cedefop forecast describes an anticipated decline at the mid-level within the assembler group to 2030. While the share of assembler jobs in electronics with low-level qualifications will remain static at around a quarter of the workforce, there is anticipated to be a shift from medium to high-level qualifications (from 6.0% of the workforce holding high level qualifications in 2018 to 13.1% in 2030). While the share of highly-qualified electrical and electronic trades workers also increases slightly over the same period (from 14.6% to 17.5%), there is not a similar scale of decline in share at medium-level (-1.1% compared with an -8.3% decline for assemblers). If one impact of the circular economy is to shift demand from assembly to repair, this may be consistent with an increased demand for higher skilled levels and more cross-cutting skills.

6.6. Conclusions / Implications for skills demand

Looking across the various sectors and occupations, the additional impacts of the circular economy are relatively small-scale in comparison with other drivers of change. This suggests that take-up of circular economy activities does not in itself have a transformative effect on labour markets, even under the ambitious scenario. However, this does not mean that the jobs and skills implications of the circular economy are negligible, or that there is no value in considering what the long-term impacts might be. It shows instead that change is gradual and that the impact of the circular economy should be viewed in the context of non-circular economy labour market changes (i.e. the additional effects of circular economy uptake do not take place in a vacuum). Drivers such as automation, innovation and the evolution of global markets feed the potential of the circular economy, as well as acting on labour markets more broadly.

From a skills perspective, the literature indicates changing demand for skills linked to the circular economy that generally aligns with other drivers of change, such as the impact of technological change on jobs and the shift towards high-skilled jobs in some sectors. In this context, the circular economy may amplify certain areas of future skills demand, where future demand is already being shaped by global drivers of change.

Even in the small number of sectors where the impact of the circular economy on employment runs counter to the prevailing trend, the net employment impact of the circular economy is marginal. For example, forecast growth in construction sector employment to 2030 may just be slightly mitigated by a negative employment impact associated with the circular economy, meaning that overall employment levels are steady. Furthermore, even where there is a decline in occupational employment, there is likely to be a changing demand for skills associated with those jobs. The possible decline in the number of specialist building trades jobs, for example, is probably less significant than the general knowledge upskilling requirement for these jobs associated with new materials and design processes.

The gradual nature of change is important for understanding which policy levers are likely to be most effective in meeting the changing demand for skills. It is likely that much of general skills updating as jobs evolve will be led by employers, especially where changing knowledge requirements relate to the introduction of new processes, tools and technologies. This cuts across sectors and many different occupational groups, especially within the technician and associate professional, craft and related trades, and plant and machine operator major occupational groups. The extent to which transition to the circular economy is either facilitated or inhibited by the availability of skills will therefore depend on whether employers in different sectors have the capacity to invest in training for their workforces.

The skills implications for the sewerage and waste sector are slightly distinctive, given that this is where a considerable share of the circular economy employment impact is focused. However, this distinctiveness is arguably much more about skills supply than demand. The picture in terms of changing skills demand is similar to other sectors, but on a larger scale. The evidence suggests that the circular economy creates sewerage and waste jobs across a range of occupational levels. It highlights, in common with other sectors, a reasonable scope for transition because new knowledge requirements are likely to be in scope of current job requirements (i.e. a skills evolution rather than revolution). There is also a cross-cutting nature to some of the skills and competences required for key sewerage and waste occupations, especially at the elementary and intermediate levels (e.g. processing, monitoring/compliance, maintaining records), which indicates scope to meet additional labour demand from the existing potential pool of supply. The main challenge from a skills supply perspective might relate to attracting people to a range of technical and non-technical roles (e.g. business and administration associate professionals) if there is not sufficient awareness of the (growing) job and career opportunities in the sector.

While growth in the sewerage and waste sector indicates increased demand for skills across occupational groups, there are also indications that, in other areas, circular economy take-up may shift the occupational balance within sectors. This is arguably more significant from a skills demand perspective, although it is important to reiterate that the number of jobs concerned is usually small. The prospective shift from assembler to trades roles in electronics illustrates where the circular economy could alter skills demand - but it may do so in a way that increases demand more for cross-cutting competences (problem solving; communications etc), once again broadening the potential labour pool. In the construction sector, the evidence suggests that, even in the context of the circular economy having a negative impact on employment, there will be growth in specialist higher-skills occupations that replaces some lower-skills and trades-related roles.

Across a number of sectors the common theme is increased demand for STEM-related skills at professional and associate professional level. At the professional level, the need for highly-skilled technical specialists may increase as a result of the circular economy, but this type of expertise is already in greater demand. It is not a demand that can be easily met through re-skilling given the extent of education and specialist training required for these roles. At associate professional level, though, it is possible to identify more cross-cutting skill requirements for technicians, operators and supervisors working across a range of sectors, as well as a more general need both for skills updating and upgrading as a consequence of the circular economy.

There are also jobs and skill areas that the literature suggests are integral to circular economy take-up, but which do not map to the most affected sectors in employment terms. Remanufacture, for example, is likely to change rather than create jobs, and these jobs will be dispersed across manufacturing and service industries. The current jobs that equate to these areas tend to be niche and require a mix of knowledge of materials combined with craft skills. Future jobs might be quite different in scope. Furthermore, the impact of the circular economy on areas such as product design is not captured by the E3ME model because it does not have a substantial net employment impact, even though it is a theme that clearly underpins skills and knowledge across a wide range of sectors.

7. Policy Implications

7.1. Priority issues to be addressed

This report confirms that the circular economy has the potential to contribute to employment. In this respect the EU is on the right track by making the circular economy a policy priority as a more circular economy can contribute to resource efficiency and reduce negative environmental impacts, while simultaneously contributing to employment.

One important caveat of this study is that the magnitude of results is largely driven by the expected market uptake of circular activities in the five sectors examined. The larger the market uptake (ambitious vs moderate scenarios), the larger the impacts. Moreover, our circular economy scenarios are not a one-to-one translation of the policy instruments suggested in the EU Circular Economy package. Rather they are scenarios based on the circular potential existing in five focus sectors.

The analysis carried out in this study suggests that circular economy can have a net positive impact on the European economy across a range of economic indicators, including a 0.5% increase in EU GDP, a 0.3% increase in EU employment, a 0.4% increase in EU consumer spending and investment and a 0.1% decrease in consumer prices (in the ambitious scenario) by 2030.

However, inevitably there will be some ‘winners’ and ‘losers’ in such a transition. Some sectors will be positively affected, while others will see more negative impacts. Moreover, some Member States may be disproportionately affected. For example, Member States that produce and export durable goods will see reduction in their product demand from higher circular economy activities.

Based on the results of the analysis, the priority areas that would be affected are the following:

Addressing employment impacts in negatively affected sectors – mitigating any job losses

The transition to a circular economy will negatively affect employment in several sectors, in particular construction (with a knock-on effect on forestry), production of consumer electronics in Western Europe (with a knock-on effect on plastics), motor vehicles, and agriculture and food manufacturing (with a knock-on effect on chemicals). Sectors that extract and process raw materials sector are also likely to be negatively affected. However, these sectors have been in decline for some time now and in most cases are not major employers.

Addressing employment impacts in positively affected sectors – bridging any skills gaps and shortages

There are also sectors that stand to gain from the circular economy transition, namely the recycling and repair services, and utilities (gas, electricity and water; with knock-on effect on alternative materials and energy sources). Due to the rebound effects of increased consumer spending and increased demand for technology platform providers and R&D, the general services sector will also benefit from the transition. In particular, the use of innovative business models, such as collaborative economy platforms, has a high potential in terms of employment generation. However, this positive effect could be counterbalanced by negative impacts in other sectors, such as the so-called traditional economies (Trinomics, et al., 2018).[12]

Special attention to the EU waste markets and repair services – as the biggest winners of the circular economy

A particular attention should be paid to the waste sector and repair services as these are the two main sectors benefiting from the transition to a more circular economy. EU waste markets are extremely complex, and several bottlenecks exist, which make them work inefficiently in the EU. Moreover, EU waste legislation is not clear enough on the applicability of end-of-waste criteria, as a result of which some materials/products become waste in some Member States, while they become products (through reuse) in others (Arcadis & Trinomics, 2016).

[12] A number of studies explores these impacts, e.g. Trinomics et al. (2018), The environmental potential of the collaborative economy, Final report for DG Environment, European Commission

However, there is still a great potential to be tapped for repair services, as consumers tend to often choose buying a new product rather than repairing an old one. Besides the attitudes of consumers towards new and fashionable products, the preference for new products is also due to the fact that information on repair services, the availability of spare parts and their prices is often not easily available to consumers (London Economics et al., 2018).

Reconciling potential opposite effects of promoting circular economy and renewable energy sources

There are also other EU policies whose impacts are not fully coherent with the impacts of the circular economy transition. As noted in previous chapters, renewable energy technologies were not part of the analysis. A push for renewables could lead to further demand for raw materials, such as metals for wind turbines, and glass for solar panels. Such demands might have a counterbalancing effect on the circular economy transition. There might be other policies with similar effects on the circular economy transition, in which case the full employment potential of the circular economy would not materialise.

7.2. Policy implications and recommendations

There are several ways in which the European Commission and Member States can address the main issues and promote the transition to a circular economy, focusing on job creation and the provision of adequate skills. Such policy instruments and supporting measures can be categorised into four groups:

1. Promoting good functioning of the EU waste and repair markets
2. Integrating employment and skills aspects into circular policies and instruments
3. Integrating circular aspects into employment and skills policies.
4. Addressing any skills shortages and mismatches.

The next section presents the key policy recommendations for each of these four categories.

7.2.1. *Good functioning of the EU waste and repair markets*

Recommendation 1 Ensuring good functioning of EU waste markets

One of the key findings from the study is that the waste sector plays an essential role in achieving a net positive effect on the amount of employment (and GDP) in the EU. This beneficial impact is due to higher demand for such services from other sectors, which results in higher demand and investment in recycling plants and increased labour demand to process recycled materials. This employment impact can only be created if the EU waste markets, as a key sector in the EU generating circular jobs, are functioning properly and ambitious waste targets are set, where landfilling is virtually banned and waste incineration is limited as far as possible, while recycling and high-value loops such reuse and remanufacturing are promoted. The current legislative proposals on waste already contain ambitious targets for the recycling of municipal waste and packaging waste as well as a reduction of landfilling. Such targets will be important in creating a larger market for recycling, resulting in investments in more recycling facilities and demand for more workers in this sector.

Besides ensuring higher recycling, reuse and remanufacturing, waste markets also need to function properly. A study for DG Environment (2016) on 'The efficient functioning of waste markets in the EU' (Arcadis & Trinomics, 2016) identified and assessed a number of bottlenecks in the EU waste markets, and presented a set of policy recommendations, including developing a Schengen area for waste for recycling and recovery, within which waste would move freely. If the EU's waste markets function efficiently, without unjustified restrictions, waste would be routed to better sorting techniques, optimized processes and more effective treatment, recycling and recovery. This would in turn not only protect the environment and health, but also create more jobs and economic growth in the EU's waste management and recycling sectors.

Recommendation 2 Promoting repair services among consumers

The repair services sector has been found as another key sector supporting circular jobs. An ongoing DG JUST/CHAFEA study has been investigating consumers' willingness and engagement with repair services, renting and leasing (London Economics et al., 2018). The study found that consumers often use repair services and frequently look out for repair information on products, but they often find that this information is difficult to get and would like to receive better information regarding these product characteristics. The study also found that the preference for new and fashionable products is an important barrier to circular economy engagement.

This study presented a set of policy recommendations on how to engage consumers more in repair which includes:

- Information awareness tools, such as campaigns, development of a reparability label, providing information on the availability and price of spare parts and repair services;
- Economic incentives, such as a reduction of the VAT rate on repair services to decrease the costs of repair; and
- Regulatory tools, such as making the essential components in a product replaceable by consumers themselves (via e.g. Ecodesign Directive, or Batteries and accumulators Directive), extending the EU legal guarantee on repair or replacement of a defective product, as having a legal guarantee encourages consumers to engage in repair services.

This would ensure that repair services are more widely used, which would contribute to greater circular economy employment.

7.2.2. *Employment and skills aspects in EU circular economy policy*

Recommendation 3 Supporting job creation, re-skilling, training and capacity building through EU environment instruments – LIFE and H2020

There are two main EU programmes investing in the circular economy, which could be used to enhance employment and skills in this area. These programmes could also be used to ensure enough skilled workers exist in positively affected sectors, such as waste, repair and utilities, and services, and to mitigate job losses in negatively affected sectors, such as construction and electronics.

LIFE Programme

The LIFE Programme is currently the only EU fund exclusively dedicated to protecting the environment and fighting climate change. The current LIFE Programme has two sub-programmes – Environment and Climate-Action. Circular economy activities are supported through the Environment sub-programme, which receives approximately 75% of the total LIFE budget. Even though the aim of the programme is not to create jobs and develop skills, the programme has played an important role in this (Camarsa et al, 2013). The funded projects offer training courses, capacity building for Member State authorities, support of tertiary education, a specific job creation/training plan and other employment/skills aspects.

To better consider the skills and employment aspects in the LIFE programme, its annual priorities and/or guidelines for project applicants could be adapted. The application package contains a list of priorities that could be amended on a yearly basis given the limits of the LIFE Regulation. There is also a list of indicators that could be used to measure the output and impact of the project, including social indicators such as the number of training courses offered, or the numbers of jobs created.

Currently, the new LIFE Regulation proposal for the programme period 2021-2027 is being prepared.

Horizon 2020 Programme

Horizon 2020 is the financial instrument implementing the EU's Innovation Union strategy[13], a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. It is the biggest EU Research and Innovation programme ever, with nearly €80 billion of funding available over 7 years (2014 to 2020), in addition to the private investment that this money will attract. Given Horizon 2020's focus on investing in smart, sustainable growth and jobs in Europe and tackling societal challenges, there is scope for a project within this programme that would aim to support

[13] http://ec.europa.eu/research/innovation-union/index_en.cfm

capacity building in the circular economy. The former IEE programme has been merged into the H2020 Programme, where for example the BUILD UP Skills programme (currently construction skills under H2020) aimed to address the skills shortages in energy efficiency and renewable energy sources in the construction sector.

A call for proposals addressing employment and skills aspects in circular economy could be launched under this programme. This could be, for example, in terms of developing a knowledge base on skills gaps and shortages, or in terms of provision of training courses and materials for specific sectors (construction and electronics), to re-skill or up-skill workers.

Recommendation 4 Supporting the use of innovative business models through collaborative economy platforms as employment creators

According to the European Commission (as well as recent studies), collaborative economy platforms have the potential to create new employment opportunities, boost flexible working arrangements and create new sources of income (European Commission, 2016). There is an ongoing discussion at EU and Member State level on how to regulate these platforms and the jobs that they create, as the offered services are generally in between the formal and informal economy.

Under certain conditions, collaborative economy platforms have a positive impact on the environment and contribute to an increased circular economy due to increased utilization of goods and assets, such as cars, buildings or other consumer products and machinery. A recently published study for DG Environment on 'The environmental impacts of the collaborative economy' (Trinomics et al., 2018) analysed to what extent and under which conditions the collaborative economy contributes to sustainability in the transport, accommodation and consumer durables sectors. The study also proposes policy actions to contribute to sustainable growth of the EU economy.

By supporting the development of collaborative economy business models, while ensuring that these businesses contribute to sustainable growth and 'fair' jobs, a specific type of circular job could be promoted. Even though currently the size of this market could be considered niche, it is expected to grow considerably in the future.

7.2.3. *Circular aspects in EU employment & skills policy*

Recommendation 5 Introducing Circular Economy aspects into schools' curricula

Many of the improvements that are possible in a product's lifecycle are dependent on the design of the product. A product's design determines the resource use during production, but also its energy demand and need for maintenance in the use phase, its lifespan as well as the reparability of the product when it gets broken. Lastly, the design of the product and the materials chosen affect how easily the product can be refurbished or recycled or how its components can be remanufactured into a new product, when the product has become obsolete. So to optimise the circular potential of products produced and used in Europe, design with circular principles in mind is key. The EU could contribute to this by providing Member States with guidance on how to mainstream circular economy thinking into industrial engineering and industrial design educational programmes.

Another key requirement for reaching a circular economy is to engage all EU citizens and create awareness on the necessity of a circular economy and a more general awareness on environmental issues. In order to reach the goal of 'living well within the limits of our planet', it is essential that the European youth is taught how to develop sustainable lifestyles. Therefore, it is important that schools pay sufficient attention to teaching children what the environmental impacts are of consumption and to teach them environmentally friendly behaviours and how to make sustainable choices as a consumer.

7.2.4. *Addressing skill shortages and skill mismatches*

Recommendation 6 Focus on skills updating rather than wholesale employment shifts

The modelling and analysis in this report indicates that the nature of circular economy labour market impacts means that there is no 'silver bullet' policy solution. Policy makers should be somewhat cautious about enacting major change specifically to tackle the labour market impact of the circular economy, because the overall scale of impact in terms of jobs and the occupational mix is smaller than that for other drivers of labour market change.

Any prospective policy intervention from an employment and skills perspective needs to distinguish labour market impacts related to supporting employment growth (new jobs created by the circular economy), mitigating employment decline and changing job and skill requirements as a consequence of circular economy take-up:

- With the exception of the waste sector, net employment growth at sector level driven by the additional impacts of circular economy take-up is of a manageable scale.
- Some of the sectors that are anticipated to see a decline in employment, such as mining and extraction, are small and the circular economy impact can arguably be seen as a continuation of existing trends. The modelling results suggest a larger decline in employment in the construction sector, but it arguably has a distinctive labour market dynamic anyway and the policy implications of circular economy take-up have to be considered in that context.

The most substantial labour market impact is likely to be on changing job and skill requirements as consequence of circular economy take-up. The closest policy focus should therefore be on supporting organisations and individuals to adapt and upskill to meet changing job requirements.

Recommendation 7 A joined-up approach with other structural changes to employment

In the main, the circular economy is not an outlier in terms of the trends that are shaping future jobs and skills. It connects with and provides further resonance to important trends shaping future jobs, such as automation. It is important therefore that policy makers consider the circular economy as part of these wider structural changes to employment and not as a silo in itself.

Furthermore, it is important to recognise that there are ongoing programmes of work at European level that are likely to dovetail with labour market needs associated with the circular economy. The need for 'new' action might therefore be limited and the focus could instead be on ensuring that existing actions explicitly reflect needs associated with the circular economy (although in some areas this is already the case).

The analysis further suggests that policy makers need to consider action at two levels: to meet the needs of specific sectors and to tackle broader or cross-cutting skill needs associated with the circular economy.

A sector-based approach

One of the key questions for policy makers is whether the circular economy evidence indicates a need for a sector-focused programme of support to facilitate transition to the circular economy. In most areas, the case is not clear cut. However, there is a clear opportunity in the form of the Sector Skills Alliances funded under Erasmus+ Key Action 2, which specifically identifies supporting transition to the circular economy, alongside digital skills and the greening of the economy as transversal aspects of the programme. The focus is on qualifications and training curricula, but objectives relating to competitiveness and innovation perhaps provide scope for action that explicitly supports reskilling and upskilling in relevant sectors.

The fundamental consideration for policy makers in this context is the extent to which emerging skills needs and evolving role profiles will be addressed through the normal course of skills updating that is driven by companies undertaking circular economy related activities (e.g. through the introduction of new processes and technologies to the workplace over time). The example of how the motor vehicle manufacturing sector has, partly as a consequence of environmental regulation, adapted to reduce material use and make the production process more efficient signals how sector-driven change can occur.

The potential added value from policy intervention, such as through the Sector Skills Alliances, is that it may enable this transition to take place more quickly/smoothly, and in doing so be a catalyst for realising the potential benefits of the circular economy. The Blueprint for sectoral cooperation on skills provides a further infrastructure for bringing stakeholders together to collaborate on tackling skills issues. Some of the sectors currently covered (e.g. construction, automotive, renewable energy & green technologies) are relevant from a circular economy perspective.

There is a case for policy makers to consider whether additional collaborative action focused on skills is required for the waste sector specifically, following the model set out in the Blueprint for sector collaboration, as it is the area most directly affected by the circular economy. In this context, however, policy makers should note that the scale of change and the nature of sector employment means that actions just focused on education and training are likely to be necessary but insufficient to meet the needs associated with the circular economy. Jobs are likely to be created across the board. In this context, the most useful tools available to policy makers may relate to communications, promotion of career opportunities and provision of Information, Advice and Guidance to boost the skills pipeline in the long term, by raising the profile of the sector, especially in terms of otherwise high-demand occupations such as business and administration associate professionals.

The circular economy impact on the construction sector is also substantial, but the factors driving change in the sector are well-known. For example, as far back as 2012, the feasibility study exploring the set-up of a European Sector Skills Council in Construction identified a need to look at "how is the development of the construction process (technology, work organisation, labour process) transferred into training, etc." The specific circular economy evidence indicates a potential shift from building trades to science and engineering associate professional roles. It is not clear, however, that this translates into a need for redeployment given the specialist nature of construction trades and the cyclical nature of employment in the sector. The reflection for policy makers may be that training not only needs to keep pace with the evolution of construction processes, but that training investment may need to be increasingly directed towards construction associate professional roles.

Cross-cutting skill needs

A key way to support adaptation to the circular economy and to mitigate employment decline is for policy makers to focus on the cross-cutting applicability of skills. The profile of the likely-affected occupations in many cases combines job-specific skills and knowledge with broader competences that have cross-cutting relevance. Some of the potential shifts associated with the circular economy, such as a transition from assembly jobs to repair and reuse, are likely to be associated with a need for more transversal skills (e.g. customer focused skills, creating solutions etc).

This both provides the potential for a wider pool of labour to fill these jobs and should provide a prompt for policy makers for continued focus on broadly-applicable competences. The Commission adopted a proposal for the new Recommendation on Key Competences for Lifelong Learning in January 2018. While the focus is on basic skills, the original Reference Framework listed a set of transversal themes across all key competences. These transversal elements (such as critical thinking, problem solving and risk assessment) are highly relevant to developing a workforce with sufficient adaptability to meet the needs of the circular economy and should be emphasised by policy makers.

Beyond this, the circular economy evidence further reiterates the importance of science and engineering-related skills. The need to boost skills supply in the context of the STEM agenda is well-known and a priority for policy makers beyond the specific implications of the circular economy. It is clear that, over time, transition to the circular economy will be inhibited if there is insufficient supply of STEM-related skills. This is a skills challenge that percolates through the education and training system.

In terms of how this translates into jobs, however, the analysis of circular economy affected occupations shows that, at professional level, the specialist nature of skills required can inhibit supply. In this context, policy makers should consider ways to support skills transfer and career transition (e.g. through re-skilling programmes for professionals). At associate professional level the potential for job transition is greater and the skill areas, across multiple occupations and sectors, that are likely to require boosting relate to design, monitoring, operations and communications activities. This is in addition to the wider specialist need for education and training on design for reuse.

8. Conclusion

Conclusion 1 The EU is on the right track by making the circular economy a policy priority because the circular economy can contribute to resource efficiency and reduce negative environmental impacts, while simultaneously boosting employment.

By moving towards a more circular economy, GDP in the EU increases by almost 0.5% by 2030 compared to the baseline case. The net increase in jobs is approximately 700,000 compared to the baseline. Although the magnitude of the job creation is driven by our assumption of the rate of circular economy uptake in the scenarios, our analysis confirms that it is possible to become more resource efficient and increase employment at the same time. A 'double dividend' is possible.

Our analysis is the most comprehensive quantification of the EU jobs impacts from the circular economy to date. It considers both direct job losses and job creations that result from a shift to a more circular economy. It also captures indirect, induced and rebound impacts from interactions between sectors, Member States, and between economic, environment, material, energy and labour market indicators.

Conclusion 2 The sectoral composition of employment will change in a shift to a more circular economy. Sectors that produce and process raw materials will decline in size while the recycling and repairing sectors will experience additional growth.

It is not surprising that circular economy activities shift demand from the extraction and raw material sectors toward sectors that produce recycled materials and offer repairs. In the waste management sector alone, the net increase in employment could be as high as 660,000 jobs in the ambitious scenario in this report.

Since the level of employment in the extraction and manufacturing of raw materials in Europe has been declining for quite some time, the negative employment impacts from the transition to a more circular economy in the EU are relatively small in magnitude. Our modelling results confirm this finding.

It is important to note that, although the level of job creation in the recycling activity is in line with previous studies, there are also large uncertainties surrounding the future labour intensities in the waste sector due to increased automation, product material enhancement (to ease recycling) and technology. Our employment results for the waste sector could be overestimates if there was a sustained drive to increase mechanisation in the sector.

Other winners from a shift to a more circular economy are likely to include services sectors, agriculture and electricity. Services and some manufacturing sectors benefit from the rebounds in consumer spending and stimulus from higher recycling demand. If consumers spend less on new products then they have additional income to spend on services.

While the agriculture and food sectors will see a reduction in demand as Europe tackles food waste, the demand for organic materials and by-products from food production will compensate this loss, resulting in net small increase in employment.

The electricity sector also benefits from electrification of the transport sector.

Sectors that produce durable goods are expected to lose out overall, due to longer product lifetimes and trends towards a more collaborative economy. These sectors include electronics, machinery, cars and accommodation, as well as sectors that are related to them through supply chain activities.

New construction techniques and better utilising of existing housing stocks would lead to a reduction in construction employment. Our study, however, excludes employment impacts from energy efficiency in buildings which is expected to increase as a result of energy efficient investment (European Commission, 2016).

Conclusion 3 As always, rebound effects are important

The rebounds in consumer spending occur as a result of efficiency gains and cost savings from circular economy activities. They can only be captured in a full modelling framework, as was used in this analysis. Although rebound effects are good for the economy, they also mean that there is a rebound in material consumption associated with additional consumer spending. Additional policies may therefore be needed if Europe is to meet ambitious targets to reduce overall material use.

Conclusion 4 Addressing employment impacts in negatively and positively affected sectors, with a special attention to the waste and repair sectors, are the priority issues to be addressed by policy.

The sectoral employment shifts due to the transition to a circular economy will inevitably lead to some 'winners' and some 'losers', where policy will need to ease problems of skills constraints and stranded human capital. The waste and the repair sectors are overall the biggest winners of this transition, which requires that these markets function efficiently. Workers that are displaced from extraction sectors and heavy industry may require intensive retraining.

Conclusion 5 There are several ways that policy tools can address the circular economy transition while promoting jobs and adequate skills – through circular economy policies as well as through education and training policies.

One way of ensuring that the circular economy transition addresses the identified employment and skills issues is through introducing employment and skills aspects into circular economy and environmental policy. Such activities are already integrated into LIFE and Horizon 2020, which both aim at promoting a circular economy transition as well as economic growth and jobs. Employment and skills policies also offer a gateway to introduce circular economy aspects into, for example, schools' curricula, as well as education and training. The focus of policies should be on adapting and reskilling to meet changing job requirements, including promoting new skills to support the implementation of new technologies.

Conclusion 6 The circular economy may amplify certain areas of future skills demand, where future demand is already being shaped by global drivers of change.

From a skills perspective, the requirements for a more circular economy are generally aligned with the anticipated impact of other drivers of change on the labour market, such as the impact of technological change on jobs and the shift to high-skilled jobs in some sectors. The jobs and skills implications of the circular economy should be seen in this inter-connected context. Much of the infrastructure is already in place or under development at European level to enable a sector-based response to meet changing skills needs (e.g. under Erasmus+ Key Action 2). The circular economy is already on the agenda, to some extent, as part of these developments. There is a need for additional action to support the waste management sector specifically, but this may be as much about promoting career opportunities as it is about developing new skills.

There are some exceptions, where the impact of the circular economy may shift the occupational balance, such as a shift from assembler to trade and repair roles in the electronics sector. The general trend in this context is towards increased demand for cross-cutting competences, such as problem solving and communications. Transition to the circular economy therefore provides evidence of the importance of transversal skills, not least because jobs will evolve and workers will need to be adaptable.

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Impacts of circular economy policies on the labour market – Annexes to the main final report

Sector profiles

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Cambridge Econometrics
Cambridge, UK

uc@camecon.com
www.camecon.com

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Final			Annexes to the main final report

Contents

ANNEX A: E3ME NON-TECHNICAL DESCRIPTION

1 E3ME Non-Technical Description

1.1 Introduction

Overview

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes. The global edition is a new version of E3ME which expands the model's geographical coverage from 33 European countries to 59 global regions. It thus incorporates the global capabilities of the previous E3MG model.

Compared to previous model versions, version 6 of E3ME provides:

- better geographical coverage
- better feedbacks between individual European countries and other world economies
- better treatment of international trade with bilateral trade between regions
- a new model of the power sector

This is the most comprehensive model version of E3ME to date and it includes all the previous features of the previous E3MG model.

Recent applications

Recent applications of E3ME include:

- a global assessment of the economic impact of renewables for IRENA
- contribution to the EU's Impact Assessment of its 2030 climate and energy package
- evaluations of the economic impact of removing fossil fuel subsidies in India and Indonesia
- analysis of future energy systems, environmental tax reform and trade deals in East Asia
- an assessment of the potential for green jobs in Europe
- an economic evaluation for the EU Impact Assessment of the Energy Efficiency Directive

This model description provides a short summary of the E3ME model. For further details, the reader is referred to the full model manual available online from www.e3me.com.

1.2 E3ME's basic structure and data

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2014 and the model projects forward annually to 2050. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

1.3 The main dimensions of the model

The main dimensions of E3ME are:

- 59 countries – all major world economies, the EU28 and candidate countries plus other countries' economies grouped
- 43 or 69 (Europe) industry sectors, based on standard international classifications
- 28 or 43 (Europe) categories of household expenditure
- 22 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the six greenhouse gases monitored under the Kyoto protocol

The countries and sectors covered by the model are listed at the end of this document.

1.4 Standard outputs from the model

As a general model of the economy, based on the full structure of the national accounts, E3ME is capable of producing a broad range of economic indicators. In addition there is range of energy and environment indicators. The following list provides a summary of the most common model outputs:

- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade)
- sectoral output and GVA, prices, trade and competitiveness effects
- international trade by sector, origin and destination
- consumer prices and expenditures
- sectoral employment, unemployment, sectoral wage rates and labour supply
- energy demand, by sector and by fuel, energy prices
- CO_2 emissions by sector and by fuel
- other air-borne emissions
- material demands

This list is by no means exhaustive and the delivered outputs often depend on the requirements of the specific application. In addition to the sectoral dimension mentioned in the list, all indicators are produced at the national and regional level and annually over the period up to 2050.

1.5 E3ME as an E3 model

The E3 interactions

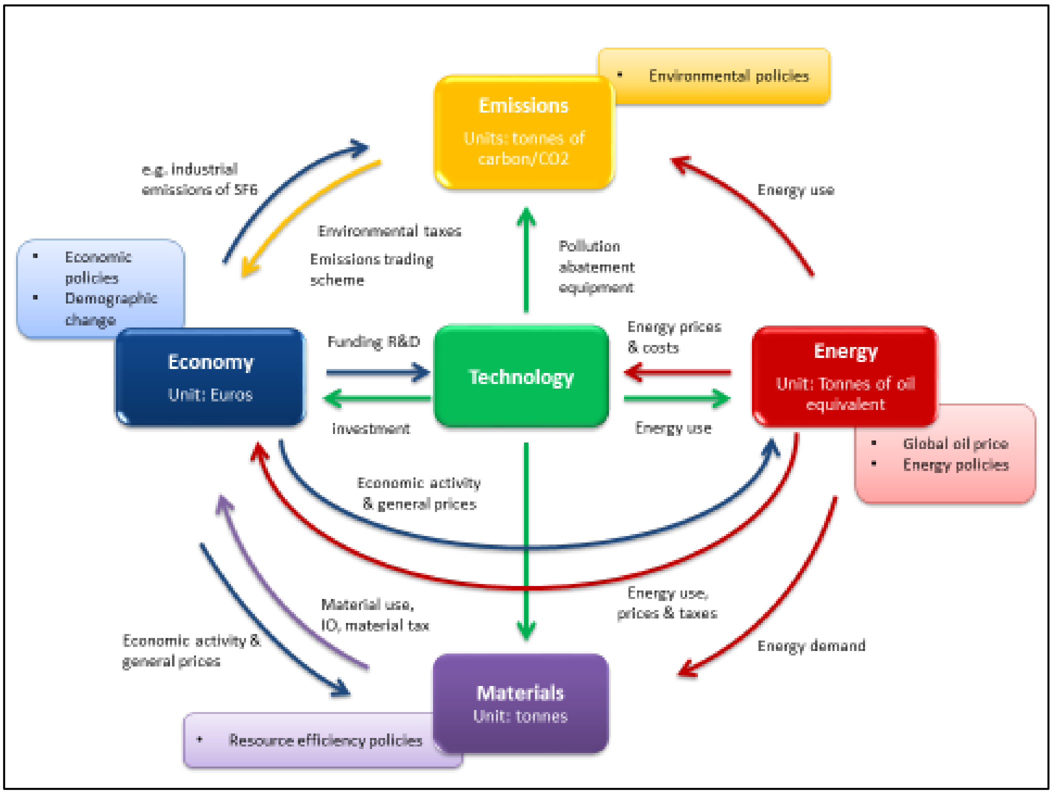
Figure 1.1 shows how the three components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box. Each data set has been constructed by statistical offices to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For each region's economy the exogenous factors are economic policies (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of the energy industries). For the environment component, exogenous factors include policies such as reduction in SO_2 emissions by means of end-of-pipe filters from large combustion plants. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module, which in turn can give measures of damage to health and buildings. The energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

The role of technology

Technological progress plays an important role in the E3ME model, affecting all three Es: economy, energy and environment. The model's endogenous technical progress indicators (TPIs), a function of R&D and gross investment, appear in nine of E3ME's econometric equation sets including trade, the labour market and prices. Investment and R&D in new technologies also appears in the E3ME's energy and material demand equations to capture energy/resource savings technologies as well as pollution abatement equipment. In addition, E3ME also captures low carbon technologies in the power sector through the FTT power sector model[1].

Figure A.1 E3 linkages in the E3ME model



[1] See Mercure (2012).

1.6 Treatment of international trade

An important part of the modelling concerns international trade. E3ME solves for detailed bilateral trade between regions (similar to a two-tier Armington model). Trade is modelled in three stages:

- econometric estimation of regions' sectoral import demand
- econometric estimation of regions' bilateral imports from each partner
- forming exports from other regions' import demands

Trade volumes are determined by a combination of economic activity indicators, relative prices and technology.

1.7 The labour market

Treatment of the labour market is an area that distinguishes E3ME from other macroeconomic models. E3ME includes econometric equation sets for employment, average working hours, wage rates and participation rates. The first three of these are disaggregated by economic sector while participation rates are disaggregated by gender and five-year age band.

Compared to other models, E3ME offers a highly detailed approach:

- Unlike the CGE approach, markets do not clear, so unemployment (including both voluntary and involuntary unemployment) is a standard output of the model.
- Employment demand is modelled at the sectoral level, so E3ME results can be disaggregated to 69 sectors.
- Wages are modelled at the same sectoral level, with the parameters on how wages adjust determined by the historical data.
- Labour supply is modelled by gender and five-year age band.

The labour force is determined by multiplying labour market participation rates by population. Unemployment (including both voluntary and involuntary unemployment) is determined by taking the difference between the labour force and employment. This is typically a key variable of interest for policy makers.

1.8 Comparison with CGE models and econometric specification

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches.

In a typical CGE framework, optimal behaviour is assumed, output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. In E3ME the determination of output comes from a post-Keynesian framework and it is possible to have spare capacity. The model is more demand-driven and it is not assumed that prices always adjust to market clearing levels.

The differences have important practical implications, as they mean that in E3ME regulation and other policy may lead to increases in output if they are able to draw upon spare economic capacity. This is described in more detail in the model manual.

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects[2], which are included as standard in the model's results.

1.9 Key strengths of E3ME

In summary the key strengths of E3ME are:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios
- its global coverage, while still allowing for analysis at the national level for large economies
- the econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to CGE models
- the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends

1.10 Applications of E3ME

Scenario-based analysis

Although E3ME can be used for forecasting, the model is more commonly used for evaluating the impacts of an input shock through a scenario-based analysis. The shock may be either a change in policy, a change in economic assumptions or another change to a model variable. The analysis can be either forward looking (ex-ante) or evaluating previous developments in an ex-post manner. Scenarios may be used either to assess policy, or to assess sensitivities to key inputs (e.g. international energy prices).

For ex-ante analysis a baseline forecast up to 2050 is required; E3ME is usually calibrated to match a set of projections that are published by the European Commission and the IEA but alternative projections may be used. The scenarios represent alternative versions of the future based on a different set of inputs. By comparing the outcomes to the baseline (usually in percentage terms), the effects of the change in inputs can be determined.

It is possible to set up a scenario in which any of the model's inputs or variables are changed. In the case of exogenous inputs, such as population or energy prices, this is straight forward. However, it is also possible to add shocks to other model variables. For example, investment is endogenously determined by E3ME, but additional exogenous investment (e.g. through an increase in public investment expenditure) can also be modelled as part of a scenario input.

Price or tax scenarios

[2] Where an initial increase in efficiency reduces demand, but this is negated in the long run as greater efficiency lowers the relative cost and increases consumption. See Barker et al (2009).

Model-based scenario analyses often focus on changes in price because this is easy to quantify and represent in the model structure. Examples include:

- changes in tax rates including direct, indirect, border, energy and environment taxes
- changes in international energy prices
- emission trading schemes

Regulatory impacts

All of the price changes above can be represented in E3ME's framework reasonably well, given the level of disaggregation available. However, it is also possible to assess the effects of regulation, albeit with an assumption about effectiveness and cost. For example, an increase in vehicle fuel-efficiency standards could be assessed in the model with an assumption about how efficient vehicles become, and the cost of these measures. This would be entered into the model as a higher price for cars and a reduction in fuel consumption (all other things being equal). E3ME could then be used to determine:

- secondary effects, for example on fuel suppliers
- rebound effects[3]
- overall macroeconomic impacts

1.11 E3ME main classification

Table 1: Main dimensions of the E3ME model

	Regions	Industries (Europe)	Materials	Material users
1	Belgium	Crops, animals, etc	Food	Agriculture
2	Denmark	Forestry & logging	Feed	Mining
3	Germany	Fishing	Forestry	Energy
4	Greece	Coal	Construction Minerals	Food, Drink & Tobacco
5	Spain	Oil and Gas	Industrial Minerals	Wood and Paper
6	France	Other mining	Ferrous Ores	Chemicals
7	Ireland	Food, drink & tobacco	Non-ferrous ores	Non-metallic Minerals
8	Italy	Textiles & leather	Water	Basic Metals
9	Luxembourg	Wood & wood prods	Waste	Engineering etc
10	Netherlands	Paper & paper prods	Unallocated	Other Industry
11	Austria	Printing & reproduction		Construction
12	Portugal	Coke & ref petroleum		Transport
13	Finland	Other chemicals		Services
14	Sweden	Pharmaceuticals		Households
15	UK	Rubber & plastic products		Unallocated
16	Czech Rep.	Non-metallic mineral prods		
17	Estonia	Basic metals		
18	Cyprus	Fabricated metal prods		
19	Latvia	Computers etc		

[3] In the example, the higher fuel efficiency effectively reduces the cost of motoring. In the long-run this is likely to lead to an increase in demand, meaning some of the initial savings are lost. Barker et al (2009) demonstrate that this can be as high as 50% of the original reduction.

20	Lithuania	Electrical equipment		
21	Hungary	Other machinery/equipment		
22	Malta	Motor vehicles		
23	Poland	Other transport equip		
24	Slovenia	Furniture; other manufacture		
25	Slovakia	Machinery repair/installation		
26	Bulgaria	Electricity		
27	Romania	Gas, steam & air cond.		
28	Norway	Water, treatment & supply		
29	Switzerland	Sewerage & waste		
30	Iceland	Construction		
31	Croatia	Wholesale & retail MV		
32	Turkey	Wholesale excl MV		
33	Macedonia	Retail excl MV		
34	USA	Land transport, pipelines		
35	Japan	Water transport		
36	Canada	Air transport		
37	Australia	Warehousing		
38	New Zealand	Postal & courier activities		
39	Russian Fed.	Accomm. & food serv		
40	Rest Annex I	Publishing activities		
41	China	Motion pic, video, television		
42	India	Telecommunications		
43	Mexico	Computer programming etc.		
44	Brazil	Financial services		
45	Argentina	Insurance		
46	Colombia	Aux to financial services		
47	Rest Latin Am.	Real estate		
48	Korea	Imputed rents		
49	Taiwan	Legal, account, consult		
50	Indonesia	Architectural & engineering		
51	Rest ASEAN	R&D		
52	Rest of OPEC	Advertising		
53	Rest of world	Other professional		
54	Ukraine	Rental & leasing		
55	Saudi Arabia	Employment activities		
56	Nigeria	Travel agency		
57	South Africa	Security & investigation, etc		
58	Rest of Africa	Public admin & defence		
59	Africa OPEC	Education		
60		Human health activities		
61		Residential care		
62		Creative, arts, recreational		
63		Sports activities		
64		Membership orgs		
65		Repair comp. & pers. goods		
66		Other personal serv.		
67		Hholds as employers		

68	Extraterritorial orgs		
69	Unallocated/Dwellings		

Source(s): Cambridge Econometrics.

ANNEX B: LITERATURE REVIEWS

1 Introduction

1.1 Introduction

This document forms the first interim report for the project. It summarises key findings from the literature review that aims to answer a set of predefined research questions on the circular economy and its impacts on the labour market. The scope of the circular economy that will be covered in our analysis, defined by sectors and activities, is also discussed in this report.

The remaining parts of this chapter provide a summary of the study context and the research questions that were asked at the beginning of the literature review. Chapter 2 contains findings from the literature review task that addresses these questions. Chapter 3 discusses the scope of circular economy activities and sectors that will be covered in our analysis. The final chapter concludes and discusses the next steps of the study.

1.2 Context

The world's growing population and its rising welfare, is accompanied by increased consumption of natural resources which is putting increasing pressure on the earth's resources and the environment. As the economist Kenneth Boulding said: 'Anyone who thinks that you can have infinite growth on a planet with finite resources is either a madman or an economist.' In 1972 the Club of Rome published its famous report 'Limits to growth', describing the results from a modelling exercise investigating the relation between population growth and the impacts thereof in terms of environmental pollution and resource depletion (The Club of Rome, 1972). This report confirmed Boulding's intuition on the limits regarding earth's resources, but also suggested that there are possibilities for humanity to develop ways to live within the boundaries of those limits.

An essential step to re-synchronise human economic activities with the earth's carrying capacity is to move from the 'linear economy' model, to a circular economy model. The current economy is predominantly based on a one-way use trajectory of products (linear model), beginning with resource extraction, followed by product manufacturing, product use and its disposal in the form of waste in the end of the product's lifetime. In a circular economy on the other hand, products and by-products are fed back into the system at different stages of their life-cycle, creating multiple loops connecting resource outputs back to the inputs. This creates a sustainable flow of energy and materials available in the economy to produce goods and provide services.

The European Commission has the ambition to support the European economy in a quick transition to circularity and has articulated its vision of how to do so in the action plan 'Closing the loop' (EC, 2015). To arrive at a circular economy, our entire economic system has to make a transition in terms of its practices, institutions, as well as the mindset and behaviour of consumers and producers. This transition will result in large structural changes within sectors and between sectors. In some sectors (e.g. mining), employment will be lost due to a higher degree of circularity, while in other sectors, e.g. in recycling, large numbers of new jobs will be created. In response to the call for tender ENV.F.1/SER/2016/0025 by DG ENV, this study aims to assess the effects of the transition to a circular economy on net employment effects.

1.3 Research questions for literature review

Research question	Section in the report
1) Which sectors are expected to see most job gains and most job losses, in the short and medium term? The gains and losses should be quantified and trends per sector should be summarised as far as possible. – Answering this question will help identify the most important (economic) sectors in which circular economy-related jobs are being or will be created as well as lost and what are the numbers.	2.6
2) What kind of jobs are created and lost? This should include, as far as possible, an estimate of the range of skills levels involved (i.e. high, medium and low skills) and a breakdown by the main age groups. – This will provide qualitative and quantitative insights into the skills and occupations needed to pursue circular economy activities in the EU.	2.3
3) Does an improvement in resource efficiency lead to more or better jobs (in terms of precariousness, safety, duration)? – This will provide information on the quality and sustainability of resource efficiency and circular economy-related jobs.	2.3
4) What can be expected regarding the substitution between capital, use of materials and labour? What are the consequences for labour? – Would there be any losers from more circular economy and resource efficiency? Who are the winners?	2.4
5) What are the most important circular economy activities and business models, how do they relate to/what is their impact on ‘traditional’ activities and sectors?	2.2
6) *How* do these circular economy activities and business models impact jobs? (e.g. what are the drivers behind the impacts? Are the effects on labour direct or indirect?)	2.5
7) Literature/data on the skills and training needs associated with the transition to a circular economy.	2.3
8) Literature/data on (existing or potential) policy responses and their impacts, e.g. training initiatives, measures for mainstreaming the circular economy in employment and education policies (which could feed into Task 3).	2.7
9) Data on investments and expenditures for circular economy activities and sectors for the EU and in different Member States (if available – could be used to feed into the modelling of employment impacts).	2.2

2 Literature Review

2.1 Main conclusions

- Various definitions and interpretations of the Circular Economy exist, but the definition from the Ellen MacArthur Foundation (Ellen MacArthur, 2014) is most commonly cited. It is used as the circular economy definition in this study as well. In essence, the circular economy aims at keeping products, components, and materials in the economy for as long as possible and thus tries to reduce or eliminate waste. The two main strategies to increase the circularity of the economy are: (1) Regeneration of biotic materials and (2) maintaining the value of abiotic materials for as long as possible through various feedback loops and recovery schemes (Figure 1).
- Circular economy activities are often cross-sectoral and also involve new kind of activities that are not captured yet by traditional classifications of economic sectors. Though some specific sectors can create circular business models largely within their own sector, such as within the food industry or the construction sector, other (horizontal) circular economy business actions such as design for re-use and recyclability, repair, reuse or waste management, can involve a variety of economic sectors, which complicates the analysis of circular economy labour impacts.
- Several studies find that increasing the circularity of the economy would have a positive net employment impact and could create jobs across all skill levels. However, most of the previous studies focused primarily on increasing resource efficiency and increasing recycling rates. Studies considering the employment effects of inner loops of the circular economy (reuse, remanufacturing, etc.) are needed.
- Circular economy activities will require both high and low-skilled jobs. For example, there would be more design and technology related jobs attracting high-skilled workers, while the increased recovery and reuse of waste would create the need for new low-skilled jobs. Overall, the transition to a circular economy will entail new and more specialised skills, and reskilling strategies will be needed to enable workers to move from high to low-carbon sectors.
- The transition to a circular economy might change production processes by substitution of some capital inputs with labour inputs. The expected impact on the overall capital-labour ratio in the economy is likely to be driven by two main effects:
  - (a) Circulating materials for as long as possible will result in a shift in focus from the primary economic sectors (agriculture, mining & quarrying, etc.) to the secondary and tertiary sectors.
  - (b) Within sectors the share of labour-intensive activities like repairing or refurbishing might increase compared to the production of new products. Even though this could lead to a higher labour to capital ratio, it does not automatically increase net employment.
- The most important sectors for circular economy related jobs are those engaging in recycling, maintenance and repair activities, as well as sharing

and regenerating (shifting to renewable energies and biological materials). However, this scope of activities still includes a relatively large number of sectors; it is not clear from the literature which sectors are the most important.

- At the EU and Member State levels, there are a number of policies that are targeted at the transition towards the circular economy, including training programmes that are of relevance to the circular economy. However, at both levels, there are no real skills-related policies specifically designed to foster the transition to a more circular economy.

2.2 Introduction

There is ample literature on the circular economy, although it must be noted that the exact meaning of the concept can differ from one source to another. For this literature review, at least 84 sources were assessed, many of which also touch upon employment effects, but only a dozen of these contain any quantitative assessments of the effect that the circular economy will have on the labour market. The reports published by the Ellen MacArthur Foundation play a leading role in the circular economy discourse. They give a comprehensive overview of what the circular economy is, provide examples of what it can bring and how it is currently applied, and develop tools to analyse its future impacts. Other studies often look into specific aspects of the circular economy, such as:

- The definition of the circular economy.
- Circular economy activities such as remanufacturing or reducing waste.
- The effect that the circular economy will have on a certain sector.
- The opportunities & challenges to achieve circularity in a certain sector.
- The economic impacts of the transition to a circular economy.
- The policies needed to arrive at a circular economy.

2.3 What is the circular economy?

Research Question 5: What are the most important circular economy activities and business models and how do they relate to/what is their impact on ‘traditional’ activities and sectors?

Defining circular economy

European Commission in its EU Action Plan for the Circular Economy (EC, 2015) defines circular economy as a transition, *‘where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised*.’

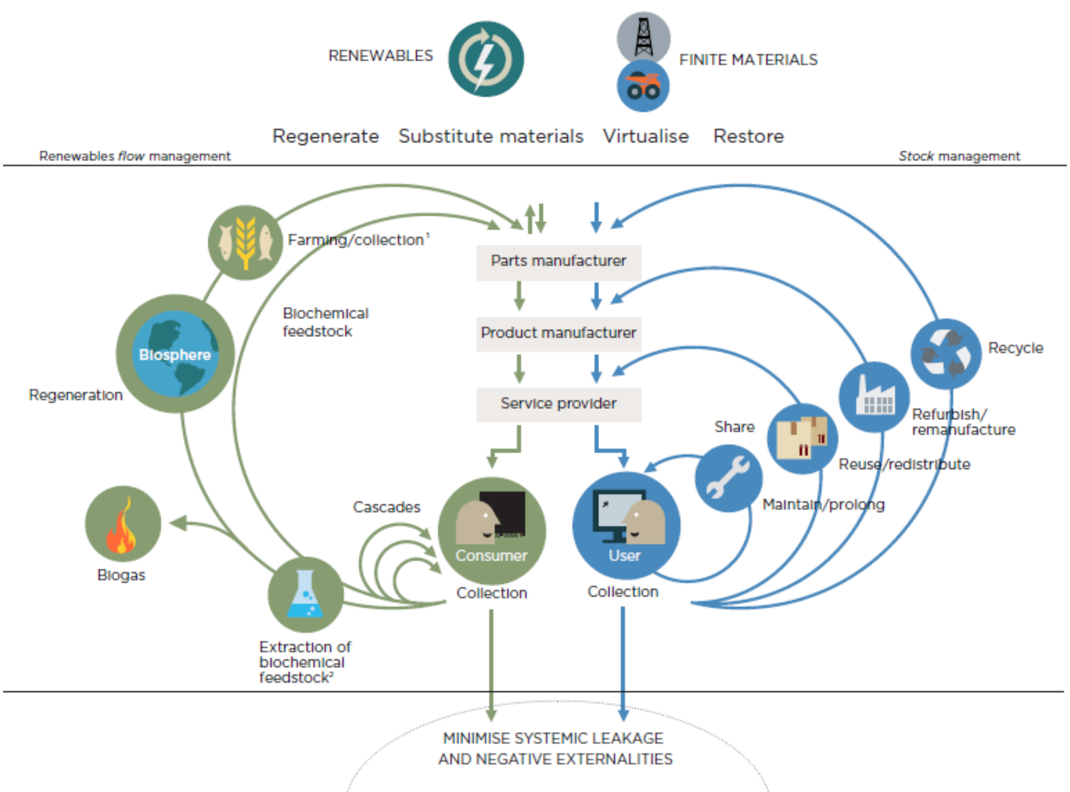
The literature contains various definitions of the circular economy. The most cited definition is by the Ellen MacArthur Foundation (Ellen MacArthur, 2014).

In general, it is agreed that there are two main strategies by which the circularity of the economy can be increased. One strategy is to replace the materials used in production processes with bio-based (biological) materials (left cycle, figure 1), often referred to as the bio-based economy. This strategy is especially relevant for products with a short life-cycle, such as fast moving consumer goods (e.g. bioplastics for packaging) or fuels (e.g. bio-ethanol or biodiesel). The second strategy applies to goods and resources that have a longer lifetime and are composed of a more complex mix of technical materials (incl. metals and potentially toxic/hazardous chemicals) (right cycle, figure 1). For these products, components and materials, circularity means that the aim is to keep them in the economy as long as possible through a variety of feedback loops and recovery strategies to avoid waste (Ellen MacArthur, 2014, 2015). In its scoping study (2014), the Commission also makes the distinction between technical and biological nutrients and presents the strategies used to keep them as long as possible in the economy. As such, the Commission definition is in line with the following definition provided by Ellen MacArthur Foundation.

Defining circular economy, Ellen MacArthur Foundation (2015)

The circular economy is one that is restorative or regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption.

Figure 1 – Overview of loops that can be used to make the economy more circular



Source: Ellen MacArthur Foundation, 2015.
Note: The cycle on the left concerns the resourcing of material inputs to more bio-based materials. The right (blue) part shows the processes that help to close the loop of non-biological materials

ReSOLVE framework

According to the Ellen MacArthur Foundation ReSOLVE framework (Ellen MacArthur Foundation, 2015; also visible in Figure 1 above), there are six action areas for businesses and countries wanting to move towards a circular economy:

- **Regenerate –** shift to renewable energy and materials, restore health of ecosystems, return recovered biological resources
- **Share –** share assets, reuse, prolong life through maintenance, etc.
- **Optimise –** increase performance, efficiency, remove waste, automation
- **Loop** – remanufacture, recycle, digest anaerobically
- **Virtualise –** dematerialise directly and indirectly
- **Exchange –** replace old with advanced non-renewable materials, apply new technologies, choose new products and services

As can be seen from these definitions and action areas, the circular economy affects many economic sectors and includes measures that can be applied horizontally across these sectors, where the feedback loops for technical materials and the replacement of technical materials by biological ones will determine the socio-economic and environmental impacts.

Typology of circular economy activities

The typology of economic activities defining the circular economy in this study are largely based on the sectors and activities identified in the following studies:

- the European Commission Communication 'Closing the loop - An EU action plan for the Circular Economy' and its Annex (European Commission, 2015)
- the 'Scoping study to identify potential circular economy actions, priority sectors, material flows & value chains' (European Commission, 2014b)
- the study on 'Economic Growth Potential of More Circular Economies' (WRAP, 2015b)

Further studies, such as those from the Ellen MacArthur Foundation also contributed to the selection of sectors and activities to be included in our scope (for details on this see Section 3).

The typology coming from the literature includes a broad range of circular economy activities (non-exhaustive, see Table 2-1). Several studies have estimated employment impacts in circular economy sectors; these studies contribute to the selection of sectors and activities with potentially significant labour impacts, one of the key criterion for selection of sectors in this study (see section 3). An overview of these studies and a table with key employment statistics are discussed in the next sections.

The lifecycle-oriented nature of the circular economy automatically implies that circular economy activities tend to be cross-sectoral or consist of new activities that are not yet captured by traditional definitions. The aim of the typology is to create a bridge between circular economy activities and the 'traditional' economic sectors, as defined in the published economic statistics (e.g. using the NACE Rev.2 classification), which allow linkages to the E3ME macroeconomic model. E3ME can then capture indirect linkages as well as further rebound effects to provide macroeconomic and labour market impacts.

From a life cycle perspective, each sector has then activities involving the design, manufacturing, usage and end of life phase of products/ services which enhance circularity in that sector.

Table 2-1 below presents the list of circular economy sectors and activities presented in the literature, showing which activities are included in the three main reference sources, being: (1) an EU action plan for the circular economy, (2) EC scoping study to identify circular economy priority sectors, and (3) WRAP study on economic potential of circular economy in the EU.

Table 2-1: Typology of circular economy activities according to the sectoral approach

Sector	Circular economy activity	EC, 2015	EC, 2014b	WRAP, 2015b
Waste management	Waste collection (Separate collection, improved separating technology; deposit return schemes)	X	X	X
	Recycling (packaging, e-waste, plastics, materials, etc.)	X	X	X
	Composting		X	
	Processing recyclable materials	X		X
	Reuse of recyclable materials	X	X	X
	Waste-to-energy	X	X	
	Recovery of sorted materials			X
	Waste shipments			
Repair of machinery and equipment	Repair of fabricated metal products			X
	Repair of machinery			X
	Repair of electronic and optical equipment		X	X
	Repair of electrical equipment		X	X
Repair of computers, electronics & household goods	Repair of consumer electronics		X	X
	Repair of computers		X	X
	Repair of household appliances and home equipment		X	X
	Repair of footwear, leather goods			X
	Repair of furniture, watches,		X	X
Construction	Deconstruction of buildings instead of demolition		X	
	Preventing new construction through sharing and repurposing of current buildings			
	Design for deconstruction/ modular building	X	X	
	Use of sustainable construction materials – e.g. isolation materials, which are more recyclable, or other materials which are fully recyclable, use of bio-products in construction	X	X	
	Reuse and high-value recycling of components and materials	X	X	
	Construction and demolition waste	X	X	
	Industrial production (i.e. off-site pre-fabrication to reduce waste) and 3D printing of building modules		X	
Product packaging (mainly plastics)	Use of recycled PET	X		X
	Move from single-use packaging to reusable packaging (beverages)	X		
	Re-use processes	X	X	
	Innovative design for packaging (to improve biodegradability, recyclability, etc.) – e.g. bioplastics, substitutes for plastics, self-cleaning packaging	X	X	X
	Reduction of packaging (particularly of fruit and vegetables but also multiple packaging containers)			

Sector	Circular economy activity	EC, 2015	EC, 2014b	WRAP, 2015b
Food and food waste	Anaerobic digestion of food wastes/ organic waste		X	X
	Food waste reduction	X	X	
	Use of former foodstuffs and by-products from the food chain in animal feed production	X		X
	Resource efficient production and distribution	X	X	
	Food donation platforms (using unsold safe food)	X	X	
	Renewable energy production from unsold food/food waste		X	
	Use of biological nutrients/ fertilisers in agriculture	X	X	
	Use of former foodstuffs and by-products from the food chain in other bio-based products (chemicals, plastics)			
Consumer electronics	Re-use, refurbishment, remanufacture of electronic appliances	X	X	X
	Design for increased recycling, re-use, repair and materials extraction (e.g. flat screens, in-use and user-led	X	X	
	reparation)		X	
	Modulation of components	X	X	X
	Sharing and renting platforms – renting and leasing of personal and household goods			X
	Resale of consumer electronics	X		X
	Selling 'services' rather than products		X	
	Recovery of critical raw materials and other advanced recycling technology	X		
	Increased lifetime of a product			
Transport (mainly automotive sector)	Design to facilitate repair, refurbishment, recyclability and end-of life material management – the type of materials		X	
	used (e.g. replacement by plastics)			
	Logistics – efficient delivery, access to materials and resources, improved logistics to bring back products and		X	
	materials		X	
	Increased fuel efficiency of vehicles		X	
	Vehicle sharing activities – renting and leasing of cars and light motor vehicles		X	X
	Modular car and remanufacturing		X	
	End of life vehicles activities		X	
	Hybrid/ electric cars		X	
	Batteries recycling			
Biomass and bio-based products	Bio-based chemicals		X	
	Separate collection of bio-waste	X	X	
	Reuse and recycling of bio-based materials	X		
	Replacement of mineral fertilizers with organic fertilizers			
	Increased use of lignin and other by-products pulp and paper industry			
	Bio-based packaging (instead of plastics)			
			X	

Sector	Circular economy activity	EC, 2015	EC, 2014b	WRAP, 2015b
Administration, Finance & insurance	Extended warranties for products, warranties for refurbished/ remanufactured products		X	
	Insurance products for collaborative platforms			
	Rental & leasing activities			
Water management	Water reuse for irrigation	X		
	Reuse of nutrients in wastewater	X		
Apparel	CE-related changes in design/manufacturing, supply, use, disposal and recycling of clothing			
	Increased lifetime of clothing			
	Renting and resale of clothing			
Horizontal measures	R&D support for circular economy innovations	X	X	
	ICT-tools for digitalization			
	Innovative business models (e.g. selling services rather than products, sharing, etc.)			
	Green public procurement	X	X	
	Eco-design (applies to a variety of products)	X		
	Ecolabeling	X		
	Environmental footprint	X		
Recovery of critical raw materials	Recovery of critical materials from mining waste and landfills	X	X	

There are two other circular economy market issues discussed on EU level among stakeholders. One is the development of a market for secondary raw materials and the second is the development of industrial symbiosis.

Secondary raw materials market

Secondary raw materials are recycled materials that are reused for the production of new products. Today, the share of secondary raw materials used in EU is relatively low. The main obstacle to the development of a secondary raw materials market is the uncertainty regarding the quality of secondary materials compared to virgin ones. Setting up waste management practices and EU-wide standards that guarantee the quality of these materials might increase the trust and the use of these materials. Recycled nutrients are typically the type secondary raw materials for which quality standards should be designed. Indeed, the trade of fertilisers that are based on recycled nutrients is today hindered by different environmental and quality standards across member states. In order to develop a secondary raw materials market, cross-border circulation of these materials should be facilitated to ensure that they can be traded easily. One other reason why there is a distrust over secondary raw materials is that chemicals that are dangerous for human health can sometimes be found in recycling streams. There is thus a safety-related risk for new products that are made from these recycled materials. In its Action Plan for Circular Economy (EC, 2015), the European Commission has proposed solutions to tackle these various issues and promote the further use of secondary raw materials.

Industrial symbiosis

Industrial symbiosis can be defined as a system approach in which "traditionally separate industries [engage] in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products" (Chertow, 2000). By using the waste streams of one sector as resources for other sectors, industries have the opportunity to replicate the functioning of the natural eco-system, in which everything has a function and where waste is systematically regenerated into something new. Industrial symbiosis allows us to better understand the resource flows in the economy and thus to identify areas of inefficiency.

In this study, we acknowledge that these circular economy market developments are taking place in Europe, however, this study does not focus on modelling their labour impacts.

Available quantitative estimates of investments and, costs savings

RQ 9) Data on investments and expenditures for circular economy activities and sectors for the EU and in different Member States (if available – could be used to feed into the modelling of employment impacts).

The published literature has been used to find quantitative estimates of investment needs, cost savings, material savings and value created through circular economy sectors and activities. Most of the published estimates are based on modelling of the circular economy in specific sectors by scaling up bottom-up information (e.g. Ellen MacArthur Foundation studies), modelling different rates for recycling, remanufacturing, repair and reuse (e.g. WRAP, 2015), modelling different material efficiencies and material flows (e.g. Tuladhar et al., 2016; Haas et al., 2015), or modelling reductions in expenditures from consumers (e.g. Bohringer & Rutherford, 2015). In its scoping study (2014), the European Commission identifies different priority materials for the circular economy and assesses the potential savings to the economy.

An overview of available estimates by sector and circular economy activity can be found in Appendix A. This list is non-exhaustive but provides a rather detailed overview of available data.

2.4 What are circular economy jobs and skills?

RQ 2) What kind of jobs are created and lost? This should include, as far as possible, an estimate of the range of skills levels involved (i.e. high, medium and low skills) and a breakdown by the main age groups. – This will provide qualitative and quantitative insights into the skills and occupations needed to pursue circular economy activities in the EU.

RQ 3) Does an improvement in resource efficiency lead to more or better jobs (in terms of precariousness, safety, duration)? – This will provide information on the quality and sustainability of resource efficiency and circular economy-related jobs.

RQ 7) Literature/data on the skills and training needs associated with the transition to a circular economy.

It is difficult to define ‘types’ of circular economy jobs and skills. The literature generally provides an indicative steer of the direction of travel (examples of new jobs) and typically only focused on aspects of the circular economy in each case. These qualitative indications do not generally piece together to form an overall picture, although consistent themes do emerge. The general literature on changing demand for skills is focused on higher-order trends, and connects more clearly within the qualitative circular economy evidence base.

There is no strong evidence that the changing skills composition of jobs in the circular economy will differ radically from wider trends across the EU, which indicate a decline in employment for people with low-level qualifications (from 25.5% of jobs in 2005 to 15.4% in 2025) and a substantial increase in employment of people with high-level qualifications (25.3% in 2005 to a forecast 38.4% in 2025)[4].

However, there is evidence suggesting that circular economy are primarily higher-skilled jobs, but there are also a significant number of low-skilled jobs – often in tandem. In general terms, the literature argues for increases in design-related[5] and technology-related jobs, potentially across a range of circular economy sectors, which will drive much of the growth in high-skilled jobs. This

[4] Cedefop skills forecasts (2016)

[5] CEPS (2016), The impact of the collaborative economy on the labour market

includes jobs in planning and the development of 'smart' digital systems[6], as well as a range of ICT-jobs relating to big data, cloud computing, 3D printing and other enabling technologies[7].

The literature points to not just the creation of more higher-skilled jobs, but a specific need for specialist skills. It has been suggested that the low-carbon technology sector faces shortages in areas such as technical engineers in Germany and technical specialists, designers, engineers and electricians in the UK[8]. Aspects of the circular economy reflect wider challenges across the EU in terms of the availability of cutting edge science, technology, engineering and maths (STEM) skills – although it is plausible to suggest that the growth of the circular economy is particularly affected (for example, knowledge in areas such as material uses and flows[9]). This is a long-running challenge for education and skills policy.

If a distinction is drawn between green jobs 'that respond to the impact of the linear economy' and green jobs in a circular economy that focus on 'generating value', it is possible to get a clearer sense of how these different types of new jobs co-exist[10]. This, and the combination of new high- and low-skilled jobs, is illustrated well by the case of remanufacturing, which is arguably one of the aspects of the circular economy in which the development of genuinely new roles is clearest – as opposed to a refashioning of existing occupations into new sectoral combinations. Remanufacturing creates new skilled jobs[11] [12], including roles related to refurbishment, disassembly, maintenance and redistribution that are a mix of high and low skilled jobs[13]. Conversely, in the consumer goods sector, the circular economy is expected to primarily create entry level and semi-skilled jobs[14], and a similar picture emerges in relation to waste management and recycling – although in both of these cases it is possible to link to higher-skilled jobs in product and process design.

This finding reflects the fact that jobs are created across the lifecycle of circular economy 'products'. For example, the growth of anaerobic digestion in the food and green waste recycling sector creates a range of roles associated with design, construction, operation and maintenance of the plants to

[6] UPS/Greenbiz (2016), The growth of the circular economy

[7] Accenture (2015), Waste to wealth

[8] European commission (2012), Staff working document: Exploiting the employment potential of green growth

[9] Ellen MacArthur Foundation (2014), Towards a circular economy - Accelerating the scale-up across global supply chains (volume 3)

[10] ECOAP (2014), Transforming jobs and skills for a resource efficient, inclusive and circular economy

[11] reNEW (2015), Job Creation in the Circular Economy - Increasing Resource Efficiency in Northern Ireland

[12] EEB (2016), Fact sheet - Measuring and monitoring resource efficiency

[13] ECOAP (2014), Transforming jobs and skills for a resource efficient, inclusive and circular economy

[14] Ellen MacArthur foundation (2013), Towards a circular economy - Opportunities for the consumer goods sector (volume 2)

feedstock purchasing and products sales and marketing positions[15]. This combination helps to explain the complex skills mix associated with the circular economy.

To a certain extent, the circular economy might appear to mirror the broader trend of 'hollowing out' of jobs across the skills spectrum, with increases in high- and low-skilled employment combined with fewer medium-level jobs. The weight of evidence suggests that medium-skilled workers are at 'greater risk of inadequate adaptation and access to training possibilities'[16].

What this means in terms of the dynamics of employment is debatable. Much of the literature on job creation and destruction is speculative in nature – although plausible. In general terms, it is noted that the share of low-skilled labour in high-carbon sectors is higher than the respective share in low-carbon sectors. Moving people between these sectors therefore requires re-skilling strategies[17]. It is not clear, however, that this process explains the actual or likely movement of people between changing jobs and sectors. There are some examples of job shifts within existing sectors that could be supported through re-skilling, such as from new building to renovation in housing, and from public transport to electric vehicles[18], but it is not clear that the training requirements are particularly onerous in these cases.

There is no evidence to suggest that improvements in resource efficiency directly lead to more jobs or better-quality jobs. This partly reflects the wide-range of occupations across the sectors that are defined within the circular economy, making it reductive and analytically impossible to provide a meaningful direct comparison.

There is an arguable policy position that a transition to a circular economy provides an opportunity to improve job quality[19], and the trend towards a greater concentration of high-skilled jobs is associated with increased job security and safety. However, the shifts are likely to be uneven between sectors and countries across the EU[20].

It is possible that increased resource efficiency could indirectly lead to improved job security via policy measures. For example, it is plausible to

[15] reNEW (2015), Job Creation in the Circular Economy - Increasing Resource Efficiency in Northern Ireland

[16] European commission (2012), Staff working document: Exploiting the employment potential of green growth

[17] European commission (2012), Staff working document: Exploiting the employment potential of green growth

[18] Begg, Ian/LSE (2014), Decarbonising the EU Economy: threat to jobs or opportunity?

[19] European commission (2012), Staff working document: Exploiting the employment potential of green growth

[20] OECD (2012), The jobs potential of a shift towards a low-carbon economy

suggest that should the tax burden shift from labour to resources, job security could increase[21], although this is somewhat speculative.

Even if the overall trend towards higher-skilled jobs increases job quality, it is also important not to over-estimate the shift, and to recognise risks in areas such as health and safety that can arise "in jobs such as 'green' construction, building insulation activities and consumer waste disposal"[22].

Furthermore, certain aspects associated with the circular economy, such as the sharing economy and peer-to-peer networks, are associated with weaker job security and a mixed picture on job quality[23] [24].

A lack of skills has been described as a barrier to investment in energy efficiency opportunities[25], and several commentators identify training and skills development needs in relation to SMEs (to add training). This reflects a common view that in order for the full potential of the circular economy to be unlocked there is a requirement for a combination of engineering/science-related skills and business development or management skills[26] [27].

2.5 Does the circular economy change the relation between the use of capital, materials and labour and what are the consequences for labour?

4) What can be expected regarding the substitution between capital, use of materials and labour? What are the consequences for labour? – Would there be any losers from more circular economy and resource efficiency? Who are the winners?

Substitution impacts

For mainstream macro-economists, long-term economic growth is assumed to stem from one of the three core foundations related to production: labour productivity, capital productivity and a 'residual' (named after Solow) that is supposed to capture growth from any other source of productivity (Ayres & Warr, 2004). As presented in Section2.3, the circular economy represents an economic system that is restorative and regenerative by intention and design, where resources and materials are kept in use for as long as possible. It represents the alternative to the 'linear' take-make-waste system on which the majority of our economy is currently based on. Very simply put, as the circular

[21] The Extax Project (2014), New Era-New Plan-fiscal reforms for an inclusive, circular economy

[22] European commission (2012), Staff working document: Exploiting the employment potential of green growth

[23] CEPS (2016), The impact of the collaborative economy on the labour market

[24] Amar, N and Viossat, L-C (2016), Collaborative platforms: Labour and social protection

[25] Smith (2015), Doubling Energy & Resource productivity by 2030 volume 3: A Guide for Business Leaders and Policy Makers

[26] ASPRG & APMG (2014), Triple win: The Economic, Social and Environmental case for remanufacturing

[27] European commission (2012), Staff working document: Exploiting the employment potential of green growth

economy aims to create at least the same amount, but often more economic value, using the same or less amount of resources and materials, it decouples economic growth from the use of resources. Without a change in the ratio between the use of labour and capital input, the resource productivity gain is captured by the Solow residual (as for example found by Ayres & Warr, 2004). An older study in Germany, Japan and the US found that resource use accounted for almost 50% of economic growth between 1960 and 1990 (Kümmel, 1998).

The circular economy's principles go beyond solely increasing resource efficiency and intensity of production, however. The circular economy alters the way in which goods and services are produced and consumed. It could potentially affect the overall relation between capital and labour in two ways:

(i) **A redistribution effect between sectors** - by stimulating growth in sectors that play a crucial role in regenerating and restoring the value of existing assets and materials (e.g. recycling, refurbishing etc.), whose production processes typically have high labour-to-capital ratios in production, and reducing demand for services from services that need to be phased out: extractive industries, manufacture of new products and waste management sectors. EllenMacArthur notes in one of the first defining circular economy papers (2013) that labour intensity per unit of GDP is much higher for the secondary (manufacturing) and tertiary (services) sectors than for the primary (resources and agriculture sectors). Overall, and on average, the circular economy stimulates growth in the secondary and tertiary sectors more than in the primary sectors[28];

(ii) **A substitution effect within sectors** – by stimulating a longer useful life of products and materials, delivery of economic value within a sector ('production') can change to include more repair and refurbishing activities instead of producing more new products. Repair and refurbishment often tend to be more labour intensive than the production of new goods, so such a shift could increase the labour-to-capital ratio within a sector.

However, the impact of the circular economy on the overall capital-labour ratio is more complex. Based on a large meta-analysis of existing literature on the employment effects of material and resource efficiency, the *Growth Within* report from the Ellen MacArthur foundation concludes that the direct redistribution effects between the waste and recycling sectors (positive) and materials sectors (negative) are approximately equal. The nature of the employment effects thus depend on the indirect and induced effects of the circular economy, which are described to be net negative for manufacturing sectors (despite servitisation and an increase in refurbishing and repairing

[28] Ellen MacArthurFoundation, 2013, Towards a circular economy - Opportunities for the consumer goods sector (volume 2), Figure 11 on pp. 88

activities), but strongly positive overall due to the rebound effect of increased consumption due to overall lower prices across all sectors and some additional 'eco-innovation' jobs.[29] In addition, the circular economy relies to a large extent on further digitalisation and automation of the economy (Ellen MacArthur, 2015), which can increase the importance of capital within and across sectors and, in turn, decrease the labour-to-capital ratio of the above two effects. In terms of the RESOLVE levers defined by the Ellen MacArthur foundation, the 'virtualise' and 'optimise' loops rely quite strongly on the use of capital goods (IT, big data, automation, etc.), whereas the 'share' and 'loop' levers rely more strongly on the more intense use of labour. We should also not forget that technological advances would also influence the economy without any development of the circular economy and would affect the relation between capital and labour in production in the future (Ellen MacArthur, 2015). It is therefore *a priori* very difficult to predict the impact of the circular economy on the capital-to-labour ratio.

Moreover, even if the circular economy would lead to a higher labour to capital input ratio in the economy, this does not mean that employment automatically increases. As presented in a German paper on the effects of a reduction in material input in production by Fischer, Lichtblau, Meyer and Scheelhaase (2004), the characteristics of the labour market can fully determine whether productivity improvements (due to higher material efficiency) would lead to additional jobs or only to higher wages and no additional jobs. In case the gains in productivity are fully incorporated in the returns to labour (wages) and the higher output is delivered by the same number of employees, no new jobs are created and existing workers receive the full benefits of the productivity increase in wages. The productivity gain will however also result in lower prices (due to lower costs of production), which increases demand for the goods and can increase production from this rebound effect, leading to more employment. Next to this, there is a direct loss of demand and output in the material producing sectors with a loss in employment as a result. The combined effect of these partial effects in opposite directions on employment is according to Fischer *et al* (2004) negative in the scenario that most closely resembles the German labour market in 2004 (an increase in material efficiency of 10% would lead to a loss of 480,000 jobs) as wages would reap part of the increase in productivity. The winners from material productivity increases in such scenarios are workers already employed in the expanding sectors due to the increase in wages, whereas the losers are the workers in the contracting sectors that face a reduction in demand.

[29] Ellen MacArthurFoundation, 2015, Growth Within – A circular economy vision for a competitive Europe, Figure 17 on pp. 36

2.6 What are the impacts of the circular economy on jobs?

6) How do circular economy activities and business models impact jobs? What are the drivers behind the impacts? Are the effects on labour direct or indirect?

The amount of literature that discusses the employment effects of the circular economy is still relatively limited but there are some studies available. There are several ways in which these studies approach the topic of employment impacts. Some of them take a sectoral approach where certain sectors were labelled as 'circular sectors' and changes in the amount and type of employment in these sectors are then considered to be the employment effects of the circular economy (e.g. WRAP, 2015b). Other studies, especially those addressing new circular activities such as remanufacturing or service-based business models, primarily describe the employment effects of the circular economy in a qualitive way, using anecdotal evidence.

Qualitative aspects of circular economy jobs

Most studies show that the circular economy has the potential to generate employment throughout all skill levels (WRAP, 2013; CEDEFOP, 2012; Ex'tax project, 2014). Expansion of the recycling sector will create jobs for low-skilled workers, but to an increasing extent, also create high-skilled jobs (The European files, 2015). The Ellen MacArthur foundation predicts that the circular economy will increase the demand for entry-level and semi-skilled workers (Ellen MacArthur, 2014). There will also be a need for some high-skilled tasks, such as the development of smart ICT solutions to efficiently organise reverse logistics; that are required for reuse and remanufacturing practices (UPS, 2016). Furthermore, high-skilled ICT staff will be needed to connect more products to the 'internet of things', so that the location, performance and maintenance state of products can be tracked more easily, which can facilitate more efficient logistics, repair and replacement of products (WEF, 2015).

Another aspect that is often mentioned is that there will be a change in the types of skills that will be required in the circular economy. One of the most important aspects in this regard is that product designers need to develop their products with circular principles in mind, so that products can more easily be reused, remanufactured, refurbished or recycled. This approach will require designs that are more modular in nature and have less mixed-material inputs (Ellen MacArthur, 2014). Therefore, it is important that education programmes for designers also put more emphasis on the consideration of circular economy principles in the design phase (Ellen MacArthur, 2013; Andrews, 2015). Next to that it is important that supply chains managers become more aware of all the kinds of material inputs that are used in production processes and what alternative materials are available (Ellen MacArthur, 2013). These managers should also know which by-products are generated and what the potential uses of such by-products are, including in other industries. This emphasises the fact that cooperation between different companies, sometimes even from different sectors, is essential to reduce material flows (Ellen MacArthur, 2014).

For the rest of this section the focus is on the results from modelling studies, as these are most relevant for the purpose of the current study.

What are the projected impacts of the circular economy on jobs?

Main outcomes of modelling studies

The number of studies that have modelled the impacts on labour markets of a transition to a circular economy is quite limited. The only relevant national studies are for the Netherlands, the U.K. and Denmark (TNO, 2013; WRAP, 2015; Ellen MacArthur, 2015). These studies all find positive job impacts with a similar order of magnitude. The Dutch study estimated that 54,000 jobs could be created by utilising the estimated current potential for implementation of circular economy practices (TNO, 2013). The UK study estimated that, with the current rate of developments in the circular economy, 54,000 additional jobs would be created in 2030 resulting in a 0.15% decrease in overall unemployment (WRAP, 2015). In a more ambitious scenario modelled in this study, where among other things, much higher recycling, remanufacturing and reuse rates are assumed, 102,000 additional jobs could be created by 2030, which leads to a 0.285% decrease in overall unemployment. The case study for circular economy opportunities in Denmark estimated that 7,000 additional jobs could be created by 2035 in a conservative scenario, increasing to 13,000 in an ambitious scenario (Ellen MacArthur, 2015). It should be noted, however, that this is likely to be an underestimate of the total employment effect as it was only based on five sectors.

Many more studies have looked into the employment impacts of increasing resource efficiency, energy efficiency or large-scale deployment of renewable energy technologies. Resource efficiency/productivity can be related to the circular economy, but is not necessary the same thing. The drawback of such metrics is that they are relative, meaning that resource efficiency can increase while there is no absolute decrease or even an increase in the use of raw material inputs. As long as economic output increases faster than the amount of material inputs required, resource efficiency increases. This is called the relative decoupling of resource use from economic growth. The concept of the circular economy, however, is built on the concept of absolute decoupling: economic growth with declining (and ideally no) raw material inputs (Van Ewijk & Stegemann, 2014).

Ambitious resource efficiency goals are estimated to have a major positive effect on the European economy. A study by GWS estimated that each percentage point increase in resource efficiency in the EU could create between 100,000 and 200,000 additional jobs and an additional increase in resource efficiency of 25% could create up to 2.6 million jobs (Meyer, 2011). Another study estimated that increasing the annual resource efficiency improvement from the current rate of 0.85% to 2% or 3% could create 1 million and 2 million additional jobs in 2030, respectively (European Commission, 2014). A study by the Club of Rome estimated that a 25% increase in resource efficiency combined with the replacement of 50% of the raw material inputs with recycled materials could create more than 50,000 jobs in both Finland and Sweden, more than 100,000 in the Netherlands, more than

200,000 in Spain and over 300,000 in France (Club of Rome, 2016). Table 2-2 gives an overview of economy-wide employment related to the circular economy and other 'green economy' objectives.

Table 2-2- Estimates for economy-wide employment impacts related to the circular economy

Sector	Jobs created	Geographical scope	Relevant assumptions	Methodology applied	Source
Food & beverage, construction & real estate, machinery, plastic packaging and hospitals	7,000-13,000 in 2035	DK	Conservative scenario – ambitious scenario	Dynamic General computable equilibrium (GCE) model	Ellen MacArthur, 2015[30]
Economy-wide	54,000 (0.15% decrease in net unemployment)	UK	Current rate of development	Not specified	WRAP, 2015[31]
Economy-wide	102,000 (0.28% decrease in net unemployment)	UK	Transformation scenario	Not specified	WRAP, 2015[32]
Economy-wide	54,000	NL	Circular economy potential in the metal-electro sectors was extrapolated to entire economy	Jobs created were calculated from additional value added and share of labour cost in VA	TNO, 2014[33]
Economy-wide	>300,000 >50,000 >50,000 >100,000 >200,000	FR FI SE NL ES	Material efficiency scenario: 25% increase in resource efficiency 50% replacement of virgin material	Input-output modelling with sector data input from WIOD database	Club of Rome, 2015[34]

[30] Ellen MacArthur Foundation, 2015.

[31] WRAP, 2015. Employment and the circular economy -Job creation in a more resource efficient Britain

[32] WRAP, 2015. Employment and the circular economy -Job creation in a more resource efficient Britain

[33] TNO, 2014. Opportunities for a Circular Economy in The Netherlands

[34] Club of Rome, 2015. The Circular Economy and Benefits for Society Jobs and Climate Clear - Winners in an Economy Based on Renewable Energy and Resource Efficiency

			inputs with recycled inputs		
Economy-wide	500,000 75,000 100,000 200,000 400,000	FR FI SE NL ES	Integrated scenario: material and energy efficiency + renewables -Same assumptions for material eff. 25 % in energy efficiency 50% of energy from fossil fuels replaced with renewables	Input-output modelling with sector data input from WIOD database	Club of Rome, 2015[35]
General resource efficiency/productivity & recycling studies					
Economy-wide	2,000,000	EU	- Resource productivity increase of 30%, leading to an 1% increase in the EU GDP	Not specified, likely GCE modelling	ECOAP, 2014[36]
Economy-wide	100,000-200,000 additional jobs Up to 2.6 M additional jobs	EU	Increase of resource efficiency with 1 percentage point Increase resource efficiency with 25%	Modelling with E3Me and GINFORS	Meyer, 2011
Economy-wide	1 M additional jobs in 2030 2 M additional jobs in 2030	EU	2% increase resource productivity p.a. 3% increase resource productivity p.a.	Modelling using E3Me.	EC, 2014

[35] Club of Rome, 2015. The Circular Economy and Benefits for Society Jobs and Climate Clear - Winners in an Economy Based on Renewable Energy and Resource Efficiency

[36] ECOAP, 2014. Transforming jobs and skills for a resource efficient, inclusive and circular economy.

			Resource productivity did not have to increase equally in all sectors or member states		
Economy-wide	50,000	UK	A £10 bn investment	Not specified	Environmental services association, 2013
Economy-wide		EU	Increased rate of recycling and reuse		EEB, 2014

Sector-specific employment impacts

In addition to the studies above, several studies have looked into sector-specific employment effects relating to a shift towards a circular economy. Most of these studies have focused on the recycling and waste treatment sector. According to an EU-wide study, increasing the overall recycling rate to 70% could create direct 322,000 jobs, plus 160,900 indirect jobs and 80,400 induced jobs (Friends of the Earth, 2010). A UK study found that ‘improved waste management’ could create a total of between 19,000 and 36,000 direct jobs and 25,000-48,000 indirect jobs (Sita UK, 2012). It has been also estimated that energy production from anaerobic digestion of organic waste could create 35,000 jobs if the full potential is utilised (Defra, 2011). In addition to the recycling sector, the employment effects of implementing circular activities have been estimated for several other sectors. For an overview of these sector-specific labour market effects (see Table 2-3)

Table 2-3 - Estimates for sector-specific employment impacts related to the circular economy

Sector	Activity	Employment data	Source
Recycling and waste treatment	Increasing the overall recycling rate in EU to 70%	322,000 direct jobs, 160,900 indirect jobs and 80,400 induced jobs can be created	Friends of the Earth, 2010
Recycling and waste treatment	Generate energy from organic waste through anaerobic digestion	35,000* jobs can be created within UK only if full potential is utilised	Defra, 2011
Recycling and waste treatment	Implementing all waste management policies formulated by the EU that were known by 2011	400,000 additional jobs could be created in 2020 compared to scenario with no further waste management polices implemented after 2008	Bio intelligence service, 2011
Recycling and waste treatment	Overall improved waste management in the UK	Between 19,000 and 36,000 direct jobs and 25,000-48,000 indirect jobs	Sita UK, 2012

Recycling and waste treatment	Energy recovery from waste	Between 4,800 and 5,500 direct jobs and 6,500-7,500 indirect jobs	Sita UK, 2012
Recycling and waste treatment	Material recycling facilities	Between 7,500 and 12,000 direct jobs and 9,000-16,000 indirect jobs	Sita UK, 2012
Recycling and waste treatment	Organic treatment	Between 4,000 and 6,000 direct jobs and 6,000-8,000 indirect jobs	Sita UK, 2012
Recycling and waste treatment	Dismantling etc.	Between 3,000 and 12,500 direct jobs and 3,500 and 16,500 indirect jobs	Sita UK, 2012
Recycling	**Modest scenario:** 55% recycling in 2025, 65% by 2030 **Medium scenario:**60% recycling in 2025, 70% by 2030 **Ambitious scenario:** 55% recycling in 2025, 65% by 2030	442,350 jobs in 2025, 482,570 in 2030 482,570 jobs in 2025, 567,500 in 2030 482,570 jobs in 2025, 567,500 in 2030	EEB, 2014
Construction and real estate	Deconstructing buildings instead of demolishing them	1 FTE job per house per year that is deconstructed instead of demolished (estimate for U.S.)	Ellen MacArthur, 2013[A]
Packaging industry	Shifting from one-way packaging to reusable packaging or vice versa	switch from 73% linear to 100% linear job loss of 27,000, from 73% linear to 100% reusable 53,000 jobs created	Ellen MacArthur, 2013[B]
Industrial biotechnology	Increasing activities in this sector which includes circular economy activities, but also other activities such as jobs in biomedical innovation	400,000-1,000,000 additional jobs in 2030	EuropaBio, 2016
Forestry	Increased use of biomass as feedstock for products and fuels	12,000-21,000 jobs created in Denmark, depending on policy options chosen	Ellen MacArthur, 2015
Consumer electronics	Implementing resource efficient business models for TVs, such as take-back for re-sale	4,000 jobs created in the UK	WRAP, 2013
Clothing industry	Implementing resource efficient business models for clothing, such as take-back for re-sale	3,000 jobs created in the UK	WRAP, 2013

Clothing industry	**Modest scenario**: 15% reuse of textile waste in 2025, 20% in 2030 **Medium scenario:** 215% reuse of textile waste in 2025, 30% in 2030 **Ambitious scenario:** 30% reuse of textile waste in 2025, 35% in 2030	13,500 jobs in 2025, 17,400 in 2030 21,750 jobs in 2025, 26,100 in 2030 26,100 jobs in 2025, 30,450 in 2030	EEB, 2014
Furniture	**Modest scenario:** 30% reuse of textile waste in 2025, 35% in 2030 **Medium scenario:** 35% reuse of textile waste in 2025, 40% in 2030 **Ambitious scenario:** 40% reuse of textile waste in 2025, 45% in 2030	179,369 jobs in 2025, 209,205 in 2030 209,205 jobs in 2025, 239,159 in 2030 239,159 jobs in 2025, 269,053 in 2030	EEB, 2014

NB For many of these employment effects no time frames are mentioned, because the effects are calculated based on the assumption that the stated potential is completely utilised or goals are achieved, regardless of the time that is needed for this.

Methodologies and assumptions

The studies that specifically looked into the employment effects of circular economy activities have mostly used a bottom-up approach, starting from sector-specific circular potentials. The Dutch study, for example did an in-depth analysis to estimate the remaining potential for the metal-electro sectors and bio-waste sectors and these potentials were used for extrapolation to similar sectors (TNO, 2013). Similarly, the study on circular economy opportunities in Denmark focused on sector-specific potentials, which were subsequently fed into a general computable equilibrium model (Ellen MacArthur, 2015[A]; Ellen MacArthur, 2015[B]). In this study the potentials were not extrapolated to the entire economy.

The studies that investigate the labour impacts of resource efficiency improvements have mostly used more top-down approaches, using macro-economic models. Several studies have used input-output models or similar models and have constrained the model outcome in such a way that it achieves a certain level of resource efficiency (Club of Rome, 2015; .EC, 2014; Meyer, 2011). This approach has the advantage that it covers the entire economy, but due to data limitation, the approach is too coarse to cover the detailed sector-specific changes that occur during a shift to a more circular economy. The bottom-up approach as developed in the circular economy policy toolbox by the Ellen MacArthur Foundation (2015[B]), which was also used for the Denmark study, may be the preferred starting point for further development of methodologies to model circular economy impacts.

Unfortunately, many studies that looked into the economic and labour market effects of ‘green economy’ objectives such as increased resource efficiency or circularity, do not explain their methodologies and assumptions in sufficient detail. A study by the European Environmental Bureau for example states in its report 'we have made conservative estimates based on a review of literature and *some assumptions about employment potential* in under researched areas such as reuse' and that it used 'established economic modelling techniques' (EEB, 2014). The study on the labour effects of the circular economy in the UK mentions its scenario assumptions, but not which model it used to calculate the results (WRAP, 2015). Other studies do not mention which method was used at all (ECOAP, 2014; Defra, 2011; Sita, 2012). It is also not clear whether these studies have taken into account the rebound effects, i.e. increased resource use resulting from increased resource use efficiency and increased employment and the corresponding increase in household income.

Lack of comparability between studies

For several of the studies on employment effects that have been published to date it is hard to compare the outcomes, for several reasons. First of all, the studies differ a lot in their geographical and temporal scope; some look at a specific Member State, others at Europe as a whole and some use 2035 as the future time horizon, whereas others use 2030 or 2025. Secondly, some studies use a scope that is much broader than only the circular economy. Some studies look into the employment effects of a transition to the green economy, which also covers employment effects occurring in the energy sector because of replacement of fossil fuels with renewables. Thirdly, studies use different methods and different assumptions and, in many cases, these are presented in a transparent way. One of the most important assumptions in this respect might be the ambition level that is chosen for the future circular economy, which can vary from only increased levels of recycling or mere resource efficiency improvements to more ambitious cases that also include increased reuse and remanufacturing. Lastly, there can be large differences in how job impacts are defined, as described below.

When calculating the numbers of jobs created it is important to distinguish between gross and net employment creation. Gross measures can be misleading as they do not take into account jobs that are lost due to substitution effects. Many studies providing estimates on the employment effects of the circular economy do not state whether their estimates involve gross or net figures, which makes it hard to compare figures from different studies.

Another aspect that is important to take into account when discussing numbers of jobs created is the baseline level of unemployment.. Many economists argue that unemployment will not decline below the NAIRU ('non-accelerating inflation rate of unemployment') because low unemployment levels lead to increases in wages and inflation (WRAP, 2013). Therefore, there will only lead to a decrease in unemployment (and a net increase in employment) if the unemployment rate is above the NAIRU level, which is estimated to be somewhere around 5%. However, in many Member States the unemployment level is still substantially higher than the NAIRU level and as such there is still room for net job creation. As an illustration, 8.5% of the active labour force in the EU28 was unemployed in 2016 (EUROSTAT,2017).

Uncertainties in modelling outcomes

For all modelling studies that investigate the employment effects of the circular economy it is very important to consider that there are some inherent uncertainties underlying the results of these studies. First of all, effects are often aggregated to a sector-level, while many changes take place at sub-sector level, company level or even at the level of business models. Secondly, many studies extrapolate the impacts that were obtained through a relatively detailed assessment of a certain sector to other sectors that are similar (e.g. TNO, 2013; Ellen MacArthur, 2015). This approach might add to the error margin in the estimates obtained. The last, and perhaps most important uncertainty in the modelling, is that we simply do not know how the economy will develop in the future and how technological and societal innovation will change the economic structure (i.e. the baseline projections).

It is important to note that many employment effects calculated through modelling studies arise from substitution of production between sectors with different labour intensities. Increased recycling is for example often assumed to have positive job impacts as the labour intensity is relatively high in this sector (Tellus Institute, 2011; ESA, 2013; Friends of the Earth, 2010). It should be noted, however, that extrapolating this into future job impacts should be done with care. A study done for the European Commission in 2001 already indicated that future increases in demand for waste management services does not necessarily lead to more jobs in this sector (European Commission, 2001). For a lot of products, for example smart phones and tablets it is currently not economically feasible to disassemble them and separate the different materials by using human labour because it requires too much time (NCER, 2016). Automation might be a solution to make such processes profitable (NCER, 2016; recyclingproductnews, 2016), but this clearly reduces the amount of additional jobs that will be created in the waste management sector.

Another complication is that the ambition level that is chosen for the implementation of circular economy principles will also affect the labour impacts, both in qualitative and quantitative terms. When the developments will be focused merely on making the treatment of waste more efficient and increasing the recycling rate, employment will increase in the waste-and recycling sector, but not so much in other sectors. In a very ambitious circular economy, however, waste is hardly generated anymore because goods are being reused at the product or component level and no longer at the level of materials. Since these strategies related to the inner loops of the circular economy are still under development it is challenging to predict the employment effects of these activities. The creation of service-based business models for example, might increase turnover and employment in manufacturing companies, while leading to a loss of jobs for intermediary companies selling products. To what extent this substitution will happen will all depend on how fast these new business models will develop and whether they will be embraced by the general public.

2.7 Which are the most important sectors for circular economy-related jobs?

Sectors with the most job gains and losses

RQ 1) Which sectors are expected to see most job gains and most job losses, in the short and medium term? The gains and losses should be quantified and trends per sector should be summarised as far as possible. – Answering this question will help identify the most important (economic) sectors in which circular economy-related jobs are being or will be created as well as lost and what are the numbers.

In a study requested by the Club of Rome, Wijkman and Skånberg (2015) issue general trends on job gains and losses across different sectors affected by the circular economy. The sectors that offer virgin materials and those providing durable goods will suffer from a lower demand. In particular, primary sectors engaged in commodity extraction and trading are likely to lose market shares, especially those that specialise in fossil fuel-based and mining activities. On the contrary, sectors engaging in recycling, maintenance and repair activities will grow rapidly and create new jobs. Companies that offer know-how and technology to enable material-efficiency will also benefit from the transition to a circular economy.

The Ellen McArthur Foundation (2015) estimates that three sectors, namely the mobility, food and housing sectors, account for 60% of European household spending and 80% of total resource use. These sectors are therefore expected to experience a profound change, both in terms of organisation and employment. From the literature, we find that these sectors will be most affected by a shift to a more circular economy, in terms of jobs: recycling and waste management, construction, food and beverages, packaging, agriculture and forestry, apparel, furniture, consumer electronics, and the automotive sector.

The Ellen Mc Arthur report (2015) foresees that jobs in the **recycling sector** will be positively impacted by developments towards a more circular economy. It highlights the fact that waste disposal generates only 0.1 jobs per 1,000 tonnes, while recycling processing creates two jobs per 1,000 tonnes. The report concludes that increasing recycling rates would automatically create more jobs in the sector. Moreover, the employment opportunities in the recycling sector affect a wide range of jobs, mainly low-skilled work but also medium and high-skilled jobs (EEA, 2011). Another study shows that if a target of 70% for recycling of key materials was met, 322,000 direct jobs could be created at the EU level in recycling an additional 115 million tonnes of glass, paper, plastic, metals, wood, textiles and biowaste. The study also takes into account indirect and induced jobs creation resulting from knock-on effects in down and upstream sectors and the wider economy. Overall, the total potential for job creation corresponds to more than 563,000 net new jobs (Friends of the Earth, 2010).

The same positive trend for job creation applies to **waste management**. A study estimates that 35,000 new jobs could be generated from the use of anaerobic digestion technologies in the UK (Defra, 2011). Processing biomass would also require the creation of new jobs. A study from the University of Copenhagen has shown that it would be possible to produce an additional 10 million tonnes of biomass without significantly altering land use or output from agriculture and forestry sectors. It estimates that processing this biomass (mainly for fuel) would generate 12,000 to 21,000 new jobs, depending on the type of policy implemented (Ellen McArthur, 2015). Sita UK (2011) estimates that improved waste management in the UK could create between 19,000 and 36,000 direct jobs and 25,000-48,000 indirect jobs.

In the **packaging sector**, it is likely that the transition to circular economy will create new jobs. A study that focuses on Germany, a country characterised by a large proportion of both reuse and one-way packaging (73% of reusable bottles) shows that switching to a completely one-way packaging system for beverages would destroy 53,000 jobs while increasing the share of reusable packaging to 100% would result in 27,000 additional jobs (Ellen McArthur, 2013b).

As for the **clothing sector**, studies assess that more circularity in the economy could create new jobs. In a study on resource efficiency in Europe, the European Environmental Bureau (EEB, 2014) models three scenarios based on the reuse percentage of textile waste and deduces what effect each scenario would have on employment in the textiles sector. The modest scenario predicts a textile waste recycling rate of 20% in 2030, which would lead to 17,400 new jobs, the medium one, a rate of 30% creating 21,600 new jobs and the ambitious one, a rate of 35% creating 30,450 jobs. Another study focusing on the UK highlights that new business models in the clothing industry, promoting take-back for resale for instance, could create up to 4000 new jobs by 2020 (WRAP, 2013).

As a result of activities such as recycling, repair or reuse, a more circular economy is likely to impact the **furniture sector**. The study by the EEB (2014) also addresses the impact of the circular economy on the furniture sector. It uses the same three scenarios as for the clothing sector and concludes that in the modest scenario, furniture reuse would lead to 209,205 new jobs, while in the medium and the ambitious scenarios, it would respectively lead to 239,159 and 269,053 new jobs. However, the WRAP study (2013) found that practices like remanufacture or leasing in the furniture sector would not have a significant impact on jobs.

The broader **manufacturing sector** represents approximately 14% of EU jobs. Activities like repair and remanufacturing induced by the shift to a more circular economy are labour intensive and would therefore lead to job creation. However, this trend could be offset by job losses in new product manufacturing. On the other hand, in the sectors that provide components to wind power plants and solar panel installations, new jobs are likely to be created. Indeed, as the number of electric vehicles increases within the transport sector, there will be more demand for wind power plants, solar panels or other components of renewable energy sources (Wijkman and Skånberg, 2015).

The **agriculture sector** is expected to be negatively impacted by the circular economy in terms of employment. Agriculture, together with **forestry,** sells raw materials. The transition to a more circular economy would imply that sales of raw materials would drop, as the materials already present in the economy would be reused. On the other hand, a study by Wijkman and Skånberg (2015) predicts that sectors able to offer increasing volumes of biofuels – like agriculture and forestry - will gain market share. For instance, modifying plants to produce more auxiliary biomass to be used in bio-refineries is being considered. It should however be noted that such practices would mainly create jobs that are related to biomass processing. Their impact on jobs in agriculture as such is hard to evaluate.

In the **automotive sector**, remanufacturing, as well as the introduction of recycling technological equipment, could lead to a decrease in demand which would translate to job losses in this sector. On the other hand, we can also predict that in a more circular economy the recovery of valuable car resources for the manufacturing of new products would require labour and create job opportunities.

In the **construction sector**, jobs could be created if more buildings are deconstructed instead of demolished. Deconstruction is considered to contribute to resource recovery and the circularity of the economy. Indeed, deconstruction prevents the rubble produced during demolition from going to landfill, thereby avoiding landfill costs and preserving valuable building components and materials for recycling and reuse. Estimates for the US show that if deconstruction was fully integrated into the US demolition industry (which takes down about 200,000 buildings annually), the equivalent of 200,000 jobs would be created (Ellen McArthur Foundation, 2013).

Increased repair and reuse of **consumer electronics** would generate more jobs. For instance, the WRAP study (2013) finds that implementing resource efficient business models for TVs, such as take-back for re-sale could create up to 4,000 jobs by 2020. More generally, a study finds that in the US, 200 repair jobs can be created for every 1,000 tons of used electronics, which equivalates to approximately 45,000 jobs for the estimated 455 million tons of devices collected in 2015 in the US (NCER, 2016).

For the food and beverage processing sector, there has been no analysis found on the general trends of gains and losses from a more circular economy.

2.8 What are the policy responses to circular economy jobs and skills?

Policy responses

8) Literature/data on (existing or potential) policy responses and their impacts, e.g. training initiatives, measures for mainstreaming the circular economy in employment and education policies (which could feed into Task 3).

There are a relatively large number and variety of EU and MS level policies and programmes that are described as being targeted at the promotion and expansion of the circular economy. At the EU level the recent report from the Commission on the Implementation of the Circular Economy Action Plan[37] lists a number of policy and other actions in 2016 and January 2017 that the Commission has taken with regard to the circular economy. There are no skills related policies or actions listed in this report. At Member State Level there are a number of reviews of the policies and measures related to the circular economy, although there is no specific review of the skills for a circular economy. A review which covers the recycling and resource efficiency aspects of the circular economy are the country reviews for the Eco innovation observatory[38]. These country reviews include a specific review of the existence or circular economy specific policies. A number of the countries have green skill strategies, which are of clear relevance to the circular economy, however there are no examples of skills policies specifically branded as targeting the circular economy.

Despite this lack of skills related policy that is described as circular economy it should not be assumed that there are no skills policy responses of relevance. There are numerous training programmes that are of relevance to the circular economy, for example training in the repair of electronic equipment, training in the financial aspects of leasing, training in the design of products to make them longer lasting and training in recycling waste. The key issue is that these skills are not described as circular economy. The waste and recycling and the eco-design skills are already captured under the long standing ‘green skills’ area, however other skills are arguably mainstream / well established aspects (e.g. leasing and renting as part of accountancy / financial management). An interesting example of a skills focussed initiative of relevance to the circular economy is the Build Up Skills[39] programme, which is focussed on the energy efficiency and renewable energy skills needs of the construction sector. This programme started under the Intelligent Energy Europe programme but is now part of the H2020 programme. The first step in the programme was to map the skills needs and current training provision for each MS. The second step was to develop and pilot training programmes designed to address some of the key gaps between needs and provision.

Training initiatives

There is little available evidence on training initiatives to support the transition of jobs related to the circular economy. This probably partly reflects that shifts

[37] http://ec.europa.eu/environment/circular-economy/implementation_report.pdf

[38] https://ec.europa.eu/environment/ecoap/country-reports-2014-2015_en

[39] http://www.buildup.eu/en/skills

apparent to date are relatively niche in nature or that job shifts are forecast for the future. There is, however, a body of evidence about where training initiatives could focus and the nature of current, perceived training-related gaps and shortages.

Significantly, the literature tends to focus on training required to facilitate the transition to the circular economy (i.e. to support or unlock the growth of the circular economy) rather than re-skilling initiatives to support transition between sectors. There is considerable focus on product design, including embedding systems thinking[40] and sustainable design[41] within academic and professional training, as well as extensive literature on the importance of promoting 'green awareness', although this tends to focus on its importance in general education[42].

2.9 Key challenges

- There is a vast amount of literature covering the circular economy on a variety of topics. Some reports covered the circular economy as a whole, while some others looked at specific sectors. Across the literature, we notice that circular economy is still an evolving concept, as its definition varies between studies. For example, some studies interpret the circular economy as mere resource efficiency improvements and/or improved recycling of waste, but our definition recognises that it is more complex and goes beyond that.
- There was relatively little literature on specific sectors. Most of the studies focus on the sectors for which the effects of the circular economy are most obvious, like the waste management or the packaging sector. However, when looking at sectors such as water, chemicals or the bio-economy, little qualitative and quantitative information was available. Overall, there was a lack of consistent and comprehensive quantitative data on circular economy activities and/or its impacts on employment, which emphasises the importance of the current study.
- Designing a typology of circular economy activities proved to be difficult, as all studies take a different approach to how sectors are labelled and which type of activities are included. Some activities such as design, waste management or repair are cross-sectoral, while others are sector-specific.
- There is a lack of comparability between studies mainly because they use different calculation methodologies, geographical and temporal scope. Their outputs have to be carefully considered, as we do not always know which methodology was used. Some studies, for example, extrapolated

[40] Ellen MacArthur foundation (2013), Towards a circular economy - Opportunities for the consumer goods sector (volume 2)

[41] Andrews, Deborah/London South Bank University (2015), The circular economy, design thinking and education for sustainability

[42] ECOAP (2014), Transforming jobs and skills for a resource efficient, inclusive and circular economy

results from one sector to another similar sector, which entails a margin for error. Moreover, the studies had to take into account the fact that the future is unpredictable and that, depending on technological innovations and the ambition level of policies implementing circular economy principles, the resulting employment figures could vary substantially.

3 Identification of Key Sectors

3.1 Main conclusions

- Five key focus sectors were chosen. They are broad enough to represent the most important circular economy sectors and activities in the EU and their potential effects on employment and the labour force. Limiting the number of sectors to five allows us to examine these sectors in more detail in order to understand the impacts of circular economy on the economy.
- We used three selection criteria to identify the most important sectors in the circular economy. These are:
  - (a) the importance of the sector to the EU economy in terms of value added generation and employment
  - (b) the potential of circular economy business models in the sector
  - (c) whether the sector is a priority in terms of policy action and/or whether the sector was identified by previous literature on this topic as a priority or focus sector in terms of its potential for the circular economy
- The sector selection process is based on the NACE sector classification. For each NACE 2-digit sector, we gathered the data and information for the three selection criteria. The results are presented in a comprehensive table that indicates which NACE sector(s) are the most significant in terms of the three selection criteria.
- The five focus sectors proposed are: Food products & beverages, Motor vehicles, Construction, Electronics and Electrical equipment and Waste treatment. The first four sectors will analyse core sectors and their respective life cycle stages up to the point when material/products become waste and go to the waste industry. Waste management and treatment will then be analysed in the fifth sector, waste treatment.

3.2 Why do we need a selection of key focus sectors?

As shown in the literature review section and illustrated by our typology table, circular economy activities have a very wide scope, and cover a broad range of economic sectors.

The literature has also shown that a variety of approaches have been taken to defining a ‘sector’ that is, or will be, affected by the circular economy. Some studies, such as WRAP (2015b) have analysed the employment impacts of the circular economy by defining sectors according to the NACE classification. These sectors include repair services, waste collection, treatment, recovery, retail sale of second-hand goods and rental & leasing activities. An alternative approach has been adopted by EU policy documents, such as the EU action plan for a circular economy (EC, 2015) and the EU scoping study (EC, 2014b) which define 'priority sectors' in terms of a mixture of product perspective (e.g. food, construction, furniture, biomass and bio-based products, electronics, transport) and materials & waste streams perspective (e.g. plastics, critical raw materials, food waste, construction and demolition waste). This approach crosses multiple NACE sectors. The Ellen MacArthur Foundation reports have taken a product market approach in their analysis.

Defining what we understand as a sector was the first challenge of our work. The typology table in Chapter 2 includes the three approaches mentioned above, which results in a long list of potential sectors. However, in order to make the study practically feasible while maximising results from it (going deep enough into the sector analysis), we have taken the decision to base the scope of further analysis (i.e. the preparation of scenarios and modelling) in this study on five key focus sectors. These five key focus sectors are broad enough to cover the most important circular economy sectors and activities in Europe and their potential effects on the labour force, supply chain linkages between the different sectors, and both technical and biological materials and waste streams. The five sector profiles are a combination of circular economy activities and NACE codes, and look at all the linkages/impacts to NACE sectors that an increase in circular economy activity in these areas would generate.

The methodology for the selection of sectors is described in Section 3.3. It has been developed to allow for a systematic assessment of product and waste streams, linking the streams to NACE (and E3ME) sectors. As such, it covers the vast majority of relevant NACE sectors and circular economy activities.

The EC action plan on the circular economy and the scoping study included some other horizontal measures; we consider these as an enabling framework rather than measures that affect the sectors directly.

The added value of this approach is that we look at both NACE sectors and product/ waste streams, and develop a methodology that systematically assesses the importance of all economic sectors.

3.3 Selection criteria for the focus sectors

As explained in the previous section, the aim of the selection of focus sectors is to be able to examine these sectors in more detail to understand what the circular economy could change in them, how we could model the most realistic circular economy transformations in this sector (later on in Task 2 using the E3ME model) and, on the basis of that, understand the impacts that the circular economy could have on the labour market in the EU. As the modelling inputs and the scenarios for the E3ME modelling will be derived from the analyses in these focus sectors, and in turn therefore the overall conclusions to this study, it is important that they:

- Jointly capture a large share of the total potential that the circular economy could deliver to the EU economy by 2030 (the timeframe of this study);

- Represent the sectors and supply chains in the EU economy that are likely to be most significantly transformed by the circular economy towards 2030;
- Represent a variety of potential changes that the circular economy could bring about to the EU economy (in terms of which value transformation processes – circular loops – and business models are likely to be important in the future), including both the technological and biological cycles of the circular economy;
- Jointly represent an adequate mix of the different types of labour classes and categories employed in the EU and that could be affected by the circular economy.

In order to arrive at a representative and balanced set of focus sectors that jointly meet the above criteria, we have developed three selection criteria against which all sectors of the EU economy are scored. The focus sectors for this study are derived from these criteria. The selection criteria are chosen on the basis of our interpretation of the aim and focus of this study, the sector selection approach proposed by the Ellen MacArthur Foundation in their *A Toolkit for Policymakers* publication (2015) and the sector's priority in terms of political action in this field in the EU. Jointly, they reflect the requirements above. The selection criteria are:

1 Importance of the sector to the EU economy in terms of value added generation and employment;

2 Potential of circular economy business models in the sector;

3 Whether the sector is a priority in terms of policy action and/or whether the sector was identified by previous literature on this topic as a priority or focus sector in terms of its potential for the circular economy.

Selection criterion 1: Importance of the sector in the EU economy

In order to select sectors that are likely to observe significant changes in their economic structure and employment effects due to the transition to a circular economy, it is important to select sectors that are currently producing significant value added and employ a large share of the EU workforce. Merely due to their size, the changes to the sector due to the transition to the circular economy will affect many workers and/or have a significant impact on economic output. We use data from Eurostat's Structural Business Statistics and National Accounts for the year 2013 on number of people employed in the sector and value added at factor cost at the NACE 2-digit sector aggregation level to score each sector for their role in the EU economy.

Selection criterion 2: Potential of the circular economy in the sector

The central theme in the transition to a circular economy is the shift to innovative ways of using and reusing resources, components and products. As the circular economy stands for extending the life and value of materials, components and products in the economy, a cross-sectoral approach is needed. Still, the potential of the circular economy to transform a sector still differs. Sectors that use a lot of materials, for example, are likely to be more strongly affected than sectors that are less material-intensive, such as services sectors. However, services sectors can play a crucial enabling function in the transition to a circular economy. Therefore, we largely take a life-cycle approach to analysing the (labour) impact of the circular economy in the focus sectors. In order to select sectors that are most significantly affected by the circular economy, we score the sectors on their circular economy potential as defined by the Ellen MacArthur Foundation in their *Growth Within: a circular economy vision for a competitive Europe* (2015). On page 27 of the report, they present the potential of the six ReSOLVE circular economy levers in most economic sectors of the EU economy(low/medium/high). We assigned a 1 for low, 2 for medium and 3 for high potential and derived the average score for each NACE 2-digit sector to define the 'circular economy potential' for the sector. In our selection of focus sectors (see next section), we have also considered that the selected focus sectors jointly cover many of the different ReSOLVE levers. Together with selection criterion 1 on the economic importance of the sector, this selection criterion shows which sectors might see important labour impacts from a more circular economy.

Selection criterion 3: Policy priority area and other literature

In line with the ToR for this study, the third selection criterion covers the direction of expected policy action. In 2015, the EC adopted an ambitious Circular Economy Action Plan[43] which identifies priority areas for which a transition to the circular economy will be actively supported in the coming years by, amongst others, the measures identified in the Annex of the Plan. It can therefore be expected that future economic and labour impacts will be greatest in these areas and they should be considered. In addition, previous literature on the topic that reviewed the potential of the circular economy for European sectors – particularly in relation to jobs – has also indicated a number of focus sectors. Through this criterion, we also take these findings into account for the selection of focus sectors in this study. The main studies used for this criterion are the IEEP *Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains* (2014) and the WRAP *Employment and the circular economy - Job creation in a more resource efficient Britain* (2015).

3.4 Results of the sector selection criteria

One of the two ultimate aims of the analysis on focus sectors is to develop modelling inputs for the E3ME model. Therefore, we base the sector selection process on the NACE sector classification, as this is what the E3ME model uses. For each NACE 2-digit sector, we gathered the data and information for the three selection criteria as described in the previous section. The result of this mapping is provided in Table 3-1.

The values in *italics* for selection criterion 1 (value added) refer to 'gross value added' figures instead of 'value added at factor cost' figures (in regular font).

[43] Commission Communication COM(2015)614 final "Closing the loop - An EU action plan for the Circular Economy"

The summary results for selection criteria 1 indicate:

- High employment in the services sectors: categories M-U jointly account for ~37% of employment in the EU. Employment in the primary sector (A) equals 4% of the total labour force in the EU in 2013. The manufacturing sector – due to its material intensity an important circular economy sector – accounted for 12% of EU employment in 2013. 22% of the EU workforce works in the wholesale and retail trade sectors (G-I).
- Significant value added is created in the services sectors (29% of total EU value added in 2013 in sectors M-U). A large share of value added is generated by the real estate sector (including imputed rents) – 10% of the total – for which value added measurement errors are common. Contrary to the relatively large share of employment in the agricultural sectors (4%-A), relatively little value added is created by this sector (1%).

The summary results for selection criteria 2 indicate:

- The highest potential for circular actions (ReSOLVE levers) can be found in the manufacturing sectors (section C – 2.1 average for all), the construction sector (Section F – 2.2 average) and the wholesale and retail sector (Section G – 2.5 average).
- The electricity sector (Section D – 2.3 average) also shows a high potential for the circular economy. This is likely to largely stem from its role in providing renewable energy to circular business models, though, and therefore plays a largely enabling function to circular initiatives in other sectors.
- Most of the services sectors (J-N, P, Q and R) score low on circular economy transformation potential.

Selection criteria 3 indicates that *agriculture, forestry and fishing, food and beverages, rubber and plastics products and construction activities* are important sectors according to both policy and other literature. The Circular Economy Action Plan also indicates critical raw materials and bio-based materials which are difficult to map to NACE sectors (sector 16 for bio-based and sectors 26-27 for critical raw materials).

Table 3-1 Sector selection table

NACE sectors			E3ME		1. Economic importance		2. Circular Economy Potential							3. Policy priorities & literature	
					Value added[A] (EUR '000) - 2013	Employment 2013[B]	RESOLVE framework - Growth Within							CE Action Plan - Priority[C]	Other literature[D]
Code		Description	#	E3ME sector			Regenerate	Share	Optimise	Loop	Virtualise	Exchange	*Avg.*		
A		**Primary sector**			**207,644**	**11,296,680**									
	01	Agriculture, forestry and fishing	1	Crop, animals, etc.	*207,644*	*11,296,680*	3	1	2	1	1	3	1.8		IEEP
	02		2	Forestry & logging											
	03		3	Fishing											
B		**Mining & Quarrying**			**78,459**	**526,400**									
	05	Mining of coal and lignite	4	Coal	7,800	194,800	1	1	2	3	1	3	1.8		
	06	Extraction of crude petroleum and natural gas	5	Oil and gas	46,199	76,900									
	07	Mining of metal ores	6	Other Mining	5,674	n.a.									
	08	Other mining and quarrying			11,856	185,300									
	09	Mining support service activities			6,931	69,400									
C		**Manufacturing**			**1,630,000**	**28,000,000**									
	10	Food products	7	Food drinks & Tobacco	174,000	3,822,400	3	1	2	3	1	3	2.2		IEEP
	11	Beverages			37,636	425,900									IEEP
	12	Tobacco products			7,121	41,300									
	13	Textiles	8	Textiles & leather	21,000	556,300	3	3	2	1	2	2	2.2		
	14	Wearing apparel			18,763	876,200									
	15	Leather and related products			13,387	402,400									
	16	Wood and of products of wood and cork	9	Wood & wood prods	29,585	823,000	3	3	2	1	3	2	2.3		IEEP

	17	Paper and paper products	10	Paper & paper prods	41,282	621,700									IEEP
	18	Printing and reproduction of recorded media	11	Printing & reproduction	30,000	655,100									
	19	Coke and refined petroleum products	12	Coke & ref petroleum	13,547	118,800	1	1	2	2	1	3	1.7		
	20	Chemicals and chemical products	13	Other chemicals	110,000	1,100,000									
	21	Basic pharmaceutical products and preparations	14	Pharmaceuticals	79,545	554,400	2	1	2	2	1	2	1.7		
	22	Rubber and plastic products	15	Rubber & plastic products	82,000	1,586,300	2	2	2	3	1	3	2.2		IEEP
	23	Other non-metallic mineral products	16	Non-metallic mineral prods	59,166	1,155,300	n.a.								
	24	Basic metals	17	Basic metals	57,000	900,000	2	2	2	3	1	3	2.2		
	25	Fabricated metal products, except machinery and equipment	18	Fabricated metal prods	159,513	3,273,100									IEEP
	26	Computer, electronic and optical products	19	Computer, optical & electronic	75,260	1,092,900	1	2	2	3	2	2	2.0		
	27	Electrical equipment	20	Electrical equipment	84,609	1,410,000									
	28	Machinery and equipment n.e.c.	21	Other machinery & equipment	191,000	2,850,000	1	2	2	3	2	2	2.0		
	29	Motor vehicles, trailers and semi-trailers	22	Motor vehicles	158,081	2,284,500	1	3	2	3	3	2	2.3		
	30	Other transport equipment	23	Other transport equipment	53,645	704,800									
	31	Furniture	24	Furniture; other manufacturing	28,282	867,700	3	3	2	2	1	1	2.0		
	32	Other			41,613	740,000	n.a.								
	33	Repair and installation of machinery and equipment	25	Repair & installation machinery	60,879	1,099,500									WRAP
D	35	Electricity	26	Electricity	**227,309**	1,187,400	3	1	2	2	3	3	2.3		
			27	Gas, steam & air conditioning											
E	**Water supply & waste treatment**				**97,500**	**1,420,000**									
	36	Water collection, treatment and supply	28	Water, treatment &supply	34,000	387,700	3	2	2	1	1	2	1.8		
	37	Sewerage	29	Sewerage & waste management	15,652	148,700									
	38	Waste collection, treatment and disposal activities;			46,634	850,300									IEEP, WRAP
	39	Remediation activities and other waste management services			1,394	30,000									IEEP, WRAP
F	**Construction**				**487,022**	**9,693,500**									

	41	Construction of buildings	30	Construction	133,563	2,547,600	1	3	2	3	2	2	2.2		IEEP
	42	Civil engineering			75,410	1,453,100									IEEP
	43	Specialised construction activities (incl. demolition)			278,050	5,692,800									IEEP
G	**Wholesale & retail**				**1,146,642**	**27,134,700**									
	45	Wholesale and retail trade; repair of motor vehicles	31	Wholesale/retail motor vehicles	135,959	3,057,200	3	3	2	2	3	2	2.5		WRAP
	46	Wholesale trade, except of motor vehicles and motorcycles	32	Wholesale excl. motor vehicles	557,231	8,998,400									
	47	Retail trade, except of motor vehicles and motorcycles	33	Retail excluding motor vehicles	453,453	15,079,100									WRAP
H	**Transport & Storage**				**499,482**	**9,537,100**									
	49	Land transport and transport via pipelines	34	Land transport, pipelines	212,941	4,720,500	1	2	2	3	1	3	2.0		
	50	Water transport	35	Water transport	23,000	n.a.									
	51	Air transport	36	Air transport	28,094	347,700									
	52	Warehousing and support activities for transportation	37	Warehousing	177,536	2,500,000									
	53	Postal and courier activities	38	Postal & courier activities	57,911	1,750,400									
I	**Accommodation & food services**				**212,348**	**8,663,000**									
	55	Accommodation	39	Accommodation & food services	70,346	2,144,000	2	3	2	2	2	1	2.0		
	56	Food and beverage service activities			142,002	6,519,100									
J	**Information and communication**				**518,743**	**5,454,200**									
	58	Publishing activities	40	Publishing activities	n.a.	813,900	1	2	2	1	3	1	1.7		
	59	Motion picture, video and television programme production	41	Motion picture, video, television	25,507	332,100									
	60	Programming and broadcasting activities			26,897	248,400									
	61	Telecommunications	42	Telecommunications	158,952	1,000,000									
	62	Computer programming, consultancy and related activities	43	Computer programming, info serv.	210,000	2,600,000									
	63	Information service activities			34,215	443,300									
K	**Financial and Insurance activities**				**650,922**	**6,043,060**									

	64	Financial service activities, except insurance	44	Financial services											
	65	Insurance, reinsurance and pension funding	45	Insurance	*650,922*	6,043,060	1	2	2	1	3	1	1.7		
	66	Activities auxiliary to financial services and insurance activities	46	Aux to financial services											
L	68	**Real Estate activities**	47	Real estate	*1,371,251*	2,436,030									
			48	Imputed rents			1	3	2	1	2	1	1.7		
M	**Professional, scientific and technical activities**				**625,376**	**8,640,000**									
	69	M69 - Legal and accounting activities	49	Legal, account, & consulting serv.	180,536	2,384,200									
	70	M70 - Activities of head offices; management consultancy			153,564	1,850,000	1	2	2	1	3	1	1.7		
	71	M71 - Architectural and engineering activities	50	Architectural & engineering	161,275	2,237,100									
	72	M72 - Scientific research and development	51	R&D	27,355	520,900									
	73	M73 - Advertising and market research	52	Advertising & market research	54,119	941,000									
	74	M74 - Other professional, scientific and technical activities	53	Other professional	41,000	550,000	1	2	2	1	3	1	1.7		
	75	M75 - Veterinary activities			8,000	150,000									
N	**Administrative and support service activities**				**443,781**	**12,512,500**									
	77	N77 - Rental and leasing activities	54	Rental & leasing	88,003	539,600									WRAP
	78	N78 - Employment activities	55	Employment activities	121,787	4,335,400									
	79	N79 - Traveling related services	56	Travel agency	29,000	n.a.	1	2	2	1	3	1	1.7		
	80	N80 - Security and investigation activities			30,914	1,360,000									
	81	N81 - Services to buildings and landscape activities	57	Security & investigation, etc.	88,200	4,023,000									
	82	N82 - Office administrative, office support…..			86,197	1,824,200									
O	84	**Public administration and defence**	58	Public administration & defence	*2,340,809*	*52,996,360*	1	3	2	2	3	2	2.2		
P	85	**Education**	59	Education			1	2	2	1	3	1	1.7		
Q	**Human care services**														
	86	Human health activities	60	Human health activities			1	2	2	1	3	1	1.7		
	87	Residential care activities	61	Residential care											

	88	Social work activities without accommodation													
R		**Arts, entertainment and recreation**			*427,703*	*13,743,920*									
	90	Creative, arts and entertainment activities	62	Creative, arts, recreational			1	2	2	1	3	1	1.7		
	91	Libraries, archives, museums and other cultural activities													
	92	Gambling and betting activities													
	93	Sports activities and amusement and recreation activities	63	Sports activities											
S		**Other Services**													
	94	Activities of membership organisations	64	Membership organisations			n.a.								
	95	Repair of computers and personal and household goods	65	Repair computers & personal goods											WRAP
	96	Other personal service activities	66	Other personal services.											
T		**Activities of households as employers**													
	97	Activities of households as employers of domestic personnel	67	Households as employers			n.a.								
	98	Undifferentiated goods-and services-producing…													
U	99	**Activities of extraterritorial organisations**	**68**	**Extraterritorial organisations**											

A = Value added at factor cost (Eurostat - Structural Business Statistics)

B = Number of employees (Eurostat - Structural Business Statistics)

C = Sectors mentioned in the section 'priority -areas' section of the Action Plan

D = IEEP - Scoping Study (EC, 2014)

WRAP - Economic Growth Potential of More Circular Economies - table 4 (official sector proxies for circular activities)

3.5 The choice of and approach to selected focus sectors

As outlined in Section 3.1, there are various approaches to defining focus sectors for the in-depth research in this study. Since this study's approach relies strongly on the modelling of employment effects by the E3ME model, we have stayed close to the NACE sector classification of the E3ME model. At the same time, we recognise that the circular economy has a cross-sectoral nature (looping materials and extending the value of products typically happens across sectors) and therefore we aim to study focus sectors from a life cycle perspective (from extraction to use) stages of products (see next section). Finally, we also take the material/waste stream focus of the circular economy action plan priority areas into account by selecting focus sectors that cover many of the key material flows indicated in the Action Plan. Taking these issues into account, we have chosen to define focus sectors in terms of one or two **core NACE 2-digit sectors** that will be studied in the in-depth analysis, along with a number of NACE 2-digit sectors that are relevant from a life cycle perspective from the perspective of these core 2-digit sectors. As the E3ME model is set up as an input-output model, we have selected a number of upstream and downstream sectors (from a supply chain perspective) for each core focus sector to be studied in a 'light' manner as part of the focus sector analysis.

The table in Appendix B shows the proposal of the five focus sectors as the last five columns of the sector selection table. The five focus sectors proposed are:

1. Food products & beverages (NACE 11 and 12)
2. Motor vehicles (NACE 29)
3. Construction (NACE 41, 42 and 43)
4. Electronics and Electrical equipment (NACE 26 and 27)
5. Waste treatment (NACE 38 and 39)

The cells shaded light-red in the table are the indicative sectors that matter from a life cycle perspective. The first four sectors take a life cycle approach, whereas the waste treatment sector (the end of life phase of products) has been chosen for its critical role in the life cycles of virtually all products and sectors (also illustrated by its important end of life phase role for all other four sectors). As such, the first four sectors will analyse core sectors and their respective life cycle stages up to the point when material/ products become waste and go to the waste industry. Waste management and treatment will then be analysed in the fifth sector, waste treatment. There are of course some choices to be made when the sector specific waste is to be treated as part of the first four focus sectors and when it is to be treated as part of the waste industry, in order to avoid double counting.

The analyses on the core focus sectors will identify which sectors and activities matter most from a life cycle, circular economy and employment perspective to be assessed in a 'light' manner, but to illustrate this we list a number of likely relevant activities below:

Food products & beverages

Food products & beverages (NACE 10 & 11)

- ✓ Part of circular economy activities in agriculture, forestry and fishing – the circular economy activities include e.g. organic farming, biological nutrients, etc.
- ✓ Manufacturing of chemical and chemicals products → in terms of fertilisers, bio-economy in the food sector.
- ✓ Food waste – to be clearly defined whether this will be part of the food sector or of the waste treatment sector.

Motor vehicles

Motor vehicles (NACE 29)

- ✓ Mining of metal ores, mining support service activities – these activities are linked to the extraction of raw materials used in the automotive industry.
- ✓ Manufacturing of fabricated metal products – these activities are linked to the production/ manufacture of components, parts of vehicles.
- ✓ Wholesale and retail trade, retail of motor vehicles – this is linked to the use phase of motor vehicles.
- ✓ Rental and leasing activities – strongly linked to circular economy activities in the use phase of motor vehicles.

Construction

Construction (NACE 41-43)

- ✓ Mining activities, manufacturing of wood products and fabricated metal products – representing virgin inputs for building materials, which are ideally designed out (or minimised) in a circular economy approach to the built environment.
- ✓ Other non-metallic mineral products – the processed virgin materials to building materials (which can also use secondary materials as input to their sector).
- ✓ Accommodation and real estate activities – representing the sectors in which changes to the use phase of buildings can create impacts on labour skills and volume requirements.
- ✓ Construction & Demolition waste activities as crucial link to increasing the market for secondary materials (covered by the waste treatment, NACE 38 and specialised construction activities NACE 43) sectors.

Construction

Electronics and Electrical Equipment (NACE 26-27)

- ✓ Critical raw materials, which are often not produced in the EU (and therefore constitute critical materials) and therefore do not have a clearly assigned NACE sector (potentially 'other mining', NACE 08).
- ✓ Waste of Electrical and Electronic Equipment (WEEE) – covered as part of the waste treatment sector.
- ✓ Rental and leasing activities – to cover the optimisation of the use phase of this products by renting and sharing activities.
- ✓ Repair sector – to cover the remanufacturing and refurbishing of these products (covered largely by NACE 95).

Construction

Waste collection and treatment sector (NACE 38 and 39)

- ✓ Approached from a reverse life-cycle perspective where the most important waste streams from the four other focus sectors are analysed (also as their share in the total waste handled by the sector) and to analyse the overall changes and transformation that the sector might go through from adopting circular business models in the waste sector as well as the other core sectors.

3.6 Key challenges

- The main challenge to define key sectors for the circular economy from a labour market perspective is the cross-sectoral nature of the circular economy. Actions like eco-design, sharing, repairing and reuse of materials work best in a cross-sectoral manner. Therefore, an ambitious transition of the circular economy would transform the entire economy. It is difficult to focus on a few isolated sectors to illustrate the effect of the circular economy on the labour market.
- Moreover, the literature shows that a variety of approaches have been taken to define circular economy sectors due to the versatility and cross-sectoral nature of the concept. Some studies used the NACE classification to define and assess circular economy activities in the economy, while others identified priority sectors from a materials or a waste stream perspective.
- Therefore, trying to be exhaustive and comprehensive in capturing all circular economy activities across all sectors would be a very tedious task and would go beyond the scope of this study. Since the main method of studying the labour market impacts of the circular economy in this study is using the E3ME model, we chose an approach that can be realistically modelled in E3ME within the scope of this study and use the E3ME sector classification for the definition of key sectors in order to keep the link with the E3ME model strong. Focusing on five key focus sectors bears the risk of excluding some activities from our analysis, but it allows us to study the most important sectors in detail and to analyse more thoroughly the impact on the labour market. Through this approach, we take an activity-based (or bottom-up) perspective on the transformation that the circular economy can achieve.
- In order to take the cross-sectoral nature of the circular economy into account, the key sectors chosen are approached from both a life cycle perspective and a supply chain perspective so that the key sectors' most important links with related sectors (from a materials perspective) can be taken into account. The challenge will still be to avoid potential double counting of horizontal activities such as waste management. If the circular economy potential from the waste sector is included in all other four key sectors, its potential would be overrepresented. Therefore, we decided to take the waste management sector as a separate key sector.

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Appendix A Table – Available Quantitative Estimates on Cost Savings and Investment Needs

Sector	Activity	Investment needs/ value created	Cost savings	Material savings	Geographical scope	Reference
Apparel	Potential material cost savings apparel	n.d.	155 billion USD per annum	n.d.	global	Ellen MacArthur, 2014
Apparel	Potential material cost savings Beauty and personal care	n.d.	26 billion USD per annum	n.d.	global	Ellen MacArthur, 2014
Apparel	CE-related changes in supply, use and disposal of clothing	n.d.	3 billion GBP per annum	n.d.	UK	Wrap, 2012.
Apparel	Cost savings through increased lifetime of clothing	n.d.	2 billion GBP for 10% (3months) longer lifetime, 5 billion GBP for 33% (9months) longer lifetime	n.d.	UK	Wrap, 2012
Apparel	Potential for increased recycling of clothing	n.d.	56 mn EUR in landfill taxes avoided p.a.	1.3 Mtonnes of clothing can be recycled instad of land-fileld p.a.	EU-wide	COWI, 2011
Automotive	Potential cost savings automotive industry	n.d.	170-200 billion USD per annum	n.d.	EU-wide	Ellen MacArthur, 2014
Bio-based economy	Potentials for additional value added for the bio-based economy in NL	One-off investment of 4-8 billion EUR	An additional value of 1 billion per annum could be created	0.4 Mtonnes of raw material	Netherlands	TNO, 2013
Bio-based economy	Investments in bio-based economy short-term	3.7 billion EUR between 2014 and 2020	n.d.	n.d.	EU-wide	BBI.[44]
Biomass	Estimates for replacement of mineral fertilizers with organic fertilizers	n.d	n.d.	25%-30% of mineral fertilizers can be replaced with fertilizers from bio-waste	EU-wide	European Commission, 2016.

[44] http://www.bbi-europe.eu/about/about-bbi

Sector	Activity	Investment needs/ value created	Cost savings	Material savings	Geographical scope	Reference
Biomass	Increasing the production and use of wood in Europe	additional value added generated: 2.35 billion EUR fo the same 4% in output	n.d.		EU-wide	CEI-Bois, 2016
Construction	Conversion of empty office spaces to apartments in Finland	Additional rental income of 255 million EUR per annum	n.d.	n.d.	Finland	Sitra, 2015
Construction	Industrialised production of buiding modules and 3D printing in Denmark	n.d.	40-60 million EUR p.a. by 2020 and 450-600 million EUR p.a. by 2030.	n.d.	Denmark	Ellen MacArthur, 2015.
Construction	Preventing new construction through sharing and repurposing of currenr buildings	n.d.	100-140 million EUR p.a. by 2020 and 300-450 million EUR p.a. by 2030.	n.d.	Denmark	Ellen MacArthur, 2015.
Construction	UK levy on virging aggregates increasing the price by 20-25%	5.68 bn EUR p.a. additional tax money has to be spent by construction companies	Potential gross cost savings for entire EU 3.8 bn EUR p.a.	18 million tonnes between 2001 and 2005.	UK (realized), EU (potential)	COWI, 2011
Construction	Reuse and high-value recycling of components and materials in Denmark	n.d.	10-12 million EUR p.a. by 2020 and 100-150 million EUR p.a. by 2030.	n.d.	Denmark	Ellen MacArthur, 2015.
Consumer goods	Total potential cost savings - Fast moving consumer goods (FMCG)	n.d.	706 billion USD per annum	n.d.	global	World Economic Forum, 2014
Consumer goods	Implementing CE practices in fast moving consumer goods	n.d.	700 billion USD/year	n.d.	UK	Ellen MacArthur, 2013b
Electronics sector	CE opportunities for metal-electro sectors in NL	n.d.	n.d.	5.2 billion tonnes of raw materials	Netherlands	TNO, 2013
Electronics sector	re-using a larger share of electronic appliances	n.d.	200 million GBP if 25% of the waste from EEE is re-used instead of recycled	WRAP estimates that 25% of the electrical and aletronic waste in the UK can be reused	U.K.	WRAP, 2013b

Sector	Activity	Investment needs/ value created	Cost savings	Material savings	Geographical scope	Reference
Energy	Anaerobic digestion for energy production from organic waste	n.d.	n.d.	n.d.	U.K.	Ellen MacArthur, 2013b
Food	Anaerobic digestion of food wastes	n.d.	see table3, tab 2		UK	Ellen MacArthur, 2013b
Food	Potential material cost savings Fresh food	n.d.	98 billion USD per annum	n.d.	global	Ellen MacArthur, 2014
Food	Potential cost-savings of a 50% household food waste reduction in the value chain in Finland	n.d.	130 million EUR per annum	n.d.	Finland	Sitra, 2015
General CE	Total cost savings in the EU when shifting to CE	n.d.	1.8 trillion euro per annum	n.d.	EU-wide	Ellen MacArthur Foundation, 2015b
General CE	Total resource cost savings EU	n.d.	600 billion euro per annum	n.d.	EU-wide	Ellen MacArthur Foundation ,2015b
General CE	Value creation potential for circular economy activities in Finland	Additional value-added of 1.5-2.5 billion EUR per annum	n.d.	n.d.	Finland	Sitra, 2015
General CE	UK potential for remanufacturing	Minimum potential of an additional value-added of 5.6 billion GBP	n.d.	n.d.	UK	APSRG & APMG, 2014.
General CE	CE opportunities for Denmark in selected sectors	0.8-1.2% increse in GDP	n.d.	5-50% reduction in inputs virgin materials, 3-7% reduction in carbon footprint	Denmark	Ellen MacArthur, 2015
Industrial symbiosis	Improved use of by-products through industrial symbiosis	993 million GBP increased sales (total between 2000 and 2013)	Achieved cost savings of 1 billion GBP (total between 2000 and 2013)	n.d.	U.K.	Ellen MacArthur, 2013b
Industrial symbiosis	Estimated potential for NISP-like programmes for entire EU	167,000 EUR p.a.	1.4 bn EUR p.a.	n.d.	EU-wide	COWI, 2011

Sector	Activity	Investment needs/ value created	Cost savings	Material savings	Geographical scope	Reference
Manufacturing sector	Total savings complex durables with medium lifespans (manuafacturing sector)	Largest savings can be achieved in the 'motor vehicles' sector and 'machinery and equipment' sector.	340-380 billion USD per annum in case of transition scenario, 520-630 billion USD per annum in the advanced scenario	n.d.	EU-wide	European Commission, 2014c
Manufacturing sector	manufacturing sectors (automotive, machinery and equipment, electrical machinery)		265 to 490 bn EUR per annum; 23% of sectors current total input costs (in 2012)		EU-wide	Ellen MacArthur, 2013
Manufacturing sector	Potential for remanufacturing of components in Denmark	n.d.	50-100 million EUR p.a. by 2020 and 150-200 million EUR p.a. by 2030.	n.d.	Denmark	Ellen MacArthur, 2015
Packaging	Material savings when moving from one-way glass bottles to reusable bottles	n.d.	94% cost saving per cycle	97% material savings (from 8.4 kg raw materials to 0.277 kg per cycle)	global	Ellen MacArthur, 2014
Packaging	Material savings when moving from one-way PET bottles to reusable bottles	n.d.	41% cost saving per cycle	73% material savings (from 0.77 kg raw materials to 0.21 kg per cycle)	global	Ellen MacArthur, 2014
Packaging	one-way packaging vs reuse packaging	investment for reuse packaging 1.5 to 5 times higher than for one-way			EU- wide	Golding Andreas, 1998
Packaging	Switching from one-way beer bottles to reusable beer bottles	see table 4, tab 2	see table 4, tab 2	n.d.	UK	Ellen MacArthur, 2013b
Packaging	Potential material cost savings for packaged goods	n.d.	270 billion USD per annum	n.d.	global	Ellen MacArthur, 2014
Packaging	Potential material cost savings Beverages	n.d.	121 billion USD per annum	n.d.	global	Ellen MacArthur, 2014
Product policy	Implementing a certified Environmental Management System (EMS)		increase of sales on average by 17,238 eur per million turnover by SMEs in the UK		UK	WYG Environment, 2011

Sector	Activity	Investment needs/ value created	Cost savings	Material savings	Geographical scope	Reference
R&D	Green technologies		Worth a trillion EUR and expected to double by 2020		EU wide	ECOAP, 2014
Recycling	Recycling of plastics	200 USD additional profit/tonne of plastic collected	7.3 billion USD per annum	n.d.	United States	Ellen MacArthur, 2013b
Recycling	Turnover of seven main categories of recyclables		37,229 million EUR		EU wide	EEA, 2011
Waste management	Turning waste into by-products	993 million GBP additional revenue since its launch in 2000 until 2013	1 billion GBP since its launch in 2000 until 2013	n.d.	UK	Ellen MacArthur Foundation, 2013b
Water management	Benefits of increasing the water use efficiency in the U.S.	$ 10 bn investment (once)	If the investment of $10billion is done, a GDP increase of $13-15 bn can be achieved annually	6.5-10 trillion gallons of water	United States	UNLV, 2008

Appendix B Table- Sector Selection

					1. Economic importance		2. Circular Economy Potential							3. Policy priorities & literature		Focus sectors				
NACE sectors			E3ME				RESOLVE framework - Growth Within													
	Code	Description	#	E3ME sector	Value added[A] (EUR '000)	Employment[B]	Regenerate	Share	Optimise	Loop	Virtualise	Exchange	*Avg.*	CE Action Plan - Priority[C]	Other literature[D]	Food	Motor vehicles	Construction	Electronics & Electrical equipment	Waste treatment
	Primary sector				**207,644**	**11,296,680**														
A	01	Agriculture, forestry and fishing	1	Crop, animals, etc.	*207,644*	*11,296,680*	3	1	2	1	1	3	1.8		IEEP					
	02		2	Forestry & logging																
	03		3	Fishing																
	Mining & Quarrying				**78,459**	**526,400**														
B	05	Mining of coal and lignite	4	Coal	7,800	194,800	1	1	2	3	1	3	1.8							
	06	Extraction of crude petroleum and natural gas	5	Oil and gas	46,199	76,900														
	07	Mining of metal ores	6	Other Mining	5,674	n.a.														
	08	Other mining and quarrying			11,856	185,300														
	09	Mining support service activities			6,931	69,400														
	Manufacturing				**1,630,000**	**28,000,000**														
C	10	Food products	7	Food drinks & Tobacco	174,000	3,822,400	3	1	2	3	1	3	2.2		IEEP					
	11	Beverages			37,636	425,900									IEEP					
	12	Tobacco products			7,121	41,300														
	13	Textiles	8	Textiles & leather	21,000	556,300	3	3	2	1	2	2	2.2							
	14	Wearing apparel			18,763	876,200														
	15	Leather and related products			13,387	402,400														
	16	Wood and of products of wood and cork	9	Wood & wood prods	29,585	823,000	3	3	2	1	3	2	2.3		IEEP					
	17	Paper and paper products	10	Paper & paper prods	41,282	621,700									IEEP					
	18	Printing and reproduction of recorded media	11	Printing & reproduction	30,000	655,100														
	19	Coke and refined petroleum products	12	Coke & ref petroleum	13,547	118,800	1	1	2	2	1	3	1.7							
	20	Chemicals and chemical products	13	Other chemicals	110,000	1,100,000														
	21	Basic pharmaceutical products and preparations	14	Pharmaceuticals	79,545	554,400	2	1	2	2	1	2	1.7							
	22	Rubber and plastic products	15	Rubber & plastic products	82,000	1,586,300	2	2	2	3	1	3	2.2		IEEP					
	23	Other non-metallic mineral products	16	Non-metallic mineral prods	59,166	1,155,300	n.a.													
	24	Basic metals	17	Basic metals	57,000	900,000	2	2	2	3	1	3	2.2							
	25	Fabricated metal products, except machinery and equipr	18	Fabricated metal prods	159,513	3,273,100									IEEP					
	26	Computer, electronic and optical products	19	Computer, optical & electronic	75,260	1,092,900	1	2	2	3	2	2	2.0							
	27	Electrical equipment	20	Electrical equipment	84,609	1,410,000														
	28	Machinery and equipment n.e.c.	21	Other machinery & equipment	191,000	2,850,000	1	2	2	3	2	2	2.0							
	29	Motor vehicles, trailers and semi-trailers	22	Motor vehicles	158,081	2,284,500	1	3	2	3	3	2	2.3							
	30	Other transport equipment	23	Other transport equipment	53,645	704,800														
	31	Furniture	24	Furniture; other manufacturing	28,282	867,700	3	3	2	2	1	1	2.0							
	32	Other			41,613	740,000	n.a.													
	33	Repair and installation of machinery and equipment	25	Repair & installation machinery	60,879	1,099,500									WRAP					
D	35	Electricity	26	Electricity	**227,309**	1,187,400	3	1	2	2	3	3	2.3							
			27	Gas, steam & air conditioning																

NACE sectors			E3ME		1. Economic importance		2. Circular Economy Potential							3. Policy priorities & literature		Focus sectors				
							RESOLVE framework - Growth Within													
Code		Description	#	E3ME sector	Value added[A] (EUR '000)	Employ-ment[B]	Regen-erate	Share	Optim-ise	Loop	Virtua-lise	Exch-ange	Avg.	CE Action Plan - Priority[C]	Other litera-ture[D]	Food	Motor vehicles	Construc tion	Electronics & Electrical equipment	Waste treatment
D	35	Electricity	26 27	Electricity Gas, steam & air conditioning	**227,309**	1,187,400	3	1	2	2	3	3	2.3							
E		**Water supply & waste treatment**			**97,500**	**1,420,000**														
	36	Water collection, treatment and supply	28	Water, treatment &supply	34,000	387,700	3	2	2	1	1	2	1.8							
	37	Sewerage	29	Sewerage & waste management	15,652	148,700														
	38	Waste collection, treatment and disposal activities;			46,634	850,300									IEEP, WRAP					
	39	Remediation activities and other waste management serv			1,394	30,000									IEEP, WRAP					
F		**Construction**			**487,022**	**9,693,500**														
	41	Construction of buildings	30	Construction	133,563	2,547,600	1	3	2	3	2	2	2.2		IEEP					
	42	Civil engineering			75,410	1,453,100									IEEP					
	43	Specialised construction activities (incl. demolition)			278,050	5,692,800									IEEP					
G		**Wholesale & retail**			**1,146,642**	**27,134,700**														
	45	Wholesale and retail trade; repair of motor vehicles	31	Wholesale/retail motor vehicles	135,959	3,057,200	3	3	2	2	3	2	2.5		WRAP					
	46	Wholesale trade, except of motor vehicles and motorcycl	32	Wholesale excl. motor vehicles	557,231	8,998,400														
	47	Retail trade, except of motor vehicles and motorcycles	33	Retail excluding motor vehicles	453,453	15,079,100									WRAP					
H		**Transport & Storage**			**499,482**	**9,537,100**														
	49	Land transport and transport via pipelines	34	Land transport, pipelines	212,941	4,720,500	1	2	2	3	1	3	2.0							
	50	Water transport	35	Water transport	23,000	n.a.														
	51	Air transport	36	Air transport	28,094	347,700														
	52	Warehousing and support activities for transportation	37	Warehousing	177,536	2,500,000														
	53	Postal and courier activities	38	Postal & courier activities	57,911	1,750,400														
I		**Accommodation & food services**			**212,348**	**8,663,000**														
	55	Accommodation	39	Accommodation & food services	70,346	2,144,000	2	3	2	2	2	1	2.0							
	56	Food and beverage service activities			142,002	6,519,100														
J		**Information and communication**			**518,743**	**5,454,200**														
	58	Publishing activities	40	Publishing activities	n.a.	813,900	1	2	2	1	3	1	1.7							
	59	Motion picture, video and television programme producti	41	Motion picture, video, television	25,507	332,100														
	60	Programming and broadcasting activities			26,897	248,400														
	61	Telecommunications	42	Telecommunications	158,952	1,000,000														
	62	Computer programming, consultancy and related activiti	43	Computer programming, info serv.	210,000	2,600,000														
	63	Information service activities			34,215	443,300														

NACE sectors			E3ME		1. Economic importance		2. Circular Economy Potential							3. Policy priorities & literature		Focus sectors				
					Value added[A] (EUR '000)	Employ-ment[B]	RESOLVE framework - Growth Within							CE Action Plan - Priority[C]	Other litera-ture[D]	Food	Motor vehicles	Construc tion	Electronics & Electrical equipment	Waste treatment
K		**Financial and Insurance activities**			**650,922**	**6,043,060**														
	64	Financial service activities, except insurance	44	Financial services																
	65	Insurance, reinsurance and pension funding	45	Insurance	*650,922*	6,043,060	1	2	2	1	3	1	1.7							
	66	Activities auxiliary to financial services and insurance act	46	Aux to financial services																
L	68	**Real Estate activities**	47	Real estate	*1,371,251*	2,436,030														
			48	Imputed rents			1	3	2	1	2	1	1.7							
M		**Professional, scientific and technical activities**			**625,376**	**8,640,000**														
	69	M69 - Legal and accounting activities	49	Legal, account, & consulting serv.	180,536	2,384,200														
	70	M70 - Activities of head offices; management consultancy			153,564	1,850,000	1	2	2	1	3	1	1.7							
	71	M71 - Architectural and engineering activities	50	Architectural & engineering	161,275	2,237,100														
	72	M72 - Scientific research and development	51	R&D	27,355	520,900														
	73	M73 - Advertising and market research	52	Advertising & market research	54,119	941,000	1	2	2	1	3	1	1.7							
	74	M74 - Other professional, scientific and technical activiti	53	Other professional	41,000	550,000														
	75	M75 - Veterinary activities			8,000	150,000														
N		**Administrative and support service activities**			**443,781**	**12,512,500**														
	77	N77 - Rental and leasing activities	54	Rental & leasing	88,003	539,600									WRAP					
	78	N78 - Employment activities	55	Employment activities	121,787	4,335,400														
	79	N79 - Traveling related services	56	Travel agency	29,000	n.a.	1	2	2	1	3	1	1.7							
	80	N80 - Security and investigation activities	57	Security & investigation, etc.	30,914	1,360,000														
	81	N81 - Services to buildings and landscape activities			88,200	4,023,000														
	82	N82 - Office administrative, office support…..			86,197	1,824,200														
O	84	**Public administration and defence**	58	Public administration & defence			1	3	2	2	3	2	2.2							
P	85	**Education**	59	Education			1	2	2	1	3	1	1.7							
Q		**Human care services**			*2,340,809*	*52,996,360*														
	86	Human health activities	60	Human health activities																
	87	Residential care activities	61	Residential care			1	2	2	1	3	1	1.7							
	88	Social work activities without accommodation																		
R		**Arts, entertainment and recreation**																		
	90	Creative, arts and entertainment activities	62	Creative, arts, recreational																
	91	Libraries, archives, museums and other cultural activitie					1	2	2	1	3	1	1.7							
	92	Gambling and betting activities																		
	93	Sports activities and amusement and recreation activitie	63	Sports activities																
S		**Other Services**																		
	94	Activities of membership organisations	64	Membership organisations	*427,703*	*13,743,920*														
	95	Repair of computers and personal and household goods	65	Repair computers & personal goo			n.a.								WRAP					
	96	Other personal service activities	66	Other personal services.																
T		**Activities of households as employers**																		
	97	Activities of households as employers of domestic person	67	Households as employers			n.a.													
	98	Undifferentiated goods-and services-producing…																		
U	99	**Activities of extraterritorial organisations**	68	**Extraterritorial organisations**																

ANNEX C: SECTOR PROFILES

1 Introduction

1.1 Introduction

This document consists of five detailed sector profiles that provide examples of the circular economy and its implications on the economy and labour market and skills. The five focus sectors were chosen based on their importance from an economic, product life cycle, circular economy and employment perspective. The selection criteria were discussed in the First Interim Report of this study. The focus sectors are:

6 Food products & beverages (NACE 11 and 12)

7 Construction (NACE 41, 42 and 43)

8 Waste treatment (NACE 38 and 39)

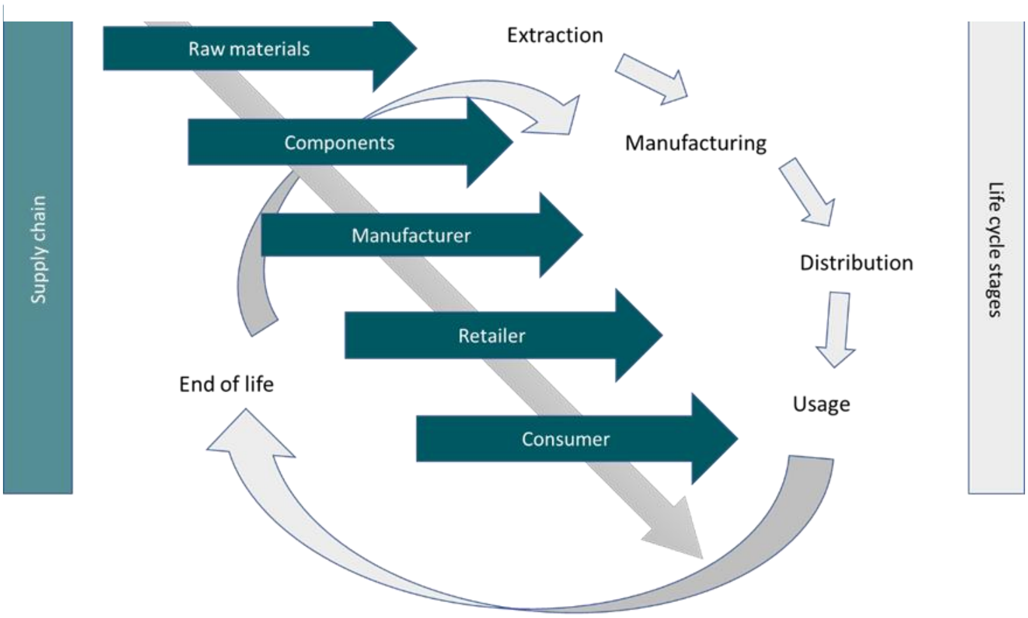
9 Electronics and Electrical equipment (NACE 26 and 27)

10 Motor vehicles (NACE 29)

Objectives

The first aim of the sector profiles is to provide an overview of the sector, map its supply chains and lifecycle stages of products/services and economic, environmental and employment characteristics of the sector. The second aim is to look at where circular economy activities are currently taking place, and what the circular economy potential and outlook is in the sector, as well as occupation and skills implications of this. For example, in the consumer electronics sector, we map circular economy activities related to the raw materials (extraction phase), production of the components and manufacture of the product (manufacturing phase), logistics (transport), the retailer and consumer (use phase) and the waste stream (end of life phase).

Figure 1-1 Link between life-cycle approach and supply chain of the focus sectors



The third step is to identify the direct impacts that these activities may have on the economy (in the future) and collect quantitative and qualitative evidence on these impacts, or make estimates using an agreed set of input assumptions. This last step will help us build circular economy scenarios that can be assessed with the E3ME macroeconomic model.

In addition to this analysis, the sector profiles will be used to look at the qualitative impacts of the circular economy on skills, occupations and jobs once the modelling is done. This part will complement the results of the modelling exercise.

Structure of the sector profiles

The structure of the sector profile in this report is split in to three main sections as follows:

- **Overview and scope**
  - **Short description of the sector** – what kind of products and services fall within the sector, i.e. the scope of the sector included in the analysis.
  - **Mapping lifecycle stages of the products/services in the sector (and their link to the supply chain of the sector)** – this will look at the interlinkages with other sectors, identify existing circular economy activities across sectors and assess where more circular approaches could be used.
  - **Economic characteristics -** what is the economic relevance of the sector in Europe? What are the levels of turnover and value added?
  - **Employment aspects** – what are the general employment trends? What is the level of circular economy and resource efficiency related employment? How has this level changed or evolved over the last five years? What is the gender balance and age demographic of current employment?
  - **Occupation and skills aspects** – what are the main circular economy or resource efficiency occupations and disciplines? What kind of skills are needed? To what extent are these skills readily available within the current pool of labour? Which related occupations and/or sectors provide (or potentially provide) the required skills and knowledge? Are there any skills mismatches? What provision is available to support skills supply?
  - **Current sectoral trends and future outlook** – assess the current trends and likely near-term future developments within the sector. This will be relevant for the modelling exercise.
- **Circular economy in the sector in question**
  - **Assessing how circular the sector currently is** – this will identify what circular processes are currently being used within the sector and to what extent.
  - **Assessing the current circular economy potential of the sector –** this will evaluate the sector and its activities according to the ReSOLVE framework[45] and assess the current situation in terms of circular economy.
  - **Assessing the employment potential of circular economy activities** – this will identify circular economy activities with high employment potential in terms of volume (number of jobs created/shifted) and job quality (a more qualitative analysis of the types of jobs and the kinds of skills and occupations are affected).
- **Modelling inputs (E3ME)**

[45] ReSOLVE framework developed by McKinsey to evaluate circular economy activities according to six actions: regenerate, share, optimize, loop, virtualize and exchange.

- This section uses the information gathered in the previous sections to build a scenario that can be used to model the economic and employment impacts of the transition to a circular economy in the sector. It will also describe where the data inputs to the model will come from.

2 Food Sector

2.1 Overview and scope

During the sector selection process, the 'food sector' appeared as one of the focus sectors because of its important contribution to the EU's economy and employment and the fact that the sector is one of the priorities in European circular economy policy. The potential for the sector to become more circular is considered to be moderate, i.e. it is neither at the top of bottom of the list of potential circular economy sectors.

Overview EU food sector and supply chain

If we look at the food sector from a life cycle perspective, we can see that is quite distinct from other sectors. In sectors that produce durable products, such as the automotive industry, there is a resource extraction phase, a production phase, a use phase, and an end-of-life (disposal) phase. By contrast, the food sector does not really have use phase, as the food or beverage is consumed and the only thing that remains for the disposal phase are the packaging materials and the human excreta that end up in the waste water. At the same time, organic by-products and waste streams are created in all parts of the food sector supply chain.

Composition of the food sector

The food sector supply chain (in this sector profile referred to as 'food sector') can be divided roughly into four parts: the primary sector, the food & drinks industry, wholesale and retail, and food drinks and services (Figure 2-1- red dashed box). Together these subsectors provide food and drink products to the final consumers (mostly households).

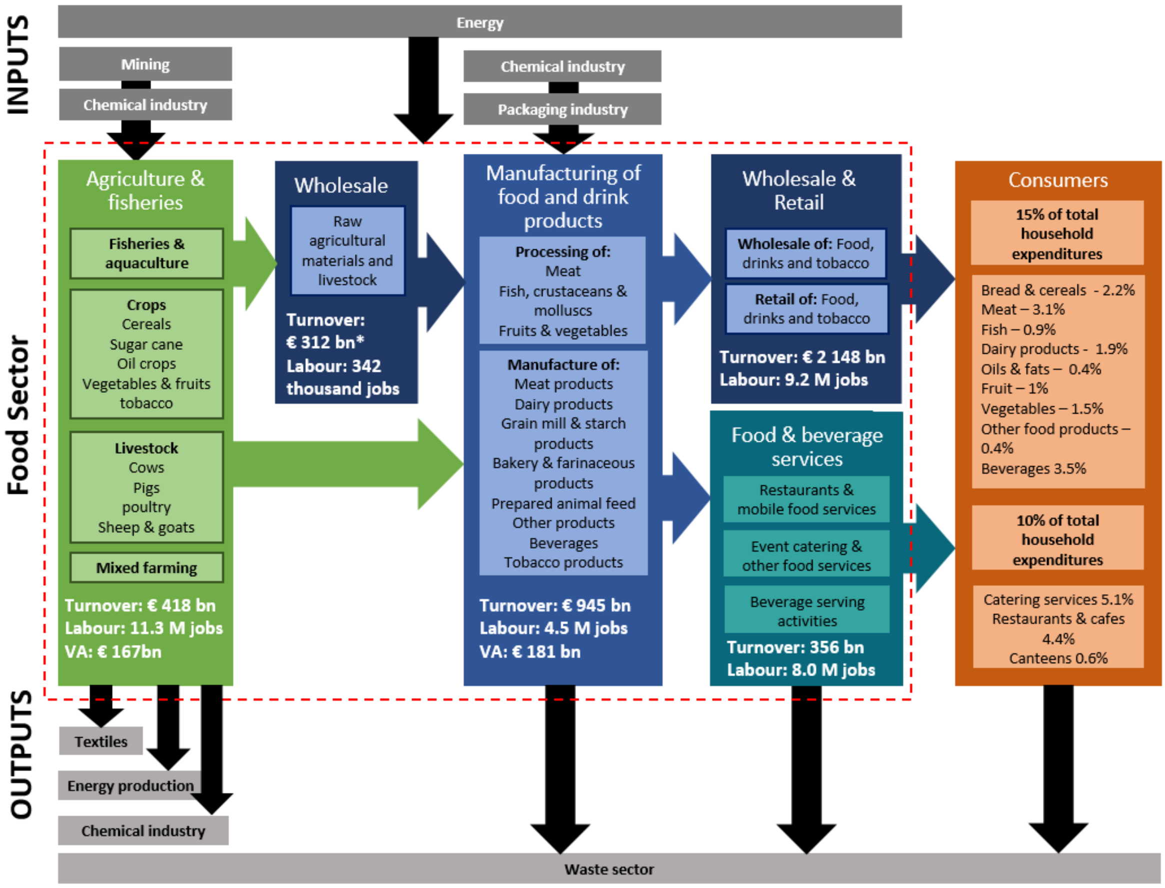
The first stage in food production is done by the primary sector (NACE A), consisting of agricultural enterprises that produce crops or breed livestock for the production of meat products, dairy products and other animal products. Fisheries and aquaculture companies also belong to the primary sector. The crops and raw animal products produced by the primary sector are further processed into consumer food products by the food & beverage industry (NACE C10-12). The food & drink industry can obtain its inputs directly from the primary sector or alternatively, via wholesale companies (NACE 46.2). Subsequently, food and drink products are sold to consumers either directly, or via specialised retail shops, supermarkets and food services such as restaurants and catering services. Alternatively, wholesale companies (NACE 46.3) can distribute the food from the manufacturers to retailers (NACE 47.2) and food services (NACE I56).

Sectors that are linked to the food sector

There are several sectors that have strong linkages with the food sector and are also important from a circular economy point of view. First of all, agriculture is heavily dependent on fertilisers for crop production. The largest share of these fertilisers consists of mineral fertilisers that are produced by the fertiliser industry, which is part of the chemicals sector. Through the use of mineral fertilisers, agriculture has become dependent on finite resource stocks. Nitrogen fertilisers are made from atmospheric nitrogen and natural gas, and phosphate fertilisers are made from mined phosphate rock. Every year, the European agriculture sector buys around 20M tonnes of mineral fertilisers[46].

The food & drink industry is also dependent on the chemical industry for the supply herbicides and pesticides for agriculture and of food additives and on the packaging industry to provide them with all the required packaging materials.

Figure 2-1 – Simplified overview of the food sector (red dashed box) and the sectors from which it receives inputs (top) or to which it provides outputs (bottom and right).



On the output side, the primary sector provides inputs for the chemical industry and energy sector, although to a limited extent. Further strengthening of these linkages is an important strategy for making the food sector more circular, as will be explained in Section 2.2.

Economic characteristics

The food sector is an important part of the European economy. The sector contributes between €700 and €780 billion to the EU economy, which corresponds to 5.0-5.5% of total gross value added created in the EU[47]. Furthermore, the food sector employs 27-33 million people in the EU,

[46] EUROSTAT (2017) Agri-environmental indicator - mineral fertiliser consumption. URL: http://ec.europa.eu/eurostat/web/products-datasets/-/aei_fm_usefert

[47] FOODDRINK Europe (2016). Data & trends – European food and drink industry 2015-2016. & own calculation based on EUROSTAT – National accounts & structural business statistics.

representing 12-15% of total EU employment[48]. EU households spend on average 12.3% of their income on food and drinks[49].

The primary sector

With over €418 bn in turnover and an added value of around € 167 bn the primary sector represents 10% and 22% of the food sector's turnover and added value, respectively, and 1.6% of the EU's gross value added[50]. Although the relatively smaller share of the primary sector in the total turnover and value added in the food sector, it employs 11.3 million people and is thereby represents the largest share of employment in the food sector and 5.1% of all employed people in the EU[51].

Agriculture in the EU consists of more than 10.8 million companies, of which the large majority (86%) are small farms (<20 hectares), 11% are medium-sized farms (20-100 hectares) and only 3% are large farms (>100 hectares). However, the large farms produce around a third of the economic output generated in the primary sector.

In total about 179 million hectares are used for agricultural purposes, which represents approximately 40% of the total land area in the EU[52]. Roughly 41% consists of meadows and pastures, 47% is arable land and 11% is permanent crops[53]. Crop production represents 51.8% of the output generated by the agricultural sector and 39.6% of the output comes from animal products. Annually the EU produces €213 bn worth of crops, of which 21% comes from the production of cereals (much of which is used as animal feed). One quarter of the cows are dairy cattle and, together with dairy goats and sheep, are responsible for the production of almost 170M tonnes of milk a year, which corresponds to a value of €52 bn. The remaining part of the livestock is used for the production of meat, totalling 45M tonnes, worth over €110 bn.

The food and drinks industry

With 4.3 million jobs, the food and drink industry represent only 14% of the employment in the food sector. However, it creates 23% of the turnover and 23% of the value added[54]. The figures show that food & drinks industry is a much more capital-intensive subsector than the primary sector. The food & drinks industry is the largest manufacturing sector in Europe, representing 15% of the total value added generated by the manufacturing sector.

The food & drink industry processes raw agricultural materials (crops and animal products) into food products, beverages and tobacco products. It produces many different kinds of products ranging from processed agricultural products such as vegetables, oils, fats, meat and milk products, to animal feed and food products such as bread, dairy products or beverages.

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[48] FOODDRINK Europe (2016). Data & trends – European food and drink industry 2015-2016. & own calculation based on EUROSTAT – National accounts & structural business statistics. *Ibid.*

[49] EUROSTAT (2017) Final consumption expenditure of households by consumption purpose (COICOP 3 digit) (nama_10_co3_p3). 2015 data.

[50] All data in the remainder of this section comes from: EUROSTAT (2016) Statistical books – Agriculture, forestry and fishery statistics – 2016 edition. – Data from 2014, unless stated otherwise.

[51] EUROSTAT (2017) Labour market and Labour force survey (LFS) statistics – data 2015.

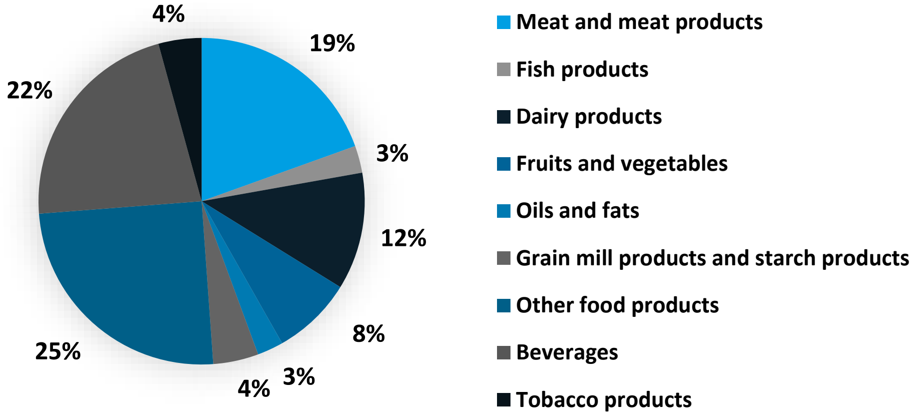
[52] EUROSTAT (2017) Agricultural census 2010 - main results.

[53] EUROSTAT (2016) Statistical books – Agriculture, forestry and fishery statistics – 2016 edition.

[54] Own calculation based on EUROSTAT – Structural business statistics - Annual enterprise statistics for special aggregates of activities (NACE Rev. 2)

Beverages are the most important source of income for the industry, followed by meat products, and dairy products (Figure 2-2). In total, the sector produces around 440 million tonnes of food and beverages annually[55]. The EU is the largest food and beverages producer in the world and has a trade surplus of €25.2 billion[56]. The most important export products are beverages (29%), followed by meat (12%) and dairy (10%)[57].

Figure 2-2 Contribution of different product categories to total value added in the food & drinks industry

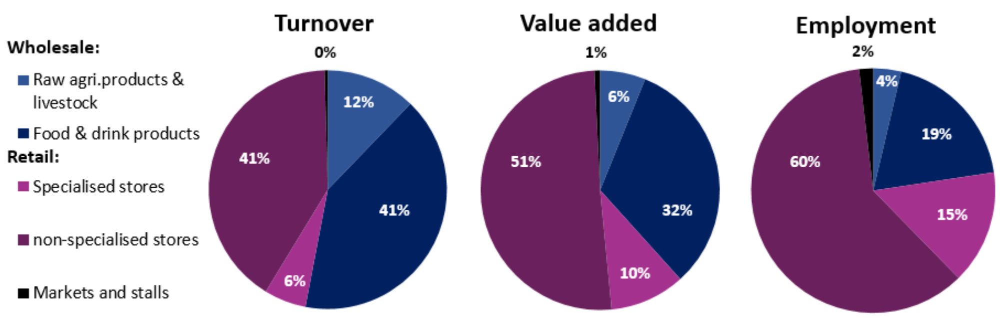


Source(s): Fooddrink Europe (2016).

Wholesale and retail

The wholesale and retail subsector are responsible for almost three fifths of the food sector's turnover and 36% of its value added. It accounts for 29% of employment in the sector. These are rough figures, since a large part of the economic activity in this subsector comes from the retail of food, drinks and tobacco in non-specialised stores (NACE 47.11, i.e. supermarkets and the like). A large part of the income and employment of these stores is related to sales of food, drinks and tobacco, but these stores also sell other products (e.g. clothing or electronics). In this sector profile, the entire income of these stores was allocated to the food sector, resulting in an overestimate of the contribution of the wholesale and retail sector to economic activity in the food sector. The contribution of the different types of wholesale and retail to the overall activity in this subsector are shown in Figure 2-3.

Figure 2-3- Overview relative contributions of the different types of wholesale and retail to the total employment, turnover and value added in the wholesale and retail subsector



55 Fusions (2016) Estimates of European food waste levels.

56 FOODDRINK Europe (2016). Data & trends – European food and drink industry 2015-2016.

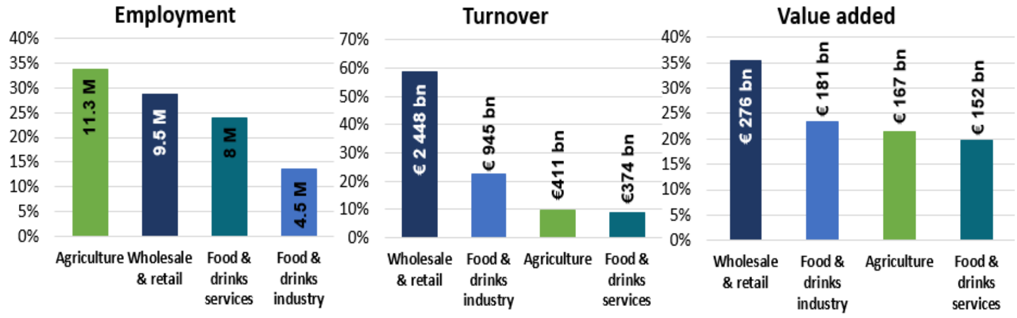
57 *Ibid.*

Food and drink services

The food and drinks services sector contribute for only 9% of the food sector's total production, but generates one-fifth of the overall value added. Of the total employment in the food sector, 24% relates to food and drink services, of which 62% is in restaurants, 25% in beverage serving activities (e.g. cafes) and the remainder in catering and other food services.

Figure 2-4 gives an overview of the relative importance of the different subsectors of the food sector.

Figure 2-4- Overview relative contributions of subsectors to total employment, turnover and value added in the food sector – Absolute values are indicated on and above the bars in numbers of persons employed (left) and euro's (middle and right).



Resource and environmental characteristics

The food sector also has several substantial environmental impacts, particularly from agriculture. For example, the food sector is responsible for 18% of total EU greenhouse gas emissions and the agricultural sector alone is responsible for around 10%[58].

Mineral fertilisers

Agriculture in the EU consumes a lot of mineral fertilisers. In 2016, 18.8 Mtonnes of nutrients were consumed in the EU, of which the 16.9 million tonnes were used as fertiliser. This total consisted of 11.5M tonnes of nitrogen (N), 2.8M tonnes of potash (K) and 2.6M tonnes of phosphate (P)[59]. Phosphate and potash are finite resources that are essential for plant growth; Europe does not produce either domestically and is almost completely reliant on imports[60]. With the current global consumption rate, phosphorus stocks will run out in 300 to 400 years and potash stocks in about 500 years, assuming that all the reserves can be mined[61].

Next to resource scarcity, excessive fertiliser use has several negative environmental impacts. First of all, the production of these fertilisers results in large amounts of greenhouse gas emissions. Furthermore, greenhouse gases are produced during the use-phase, due to microbial conversion of fertilisers in the soil (denitrification), especially of N_2O and to a lesser extent CO_2. When emissions from use and production are combined, N-fertilisers result in emissions of 8.9 -10.1 tCO_2-equivalent per tonne of nutrient, and for P-fertilisers the rate is around 0.4-0.6 tCO_2-eq./tonne nutrient[62].

[58] Eco-innovation (2012). Presentation by Anita Fassio -Overview of Food and drink.

[59] Fertilisers Europe (2017). Securing the future – fertilisers and the food chain. Overview 16/17.

[60] EC (2013). Consultative Communication on the Sustainable Use of Phosphorus.

[61] Blanco (2011). Supply of and access to key nutrients NPK for fertilisers for feeding the world in 2050.

[62] Fertilisers Europe (2008). Energy efficiency and greenhouse gas emissions in European nitrogen fertiliser production and use.

Large parts of the arable land in Europe have very high nutrient balances and if soils get saturated with nitrogen or phosphorus this results in leaching of nutrients into groundwater, rivers and lakes. This process leads to eutrophication, which causes dramatic losses of biodiversity in water ecosystems. In the period 1992-2011, the amount of nitrogen and phosphate in European freshwater bodies decreased by 57% and 20%, respectively, but this is more a reflection of improved waste water treatment and stricter laws for phosphate use in detergents, than a reduction in fertiliser use[63].

Production of animal protein has big environmental impacts

Although production of animal products represents only 40% of the economic output of the primary sector, it is responsible for a large part of the sector's environmental impacts. The production of animal products requires much more land and resource inputs than the production of vegetal products (see), because of the inherent energy (efficiency) losses when animals consume plants. Between two-thirds and three quarters of the farmland in Europe is used for the production of animal protein. Additionally, around 20 million hectares of farmland outside Europe are needed to produce the protein-rich feed such as soy that is imported into the EU. This demand worsens the pressure on arable land outside Europe and accelerates deforestation and conversion of other natural habitats into arable land. As a consequence of the enormous resource needs for making animal products, livestock breeding accounts for the GHG emissions in agriculture. In 2015, the production of animal protein accounted for almost 70% of the greenhouse gas emissions produced in agriculture.

Table 2-1), because of the inherent energy (efficiency) losses when animals consume plants. Between two-thirds and three quarters of the farmland in Europe is used for the production of animal protein[64]. Additionally, around 20 million hectares of farmland outside Europe are needed to produce the protein-rich feed such as soy that is imported into the EU[65]. This demand worsens the pressure on arable land outside Europe and accelerates deforestation and conversion of other natural habitats into arable land[66]. As a consequence of the enormous resource needs for making animal products, livestock breeding accounts for the GHG emissions in agriculture. In 2015, the production of animal protein accounted for almost 70% of the greenhouse gas emissions produced in agriculture[67].

Table 2-1- Overview of land and water requirements per unit of food product produced, for different animal and plat products.

Product	Land use (m² per Mcal)[68]	Water requirement (L/kg)[69]

[63] *Ibid.*

[64] Dutch Environment Assessment Agency (PBL) (2011). The protein puzzle – the consumption of meat, dairy and fish products in the European Union.

[65] *Ibid.*

[66] Barona *et al.* (2010) The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environ. Res. Lett*. **5**: pp. 9

[67] European Environment Agency (2017). Annual European Union greenhouse gas inventory 1990–2015 and inventory report 2017

[68] Peters *et al.* (2007). Testing a complete-diet model for estimating the land resource requirements of food consumption and agricultural carrying capacity: The New York State example.

[69] Hoekstra (2014) The hidden water resource use behind meat and dairy. *Animal frontiers* **2**: 2 pp. 3-8.

Animal products		
Beef (lean cuts)	54.6	15 415
Beef (all cuts)	31.2	
Pork (lean cuts)	17.9	5 988
Pork (all cuts)	7.3	
Poultry (lean cuts)	14.3	4 325
Poultry (lean cuts)	9.0	
Skimmed milk	9.0	1 020
Milk (whole)	3.0	
Eggs	6.0	3 265
Plant products	**Land use (m^2 per Mcal)**	**Water requirement (L/kg)**
Fruits	2.3	962
Grains	1.1	1 644
Pulses	2.2	4 055
vegetables	1.7	322

Waste

Throughout the food chain a lot of waste is created. It is estimated that approximately 20% of all the food that is produced is lost as food waste[70]. Losses occur throughout the chain, but the largest part of the food waste is generated by households. The food industry is estimated to contribute 19% of the total food waste that is created; food and drink services account for 12% and wholesale and retail for 5%[71]. In addition, the packaging of food generates a lot of waste in the EU on an annual basis. Further recycling of this packaging waste could therefore make the food sector more circular and reduce its negative environmental impacts.

In addition, the packaging of food generates a large amount of waste in the EU. Further recycling of this packaging waste and a reduction in the use of one-way plastic packaging could therefore make the food sector more circular and reduce its negative environmental impacts. However, in the past few decades the use of one-way plastic packaging has increased dramatically, sometimes even at the expense of recyclable packaging types. This means that strong policy intervention is needed to turn this trend around and increase the recycling rate of packaging materials.

Employment profile of the EU food sector

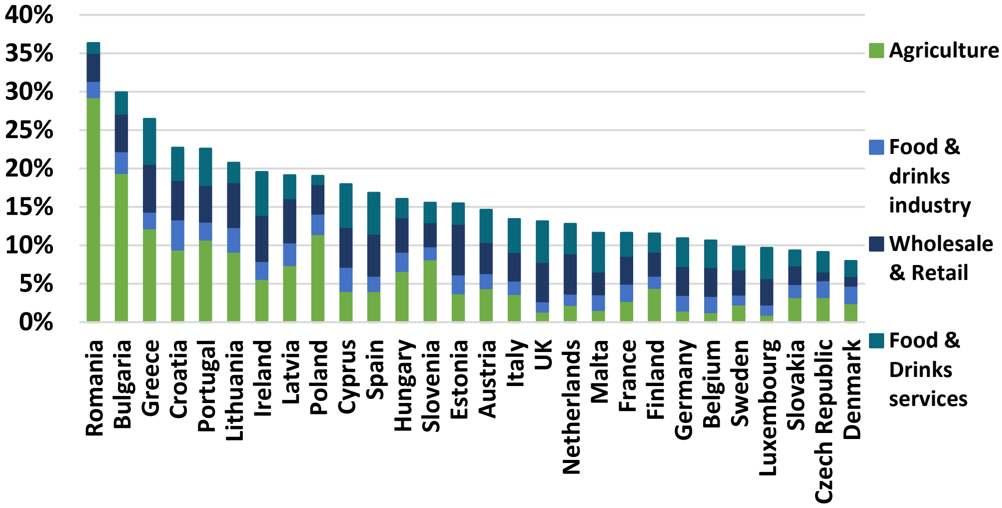
**The extent to which the food sector contributes to overall employment varies strongly across EU member states (
Figure 2-5). In general, economies in eastern and southern Europe are more dependent on the food sector than those in northern and western Europe. The exceptions are Ireland, which has a relatively large fraction of its labour force working in the food sector and Slovakia and the Czech Republic, where the contribution of the food sector to overall employment is rather low (<10%).**

Figure 2-5 shows that there are substantial differences between both the total share of employment from agriculture across Member States and the contribution from each subsector. It seems fairly obvious that any effects (either positive or negative) on the food sector from moving towards more circular practices will have more impact in the countries on the left-hand side of the figure.

[70] Fusions (2016) Estimates of European food waste levels.

[71] Fusions (2016) Estimates of European food waste levels.

Figure 2-5– The contribution of the food sector and its subsectors to overall employment in EU member states. Based on EUROSTAT data on 'persons employed'



Employment profile agriculture: large unbalance

The demographic profile of the labour force in agriculture is quite unbalanced in terms of age. Most farm managers are relatively old with over 80% of the farm managers aged >44 on small farms and roughly two-thirds aged over 44 in large farms[72]. There are also large seasonal differences in the number of jobs in agriculture. In total, there are 22.2M people who work in agriculture, but this corresponds to only 9.5M full-time jobs[73].

The food sector is a dynamic sector which has changed quite dramatically in the last few decades. In this section, the trends that are most relevant from a circular economy or employment perspective are discussed.

Current sectoral trends

Agriculture has seen a large decrease in employment in recent decades and there are no reasons to expect large changes in this trend in the foreseeable future. In the period 2005-2015, labour input declined by a quarter[74]. This trend will be difficult to reverse by means of job creation because of engagement in circular economy activities.

Decreasing labour intensity

In the last few years employment in the food and drinks industry has been relatively stable. However, Cedefop projects that between 2015 and 2025 employment in the food & drinks manufacturing sector will decline, by 2.2% in total. The biggest number of job losses is likely to take place in specialised food processing crafts, but there could be smaller reductions in jobs relating to the operation of machines or to logistics and transport (see table 2.2). In contrast to the manufacturing sector, employment in the food & drinks services sector increased by 5% between 2011 and 2014. However, the number of data points is too low here to draw conclusions on long-lasting trends.

[72] EUROSTAT (2016) Statistical books – Agriculture, forestry and fishery statistics – 2016 edition.

[73] *Ibid.*

[74] *Ibid.*

Table 2-2 – Overview of the different ISCO occupational groups active in the food industry sector, their contributions to total employment in the sector and expected growth or decline in the coming decade.

ISCO Occupational Group	Rank in food sector	Rank in total manufac-turing	Employ-ment 2015 '000s	Share of sector employ-ment	Forecast growth (% share) 2015-2025
75. Food processing, wood working, garment and other craft and related trades	1	3	1 007	21.3%	-3.3%
81. Stationary plant and machine operators	2	2	767	16.2%	-1.0%
52. Sales workers	3	16	534	11.3%	0.6%
93. Labourers in mining, construction, manufacturing and transport	4	5	412	8.7%	-1.5%
83. Drivers and mobile plant operators	5	11	288	6.1%	-0.4%
31. Science and engineering associate professionals	6	4	276	5.8%	1.4%
33. Business and administration associate professionals	7	7	210	4.4%	0.4%
43. Numerical and material recording clerks	8	8	187	4.0%	-0.7%
13. Production and specialised services managers	9	10	129	2.7%	0.3%
72. Metal, machinery and related trades workers		1	101	2.1%	-0.2%
Total			**4 727**	**100.0%**	**-2.2%**

Increased food demand

First of all, the global food demand will almost certainly grow strongly due to population growth and an increase in welfare, which leads to dietary changes (e.g. higher consumption of animal products). In the business-as-usual scenario, worldwide food production increases by 70% to feed 9.4 billion people in 2050[75].

In the period 1964-2015, global average meat consumption doubled from 24.2 to 41.3 kg per capita[76]. If this trend continues it will put a lot of pressure on the food production system and the available arable land, and it will inevitably lead to further destruction of natural habitats. It is important to note here that the average meat consumption in developed countries is still two to three times higher than the global average. Europeans consume on average 203 kg of animal protein per year, of which 87 kg is meat, 99 kg is dairy products and 16 kg is fish products[77]. However, the expectation is that between 2017 and 2026 European meat consumption per capita will remain constant, with an

[75] FAO (2009). How to feed the world in 2050?

[76] FAO (2017) ood Supply - Livestock and Fish Primary Equivalent. URL: http://www.fao.org/faostat/en/#data/CL

[77] EEA (2017) Consumption of meat, dairy, fish and seafood. URL: https://www.eea.europa.eu/data-and-maps/indicators/13.2-development-in-consumption-of/assessment-1

increasing share of poultry meat and a decreasing share of bovine meat[78]. The consumption of dairy products on the other hand is expected to increase slightly, with declining consumption of fresh milk, but increasing consumption of cream, yoghurt, butter and cheese[79].

Increasing demand for bio-based fuels, chemicals and materials

Increased demand for food is, however, not the only driver of increasing demand for bio-based products. In an effort to replace finite materials with renewable materials, the demand for bio-based materials and feedstocks will rise. Similarly, the effort to switch to a low-carbon energy system will increase the demand for biomass for heating and electricity production and biofuels for transport. These developments will put further pressure on the amount of land that will be available for the production of food. All of these developments take place against the backdrop of a declining availability of fertile arable land and in the knowledge that further conversion of natural habitats to arable land is absolutely undesirable. This situation stresses the need for optimisation of the limited amount of land resources that are available.

2.2 Circular economy in the food sector

How circular is the food sector today?

The circular economy affects all sectors in different ways and in each sector it poses specific challenges and opportunities. The recent report from the Ellen MacArthur Foundation, *Growth within*[80], has developed three main principles that shape the circular economy, being:

1. ‘Preservation and enhancement of natural capital by controlling finite stocks and balancing renewable resource flows’.
2. ‘Optimisation of resource yields, by circulating products, components and materials at the highest level of utility’.
3. ‘Reveal and design out negative externalities’.

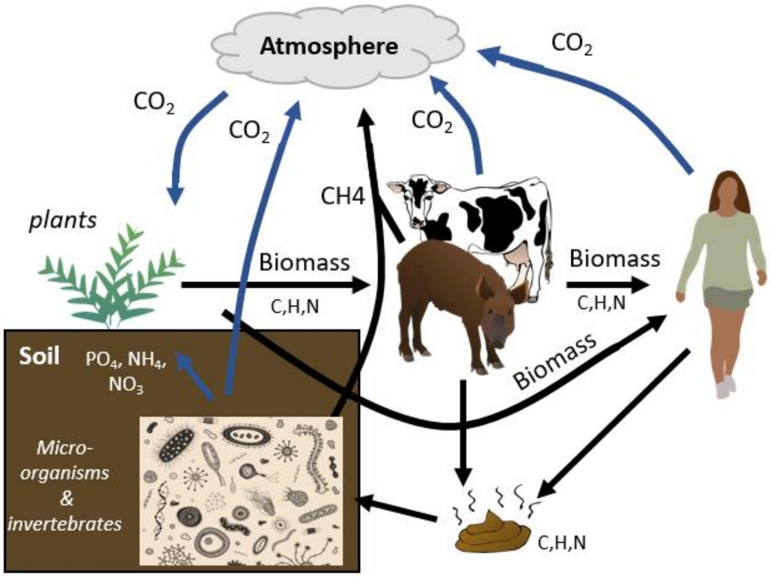
These principles are instrumental for the identification of sector-specific challenges and barriers, but can also be used to assess the current ‘degree of circularity’ in a certain sector.

[78] EC (2016) Market outlook agriculture baseline 2016-2026.

[79] *Ibid.*

[80] Ellen Macarthur (2015). Growth within: a circular economy vision for a competitive Europe.

Figure 2-6– Schematic overview of the natural carbon and nutrient cycles in the food web. Organic flows are indicated by black arrows and inorganic flows by blue arrows.



In essence, ***the circular economy is a concept that fits the food sector very well,*** *because* ***the sector is built on biological processes that are inherently cyclical***. Plants take up CO_2 from the atmosphere and nutrients from the ground to grow and produce organic matter (biomass). Plants can be eaten by animals, such as livestock and humans, who use energy contained in the biomass to live. As animals burn the biomass (organic carbon) the CO_2 is released back into the atmosphere and the nutrients return to the soil in the form of animal excreta (e.g. manure). In this way, the carbon and nutrient cycles are closed.

Industrialisation and intensification of food production, however, have pushed production beyond the carrying capacity of natural cycles. Intensification of crop production has led to overfertilization, resulting in leaching of nutrients into natural waters, with biodiversity loss as a result. Next to that intensive use and mismanagement of soils have led to the situation that many soils are degraded, which results in lower crop yields. Intensification of livestock breeding has introduced even more linearities into the agricultural system. Increasing populations of livestock in high densities generated the need to import food from other areas, leading to dispersals of crop production and livestock production. As a consequence, the livestock breeding areas develop nutrient surpluses in the form of manure and in other areas soils are depleted of their nutrients, leading to increased demand for mineral fertilisers. Table 2-3 summarises the linearities that have evolved during the process of intensification of food production using the three circular economy principles.

Table 2-3 – Linear aspects of the food sector

Finite resource stocks	Sub-optimal use of resources	Negative externalities
- Phosphate rock - Arable land - Fresh water	- Food waste - High meat production & consumption - Imports of food products over large distances	- Greenhouse gas emissions - Eutrophication - Acidification - Soil degradation

From Table 2-3 we can see that all three circular economy principles need further implementation in the food sector. It should be noted though that the emphasis will lie on the first two principles, as there is limited potential for designing out negative externalities. Optimisation of the food supply chain and consumption patterns will be essential to overcoming the challenge of increasing demand for food and non-food related agricultural products, as further explained below.

The circular economy potential of the food sector

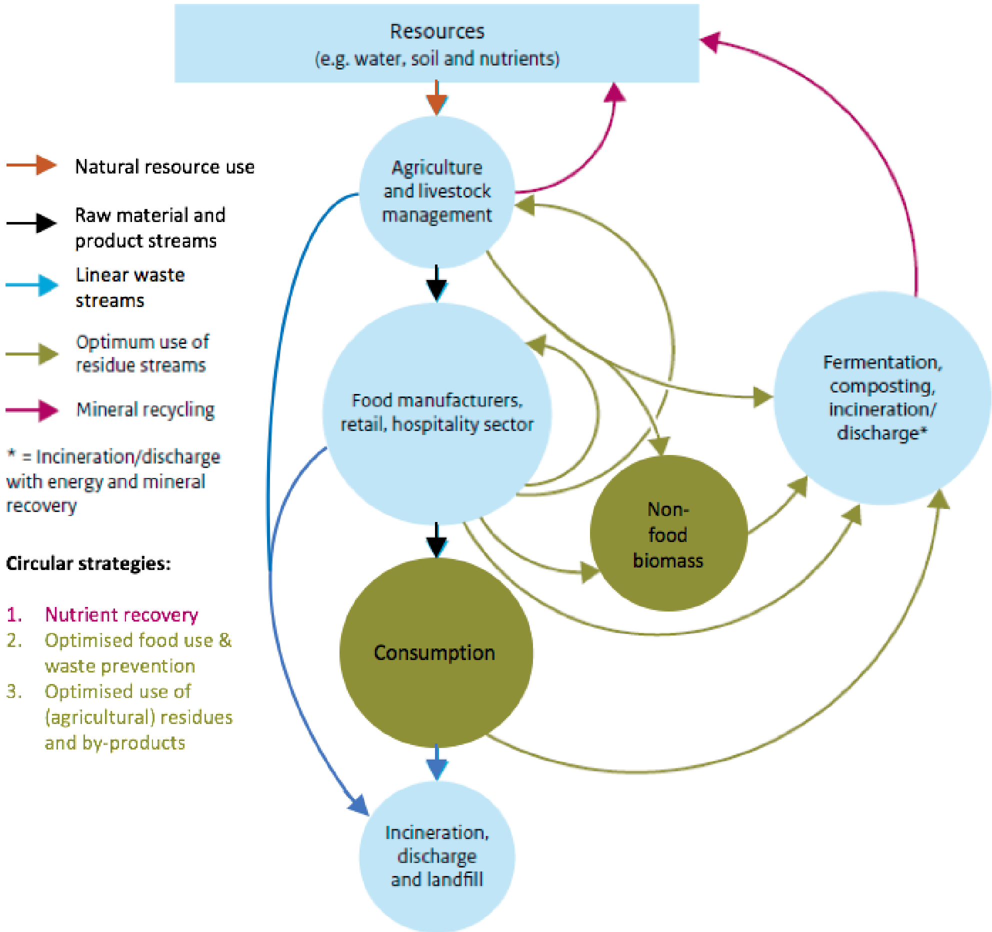
The potential for making the food sector more circular can be directly obtained by targeting the linear aspects that were identified in Table 2-3. The Ellen MacArthur foundation has defined six business activities/strategies that can be used to achieve the circular economy principles, which are the so-called RESOLVE levers. According to the *Growth Within report,* the relevant levers for the food sector are Regenerate, Optimise, Loop and Exchange. Another study, by the Dutch environmental assessment agency (PBL), also analysed the potential options for making the food sector more circular [81]. This report identified three main strategies to do this, namely:

1 Nutrient management & recovery

2 Optimal food use and waste prevention

3 Optimisation of use of agricultural residues and waste streams

Figure 2-7– Overview of linear and circular resource and product flows in the food sector.



Source: ***Adapted from*** **PBL, 2017**

[81] PBL (2017). Food for the circular economy.

Figure 2-7 gives an overview of the measures that can be taken throughout the food sector's supply chain, and indicates to which of the three strategies the measures belong. In the following paragraphs the different strategies and corresponding measures will be explained in more detail and linked to the subsectors where their application is most promising.

Strategy 1: Nutrient recovery

The first important strategy to make the food sector more circular is to improve nutrient management in order to balance nutrient supply and demand. The existence of areas with intense livestock farming and hence large amounts of manure production on one hand, and areas with extended crop production and thus fertilizer demand on the other hand, results in a geographical mismatch between manure production and fertilizer demand. As transport is expensive, manure is often applied close to where it is produced, thereby contributing to further build-up of nitrogen and phosphorus in soils that are already rich in those nutrients. In other areas with intensive crop farming, farms buy mineral fertilizers to fertilize their crops.

On an annual basis 1.4 Gtonnes of manure are produced in the EU, containing around 8 Mtonnes of nitrogen and 1.8 Mtonnes of phosphorus[82]. As a consequence, around 90% of the nitrogen and phosphorus is returned to the soils, although part of the nitrogen is lost during fertilizer storage and application. Although an estimated 7.1 Mtonnes of N and 1.75 Mtonnes of P are applied to agricultural lands there is still a need for 10.9 Mtonnes of N mineral fertilizers and 1.4 Mtonnes of P mineral fertilizers on an annual basis[83]. This mismatch could potentially be solved by concentrating the nutrients in the manure, so that these can be transported with a higher cost effectiveness so that these organic fertilizers can become cost-competitive with mineral fertilizers. The problem is, however, that up to now it has been too expensive to remove the water from nutrient-rich streams with high water contents such as manure, but also sewage sludge and digestate.

Table 2-4– Overview of N and P flows in different streams and their recycling rates

	TOTAL N in stream	Recycled N	TOTAL P in stream	Recycled P
Raw manure	7-9	7.1	1.8?	1.75
Food chain waste				
Household waste	0.5-0.7	0.16	0.11	0.03
Slaughterhouse waste	?	?	0.28	0.02
Sewage	2.3-3.1	0.5	0.32	0.10
Totals of these streams	> 10-13	>7.8	2.5	1.9
Current recycling (%)		**60-80%**		**76%**
Not recycled (Mt)		**2-5**		**0.6**
For comparison, mineral fertiliser use in crop production (Mt)		**10.9**		**1.4**
Not recycled nutrient as percent of mineral fertiliser		**18-46%**		**43%**

(Sources: see Table 4 for total nutrients in streams. Recycled amounts from Leip et al 2014, Milieu et al 2010, Saveyn and Eder 2014 and van Dijk et al 2016)

Source: Rise (2016) Nutrient Recovery and Reuse (NRR) in European agriculture – A review of the issues, opportunities and actions.

There are several ways in which nutrient management can be improved. These options include measures to apply fertilizers more effectively or to minimise losses and recover nutrients from 'waste' streams.

[82] Rise (2016) Nutrient Recovery and Reuse (NRR) in European agriculture – A review of the issues, opportunities and actions.

[83] *Ibid.*

Minimising losses (N, P, K) during cultivation:

- Precision farming (only applying fertilisers where nutrient content is low)
- Coverage of unused arable land with vegetation to prevent soil erosion
- Innovative farming methods such as vertical (indoor) farming with closed nutrient recycling systems
- Improved tillage techniques to prevent soil erosion
- Using biotechnological techniques to reduce the nutrient requirement of crops

Minimising post-harvest supply chain losses (N, P, K):

- Recover nutrients from crop residues and waste streams (e.g through anaerobic digestion (AD) or composting)
- Recover nutrients (especially P) from slaughter waste (e.g. through AD)

Minimising losses through excreta (N, P, K):

- Reduce phosphorus content of animal feed
- Increase use of manure as substitute for mineral fertiliser
- Recover nutrients from treated (digested or incinerated) manure
- Recover nutrients (especially P) from slaughter waste
- Recover nutrients from sewage sludge

Strategy 2: Optimal food use

Currently, the way in which Europeans and people from other affluent countries produce and use food is quite inefficient. About 20% of all the food that is produced in the EU ends up as food waste, which corresponds to a total amount of 88M tonnes of food with an estimated value of €143 bn[84]. Most of the food waste (53%) is generated in households, 19% during food processing, 12% in food services, 11% during primary production and 5% in wholesale and retail[85]. Reduction of the amount of food waste is thus an important way of increasing resource efficiency in the food sector. Policy instruments and strategies aimed at reducing food waste include:

- a restriction of bulk discounts on food products for consumers
- critically reviewing regulations on food conservation dates and exchange of fresh food
- increasing consumer awareness on food N
- promoting the sale of food in smaller quantities

Secondly, people consume increasing amounts of animal protein (meat, dairy products and fish), which is much more resource-intensive and leads to more negative environmental impacts than the consumption of vegetal products. Next to that the amount of animal fats and proteins that most Europeans consume are above the maximum recommended amounts for a healthy diet[86]. Therefore, promotion of a diet with less animal protein is an important part of the strategy to make the EU food sector more resource efficient. There are

[84] FUSIONS (2016). Estimates of European food waste levels.

[85] *Ibid.* FUSIONS (2016). Estimates of European food waste levels.

[86] PBL (2016). The protein puzzle.

several ways in which diets with less animal protein can be stimulated, including:

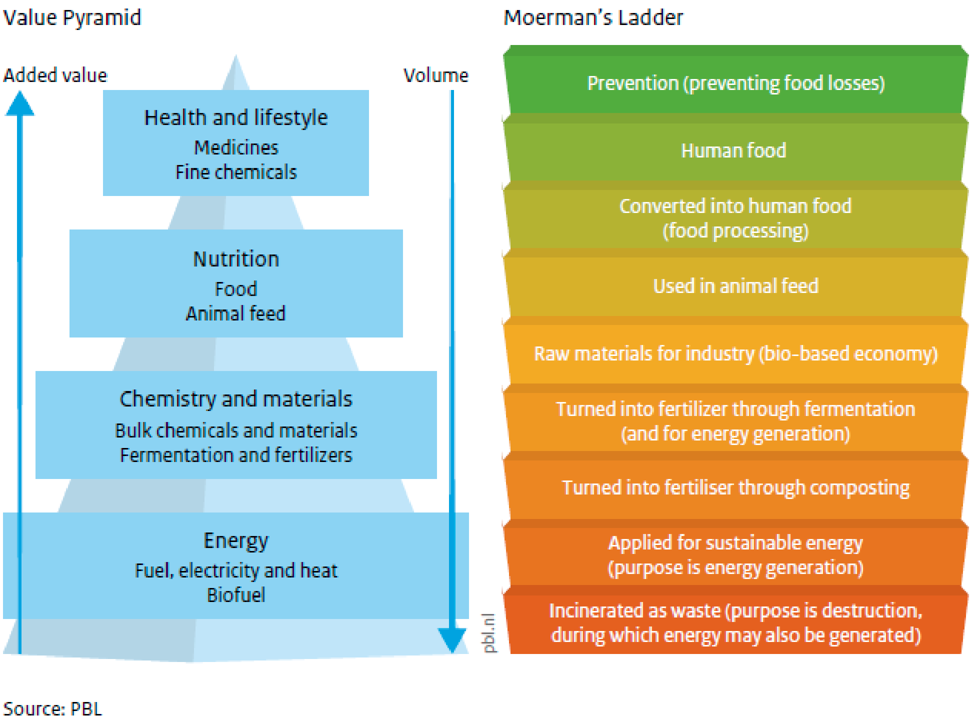
- additional taxes on meat, dairy and fish products
- better environmental labelling of food products, to inform consumers about the environmental impacts of what they buy
- awareness campaigns to inform consumers about the environmental impacts of meat and dairy

Strategy 3: Optimise use of agricultural residues and waste streams

Although the primary priority is to prevent waste from being produced, it is also important to use waste and residual streams from agriculture and food manufacturing in an optimal way. In line with circular economy principle 2, products and materials should be used at the highest possible level of utility (and value).

For food waste streams the hierarchy of utilisation options are summarised by Moerman's ladder (Figure 2-8).

Figure 2-8- The value pyramid and Moerman's ladder. Source: PBL, 2017.



If food is no longer usable as human food, it can be processed to become edible for humans again or processed into animal feed. If this doesn't work the organic matter can be processed into raw materials for (e.g. the chemical) industry; under some circumstances, for example in the case of pharmaceutical substances, this is even preferred over the use as animal feed. Animal feed can be made from agricultural crop residues, former foodstuffs and even from some types of organic waste. In the meantime, there are several companies over the world that produce animal feed out of insect larvae that are fed with organic waste. The firm Agriprotein for example, produces 7000 tonnes of protein-rich feed on an annual basis, using 91000 tonnes of organic waste as insect feed[87].

If the waste stream cannot be used by industry either, it can be used for energy generation, preferably through anaerobic digestion or otherwise through incineration with energy recovery. In both of these cases the nutrients can be recovered, from the digestate and ash, respectively. Alternatively, the organic waste could be composted, to be used as organic fertiliser.

Currently, optimal use of waste streams is often hindered because it is not economically profitable, or because of regulatory and legislative barriers. Manure, for example, can serve as an organic fertiliser or as feedstock for anaerobic digestion, but these applications are only economically feasible when done locally as revenues from sales as fertiliser or from biogas production are not sufficient to compensate for the costs of long-distance transport. Additionally, EU regulation on animal by-products restricts the transport of manure between different Member States. Similarly, it is currently not allowed to use slaughter waste, which includes the P-rich bone meal, for the production of organic fertilisers, because of (perceived) health risks.

In conclusion, the three strategies outlined above can help to transform the food sector back towards its natural resource cycles. This would lead to a reduced need for virgin materials, especially with respect to minerals required for fertiliser production. Additionally, optimised use of resource streams and changes in consumption patterns can reduce the amount of land that is needed to satisfy EU food demand. The land that is freed up can then be used for export of food to other places, or for production of bio-based chemicals, materials and fuels.

Circular economy outlook for the food sector towards 2030

With the trends, opportunities, challenges and regulatory barriers that were discussed in the previous sections in mind, we will now look to the future to see to what extent the circular economy options for the food sector can be implemented until 2030. The developments described in this section will also be used as inputs to model the circular economy transition in the food sector and obtain insight into the employment effects that it brings along. The developments will be described along the three circular economy strategies, namely: nutrient recovery, optimal food use and waste prevention and optimised use of agricultural residues and waste streams. It should be noted that neither this outlook nor the modelling exercise aim to make realistic forecasts about the future. The goal is rather to show what the effects will be on the economy and labour market, if strong policies are implemented to promote circular activities in the food sector.

Improved nutrient management

New farming techniques such as precision farming and vertical farming will reduce the amount of fertilizer inputs required to achieve the same yield levels (Box 1). We expect that overall fertiliser use can be reduced by 10% in a moderate circular economy scenario and by 20% in an ambitious scenario. Next to this a large part of the inorganic fertilizer use can be replaced by the use of organic fertilizers.

[87] Agriprotein (2017) official website – press articles. URL: http://agriprotein.com/press-articles/agriprotein-and-christof-industries-in-usd-10-million-deal-to-roll-out-100-fly-farms/

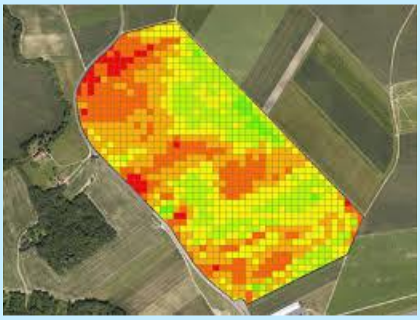
Box 1 - Innovative farming techniques that can reduce fertilizer demand

Vertical farming – is a technique where plants are grown indoors in vertical layers on top of each other, which increases the yield per m2. Also, vertical farming is very suited for local crop production in Urban environments. The indoor setup allows for strict control of the light regime and keeping the environment sterile can prevent the use of pesticides.

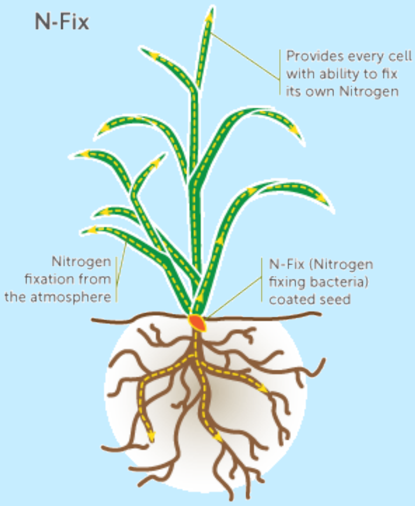
Hydroponic farming – is a technique where plants are not grown in soil, but the roots are submerged in water with dissolved nutrients. Such a system allows for strict control of nutrient concentration in solution and the use of closed systems ensured that no nutrients are lost. Hydroponic farming can be combined with vertical farming

Aquaponic farming - is a technique where hydroponic farming is combined with fresh water aquaculture, so that the cultured fish provide nutrients directly to the plants. At the same time crop residues can be used as fish feed.

Precision farming – is a set of techniques where irrigation, and application of fertilizers, herbicides and pesticides is differentiated according to the local requirements in different parts of the cropland. Drones, remote sensing with satellites and soil sampling techniques are used to map water content, nutrient levels and crop health in different parts of the cropland, so that inputs can be applied accordingly.



Biotechnological techniques – can be used to reduced nutrients of plants. Some plants are more efficient in their use or uptake of nutrients than others. Traits of efficient species can be crossed into crops that have less efficient nutrient use or engineered into the crops through genetic modification. Also, methods are being developed to optimise symbiotic relationships between plants and microorganisms. The UK-based firm Azotic Technologies for example, has developed a technology where crop seeds are inoculated with a bacterial strain that lives inside plant cells and is able to convert atmospheric nitrogen into nitrates and ammonium, which serves as nitrogen source for the pant. Field



tests with this technology commonly show a 50% reduction in demand for N-fertilizers.[88]

The P-REX phosphorus recovery project estimated that 45% of the inorganic phosphorus demand in Europe could come from phosphorus recovery, of which roughly two fifths can come from slaughterhouse waste, one third from sewage sludge and one quarter from food waste[89]. Additionally, nitrogen is currently recovered sewage sludge with a very low efficiency. Most of the nitrogen is lost through nitrification/denitrification processes, but the use of other techniques such as ammonia stripping, could increase the nitrogen recovery efficiency significantly (up to 70-90%). from These potentials for improvement will be taken along in our scenarios.

Biogas production could function as an important driver for cheap production of organic fertilizers as anaerobic digestion of manure and other organic waste leaves a nutrient-rich digestate as a residue. This digestate can be processed into an organic fertilizer. Digestate is not very suited for direct use as fertilizer because its high moisture content makes it expensive to transport, so therefore further processing is required. Doing so can improve the business case for anaerobic digestion as the revenues from biogas production and those from fertilizer sales can be combined. However, currently, processing of digestate into fertilizers is only done to a limited extent, primarily because of the low prices of inorganic fertilizers. In our scenarios we assume that all the existing legislative and economic barriers that restrict the use of digestate as a fertilizer will be removed. Compared to the current use of organic waste for biogas production, there is a potential towards 2030 to produce 480PJ of additional biogas in the reference scenario and 890PJ in an 'accelerated deployment' scenario[90]. From these 410PJ that can be produced in addition to the reference case, approximately 290PJ comes from manure digestion. We assume that under an ambitious scenario this entire 290PJ potential will be used, whereas only 145 of additional PJ of biogas production from manure digestion will be realised in the moderate scenario. We assume that in both the moderate and ambitious scenario all the digestate will be used for fertilizer production and that 50% of all the nitrogen content and 70% of the phosphorus content will be recovered.

Optimisation of food use

Next to nutrient recovery, optimisation of food use is essential to make the food sector more circular. Firstly, this comes down to reducing food waste.

[88] Azotic Technologies (2017) Official website, URL: http://www.azotictechnologies.com/index.php/technology/n-fix/ Last retrieved on: 22-11-2017

[89] P-REX (2015) Policy brief: Phosphorus recycling -now!

[90] EC (2016) Optimal use of biogas from waste streams – An assessment of the potential of biogas from digestion in the EU in 2020 and beyond.

The Ellen MacArthur Foundation has estimated that by 2050 food waste at the consumer level might be reduced with 35-40% and food waste produced throughout the supply chain can be reduced by 50%. Therefore, we assume that by 2030 food waste at the consumer level might be reduced with 25% and food waste produced throughout the supply chain can be reduced by 30%. Moreover, we assume that this full reduction potential will be reached in the ambitious scenario, while half of the potential will be fulfilled in the moderate scenario.

Another important action to optimise food use is to reduce the amount of animal products (especially proteins and fats) in the human diet. If the diet of the average European would only be adjusted to be in line with the recommendations for a healthy diet by the World Health Organisation, this would already mean an 41% reduction in protein consumption. Europeans consume over 30kg of protein per capita on an annual basis, while the recommended amount is 18 kg. If Europeans would keep the relative shares of animal and plant proteins in their diets constant, this would mean that meat consumption would have to be reduced by 41% as well. As a consequence, this would mean that about 28% of the EU's agricultural land would be freed up. Although reduction of the amount of animal products in the human diet are desirable, from a health and sustainability perspective, such dietary changes are not likely to happen automatically. Consumers perceive sustainable food choices as more expensive than less sustainable alternatives and people often buy certain products habitually[91]. Moreover, meat consumption plays an important cultural role in many European countries. Therefore, a dietary shift away from animal products will require better education and informing of consumers as well as strong policy support. The latter will be very challenging to achieve as the European Commission is still actively promoting meat consumption[92]. Similarly, many national governments are protecting their livestock farmers and meat and dairy industry because of economic motives. However, gains could be already made by shifting from beef consumption to consumption of pig meat or even better poultry, as the latter meat types have less severe environmental impacts. Such a change is already expected to happen to a small extent[93]. Awareness campaigns and price incentives could stimulate such trends.

Optimal use of waste-streams and by products

The use of agricultural residues and by-products can be optimised as well as the use of by-products and waste streams from food & drinks manufacturing and wholesale & retail. Former foodstuffs (not fit for human consumption) as well as some organic waste streams can be used for the production of animal feed. Currently, the EU livestock population consumes 480 Mton of feed, of which 60% is coming from either grazing land or cereals produced on the livestock farm[94]. The remainder consists of purchased feedstuffs and compound feed (196 Mton). Currently, 5 Mtonnes of former foodstuffs are

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[91] LiveWell for Life (2013). Adopting healthy, sustainable diets: key opportunities and barriers.

[92] URL: https://www.euractiv.com/section/agriculture-food/opinion/the-eus-promotion-of-meat-consumption-is-misguided-mr-hogan/

[93] EC (2016) Market outlook agriculture baseline 2016-2026.

[94] FEFAC (2016) Annual report 2015-2016.

processed into animal feed on an annual basis and the European Association for former foodstuff processors (EFFPA) estimates that this can grow to 7 Mton in 2025[95], which is already about 60% of all the food waste that is generated in that sector. Currently, 138-180 Mton of bio-waste is produced in the EU on an annual basis. If 20% of this bio-waste would be used for the production of insect-based animal feed, which is already a lot, this would mean that another 2 Mtonnes of animal feed could be produced. This means that combining the use of former foodstuffs and more optimal use of organic waste would generate only 4 Mtonnes of animal feed, which corresponds to only 0.8% of the total demand for feed. This emphasises once again how vital dietary changes are if one wants to achieve more substantial resource efficiency gains in agriculture and the food sector as a whole.

Employment implications of the transition to a circular food sector

The circular economy will certainly affect the labour market in the food sector, especially in terms of the kind of skills that will be needed. The circular economy will likely also impact the total number of jobs in the sector. The overall effect might be a net loss in jobs. A reduction in food waste for example, will result in a lower food production levels, as less food is required to feed everyone, which will lead to a decrease in employment throughout the food supply chain. The modelling exercise is needed to show the magnitude of such effects. What is certain, however, is that the changes that the circular economy brings about are happening in the context of a food sector in which the labour market is undergoing large changes in any case. As described earlier, the number of jobs in agriculture, and to a lesser extent also in food & drinks manufacturing is declining.

Although we cannot yet describe the magnitude of the effect that the implementation of circular strategies will have on the food sector, we can describe in qualitative terms what types of jobs we expect to be created and lost. First of all, the structure of the agricultural sector will change. The share of crop farmers will increase, whereas the number farmers involved in livestock farming will decrease. This has important implications with respect to skills-requirements, as livestock farming is completely different from crop farming in terms of skills and know-how. Additionally, the transition to a circular economy will require a larger number of highly skilled farmers that can apply high-tech farming techniques such as vertical farming, hydroponic farming and precision farming.

The shift in human diet away from animal proteins will also have serious employment implications, as the meat and dairy sector make up a very large part of the total food sector. Reduced consumption of these products could thus lead to substantial job losses in these subsectors.

The nutrient recovery strategy will have less dramatic job implications. Even substantial reductions in the use of artificial fertilisers will have a modest impact on employment, as this industry only employs around 16,600 people in total[96]. Moreover, improved use of organic waste for biogas production will generate new jobs, which compensates to a large extent for the jobs lost because of declining sales of inorganic fertilisers.

[95] EFFPA (2017) Official website -Figures & Network. URL: http://www.effpa.eu/figures-network/

[96] Fertilisers Europe. EU fertiliser market - Key graphs. Data from 2012.

2.3 Modelling inputs (E3ME)

Section 2.2 discussed in which ways the food sector could become more circular towards 2030. In this section, we will use this outlook to build scenarios and develop assumptions that can be used to model the economic and employment impacts of the transition to a circular economy in the food sector. The structural changes described in Section 2.2 will therefore be used as inputs and assumptions for the E3ME model.

Although the subsectors have been mapped to NACE codes in the beginning of section 2.1 of this chapter, the mapping to E3ME sectors works a bit different. Table 2.5 shows how the subsectors of the food sector and the interlinked sectors can be mapped to E3ME sectors.

Table 2-5– Linking of food sector subsectors, interrelated sectors and circular activities to E3ME sectors

Subsector/activity	E3ME sector
Agriculture	1. Crops, animals, etc.
Manufacturing of food and beverages	7. Food, drinks & Tobacco
Retail and wholesale of food products	32. wholesale excl. motor vehicles 33. Retail excl. motor vehicles
Consumers	Households
Waste sector	29. Sewerage & waste management
Fertiliser producers	13. Other chemicals 16. Non-metallic mineral products
Energy production from organic waste	26. Electricity 27. Gas, steam and air conditioning

Modelling assumptions

In the modelling step we will model the following circular economy activities:

- 1A - Reduction in overall fertilizer use (*Improved nutrient management*)
- 1B- Substitution of inorganic fertilizers with organic fertilizers (*Improved nutrient management)*
- 2 - Reduction of food waste (*Optimised food use*)
- 3A -Use of organic waste and former foodstuffs as animal feed (*Optimised use of residue streams and by-products)*
- 3B - Biogas production from manure in agriculture *(Optimised use of residue streams and by-products)*

An overview of how all these activities will be modelled is given in table 2.8.

New farming techniques and the use of new crop varieties have the potential to reduce the overall fertilizer demand, without reducing crop yields. Therefore, we assume a 10% reduction in the overall fertilizer use in the moderate scenario and a 20% reduction in the ambitious scenario. This will, together with the substitution of inorganic fertilizers with organic fertilizers, reduce the demand for inorganic fertilizers.

The extent to which it will become attractive in the future to substitute mineral fertilizers with organic fertilizers will depend very strongly on the policies that will be implemented to promote this development and also on the development of the mineral fertilizer prices. In our scenarios we will make rather ambitious assumptions on the replacement of mineral fertilizers with organic ones, to show the dynamics of such a change, not to make a realistic forecast of the future. Also, even though organic fertilizers are currently more expensive than mineral fertilizers, we do not model additional expenditures on fertilizer as we expect that improved policies that enable the processing of organic waste and manure into organic fertilizer will also bring down the price of those fertilizers.

For nitrogen we assume that the recovery from sewage sludge is increased from the current 18% to 35% in a moderate scenario and 50% in an ambitious scenario. Additionally, we assume that from the digestate that will be generated through increased uptake of anaerobic manure digestion (see modelling assumption 3B) 50% of all the nitrogen content will be processed into an organic fertilizer.

For phosphorus it has been estimated that that 45% of the inorganic phosphorus demand in Europe could come from phosphorus recovery from waste streams and sewage sludge. In total this comes down to 0.7 Mton of P. We assume that in an ambitious scenario all this P will be recovered and in the moderate scenario only half of it. Next to that we will assume that 70% of the phosphorus contained in the digestate from anaerobic digestion of manure will be converted into organic P fertilizers. The summary of the assumptions on fertilizers are given in Table 2.6. Combined these assumptions imply that in the moderate scenario 16% of the nitrogen fertilizers and 53% of the P-fertilizers will be organic fertilizers. In the ambitious scenario this will be 26% and 100%, respectively. Assuming that nitrogen and phosphate fertilizers have a similar price and that these prices will remain constant, this means that the cost savings on inputs from chemical industry will be € 12 bn in the moderate scenario and € 20 bn in the ambitious scenario[97].

Table 2-6– Overview on the nutrient recovery assumptions

	Biogas from manure (PJ)	Total manure use (Mton)[98]	Total nitrogen content [99]	total P content [54]	N recovery (Mton)	P recovery (Mton)
Current biogas production	45	29.7	0.170	0.04	no data	
reference scenario	230[100]	152.0	0.868	0.20		
biogas from manure biogas moderate	375[55]	247.8	1.416	0.32	0.28	0.22
biogas from manure biogas ambitious	520[55]	343.6	1.963	0.44	0.39	0.31
Waste streams and sewage sludge moderate	Not applicable/no data				0.71	0.22
Waste streams and sewage sludge ambitious					0.98	0.31

[97] Eurostat data on agricultural expenditures on fertilizers in 20XX were used as a basis for these calculations. It was assumed that P-and N fertilizers have the same price.

[98] Foged, H.L., Flotats X. , Blasi A.B., Palatsi J. and Magri A.. (2011). End and by-products from livestock manure processing - general types, chemical composition, fertilising quality and feasibility for marketing. Technical Report No. III concerning “Manure Processing Activities in Europe” to the European Commission, DG ENV.

[99] Rise (2016) Nutrient Recovery and Reuse (NRR) in European agriculture – A review of the issues, opportunities and actions.

[100] EC (2016) Optimal use of biogas from waste streams – An assessment of the potential of biogas from digestion in the EU in 2020 and beyond.

Total recovery moderate				0.95	0.35
Total recovery ambitious				1.35	0.70
Total fertilizer use moderate	Not applicable	1.65	0.57	12%	53%
Total fertilizer use ambitious		2.33	1.01	19%	100%

Optimised food use

We assume that by 2030 food waste at the consumer level might be reduced with 25%, and food waste produced throughout the supply chain can be reduced by 30%. Moreover, we assume that this full reduction potential will be reached in the ambitious scenario, while half of the potential will be fulfilled in the moderate scenario. These percentages were combined with the current monetary values of the food waste generated in the different food chain subsectors and in households[101], to calculate the cost savings or reductions in output for all these sectors (Table 2-7). So the reduction of food waste will be modelled first of all through reduced expenditures of households on food and drinks, which will have knock-on effects on other sectors. Additionally, sector-specific assumptions are made for waste reductions throughout the food production chain.

In the European policy discourse a 50% food waste reduction target has been discussed. However, since the achievement of this ambitious goal will depend very strongly on large behavioural changes of consumers. Although it is very good to have an ambitious policy goal in place we think it is questionable whether an overall food waste reduction of 50% for 2030 is feasible and therefore we propose to model a 30% reduction in the ambitious scenario.

Table 2-7– Overview of current food waste values for all subsectors of the food sector as well as the cost savings in the moderate and ambitious CE scenarios

	current value food waste (bn)	new value food waste (bn)		value of waste saved (bn)	
		moderate	ambitious	moderate	ambitious
Primary sector	1.8	1.53	1.26	0.27	0.54
processing	13	11.05	9.1	1.95	3.9
wholesale and retail	10	8.5	7	1.5	3
food services	20	17	14	3	6
households	98	85.75	73.5	12.25	24.5
Totals	**142.8**	**123.8**	**104.9**	**19.0**	**37.9**

In addition to the reduction in food waste we will model a reduction in the use of one-way packaging by reducing the purchasing of plastics from by the food manufacturing sector from the packaging industry (sector rubber and plastic products in E3ME). A recent study estimated that between 36 and 53% of the plastic packaging in Europe can be recycled in cost-effective way[102]. We assume that under the moderate circular economy scenario 5% of this cost-effective (including env. benefits) potential will be realised and in the ambitious scenario 25% of it. This means that the food manufacturing sector will reduce

[101] Fusions (2016) Estimates of European food waste levels.

[102] Denkstatt (2016) The potential for plastic packaging to contribute to a circular and resource-efficient economy.

its purchases from the packaging sector with 2.2% and 11.1% in the moderate and ambitious scenario, respectively. It should be noted though, that the business-as-usual development is that the use of one-way plastics in packaging is increasing. This means that the modelled reductions in plastic packaging will only be realised when ambitious and strict policies are implemented. Up to now the costs of one-way packaging in Europe are still only partially paid by the industries using it, so industry should pay the government more for the management of packaging waste[103].

A shift in diet towards less animal products will not be modelled in E3ME due to a lack of sub sectoral detail, as meat and dairy production are not separated from other products in agricultural production, manufacture of food products, wholesale and retail of food products, food services and household spending on food in the model. Although dietary changes will not be modelled in this study, a dietary shift away from animal products is an essential part of the transition to a more circular food sector. It might even be one of the changes with most environmental and resource benefits. Furthermore, the labour impacts of such a dietary change will probably be substantial (see labour impacts section of chapter 2.2).

Optimization of use of agricultural residues and waste streams

The third circular economy strategy in the food sector is to optimise the use of waste streams, residues and by-products. The preferred option here is to use such flows for the production of animal feed. The stream that can be used for the production of feed most easily is the stream of by-products and former feedstuffs no longer fit for human consumption, that is generated in the food manufacturing sector. However, the total value of such streams is rather limited. It is estimated that 16.9 Mtonnes of food waste are generated in the food manufacturing sector, but 5 Mtonnes of this are already being processed into animal feed. The EFFPA estimates that this can grow by another 2 Mtonnes towards 2025[104], so we assume that in 2030, the ambitious case, an additional 3Mtonnes of food waste will be processed into animal feed. In a moderate case we assume that in addition to the current feed production from food waste another 1.5 Mtonnes is converted.

In addition to production of feed from former feedstuffs, one can also produce feed from insects that are fed with organic waste. If we assume that 20% of all organic waste can be used for this purpose, which is already very ambitious as collection of organic waste is currently quite poor in many member states and use of organic waste is quite restricted via legislation, this could generate 2.0 Mtonnes of feed for livestock[105]. In a more moderate scenario, we assume that only 5% of the organic waste can be used for this purpose, which will

[103] Cruz *et al.*(2016). Packaging waste recycling in Europe: Is the industry paying for it?

[104] EFFPA (2017) Official website -Figures & Network. URL: http://www.effpa.eu/figures-network/

[105] This is based on a total bio-waste volume in the EU28 of 128 Mtonnes and assumes that this bio-waste can be converted into insect-based feed with a 7.6% efficiency. Sources: https://www.interregeurope.eu/fileadmin/user_upload/plp_uploads/2017-03-24_PB_Biowaste_amended.pdf Agriprotein (2017) official website – press articles. URL: http://agriprotein.com/press-articles/agriprotein-and-christof-industries-in-usd-10-million-deal-to-roll-out-100-fly-farms/

generate 0.5Mtonnes of livestock feed. Combined with the animal feed that is produced from former feedstuffs, this means that in the ambitious scenario 1% of the current feed consumption is replaced by optimised use of waste streams and 0.4% in the moderate scenario.

Next to the production of animal feed one can produce lower-quality waste streams for the production of biogas through anaerobic digestion, combined with recovery of nutrients from the digestate. The latter is already covered by the modelling assumptions on the replacement of inorganic fertilizers by organic ones. In the modelling exercise we will only include additional production of biogas from manure compared to a reference deployment scenario. This means that in a moderate case 145PJ of additional biogas will be produced from manure and in an ambitious case 290PJ. If we assume gas wholesale prices that are paid by industry, these production levels would represent values of € 1.32 bn and € 2.64 bn, respectively. This increased income in agriculture will be captured in a change to input-output relationship between the gas distribution and agriculture sector.

Table 2-8 – Overview of how circular economy strategies in the food sector will be modelled in E3ME

<table>
<tr><th>Circular strategy</th><th>Circular activity</th><th></th><th>How to model this?</th><th>Moderate scenario</th><th colspan="2">Ambitious scenario</th></tr>
<tr><td rowspan="3">1.Nutrient recovery and reduced nutrient use</td><td>1 A Reduced fertilizer use & 1B Substitution of inorganic fertilizers with organic fertilizers</td><td></td><td>Reduce inputs (purchases) of the agriculture sector from chemical industry</td><td>Reduce inorganic fertilizer inputs with 24% i.e. 12 bn EUR reduction in expenditures</td><td colspan="2">Reduce inorganic fertilizer inputs with 41% i.e. 20 bn EUR reduction in expenditures</td></tr>
<tr><td>1B - Use of manure or agriculturally produced digestate as fertilizer</td><td></td><td>Increase inputs from agriculture to itself and from waste sector to agriculture</td><td>3.2 bn EUR additional inputs from agriculture into itself</td><td colspan="2">4.4 bn EUR additional inputs from agriculture into itself</td></tr>
<tr><td></td><td colspan="2">1B Increase nutrients from sewage sludge as fertilizer</td><td>Increase of inputs from waste sector</td><td>4.5 bn EUR additional inputs from waste sector to agriculture</td><td>7.4 bn EUR additional inputs from waste sector to agriculture</td></tr>
<tr><td>2. Optimal food use and waste prevention</td><td>Reductions in food waste</td><td></td><td>Reduce household expenditures on food manufacturing and retail/food services</td><td>12.3 bn EUR savings on food expenditures EU-wide</td><td colspan="2">24.5 bn EUR savings on food expenditures EU-wide</td></tr>
</table>

			Reduce inputs from agriculture to food manufacturing	1.95 bn EUR savings on inputs from agriculture	3.9 bn EUR savings on inputs from agriculture
			Reduce inputs from agriculture and food manufacturing to hotels and catering	3 bn EUR savings	6 bn EUR savings
			Reduce inputs from agriculture and food manufacturing to wholesale and retail	1.5 bn EUR savings	3 bn EUR savings
			Reduce inputs from all the above mentioned sectors to the waste sector		
2. Optimal food use and waste prevention	Switch in diet towards less animal protein	*Due to lack of detail in the model, this cannot be modelled*	N.A.	N.A.	
3. Optimization of use of agricultural residues and waste streams	A. Use of organic waste and former foodstuffs as animal feed	Reduce agriculture inputs to itself			
			Increase inputs from food manufacturing to agriculture		
			Increase inputs from waste sector into agriculture		
		B. Use of manure for biogas production	Increase inputs from agriculture sector into agriculture	145 PJ of additional biogas production, worth 1.3 bn EUR	290PJ of additional biogas production worth 2.6 bn EUR

3 Construction Sector

3.1 Overview and scope of the construction sector

Scope of the sector

The construction sector (buildings and infrastructure) is a key sector for the EU economy and represents a major source of employment. It accounts for 9% of the EU's GDP and provides 18 million direct jobs[106]. The construction sector is the most material-intensive economic sector in the EU. In the EU, of all materials extracted from the earth each year, more than half (by weight) are used in construction[107]. Construction therefore has a high potential for increasing the circularity of the economy. In its EU action plan for a Circular Economy, the European Commission singled out construction as a priority sector[108]. For all these reasons, the construction sector has been selected as a focus sector in this study.

Strictly speaking, the construction sector performs three main activities:

- The construction of buildings, which accounts for 78% of total construction by value in the EU. Residential buildings make up the biggest share of the buildings stock (75%), followed by wholesale and retail, and office buildings[109].
- The construction of civil engineering work, such as railways, roads, bridges, airport runways, dams, etc. This second type of activity represents 22% of total construction in the EU[110].
- Specialised construction activities that encompass various activities like building completion, building demolition or construction installation activities such as plumbing or electrical work.

In addition to these three activities, architectural and engineering activities analysis are also accounted for as they are involved at different stages of the construction life cycle.

To perform these activities, the construction sector needs raw materials that are extracted through (mainly) mining and quarrying and forestry and logging activities. These raw materials are then transformed by the manufacturing industries into construction products. The construction industry's main needs are metals, non-metallic mineral products (such as cement or glass), wood products and electrical equipment products[111].

The construction sector also has strong linkages with the waste sector. Waste is produced both during on-site construction and during demolition activities. The waste must be collected, sorted and recycled or disposed of. Land

[106] European Commission website. Accessed at: https://ec.europa.eu/growth/sectors/construction_en

[107] BIO Intelligence Service (2013) Sectoral Resource Maps. Prepared in response to an Information Hub request, European Commission, DG Environment

[108] European Commission (2015). Closing the loop - An EU action plan for the Circular Economy.

[109] Ecorys, Copenhagen Resource Institute (2014). Resource efficiency in the building sector

[110] Eurostat (2017). Construction production (volume) index overview

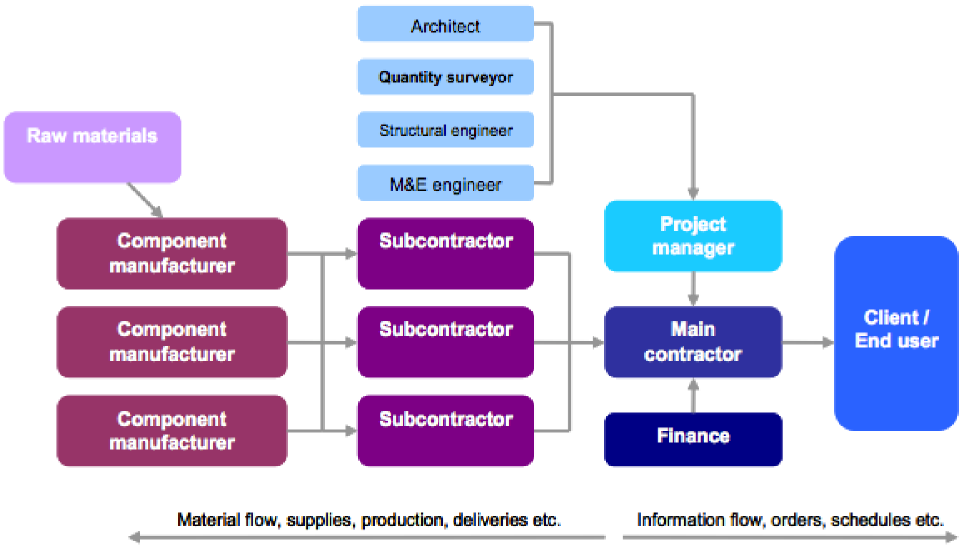
[111] Joint Research Centre's Institute for Prospective Technological Studies (2007). Contribution to the Report on Guiding Principles for Product Market and Sector Monitoring

transport is another related sector that plays an important role at different stages of the construction life cycle, by transporting construction materials to building sites or construction waste to waste facilities. For example, in the Netherlands it is estimated that the transport of resources and building materials represents 20% of all the goods transportation on the roads.

Supply chain in the construction sector

An example of a construction supply chain is shown in Figure 3-1. The construction industry has a large supply chain, and many subcontractors. The subcontractors are largely self-employed, making the industry very flexible to market demands and subsequent changes[112].

Figure 3-1 The construction supply chain



Note: This is a very simplified representation of construction supply chain. In practice a construction project may rely on tens of subcontractors and component manufacturers.

Source: Department for Business Innovation & Skills (2013)[113]

Stakeholders along the value chain include: Architects/ engineers, product designers, assemblers, manufacturers, suppliers, contractors, demolition contractors and recycling facilities.

Economics characteristics

As previously noted, the construction sector accounts for 9% of the EU's GDP. In 2016, the construction sector's output at the EU level amounted to €1,278 bn[114]. Approximately 3 million enterprises work in the sector.

The construction industry was hit hard by the economic and financial crisis that started in 2008. From February 2008 to March 2013, investment demand fell with only a slow recovery, which resulted in construction output falling by

[112] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210060/bis-13-958-uk-construction-an-economic-analysis-of-sector.pdf

[113] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210060/bis-13-958-uk-construction-an-economic-analysis-of-sector.pdf

[114] European Construction Industry Federation website. Accessed at: http://www.fiec.eu/en/the-construction-industry/in-figures.aspx

26.2%. From 2014 onwards, the sector started recovering and construction output has remained stable since then[115].

Table 3-1- Economic indicators for the construction sector in 2014

	Value
Main indicators	
Number of enterprises (thousands)	843 285
Number of persons employed (thousands)	3 174 312
Turnover (EUR million)	541 443
Purchases of goods and services (EUR million)	397 073
Personnel costs (EUR million)	79 698
Value added (EUR million)	140 067
Gross operating surplus (EUR million)	60 369
Share in non-financial business economy total (%)	
Number of enterprises	3.6
Number of persons employed	2.3
Value added	2.1
Derived indicators	
Apparent labour productivity (EUR thousand per head)	44.0
Average personnel costs (EUR thousand per head)	30.8
Wage-adjusted labour productivity (%)	143.0
Gross operating rate (%)	11.2

Source: Eurostat (online data code: sbs_na_con_r2)

Employment characteristics

The EU construction sector provides 18 million direct jobs. This sector is composed 99.9% of SMEs (employing fewer than 250 people) which are responsible for 80% of the construction output. In the EU, the average size of construction enterprises is 4 workers. Small enterprises (less than 50 employees) are responsible for 60% of the production and employ 70% of the sector's working population[116]. Men represent 90% of the workforce and 8% of workers are younger than 25.

The sector is highly fragmented and relies on local (and sometimes informal) markets. This situation sometimes results in skills mismatches (complex knowledge is needed in small enterprises) and limited sharing of international best practices[117].

Core sector

The NACE (Rev 2) *construction* sector (Section F – Divisions 41-43) employed over **14.7 million workers** in 2016 across the EU28 (see Figure 3.2). Over half of these people are undertaking specialised construction activities. Construction is a sector that is expected to be heavily impacted by the circular economy as it encompasses key aspects of the 'construction life cycle', from site preparation, through installation (e.g. plumbing, heat and air conditioning installation), finishing (e.g. plastering, painting, glazing), to site demolition.

Other workers in the core construction sector include more general activities and civil engineering projects. Employment in the construction sector is more volatile than many other sectors due to the incidence of sub-contracting and the sector's dependence on wider economic conditions (e.g. levels of investment in public infrastructure projects).

[115] Eurostat (2017). Industry and construction statistics - short-term indicators.

[116] European Builders Association website. Accessed at: http://www.ebc-construction.eu/index.php?id=3

[117] Ellen MacArthur Foundation (2015). Growth within, a circular economy vision for a competitive Europe.

Supply chain perspective

Figure 3-2 Number of employees (EU-28) Construction and related lifecycle sectors (,000)

NACE_R2/TIME	2012	2013	2014	2015	2016
Construction of buildings	4,801.7	4,578.8	4,639.4	4,677.2	4,729.8
Civil engineering	1,668.8	1,639.8	1,636.9	1,618.6	1,653.8
Specialised construction activities	8,700.6	8,433.0	8,319.3	8,296.8	8,346.6
Mining of metal ores	49.3	59.1	59.6	54.8	58.1
Other mining and quarrying	235.8	224.5	216.6	221.2	217.7
Accommodation	2,321.8	2,341.7	2,380.5	2,456.4	2,634.5
Real estate activities	1,661.6	1,685.6	1,727.3	1,735.2	1,726.7
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	1,076.9	1,039.2	1,026.0	1,016.2	1,011.6
Manufacture of other non-metallic mineral products	1,336.2	1,270.0	1,275.0	1,257.3	1,277.7
Manufacture of fabricated metal products, except machinery and equipment	3,657.4	3,507.7	3,576.3	3,528.4	3,585.5

Source: Eurostat

The construction sector from a supply perspective is potentially vast in scope – although some of the connections are potentially tenuous in nature. There are links to both the *mining of metal ores* (Division 7) and *other mining and quarrying* (Division 8). These two sectors encompass only around **275,000 workers** across the EU-28. More specifically, the activities most relevant to construction are:

- Group 7.1 Mining of iron ores
- Group 8.1 Quarrying of stone, sand and clay
- Group 8.9 Mining and quarrying not elsewhere classified (and only partially in the form materials such as bitumen, asphalt – while this category of activities also includes extraction of salt, peat and various chemical/fertiliser minerals).

There is a close link to the *manufacture of wood products, excluding furniture* (Division 16), which employs around **1 million workers** and where many of the activities (sawmilling, planning, manufacture of veneer sheets and panels, carpentry and joinery manufacture) directly support the construction industry and are likely to be significantly impacted by the shift to a circular economy.

Other construction-related manufacturing sectors are the *manufacture of fabricated metal products, except machinery and equipment* (Division 25) and the *manufacture of other non-metallic mineral products* (Division 23). The relevant activities within the fabricated metals sector are distinctive from those associated with motor vehicle manufacture, relating to:

- 25.1 Manufacture of structural metal products
- 25.2 Manufacture of tanks, reservoirs and containers of metal (which includes central heating and boiler systems)

- 25.3 Manufacture of steam generators, excluding central heating hot water boilers (which includes pipe systems)

The *manufacture of other non-metallic mineral products* sector is widely relevant to the construction life cycle. It employs **1.2 million people** in activities including the manufacture of glass, bricks, stone, cement and concrete.

Both the *accommodation* (Division 55) and *real estate* (Division 68) sectors are linked to the construction sector from a circular economy life cycle perspective in terms of managing changes to the use phase of buildings. The accommodation sector is growing in employment terms and encompassed **2.6 million workers** in 2016 across the EU28. However, most of these jobs will see only incidental impacts from the circular economy (in any way connected to construction, certainly). The relevant activities within the sector are those excluding campsites etc, namely:

- 55.1 Hotels and similar accommodation
- 55.2 Holiday and other short-stay accommodation
- 55.9 Other accommodation

It is likely that circular economy impacts related to construction have a broader potential relevance to jobs across the real estate sector (**1.7 million workers**), although the focus will be on aspects of jobs rather than the existence/shape of employment itself.

Occupational distribution in the core sector

The construction sector is relatively distinctive from the other priority sectors in being much more concentrated on a single occupational group – *building and related trades workers*, which comprises nearly half of the jobs in the sector. However, the composition of the ten largest occupational groups (each representing at least 350,000 jobs across the EU28 in 2015) is quite diverse – encompassing seven of the nine major occupational groups. This highlights the importance of understanding the impact of any changes to the sector across a wide variety of skill levels.

Table 3-2 Top jobs – Construction

Rank	ISCO Occupational Group (and ranking by volume for all sectors)	Employment 2015 (,000)	Share of sector employment	Forecast growth (% share) 2015-2025
1	71. Building and related trades workers, excluding electricians (#7)	6 342	43.6%	-3.1%
2	31. Science and engineering associate professionals (#12)	1 221	8.4%	0.5%
3	74. Electrical and electronic trades workers (#29)	1 173	8.1%	0.0%
4	93. Labourers in mining, construction, manufacturing and transport (#15)	987	6.8%	-0.5%
5	83. Drivers and mobile plant operators (#6)	743	5.1%	-0.5%

Rank	ISCO Occupational Group (and ranking by volume for all sectors)	Employment 2015 (,000)	Share of sector employment	Forecast growth (% share) 2015-2025
6	13. Production and specialised services managers (#22)	639	4.4%	0.7%
7	21. Science and engineering professionals (#16)	505	3.5%	-0.1%
8	72. Metal, machinery and related trades workers (#9)	491	3.4%	-0.2%
9	33. Business and administration associate professionals (#1)	361	2.5%	0.2%
10	41. General and keyboard clerks (#14)	360	2.5%	0.0%
	Total	14 540	100.0%	-3.1%

Source: Cedefop Forecast (EU-28)

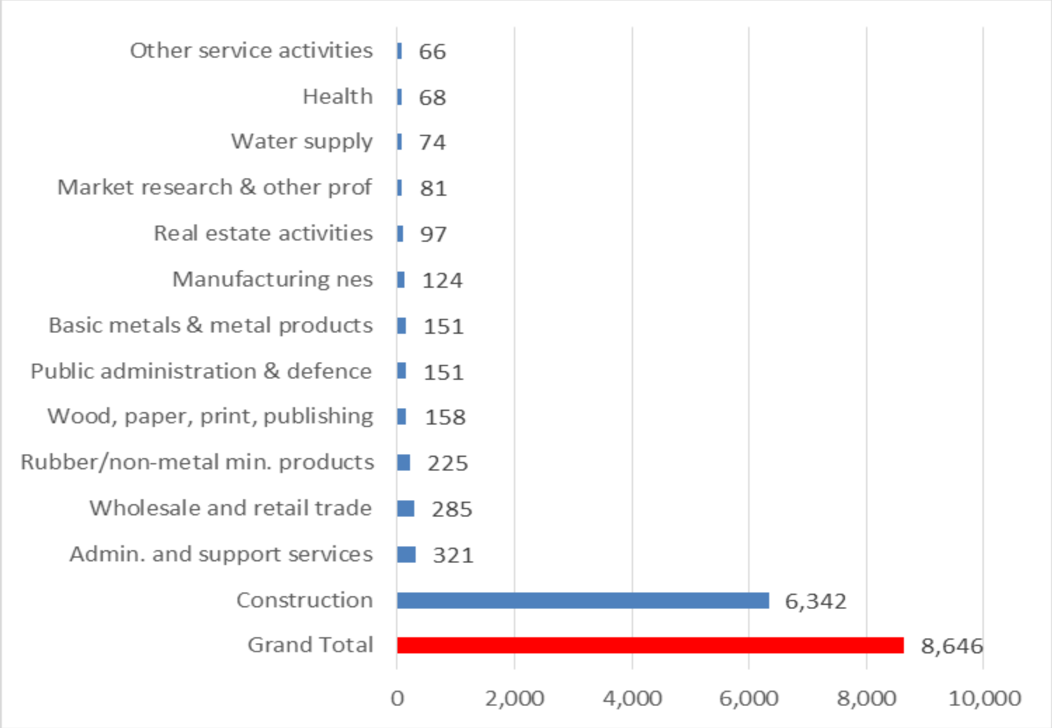
Linking key occupations and skills/competences to other industries

Three quarters (73.4%) of *building and related trades workers* are found in the construction sector, with only a residual number found elsewhere (see Figure 3-3). By way of contrast, although *science and engineering associate professionals* are also found more commonly in construction than any other sector (15.6% of all of these professionals work in construction; followed by 9.2% in architecture and engineering; and 7.4% in wholesale and retail trades), they are much more evenly distributed across a wide range of other sectors (100,000+ EU-28 workers in 25 of the 41 Cedefop industries). However, from a lifecycle perspective, this means that there are still nearly **2 million** workers in the combined construction, architecture and engineering sectors.

The *building and related trades workers* 2-digit occupational group can be divided into distinct trades:

- Building finishers and related trades workers (Air conditioning and refrigeration mechanics; Insulation workers; Roofers; Floor layers and tile setters; Plasterers; Glaziers; Plumbers and pipe fitters)
- Painters, building structure cleaners and related trades workers (Painters and related workers; Spray painters and varnishers; Building structure cleaners)
- Building frame and related trades workers (Carpenters and joiners; Concrete placers, concrete finishers and related workers; House builders; Bricklayers; Stonemasons).
- There is wide overlap in skills requirements across the building trades and, in some areas, beyond. Table 3-3 provides illustrative examples of selected skills/competences that are sector-specific and skills/competences that are aligned to other sectors.

Figure 3-3 Distribution of Building & related trades workers by sector (Num. of jobs – '000)



Source: Cedefop

Table 3-3- Building and related trades workers (ISCO 71): Skills links

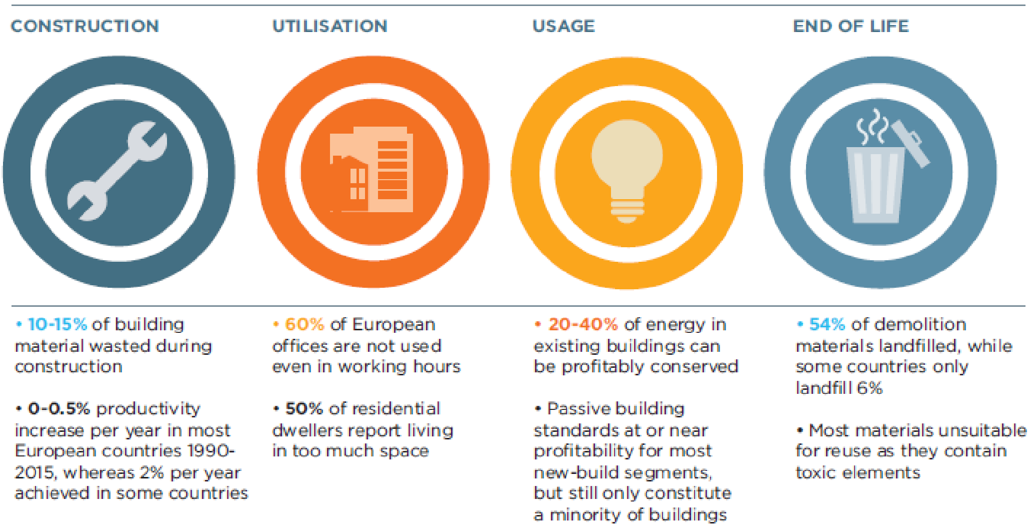
Key tasks	Selected essential skills/competences	Skills reusability and links
"Tasks include: constructing, maintaining and repairing buildings and other structures, using traditional and/or modern building techniques; constructing and repairing foundations, walls and structures of brick, stone and similar materials; breaking quarried stone into slabs or blocks; cutting, shaping and finishing stone for building, ornamental, monumental and other purposes; erecting reinforced concrete frameworks and structures as well as finishing and repairing cement surfaces; cutting, shaping, assembling and maintaining wooden structures and fittings. Supervision of other workers may be included".	Use measurement instruments	**Cross-sector:** Found in a range of engineering, marine, energy and other related roles
	Interpret 2D and 3D plans	**Cross-sector:** Found in a wide range of technician roles and in sectors such as energy and transport
	Sort waste	**Cross-sector:** Relevant across manufacturing and in distribution and transport roles
	Install construction profiles	**Sector-specific:** Relevant to bricklayers, carpenters and range of installation/fitting roles
	Work ergonomically	**Cross-sector:** Also found health, personal service and a range of other sectors
	Transport construction supplies	**Sector-specific:** Found across a wide range of construction trade specialisms

Source: ESCO Version 1.0

Resource and environmental characteristics

The construction sector is a very resource-intensive sector which has significant impacts on the environment. To assess resource and environmental characteristics, we focus on the built environment. For example, buildings account for the biggest share of EU final energy consumption (40%) and produce approximately 35% of greenhouse gas emissions[118]. Around 10-15% of building materials are wasted during construction, and 60% of office buildings in the EU are not used (including time within working hours) (see Figure 3-4)[119]. It is estimated that 20-40% of energy in buildings could be saved and a large amount of demolition waste is landfilled (6-54% depending on EU country)[120].

Figure 3-4 Structural waste in the built environment



Source: EllenMacArthur Foundation (2015)

The construction sector, and in particular the built environment, therefore, presents many opportunities in terms of circular economy practices. The biggest environmental impacts occur at two moments of the construction's life cycle: the production of construction products and the use phase of buildings. Resource use and environmental impacts of these two key moments are detailed below.

1. Production of construction products

Resource use

The construction and engineering sector is the world's largest consumer of raw materials. In the EU, of the 3 billion tonnes of materials extracted from the

[118] https://ec.europa.eu/growth/sectors/construction_en

[119] https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

[120] https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

earth annually, more than half is used in construction[121]. However, the definition of resource use should go beyond materials (e.g. metals, minerals or concrete) to cover energy, water and land (land take).

The EU construction sector's material flows are dominated by the use of mineral resources, such as limestone, clay, gravel and sand, which are used to produce, among other materials, concrete, bricks and tiles[122]. Minerals represent the highest share of materials used in buildings. Approximately 65% of total aggregates (sand, gravel and crushed rock) are used by the construction sector. Around 20% of metals are used by the sector. Overall, studies show that concrete, aggregate materials and bricks make up to 90% (by weight) of all materials used in construction[123]. For construction of buildings at the EU level (which represents 78% of total construction work in the EU), aggregate, concrete and to a lesser extent, bricks, are the most used materials. Aggregate accounts for 45% of the total materials (by weight), followed by concrete (42%) and bricks (6.7%). Steel (2.5%) represents the largest metallic fraction and wood (timber) makes up 1.6% of resource use.

Table 3-4 Raw material input in the EU economy and construction sector

Resource	Resource input in the EU economy (million tons)	Resource input in the EU construction sector (million tons)	Origin of the resources
Minerals	4700	4400	Minerals are mainly domestically extracted by the construction sector itself, as minerals are mostly used for construction
Metals	1440	480	The majority of metals used in the EU economy are imported. Less than 10% of metal ores are extracted within the EU
Biomass	1920	180	n.a
Fossil fuels	2550	300	Only about a third of fossil fuels are extracted within the EU

Source: Own table, data collected from: BIO Intelligence Service (2013) Sectoral Resource Maps. Prepared in response to an Information Hub request, European Commission, DG Environment. Data are collected for the year 2007 but Material flow accounts (Eurostat) shows a more or less stable total material use in the EU over the last ten years.

The energy used in the manufacture of construction products, as well as in the construction process, plays a significant role in the environmental impact of a

[121] ARUP (2016). The circular economy in the built environment

[122] European Union Joint Research Centre (2015). Identifying macro-objectives for the life cycle environmental performance and resource efficiency of EU buildings

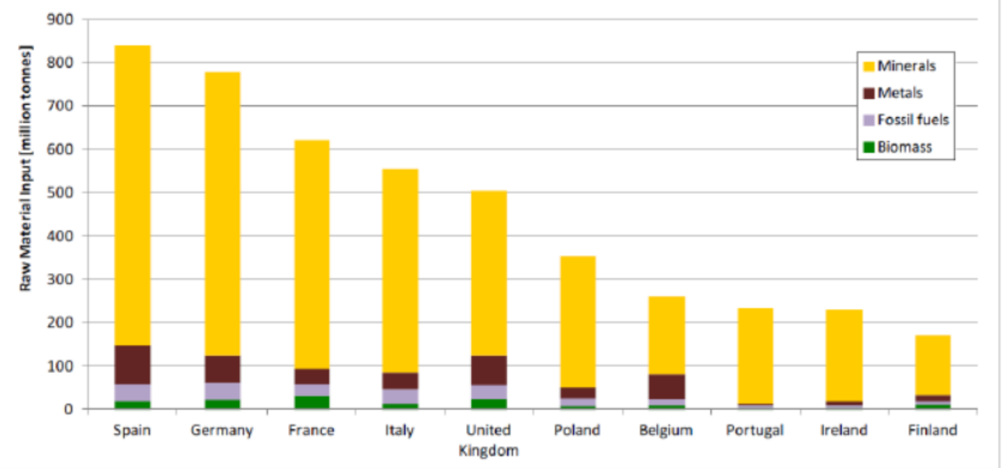
[123] Ecorys, Copenhagen Resource Institute (2014). Resource efficiency in the building sector

building. Between 5 and 10% of total energy consumption in the EU is linked to the production of construction products.[124]

Member State differences

The figure below shows EU countries that use the largest amount of resources in their construction industry. Unsurprisingly, the five biggest Member States have the construction industries that use the most resources. Relatively small Member States such as Portugal, Ireland and Finland also have material-intensive construction sectors[125]. It should be noted that the data presented here are from 2007. It is highly probable that resource use in different Member States has evolved in ten years (notably in Spain, where construction activity fell sharply in the crisis). However, this graph provides interesting insights on distinctive characteristics of national construction industries, like the share of certain materials such as metals or minerals in total resource use, which overall might still be relevant today.

European construction industries using the most resources.



Source: BIO Intelligence Service (2013) Sectoral Resource Maps. Prepared in response to an Information Hub request, European Commission, DG Environment

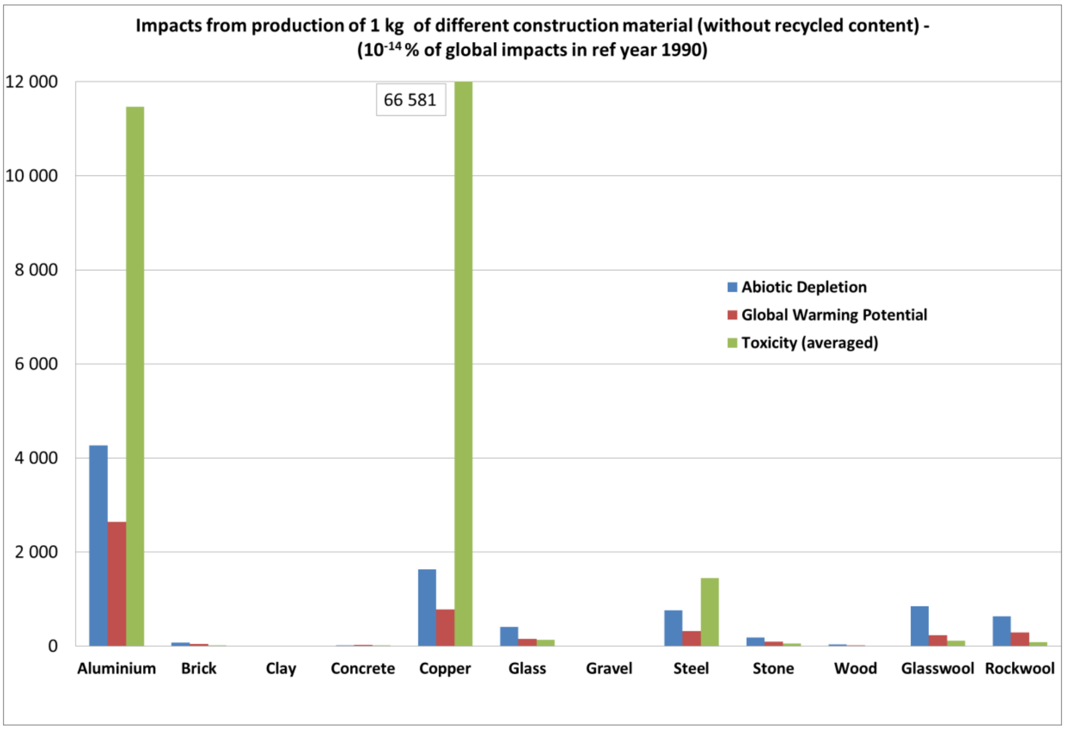
Environmental impact of the production of building materials

Figure 3-5 shows the environmental impact of the production of some of the most important materials used in construction, by assessing the Global Warming Potential, the Toxicity Potential and the Abiotic Depletion Potential in terms of per kg impacts of building materials.

[124] Ibid.

[125] BIO Intelligence Service (2013) Sectoral Resource Maps. Prepared in response to an Information Hub request, European Commission, DG Environment.

Figure 3-5 Environmental impact of the production of construction materials



Source: Ecorys, Copenhagen Resource Institute (2014). Resource efficiency in the building sector

The figure indicates that copper stands out in terms of toxicity, followed by aluminium and steel. Among the other construction materials presented here, copper, aluminium and steel have the highest global warming, toxicity and abiotic depletion potential.

Annual emissions from the production (cradle-to-gate) of the main construction materials used for buildings altogether correspond to about an annual emission of 155.8-222.5 Mt CO_2 equivalent, that is approximately 3-4.7 % of the GHG emissions of the EU27 in the last decade. The production of concrete is responsible for almost one third of total Global Warming Potential impacts from building construction materials; impacts from steel, aluminium and bricks are also significant[126].

Overall, it should be noted that the most significant environmental impacts from resource use are associated with the use of concrete and steel[127]. Together, concrete, plaster and steel account for about 48% of GHG emissions of the construction sector in Europe[128].

2. Use phase of buildings

Resource use

In the EU, buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions. Buildings consume about 25 litres of heating oil (about

[126] Ecorys, Copenhagen Resource Institute (2014). Resource efficiency in the building sector

[127] Ibid

[128] Deloitte Sustainability (2016). Circular economy potential for climate change mitigation.

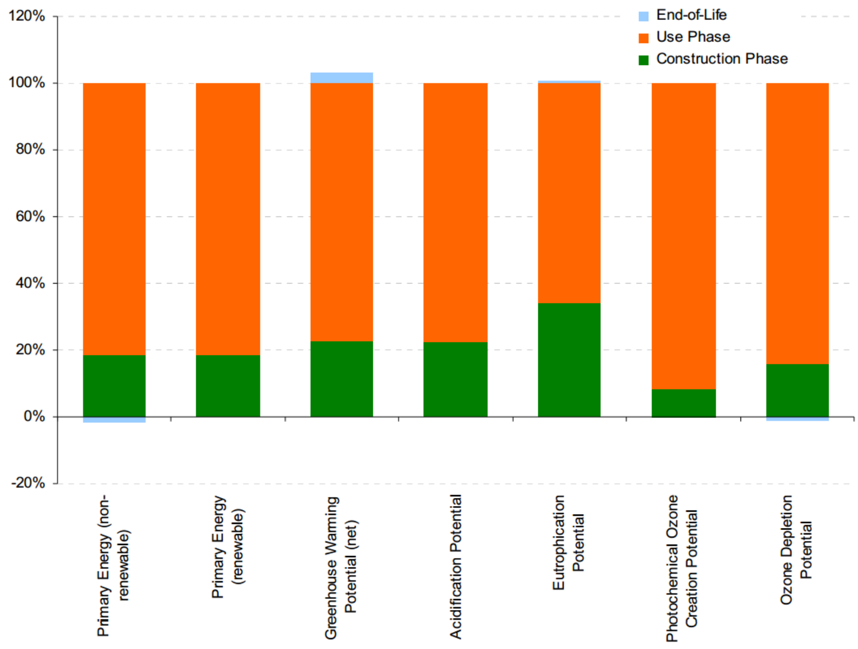
250kWh) per square metre per year, some using up to 60 litres (about 600 kWh) a year. However, new buildings are more energy efficient and generally require fewer than three to five litres[129]. Every year, approximately 2.0 to 2.8 million TJ (or 48-65 Mtoe) is contained in new buildings materials, while approximately 11.2 Million TJ is used by residential buildings in the use phase, for heating and all other forms of energy consumption including hot water and electricity[130].

Turning to water use, the public water supply accounts for about 21% of total water use in Europe, the majority of which is used in buildings. The total consumption of water in buildings represents around 9% of total European freshwater abstraction[131].

Environmental impact in the use phase of buildings

Occupation of residential buildings, through the use of energy, is responsible for most of the environmental impacts in the built environment. Around 80% of Global Warming Potential, 95% of Abiotic Depletion Potential and 85% of Toxicity Potential occurs during the occupation of buildings[132].

Figure 3-6 Life cycle environmental impact of residential buildings



Source : Nemry and Uihlein (2008). Environmental Improvement Potentials of Residential Buildings (IMPRO-Building).

Figure 3-6 shows three important phases of buildings' life cycles (construction phase, use phase and end-of-life) and shows how each phase is responsible

[129] European Commission website – Energy in buildings. Accessed at:
https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

[130] Ibid

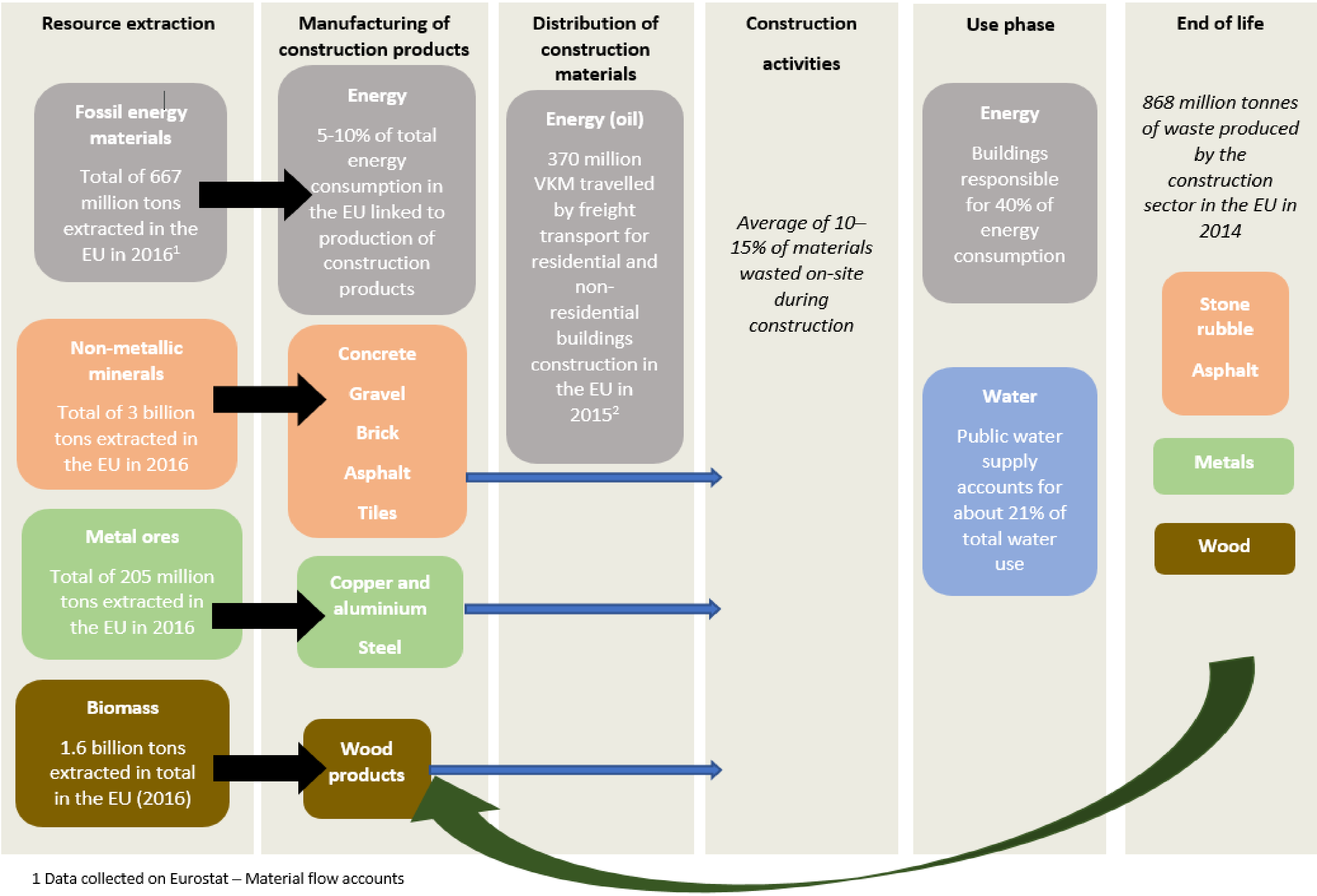
[131] Ecorys, Copenhagen Resource Institute (2014). Resource efficiency in the building sector

[132] Ecorys, Copenhagen Resource Institute (2014). Resource efficiency in the building sector

for specific environmental impacts. The figure indicates that the use phase accounts for between 65% and 90% of environmental impacts[133].

[133] Ecorys, Copenhagen Resource Institute (2014). Resource efficiency in the building sector

Figure 3-7 Overview of resource use during the life cycle of a building



1 Data collected on Eurostat – Material flow accounts

2 Data collected on Eurostat - Annual road freight transport by NACE Rev. 2

Source: own figure

3.2 Circular economy in the built environment sector

The rest of this case study is focused on the built environment.

How circular is the sector?

Increasing circularity in the built environment means reducing the amount of resources used as well as the amount of waste created during the entire construction life cycle, through reuse, recycling or remanufacturing. The life cycle of buildings can be split into the following steps: Design, Extraction of building materials, Construction, Operation/Maintenance, Retrofitting and End of Life (Demolition/Recycling). For each step, there exist concrete actions that could increase the level of circularity in the construction sector[134]. They are outlined below.

Design

- Extend buildings' durability by designing new buildings that can easily be retrofitted and reused for other purposes, in order to postpone the demolition or construction of new structures.
- Designing flexible buildings that can be remodelled, expanded, disassembled.
- Open-source design: engineers and designers will share their designs and build on each other's work.

Extraction of building materials

- Curtail the extraction of raw material by using reusable and recycled components, notably from other industries.
- Expand the use of highly sustainable materials like bio-based or recyclable materials.

Construction

- Offsite manufacturing and prefabrication to eliminate waste from construction sites.
- 3D printing using resins and substrates made from recycled or reusable materials to produce building components, thus limiting the use of concrete casts or steel components.
- Digital construction (BIM).

Operation and maintenance

- Highly efficient building structures, minimising negative externalities and environmental impacts.
- Self-sufficient buildings producing energy or equipped with water capture or filtering schemes.
- Flexible use and sharing to increase occupancy rates.

Retrofitting

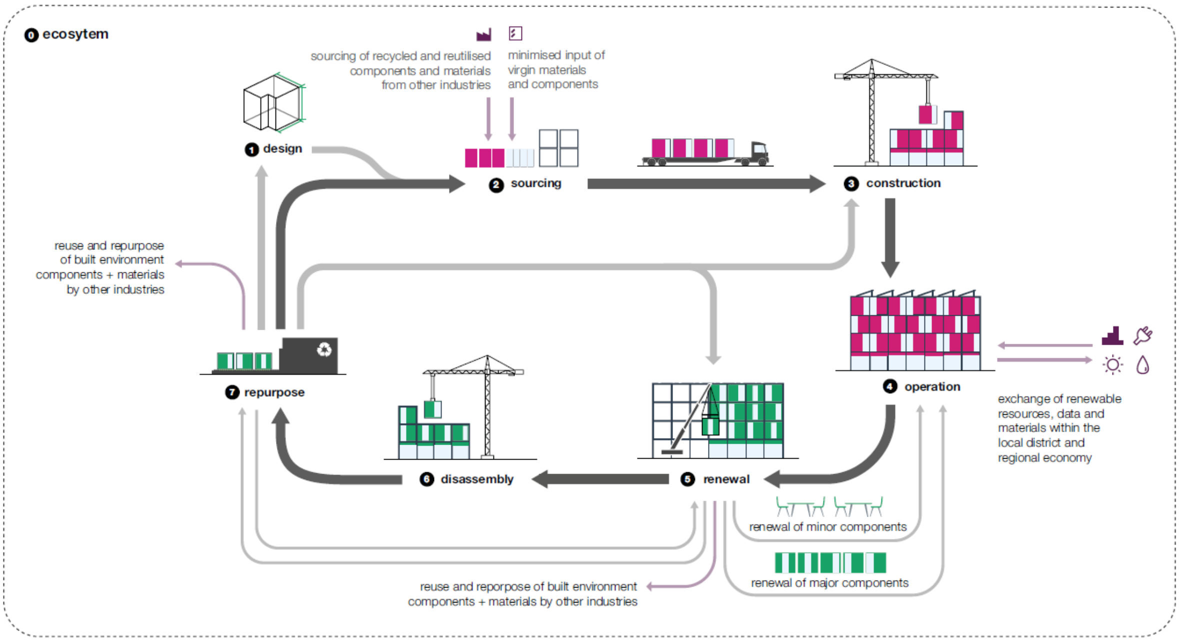
- Easier retrofitting and repurposing of buildings, which are designed to be flexible and modular. For example, demountable or reconfigurable façade systems, downsizing of apartments/rooms. Allows to minimise time and cost for renewal and to reduce waste.
- Components from different providers are interchangeable and can be reused from one building to another.

[134] ARUP (2016). The circular economy in the built environment

Demolition and recycling of materials (end of life).

- Deconstruction rather than demolition, thus substantially minimising waste produced through demolition.
- Building components of deconstructed buildings reused (material exchange platforms).
- Improved recycling and recovery of materials.

Figure 3-8 Circularity in the construction sector



Source: ARUP (2016). The circular economy in the built environment

The key circular economy actions happening today in the built environment, see Figure 3-8, can be summarised as follows:

Digital construction for a smart design of buildings

Digital construction tools have the potential to improve circular economy practices in the built environment by optimising the design, construction and operation of buildings, through 3D visualisation and improved information about the life cycle of assets. Today, a technology known as Building Information Modelling (BIM) is spreading across the construction sector. This tool provides the digital representation of a construction project and allows for the construction process to be stimulated in all its phases. BIM collects data during the operation of a building, in order to facilitate monitoring, enable preventive maintenance and perform better-informed modifications and upgrades to buildings' systems and components. The information it provides on materials allows construction actors to be aware of both negative externalities and opportunities for recycling and remanufacturing. It enables the different stakeholders involved in a construction project, such as designers, architects, contractors or building operators, to cooperate more efficiently at the different stages of construction project[135]. Today, although many construction companies have defined digital construction as a core development for their future, few of them have taken action to implement

[135] ARUP (2016). The circular economy in the built environment

digital construction into their business. Because of the economic downturn, these companies have scarcely invested in new technologies. Now that the market is recovering, the development of new technologies in this sector can realistically be expected. In some European countries, such as the UK or the Netherlands, BIM represents a major investment area for construction companies. However, it should be noted that there are strong differences between European countries in terms of digital construction and that it is mainly large construction companies investing in digital construction[136].

Maximise buildings' potential during their operation phase

As noted previously, buildings are responsible for 40% of energy consumption in the EU. Most of the energy consumption happens during the use phase. Designing self-sufficient buildings that produce energy from renewable sources is a key action to bring down energy use in the built environment. The EU Energy Performance of Buildings Directive requires all new buildings to be nearly zero-energy by the end of 2020 and all new public buildings to be nearly zero-energy by 2019. Nearly zero energy buildings (nZEB) require nearly-zero, or a very low amount of energy, which is mainly provided by renewable sources produced on-site or nearby[137], and covers all domestic energy needs such as heating, cooling, ventilation, hot water and lighting[138]. Many of the technologies required for this transition already exist but their uptake by the building sector could be improved. In 2014, nZEBs represented about one third on the reported new constructed floor area and the average nZEB share in most ZEBRA countries was below 10%[139].

Unleashing the full potential of buildings also means increasing their occupancy rate through schemes such as home or office sharing**.** In the last few years, residential rental has become increasingly popular in Europe. For example, the website Airbnb connects home owners who would like to rent a room or their whole accommodation and people (often tourists) looking for a short-term accommodation. This allows under-occupied accommodations to be rented, thus increasing the occupancy rates of buildings and lowering the demand for new ones. The number of accommodation listings in European cities is rapidly growing. In 2017, there were 55,723 accommodations listed on Airbnb for Paris, 49,648 for London and 17,369 for Barcelona[140]. Sharing of work spaces is also developing, through online platforms such as ShareDesk[141] or Vrumi[142]. It is estimated that at present peer-to-peer sharing services account for only 2-3% of the hospitality industry in terms of occupied rooms per night[143].

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[136] Deloitte (2017). European Construction Monitor

[137] European Commission website - Nearly zero-energy buildings. Accessed at: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings/nearly-zero-energy-buildings

[138] European Parliamentary Research Service (2016). Energy efficiency of buildings: A nearly zero-energy future?

[139] ZEBRA 2020 (2016). Nearly zero-energy building strategy 2020 - Strategies for a nearly Zero-Energy Building market transition in the European Union

[140] Insideairbnb (2017), retrieved on 03-03-17

[141] https://www.sharedesk.net/

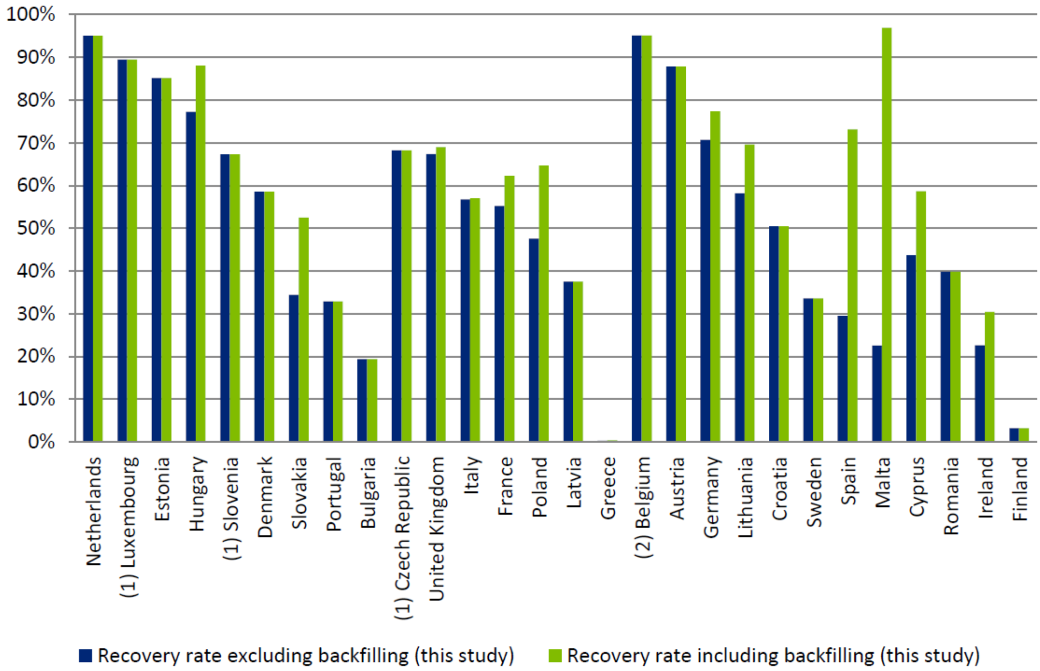
[142] https://www.vrumi.com/

[143] Ellen MacArthur Foundation (2015). Growth within, a circular economy vision for a competitive Europe

Minimising construction and demolition waste through increased recycling and recovery

Today, the main circular activity in the construction sector consists of recycling construction and demolition waste (CDW). CDW is one of the most voluminous waste streams generated in the EU. It represents about 25-30% of total waste generated in the EU and includes materials like concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled. The average recycling and material recovery rate of CDW in the EU is approximately 50%, but levels vary between 10% and 90% across the Member States[144].

Figure 3-9 Recovery rates of CDW in EU Member States (2012)



Source: Deloitte Sustainability (2016). Workshop report “Improving management of construction and demolition waste”.

Figure 3-9 shows CDW recovery rates in each Member State for 2012. It shows that nine Member States have already achieved CDW recovery rates higher than 70%, which is the target set by the Waste Framework Directive for 2020. Nine other Member States show a relatively good performance with recovery rates between 50% and 70%. These countries are on a good track to meet the 70% target by 2020 if they intensify their efforts and increase recovery and recycling operations.

In contrast, ten Member States are far from the meeting the target. It should also be noted that the inclusion or exclusion of the amounts reported as backfilling for the calculation of the recovery rate has a significant impact on

[144] European Commission (2014). Communication on resource efficiency opportunities in the building sector.

country results, especially for Member States such as Malta, Spain, Slovakia, Cyprus and Poland[145].

Today, approximately 30% of concrete waste is recovered as aggregate for road construction or backfilling in the EU. Only a small part is recycled into aggregates for concrete production. In 2010, 20% of plastic waste in the EU was recycled and 36% was incinerated with energy recovery. However, it is estimated that 70% of plastics used in this sector could be recoverable. Finally, 98% of steel is recycled[146]. The recovery of demolition waste is often not attractive because waste is often contaminated with paint, fasteners, adhesives, wall covering materials, insulation, dirt, etc. CDW is also hard to recycle because it contains toxic elements. For example, PVC formulations sometimes include plasticisers and toxic heavy metals, like cadmium or lead[147].

It should also be noted that at present an average of 10-15% of materials are wasted on-site during construction, through over-ordering, inadequate storage or poor coordination between stakeholders.

What is the circular economy potential in the sector?

To assess the potential of the circular economy in the built environment, we follow the assessment made by the Ellen MacArthur Foundation, and their use of the ReSOLVE Framework. It presents six principles to guide the transition towards a circular economy, which can be applied to different sectors, cities, regions or even to the entire economy. Applying these six principles to the built environment gives us an overview of the kind of concrete actions that could improve circularity. The following table classifies circular actions according to the ReSOLVE Framework in order to have a comprehensive view of what circularity in the construction sector means. Based on previous work from the Ellen MacArthur Foundation[148], the potential of different ReSOLVE principles in the built environment is evaluated. Finally, actions under each principle are linked to the different life-cycle stages of a building, in order to see how and where these actions could be implemented and effectively increase circularity in the sector.

[145] Deloitte Sustainability (2016). Workshop report “Improving management of construction and demolition waste”

[146] Deloitte Sustainability (2016). Circular economy potential for climate change mitigation.

[147] Ellen MacArthur Foundation (2015). Growth within, a circular economy vision for a competitive Europe.

[148] Ibid

Table 3-5 Application of the ReSOLVE framework to the built environment

Principles	Purpose	Corresponding actions/practices in construction sector[149]	Life-cycle stage	Potential of ReSOLVE principles
REGENERATE	Regenerating and restoring natural capital by: - Safeguarding, restoring and increasing the resilience of ecosystems - Returning valuable biological nutrients safely to the biosphere	Sustainable energy: -Use of renewable energy to power buildings. -Buildings as 'energy generators' (solar panels, green roofs)	Operation phase	**LOW** The use of bio-based and renewable construction materials (that are biodegradable, compostable, combustible) would be the best and most realistic means of reaching these objectives. Up to now, certain scepticism of architects, contractors and the construction industry towards biological resources resulting in slow market uptake.
		Land restoration	Extraction phase	
		Resource recovery: regenerate organic waste, compost production	End-of-life	
SHARE	Maximising asset utilisation by: - Pooling the usage of assets - Reusing assets	Residential sharing	Operation phase	**HIGH** Floor space utilisation in Europe is low. Only 35-40% of office space is utilised during work hours and approximately half of owner-occupied homes are under-occupied, with at least two bedrooms more than needed. Home renting through platforms such as Airbnb or HomeAway has become popular in the five past years and is likely to become increasingly part of Europeans' habits in the future.
		Infrastructure sharing (parking/ green shared areas)		
		Appliances/ tool sharing		
		Office sharing		
OPTIMISE	Optimising system performance by: - Prolonging an asset's life -Decreasing resource usage -Implementing reverse logistics	Industrial process, off-site production (prefabrication)	Construction phase	
		Energy/Water efficiency	Operation phase	
		Material Efficiency (Renewable, Recycled, Recyclable, Non-toxic components, Lower energy content)	Design phase	
		Reduce transport of materials	Construction phase	

149 The actions listed below are taken from the following report: Ellen MacArthur Foundation (2016). Circularity in the built environment: case studies.

LOOP	Keeping products and materials in cycles, prioritising inner loops by: - Remanufacturing and refurbishing products and components -Recycling materials	Optimisation of end-of-life of the building/materials (Durability, maintenance, repair, upgrades, removal, deconstruction, re-use…)	Design, end-of-life phases	**HIGH** As the construction sector is one of the biggest consumer of raw materials, there is a great potential for reducing the amount of raw material used by recycle and recovering construction waste. A European study[150] highlights the life cycle importance of recycling concrete instead of landfilling and of using recycled construction and demolition waste. As concrete and brick represent approximately 70% of the overall volume of waste generated, significant waste and materials savings could be achieved through increased looping.
		Modularity of the building (Modular building techniques, multi-purpose volumes, flexibility in buildings)	Design phase	
		Remanufacturing of materials (piece-by-piece demolition, material banks, stock management)	End-of-life	
VIRTUALISE	Displacing resource use with virtual use by: - Replacing physical products and services with virtual services -Replacing physical with virtual locations -Delivering services remotely	Smart appliances (smart home systems, connected appliances, efficiency for lights)	Operation phase	
		Virtualisation of processes (BIM, digital mock-up)	Design phase	
		Tele-working	Operation phase	
EXCHANGE	Selecting resources and technology wisely by: - Replacing with renewable energy and material sources -Using alternative material inputs -Replacing traditional solutions with advanced technology -Replacing product-centric delivery models with new service-centric ones	Better-performing technologies (e.g. 3D-printing, building management systems, electric engines)	Design, construction and end-of-life phases	
		Better-performing materials (Longer durability, advanced materials discovery)	Design phase, construction phase	

150 European Commission (2014). Assessment of Scenarios and Options towards a Resource Efficient Europe: An Analysis for the European Built Environment

Future outlook

Regulatory drivers and barriers (political potential)

A number of European policies are already addressing the most important aspects of the circular economy in the built environment, but they have not always been successful in tackling the underlying barriers to circular practices in this sector. In 2016 the European Commission proposed to implement an industry-wide protocol on the management of CDW (construction and demolition waste). The protocol seeks to improve identification, separation of source and collection of waste, and to also improve logistics, processing and quality management. The Waste Framework Directive 2008/98/EC has a target of 70% of CDW to be recovered by 2020. There is therefore a large potential of circularity of CDW; however, one reason why this is not yet fully exploited could be the lack of confidence in the quality of this waste stream when recycled[151].

Key barriers in the built environment include[152]:

- the economic aspect of value engineering and industrial approaches
- incentives for sharing rooms and offices
- lack of good enforcement in value engineering and industrial approaches
- transaction costs and unintended consequences for sharing rooms and offices, and value engineering and industrial approaches
- customs and habits to change
- conflicts between the Waste Framework Directive and the Construction Products Regulation[153]

Key existing regulatory drivers include:

Waste reduction (loop)

The Waste Framework Directive is regulating construction and demolition waste at the EU level and has set the target that 70% of CDW should be recycled by 2020. However, as discussed in Section 3.1, some EU Member States are still very far from meeting this objective. The European Commission itself has recognised that there are still important failures in the construction materials' recycling process where "valuable materials are not always identified, collected separately, or adequately recovered"[154]. Indeed, despite existing EU legislation, the management and recycling of CDW still faces some persistent barriers. Because negative environmental impacts are neither reflected in landfill fees nor in virgin materials costs, recycled materials are sometimes more expensive than virgin ones, which encourages the extraction

151 http://ec.europa.eu/environment/circular-economy/implementation_report.pdf

152 https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

153 Technopolis et al., 2016 Regulatory barriers for the Circular Economy

154 European Commission (2015). Closing the loop - An EU action plan for the Circular Economy.

of raw materials at the expenses of recycled materials[155]. The fact that the construction sector is very fragmented also impedes effective waste reduction practices. Indeed, the lack of vertical integration in this sector leads to important transaction costs and communication gaps. Actors along the value chain take isolated decisions and maximise their own profit at the expenses of others. This is reflected in the fact that the question of material efficiency is often only considered at the end of the construction process, when it could be more effectively tacked during the first stages, as soon as the design phase. There is also a distrust for secondary recycled materials from construction companies. Because the amount of recycled materials supplied does not always meet the demand from construction companies, the latter feel that they can't fully rely on recycled materials[156]. Another barrier to material reuse is that buildings often contain a mix of complex compounds, including hazardous ones, that are difficult to separate. Therefore, substituting materials that are difficult to reuse or recycle with non-toxic and reusable ones, or at least, making it easier to separate toxic compounds from reusable ones, would make circular practices more attractive for the construction industry[157].

Increased sharing of existing spaces (sharing)

As noted previously, the potential for sharing spaces in the EU is high. Since 2013, collaborative economy platforms have been very successful and 2015 recorded important growth rates, as large American platforms invested significantly in expanding their operations to the European market[158]. However, cities, regions and national governments have started to regulate and to impose restrictions to big accommodation platforms' activities, such as Airbnb. Cities like Madrid, Berlin, Paris, Brussels, London or Amsterdam have already restricted the conditions under which hosts can rent their accommodation. These restrictions can be seen as barriers to the development of space sharing. On June 2016, the European Commission issued a European agenda for the collaborative economy, which clarified key issues faced by market operators and public authorities, and provided guidance on how existing EU law should be applied to this fast-evolving sector[159]. However, regulations at the EU level are still needed create clear and homogeneous rules regarding space sharing.

Circular economy outlook

Whether the potential of circular practices/action in the construction sector will be fully unlocked largely depends on the regulations and incentives that will be developed by policy makers. The built environment could take very different paths. If policy developments follow the current path, it is likely that there would be improvements in some fields, but that they would not be fully connected with each other, therefore not unleashing their full potential. Digital developments would allow peer to peer sharing, tele-working, energy efficiency or building processes such as 3D printing to progress rapidly. Modularity and industrial processes would also develop, but at a slower pace.

[155] European Commission (2014). Resource efficiency opportunities in the building sector.

[156] Ellen MacArthur Foundation (2015). Delivering the circular economy – A toolkit for policymakers

[157] Ellen MacArthur Foundation (2015). Delivering the circular economy – A toolkit for policymakers

[158] EPRS (2017). Tourism and the sharing economy.

[159] European Commission - Press release: A European agenda for the collaborative economy. 2 June 2016. Accessed at: http://europa.eu/rapid/press-release_IP-16-2001_en.htm

If the whole built environment is really reorganised along circular principles, this means that circular developments would be complementary and coordinated, through smart urban planning, and that different stakeholders along the value chain and at governance levels would cooperate more. Such cooperation would allow actors to identify the key moments where resource consumption could be minimised and waste can be reused, in order to produce the minimum amount of waste. The added value of this scenario is a better urban planning that would limit urban sprawl and make cities more sustainable[160].

Employment implications of the CE transition

The CircleEconomy[161], a social enterprise that aims at accelerating the transition to circularity, has attempted to define what a circular job is. It asserts that a circular job is a job that involves, facilitates or accelerates at least one of the seven following key elements of the circular economy:

- prioritise regenerative resources
- preserve and extend what is already made
- use waste as a resource
- collaborate to create joint value
- design for the future
- incorporate digital technology
- rethink the business model

Turning to circular skills, it is generally acknowledged that the shift to a competitive eco-efficient economy will have a stronger impact on low-skilled workers through job destruction or substitution than higher skilled workers, who are more likely to benefit from job creation or from the implementation of new technologies calling for additional skills[162].

Four categories of circular skills can be identified[163]:

4 **Engineering and technical skills** used in design, construction and assessment of technology. This type of knowledge is important for eco-building, renewable energy design and energy-saving R&D projects.

5 **Science skills** stemming from bodies of knowledge such as physics and biology. A Cedefop (2009) study[164] shows that there is a high demand for this type of skills at early stages of the value chains and in the utility sector.

6 **Operation Management skills** related to change in organisational structure required to support green activities through life-cycle

[160] Ellen MacArthur Foundation (2015). Growth within, a circular economy vision for a competitive Europe.

[161] http://www.circle-economy.com/Circular-Jobs

[162] OECD/Cedefop (2014), *Greener Skills and Jobs*, OECD Publishing, Paris.

[163] Davide Consoli. What skills are needed to support sustainable industry? 22 May 2015. Published on the World Economic Forum. Accessed at: https://www.weforum.org/agenda/2015/05/what-skills-are-needed-to-support-sustainable-industry/

[164] Cedefop (2009), Future skill needs for the green economy. Office of the European Union.

management, lean production and cooperation with external actors, including regulators and customers (UNEP 2012).

7 **Monitoring skills** concerning the compliance with technical criteria and legal regulatory requirements. Compliance with environmental laws and standards is especially important for firms operating in polluting sectors[165].

Policy makers need to complement policies establishing circular principles with skills policies, such as education and training measures. Today, only a few Member States have national strategies for green skills (France, Austria, the UK). Without such policies, the implementation of circular policies could be limited due to skill shortages and gaps[166]. In a 2011 study, the ILO has identified a shortage of relevant skills needed for a low carbon economy. It found that many public policies do not address green skills needs adequately. According to the OECD, there are different policy responses to improving skills development and the transition towards a green economy. First, policy coordination should be enhanced. Second, 'portable skills' (those that can be transferred from one job to another) and lifetime learning should be fostered. Third, strategic capacity should be developed in SMEs and, fourth, more investments in R&D should be made to anticipate and address knowledge gaps[167].

Construction has been noted as a sector in which skills gaps could be a barrier to the attainment of the EU's sustainable targets. The skills of construction workers could be a possible weak link in the implementation of buildings codes that aim at improving energy efficiency of buildings. The cyclical nature of construction sector employment, which can fluctuate considerably based on the wider economic situation, also makes it harder to systematically develop skills in the sector. France has already set up policies to anticipate the need for new skills in the construction sector. It has introduced a certification system with a specific label for companies that conducted specific training of their staff on energy efficiency. Training is encouraged by linking public financial assistance for renovating buildings to the employment of companies that have been granted the label. France also launched FEEBAT, a programme for continuous vocational training, which has trained 48,000 construction professionals between 2008 and 2012[168]. At the European level, the BUILD UP Skills initiative has been launched to boost continuing or further education and training of craftsmen and other on-site construction workers and systems installers in the building sector. The aim of the initiative is to increase the number of qualified workers across Europe to deliver renovations offering a high energy performance as well as new, nearly zero-energy buildings.

Where are jobs created/destroyed?

The EU green employment initiative forecasts that 400,000 new jobs could be created by improving waste prevention and management, and another 400,000 jobs by making buildings more efficient and implementing the Energy

[165] OECD/Cedefop (2014), "Greener skills and jobs", OECD Green Growth Studies, OECD Publishing.

[167] OECD (2017). Green Growth Studies Boosting Skills for Greener Jobs in Flanders, Belgium.

[168] OCDE (2015), *Aligning Policies for a Low-carbon Economy*, Éditions OCDE, Paris.

Efficiency Directive's requirements. A 1% increase in the growth of the water industry could create between 10,000 and 20,000 jobs[169].

Most studies investigating the impact of more circularity on employment show that recycling creates significantly more jobs than waste disposal through landfill or incineration. The Environmental Agency of the United States (EPA, 2002) estimates that the incineration of 10,000 tonnes of waste can mean the creation of 1 job, while landfilling can create 6 jobs and recycling can create 36 jobs[170]. The sorting and recycling of construction materials therefore provides a high potential for job creation, since the construction sector produces a significant share of total waste in the EU.

Deconstruction is likely to create jobs as it is more labour-intensive than demolition. Estimates for the US show that if deconstruction was fully integrated into the US demolition industry (which takes down about 200,000 buildings annually), the equivalent of 200,000 jobs would be created[171]

Better resource efficiency resulting from circular policies is likely to lead to job losses in the manufacturing sector transforming raw materials into construction materials.

3.3 Modelling inputs (E3ME)

The sections above have highlighted the key priority circular economy actions in this sector:

a) **Recycling, reuse and recovery of C&D** – high potential – shift of the sector to buy from waste and less from other materials

b) **Higher utilisation of buildings** – sharing, efficient use of empty buildings (high potential identified in the Ellen MacArthur Foundation (2015) study). Offices occupy some 1.4 billion square metres. Tele-working and office-sharing, enabled by digitalisation, would likely continue to grow but would not fully solve the underutilisation issue. This trend seems likely to continue, as predicted by industry insiders. Average office space could drop as much as 55% by 2020, 70% by 2030, and 80% by 2050.

c) **Modular design** – industrial production and 3D printing: Moving construction towards factory-based industrial processes is already helping companies cut costs as much as 30% and shorten delivery time by 50% or more. Modular design typically reuses and refurbishes some 80% of the components; up to 30% of new buildings could use industrial approaches by 2020 (versus 20% today), 50% by 2030, and 80% by 2050.

d) **Refurbishment –** focus on maintenance, refurbishment to make the building more energy efficiency and the use of renewable energy

[169] OECD (2017). Green Growth Studies Boosting Skills for Greener Jobs in Flanders, Belgium.

[170] F. Pacheco-Torgal, V. W. Y. Tarn, J. A. Labrincha, Y. Ding and J. de Brito (2013). Handbook of recycled concrete and demolition waste. Woodhead publishing.

[171] Ellen MacArthur Foundation (2013). Towards a circular economy - Economic and business rationale for an accelerated transition (volume 1).

sources. This is considered out of scope as it does not fall under the circular economy.

Developing modelling inputs for the three CE activities in the sector

a) Recycling, reuse and recovery of C&D

To model recycling, reuse and recovery of C&D, we based the modelling inputs on the Waste Framework Directive (WFD) recycling, reuse and recovery targets for C&D for 2020. It is assumed that the targets will be met in the baseline scenario and that they will stay the same in 2030 without further policy intervention. The moderate and ambitious scenario assumes higher recycling targets for C&D compared to the baseline (see table **Table 3-6**). To take into account this increased recycling, reuse and recovery of C&D, we developed an assumption for the main impact of this CE activity, i.e. **increase in construction demand from recycling** as it is expected that the construction sector will use less virgin material and more recycled/ reused material.

In order to derive some estimates to measure this impact, we first looked at the current quantities of C&D waste generated and recycling/ recovery rates in the EU in MS in order to find out by how much the current demand from recycling would increase by 2030 in the baseline to reach the WFD targets. We also assume that the recycled C&D will be used by the construction sector instead of raw materials. This seems a plausible assumption as the main demand for recycled C&D comes from the construction sector itself as the material composition of C&D waste is mineral waste (85%) including concrete and masonry, and other materials such as asphalt, wood, metal gypsum and plastics (BIO IS, Arcadis, 2011).[172] However, the literature shows that C&D waste generation data are of bad quality or not existing (BIO IS, Arcadis, 2011).[173] Regarding recycling or recovery rates for C&D waste, Eurostat does not provide these rates either. BIO IS, Arcadis (2011) report states that on average the recycling rate of C&D for EU27 is 46%, however, this average is a broad estimation with a high uncertainty (BIO IS, Arcadis, 2011). We hence assume that on average, the current recycling rate of C&D waste is 50%. The WFD would increase this rate to 70% in the baseline, thus an increase of 20%. Assuming 75% recycling rate in the moderate, the increase of construction demand for recycled materials would increase by 25% compared to the current rate (or 5% from the baseline), and by 35% in the ambitious scenario compared to the current rate (or by 15% compared to the baseline).

b) Higher utilisation of buildings

To derive modelling inputs for higher utilisation of buildings, we based our estimates on estimates developed in another study for DG Environment, on assessing the "Environmental potential of the collaborative economy".[174] In this study we developed an estimate of the level of consumer spending on Peer-to-peer accommodation (e.g. Airbnb) and an estimate of revenue generated by collaborative accommodation platforms in 2030. The share of

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[172] BIO IS, Arcadis (2011) SERVICE CONTRACT ON MANAGEMENT OF CONSTRUCTION AND DEMOLITION WASTE – SR1

[173] Eurostat does provide some statistics on mineral waste from construction and demolition

[174] Trinomics (2017), Environmental potential of the collaborative economy, conducted together with Cambridge Econometrics, VITO and VVA. Still ongoing, reference to be updated once published.

consumer spending on tourist accommodation which will not be spent on traditional hotels is according to this study €6.4bn in the moderate scenario, and €18.4bn in the ambitious scenario. This will be modelled as a reduction in consumer spending on traditional accommodation (P2B) and instead the money is kept within the households sector (P2P). The payments to platforms active in collaborative accommodation is estimated to be €1.05bn in the moderate scenario and €3.03bn in the ambitious scenario. This will be modelled as money spent by households on sector where collaborative accommodation platforms operate in, e.g. marketing/ ICT. For detailed methodology, please see the aforementioned DG Environment study.

c) Modular design

We propose to model modular design as a decrease of costs of constructing new buildings. As mentioned above, in 2030 50% of new buildings could use modular design industrial approaches compared to 20% today, and these approaches (e.g. off-site production of modules in a factory) could reduce the construction cost by 10-30% per square meter (Ellen MacArthur Foundation, 2015, Growth Within). Based on this we use the following assumptions to calculate approximate cost reduction potential of new buildings by using industrial production and modular design techniques:

- Current use rate of industrial production and modular assembly on site = 20% of new buildings, baseline will have the same rate
- In 2030 use rate of industrial production and modular assembly on site = 50% of new buildings, hence 30% more than in the baseline.
- % cost reduction in the moderate scenario = 10%
- % cost reduction in the ambitious scenario = 30%.

This leads to a 3% cost reduction of new buildings construction in the moderate scenario, and 9% cost reduction of new buildings construction in the ambitious scenario compared to the baseline.

Table 3-6 Expected impacts per circular economy activity

CE activity	Baseline	Moderate	Ambitious	Impact
Recycling	Waste Framework Directive – 70% by 2020 E3ME input: increase in construction demand from recycling by 20% compared to current recycling rate.	Increase of the target to 75% E3ME input: increase in construction demand from recycling by 25% compared to current recycling rate.	Increase of the target to 85% E3ME input: increase in construction demand from recycling by 35% compared to current recycling rate.	Decrease the amount of virgin material, less waste (some shift from construction buy from recycling and less from raw materials) but also less incentives for reuse, lower costs for construction sector
Reuse of C&D	Waste Framework Directive – 70% by 2020	Increase of the target to 75%	Increase of the target to 85%	Less raw materials, less recycling, less waste, lower costs of material for construction sector
Recovery of C&D	Waste Framework Directive – 70% by 2020	Increase of the target to 75%	Increase of the target to 85%	Less raw materials, less recycling, less waste, lower costs of material for construction sector
Modular design	No change	Penetration of modular buildings techniques would reach 5% of new buildings in 2030 and 20% in 2050. The average lifetime of new buildings could be 5% longer in 2030 and 20% longer in 2050 3% cost reduction of new buildings construction	70% of new buildings would use processes allowing to reduce construction waste and tracking materials and interior components for future reuse. 9% cost reduction of new buildings construction	Lower costs for construction sector, income for industrial production/ 3D design, more reuse, less recycling.
P2P sharing	No change	P2P sharing models would cover 5% percent of accommodation services needs by 2020.	P2P sharing models would cover 10% percent of accommodation services needs by 2020.	Lower investment in construction (the shift determined endogenously through IO linkages), shift of income from accommodation to households.

CE activity	Baseline	Moderate	Ambitious	Impact
		Offices space would drop by 70% by 2030 E3ME input: Consumer spending on traditional model of accommodation reduced by €6.4bn, payments to the platforms €1.05bn	Offices would occupy 80% less space by 2030 E3ME input: Consumer spending on traditional model of accommodation reduced by €18.4bn, payments to the platforms €3.03bn	

4 Waste Management Sector

4.1 Overview and scope of the Waste Management sector

Scope of the sector

The waste sector involves a wide range of waste streams, such as industrial, mineral and solidified waste and mixed ordinary (or municipal) waste. It also covers the 'life cycle' of waste, including how waste is collected, transported and treated, through recycling, energy recovery, incineration and disposal. The issue of when waste becomes secondary raw materials is also important. This profile gives key economic and employment characteristics, including details of the number of employees in each sub-sector, number of enterprises and turnover in recent years. The volumes of waste streams are also given. The impacts of transitioning towards a circular economy on the different subsectors are also discussed.

The waste sector deals with the waste from the four sectors (food products and beverages, motor vehicles, construction and electronics or electrical equipment), which are covered in detail in this report. The waste sector differs from these other sectors, as its 'raw materials' derive from all other sectors[175]. The following diagram provides a useful overview of the structure of the waste sector as a whole.

[175] WRAP 2015 Economic growth potential of more circular economies

Figure 4-1 What does the waste sector look like (EU28)

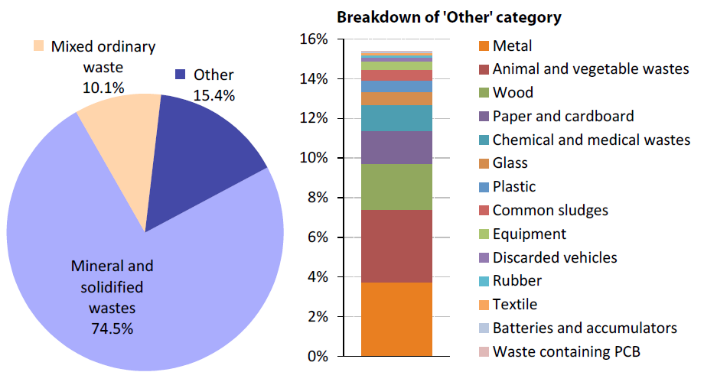
Introduction to the waste sector

Raw materials are used in the manufacturing process, producing everything from machines and vehicles to household goods and processed food. The products go out for distribution to different retailers, shops, stores and so on for consumers, private households or professional units, to purchase them. Some items will be returned and resold as used products, others be will consumed and (wholly or partly) turn into waste which then enters the waste sector.

The first step is for waste to be collected. It is then sorted and sent to specific facilities according to the treatment type. Some waste will be sent for disposal or incineration in one way or another, and some will be re-used, recovered or recycled, thereby entering into the loop once again as a secondary raw material. This recycling can continue until the material no longer possesses any value for the supply chain[176], see Figure 4-1.

The total amount of waste treated in 2014[177] in the EU was 2.5 billion tonnes. Three quarters of this derives from soils, construction and demolition waste. About 10% was 'mixed ordinary waste', which mainly consists of household waste and other similar waste types, while the 'other' category is 15% and includes wastes such as metals, animal and vegetable wastes etc. Figure 4-2 for a detailed overview of waste types.

Figure 4-2 Waste treatment by waste categories in EU, 2012 (source: eurostat, env_wastrt, 2015)



Quantities in million tonnes	
Total	2309.0
Mixed ordinary waste	1720.4
Recyclable waste	233.6
Metal	86.3
Animal and vegetable wastes	84.8
Wood	52.9
Paper and cardboard	38.8
Chemical and medical wastes	30.0
Glass	15.5
Plastic	12.7
Common sludges	12.6
Equipment	10.2
Discarded vehicles	4.8
Rubber	2.4
Textile	2.4
Batteries and accumulators	1.6
Waste containing PCB	0.04

When waste has been collected and sorted it is either re-used, recycled, recovered or it disposed of to landfill or by incineration. The table below defines treatment types.

Table 4-1 Overview of types of waste handling with definitions

Reuse	*Reuse of waste means any operation or product or components that are not waste are used again for the same purpose for which they were conceived*[178].

[176] http://ec.europa.eu/eurostat/web/waste/key-waste-streams

[177] http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Total_waste_generation

[178] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Waste

Recycling	*Recycling of waste is any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original purpose or another purpose*[179].
Recovery	*Recovery of waste means any operation where waste serves a useful purpose by replacing another material which would have been used to fulfil that particular function*[180]*. The material recovery operations include the exploitation and reutilisation of industrial and consumer scrap (plastic, paper, glass, metals and so on) in the form of "secondary raw materials".*
Landfilling (disposal)	*Landfilling is the deposit of waste into or onto land, such as specially engineered landfill sites and temporary storage of over one year on permanent sites. Landfills can be situated at internal sites and external sites*[181].
Incineration (disposal)	*Incineration is a type of waste disposal that involves the combustion of the waste and can take place on land or at sea. Incineration with energy recovery refers to incineration processes where the energy created in the combustion process is harnessed for re-use, for example for power generation. Incineration without energy recovery means the heat generated by combustion is dissipated in the environment*[182]*.*

Secondary raw materials, by-products and legislation

In order for waste materials to stop being defined legally as waste (which has implications for their transport, storage and usability in manufacturing), they need to pass certain 'end-of-waste criteria'. When waste stops being waste, it is perceived as a product or a secondary raw material, according to Article 6 (1) and (2) of the Waste Framework Directive 2008/98/EC[183]. When waste has undergone a recovery or recycling transformation and complies with legal

[179] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Waste

[180] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Waste

[181] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Waste

[182] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Waste

[183] http://ec.europa.eu/environment/waste/framework/end_of_waste.htm

conditions (see below), it has entered into a circular loop to encourage recycling[184].

- the substance or object is commonly used for specific purposes
- there is an existing market or demand for the substance or object
- the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products)
- the use will not lead to overall adverse environmental or human health impacts

Waste is defined under the Waste Framework Directive (WFD) on a case by case basis[185]. The WFD also seeks to update waste legislation according to recent developments and to merge, streamline and clarify legislation resulting in better and smoother waste legislation in the EU[186]. The European Commission's communication on waste and by-products[187] offers guidance on the issue of waste and by-products. It is often straight-forward to define waste and non-waste but, as we enter into a variety of technical and innovative situations, the distinctions become less straight forward.

The Commission realises the importance of detailing and structuring common definitions of waste, non-waste products and other terms being used; and of providing clear and effective rules on waste treatment. This is necessary to ensure that the interpretation does not differ from one EU country to another, and to ensure that environmental legislation can be implemented without barriers[188].

By-products are the non-primary outputs from a production process. By-products can exist in all business sectors and can often be of value to other production chains, but they can have negative impacts on the environment. Therefore, it is important to classify by-products correctly as there is much to be gained both economically and environmentally[189]. By following the guide in the EC communication it becomes clearer how to distinguish between by-products and other forms of waste[190].

Our globalised world and increasing trade between countries, although lucrative, poses a risk when it comes to the transboundary movement of waste. Some traded wastes involve hazardous materials, which are not only a danger to the environment but also to human health, and are sometimes exported to non-OECD countries and dumped. The Waste Shipment regulation is intended to better control what waste is traded and how it should be treated in its end-

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[184] http://ec.europa.eu/environment/waste/framework/end_of_waste.htm

[185] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0059&from=EN http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006L0012&from=EN

[186] http://ec.europa.eu/environment/waste/framework/revision.htm

[187] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0059&from=EN

[188] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0059&from=EN

[189] http://ec.europa.eu/environment/waste/framework/by_products.htm

[190] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0059&from=EN

country, as well as to provide a tool to prevent illegal trade of non-waste[191]. The Regulation also goes hand-in-hand with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal[192].

Shipments of wastes for disposal and recycling or recovery, and for hazardous and green-listed non-hazardous wastes are subject to different forms of management. Hazardous wastes and waste for disposal should be notified to the relevant authorities at the dispatch unit, transit and destination. Usually green-listed non-hazardous waste does not require consent from authorities in the EU and OECD countries[193].

An issue that has been raised by waste industry stakeholders for many years is the lack of common definitions and different levels of requirements for waste and how it is handled by authorities in different Member States. This can be a particular problem when waste moves between jurisdictions. Waste industry stakeholders also report a lack of consistency on whether a waste is a by-product or hazardous waste, which influences how waste shipments are classified and regulated. This could be part of the reason why estimates suggest that illegal shipments of waste account for 25% of the total, making it a substantial problem[194].

Economic characteristics

This section describes the main characteristics of the waste sector in the EU. It draws upon the available data from Eurostat and other relevant sources.

Turnover by Member State

The following tables present annual turnover by Member State for the three main sub sectors (collection, treatment and disposal and material recovery / sorting) of the waste sector.

Table 4-2 Waste Collection Turnover (in mill €) source: Eurostat

GEO/YEAR	2012	2013	2014	2015
BELGIUM	781.9	903.5	748.0	854.9
BULGARIA	228.8	220.4	211.1	222.9
CZECH REPUBLIC	1,881.7	1,722.1	1,610.3	1,619.8
DENMARK	735.3	660.7	761.4	775.2
GERMANY (UNTIL 1990 FORMER TERRITORY OF THE FRG)	10,255.1	10,070.0	11,956.6	10,978.3
ESTONIA	101.3	105.7	113.9	124.0
IRELAND	352.0	361.0	477.4	463.7
GREECE	:	34.3	26.3	27.5
SPAIN	2,545.9	4,097.8	4,148.5	4,149.1
FRANCE	5,302.3	5,266.7	5,452.3	5,239.0
CROATIA	245.6	272.1	292.5	297.3
ITALY	10,234.4	9,931.8	9,864.1	10,306.4
CYPRUS	24.2	20.0	:	17.6
LATVIA	101.9	95.0	93.2	110.6

191 http://ec.europa.eu/environment/waste/shipments/

192 http://ec.europa.eu/environment/waste/shipments/

193 http://ec.europa.eu/environment/waste/shipments/

194 http://ec.europa.eu/environment/waste/shipments/

LITHUANIA	90.3	99.1	98.1	107.6
LUXEMBOURG	88.2	98.5	104.1	103.5
HUNGARY	386.7	314.1	439.0	430.4
MALTA	:	:	:	21.4
NETHERLANDS	2,176.8	2,120.3	2,012.6	2,098.8
AUSTRIA	1,934.2	2,143.2	2,162.9	2,167.7
POLAND	1,889.3	2,204.1	2,467.1	2,613.1
PORTUGAL	353.8	348.0	350.3	338.7
ROMANIA	600.8	642.4	653.3	630.6
SLOVENIA	278.9	290.8	303.9	293.3
SLOVAKIA	283.2	282.5	224.8	275.5
FINLAND	328.8	305.5	362.8	337.2
SWEDEN	1,551.1	1,587.8	1,759.6	1,896.7
UNITED KINGDOM	7,993.5	7,853.6	8,677.6	11,475.8

Table 4-3 Waste Treatment and Disposal Turnover (in mill €) source: Eurostat

GEO/YEAR	2012	2013	2014	2015
BELGIUM	2,177.1	2,214.6	1,620.9	1,780.3
BULGARIA	45.1	48.0	49.3	83.3
CZECH REPUBLIC	223.7	218.4	214.7	206.2
DENMARK	742.9	850.5	788.4	761.0
GERMANY (UNTIL 1990 FORMER TERRITORY OF THE FRG)	8,643.5	8,627.6	9,501.8	10,685.6
ESTONIA	20.3	19.5	23.6	26.5
IRELAND	283.8	351.5	370.0	397.7
GREECE	55.9	27.4	:	:
SPAIN	3,247.2	3,904.1	3,522.7	3,455.9
FRANCE	5,440.6	5,168.1	6,495.5	6,835.0
CROATIA	31.1	59.6	43.2	62.4
ITALY	4,607.6	4,888.6	5,207.2	5,311.6
CYPRUS	9.2	9.1	10.6	:
LATVIA	22.9	28.3	23.9	28.0
LITHUANIA	70.5	77.7	103.8	114.4
LUXEMBOURG	20.0	20.9	31.7	:
HUNGARY	568.8	512.1	357.3	443.5
MALTA	:	:	:	:
NETHERLANDS	1,893.5	2,104.8	2,373.7	2,365.9
AUSTRIA	700.8	709.9	749.3	734.3
POLAND	524.4	556.0	597.1	730.6
PORTUGAL	496.0	498.2	503.7	536.5
ROMANIA	73.1	104.3	94.0	101.5
SLOVENIA	33.8	32.7	34.5	33.0
SLOVAKIA	122.1	132.5	161.3	218.7
FINLAND	594.9	631.9	631.0	643.9
SWEDEN	565.5	495.9	409.3	475.5
UNITED KINGDOM	3,864.4	4,643.7	5,038.2	5,283.3

Table 4-4 Material Recovery/Sorting Turnover (in mill €) source: Eurostat

GEO/YEAR	2012	2013	2014	2015
BELGIUM	2,851.7	2,747.6	2,898.0	2,838.4
BULGARIA	229.8	170.9	152.2	123.5
CZECH REPUBLIC	1,086.4	945.6	903.5	800.0
DENMARK	873.8	776.5	836.2	773.6
GERMANY (UNTIL 1990 FORMER TERRITORY OF THE FRG)	11,009.7	10,631.5	13,254.1	12,942.0
ESTONIA	115.0	119.9	99.6	109.7
IRELAND	346.4	334.9	328.3	316.7
GREECE	80.8	86.3	77.3	83.4
SPAIN	2,094.4	2,171.0	1,993.3	2,113.0
FRANCE	12,170.7	10,773.3	10,676.3	10,017.6
CROATIA	302.1	264.0	205.6	169.3
ITALY	8,661.0	8,248.4	8,119.1	7,860.7
CYPRUS	102.9	:	69.5	56.5
LATVIA	95.7	58.7	53.2	53.6
LITHUANIA	191.1	158.9	192.2	144.2
LUXEMBOURG	50.2	49.1	46.1	:
HUNGARY	394.3	372.1	341.8	379.3
MALTA	:	:	:	15.9
NETHERLANDS	2,854.8	2,650.9	2,623.2	2,706.8
AUSTRIA	1,055.2	1,130.1	1,185.1	977.8
POLAND	1,976.3	1,601.7	1,656.0	1,514.2
PORTUGAL	931.3	752.5	682.7	570.0
ROMANIA	2,250.8	1,843.9	1,553.8	1,173.4
SLOVENIA	477.5	429.6	403.8	355.4
SLOVAKIA	186.0	234.9	99.7	75.3
FINLAND	:	:	736.2	670.6
SWEDEN	2,453.3	2,289.3	2,192.3	2,045.1
UNITED KINGDOM	10,060.0	9,100.3	9,519.2	8,131.5

Turnover in the EU28

Table 4-5 Turnover for waste collection, waste treatment and disposal and material recovery/sorting in the EU28 in 2012-2015 (in mill €) source: Eurostat

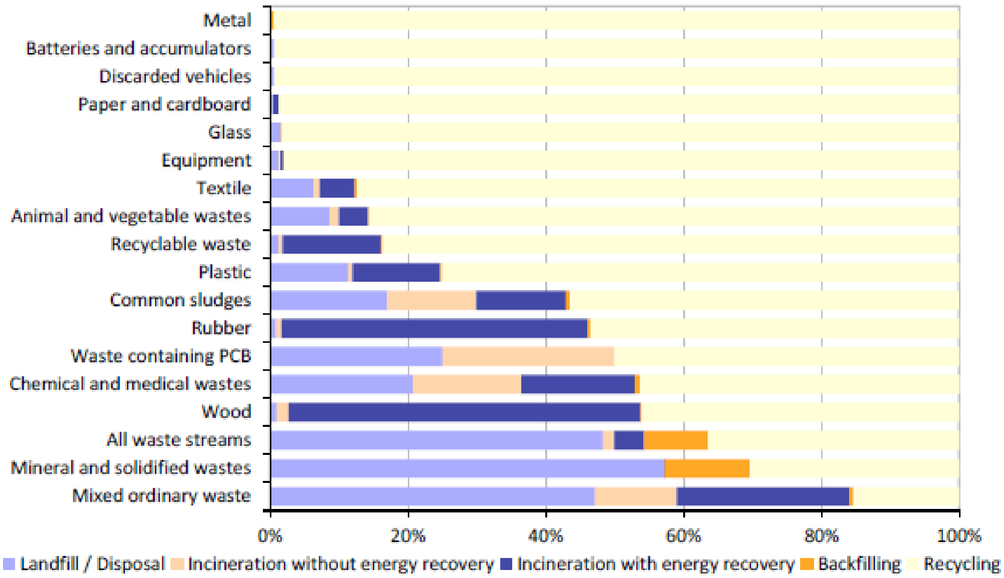
	Waste Collection			
GEO/YEAR	2012	2013	2014	2015
European Union (28 countries)	50,700.0	52,019.2	55,398.9	58,900.0
	Waste treatment and disposal			
GEO/YEAR	2012	2013	2014	2015
European Union (28 countries)	35,100.0	36,946.8	39,024.0	40,000.0
	Material Recovery/Sorting			
GEO/YEAR	2012	2013	2014	2015
European Union (28 countries)	63,847.8	58,891.3	60,929.4	56,925.2

There has been a reduction in material consumption between 2004-2012 of around 800 million tonnes (biomass, metals and minerals not including fossil fuels). The amount of recycled material increased by 163 million tonnes in this period and net imports of materials were reduced. Over the same period, the economy expanded by 8% and total population in the EU grew by 3%[195].

Waste treatment by waste type in the EU

Mineral and solidified waste (mining waste and construction and demolition waste) and mixed ordinary waste are the two largest waste streams in Europe[196] and both have seen an increase in waste treatment over 2010 to 2014. More than half of the mineral and solidified waste stream is disposed or landfilled (see Figure 4-3) and this trend has seen an increase over 2010-2014[197]. The same goes for mixed ordinary waste, although this waste stream is also treated with incineration with energy recovery, see Figure 4-3.

Figure 4-3 Treatment method by waste category in EU-28 (2012) (Eurostat env_wastrt, 2015)



Incineration per waste type for chemical and medical wastes, mixed ordinary wastes and waste excluding major mineral wastes has seen a decrease from 2010 to 2014[198].

Net imports of materials have decreased in recent years (2004-2012), whilst recovered materials have seen a slight increase, and annual domestic material consumption (DMC) went down by 8% over 2008 to 2012[199].

[195] WRAP 2015 Economic growth potential of more circular economies

[196] http://www.europarl.europa.eu/EPRS/EPRS-Briefing-564398-Understanding-waste-streams-FINAL.pdf

[197] Eurostat

[198] Eurostat

[199] WRAP study 2015

Non-hazardous waste

The EU is the world's largest exporter of non-hazardous waste destined for recovery/recycling, and is also a large importer of non-hazardous waste. The EU accounted for 34% of global exports and 20% of global imports of such wastes in 2014[200].

Employment characteristics

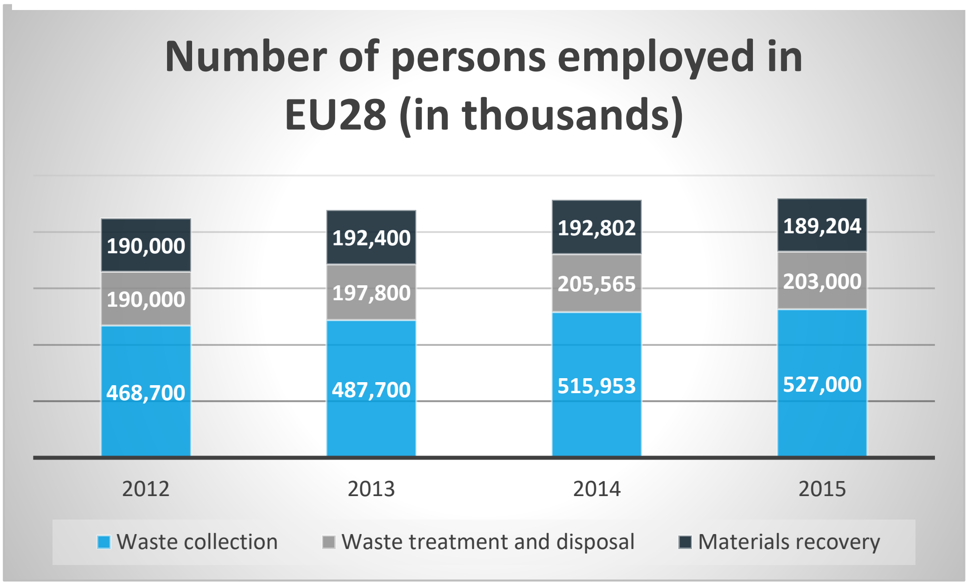
The level of employment in the waste sector appears to have moved around a bit since 2008, due to the recession, with differing impacts across the EU. Around half the employment is in the recycling and production of new materials sub-sector. However, the most stable sub-sector for employment is the collection and sorting (logistics) of household waste and civic amenity sites. There seems to be a trend in remunicipalisation of services, which is seen in larger EU countries such as Germany, UK and France, due to the fact that private sector service providers do not appear more efficient than public sector service providers[201].

In 2015, the number of waste collection enterprises in the EU was 20,000. In total, 7,000 enterprises dealt with waste treatment and disposal, and 20,222 enterprises were classified as being in the materials recovery sub-sector (Figure 4-5).

In those enterprises in 2015, 527,000 people were employed in waste collection, 203,000 in waste treatment and disposal and 189,204 in materials recovery (see Figure 4-4).

It is interesting to consider the labour intensity of the waste sector, to assess whether it is consistent between Member States whether it varies over time. This can be done by looking at the ratio of employment to waste generation.

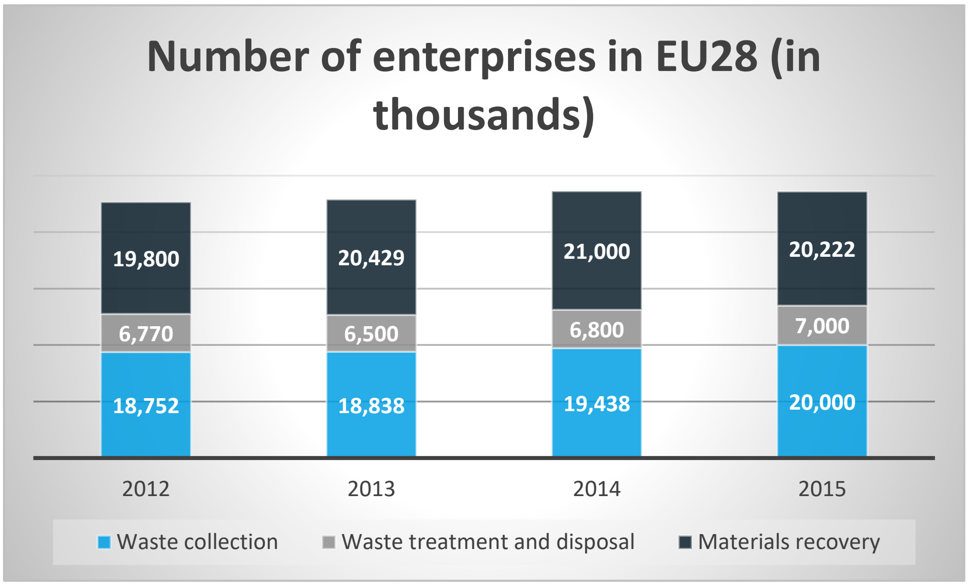
Figure 4-4 Number of persons employed in waste sector in EU28



200 http://ec.europa.eu/trade/import-and-export-rules/export-from-eu/waste-shipment/

201 http://www.swfm-qf.eu/main/wp-content/uploads/2012_Waste_mngt_EWC.pdf

Figure 4-5 Enterprises in the waste sector in EU28



The following table presents this data for the most recent years (up to 2014, data are only produced every other year), and sectoral employment.

Table 4-6 Waste collection, treatment and disposal activities; materials recovery employees

Employees (FTEs) per ktonne of Mixed ordinary waste			
Waste collection, treatment and disposal activities; materials recovery			
	2010	2012	2014
Belgium	1.5	1.7	1.4
Bulgaria	4.6	4.2	4.3
Czech Republic	6.7	7.3	7.4
Denmark	1.4	1.3	1.8
Germany	2.4	2.6	3.0
Estonia		3.5	3.5
Ireland	1.3	1.9	1.7
Greece			
Spain	2.2	2.3	3.0
France	2.0	2.3	2.7
Croatia	4.8	5.9	6.9
Italy	2.9	2.9	2.7
Cyprus		3.3	
Latvia	4.8	2.7	2.5
Lithuania	4.4	4.8	4.7
Luxembourg		3.6	4.0
Hungary	4.6	4.7	3.3
Malta		1.0	1.2
Netherlands	2.2	2.5	1.9
Austria	2.3	2.8	3.0
Poland		2.8	2.3

Portugal	2.3	2.7	2.6
Romania	5.5	7.7	7.1
Slovenia			
Slovakia	5.2	5.4	5.4
Finland	1.1		1.7
Sweden	2.3	2.5	2.7
United Kingdom	2.4	2.7	2.8

A review of the table indicates that rate of labour intensity appears to fall into two groups, with a higher intensity in CEE countries.

Resource and environmental characteristics

Waste streams in more detail

Construction and Demolition waste (CDW)

Construction and demolition waste accounts for about 30% of all waste generated in the EU and is the heaviest waste stream generated in the EU. CDW stems from activities such as waste from construction of buildings and civil infrastructure, demolition of buildings and civil infrastructure, road planning and maintenance. CDW consists of various materials such as concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil[202]. The proper management of this stream could have major benefits in terms of sustainability and quality of life. The Waste Framework Directive sets a target of 70% of CDW to be recycled by 2020; currently only about 50% is recycled in some countries and others have much lower recycling rates. One of the common hurdles for recycling and re-using CDW is the uncertainty of the level of quality of the recycled materials and the potential risks to workers' health[203].

Batteries

Batteries are an important component of many products, appliances and services. Each year approximately 800,000 tons of automotive batteries, 190,000 tons of industrial batteries, and 160,000 tons of consumer batteries enter the European Union[204].

There are six main types of **non-rechargeable batteries** (or primary batteries): Zinc, Alkaline, Button alkaline, Silver zinc, Button zinc, Lithium ion. There are eleven types of **rechargeable batteries** (or secondary batteries): Nickel-cadmium, NiMH (Nickel metal Hydride), Lithium, Lithium-Ion Polymer, Alkaline, chargeable Titanium, Lead SLI, Lead traction, Lead stationary, Nickel-iron, Nickel-zinc.[205]

The wide range of battery types and the different metals they are made of, implies specific recycling processes for each. The first step is to sort the batteries into groups before they can be recycled. However, not all batteries are

[202] http://ec.europa.eu/environment/waste/construction_demolition.htm

[203] http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8983

[204] http://ec.europa.eu/eurostat/web/waste/key-waste-streams/batteries

[205] http://ec.europa.eu/eurostat/web/waste/key-waste-streams/batteries

collected properly and some enter into the municipal waste stream which means that they either go into landfills or are incinerated. Many of the components of these batteries and accumulators could be recycled, avoiding the release of hazardous substances to the environment and, in addition, providing valuable materials to important products and production processes in Europe [206].

Biodegradable waste

Biodegradable waste (bio-waste) is garden, park, food and kitchen waste from households, restaurants, caterers and other retailers, as well as waste from food processing plants. However, it does not include forestry or agricultural residues, manure, sewage sludge, natural textiles, paper or processed wood[207].

The most significant benefits from good bio-waste management, besides avoiding the production of methane stemming from decomposing waste in landfills (the main environmental threat from bio-waste), is the production of compost and bio-gas. However, potential benefits of better soil quality and resource efficiency can be lost by taking the easier and cheaper choice of simply redirecting these waste types into landfilling or incineration[208].

4.2 The circular economy in the waste sector

Key factors shaping the future development

Recycling, reuse and recovery are essential parts of the circular economy. Waste management therefore plays a central role in the circular economy, and could in future help prevent economic losses and depletion of natural capital, as well as opportunities for the creation of new jobs[209].

Many waste sector activities are generally circular or have the potential to be. However, some waste sector activities such as landfilling and incineration with no energy recovery are not. The definition of waste and waste-related materials is an important step forward to reducing waste and encouraging circularity; for this reason an amendment to the Waste Framework Directive as part of the Circular Economy Package in 2015 has been proposed which seeks to establish a more robust Directive. The proposal includes modified definitions for ‘municipal waste’, ‘non-hazardous waste’, ‘bio-waste’, ‘construction and demolition waste’, ‘preparing for reuse’, ‘final recycling process’ and ‘backfilling’. It also seeks to provide clarification on the by-product and end-of-waste status[210].

The waste management hierarchy

If the waste sector is to become more circular, the principles to follow are generally captured by the well-known waste management hierarchy (see Figure 4-6). The yellow arrows represent the waste streams destined for different treatments; as the colours and the length of the boxes indicate, the least favourable treatment for a waste stream is disposal or incineration. The

[206] http://ec.europa.eu/environment/waste/batteries/index.htm

[207] http://ec.europa.eu/environment/waste/compost/index.htm

[208] http://ec.europa.eu/environment/waste/compost/index.htm

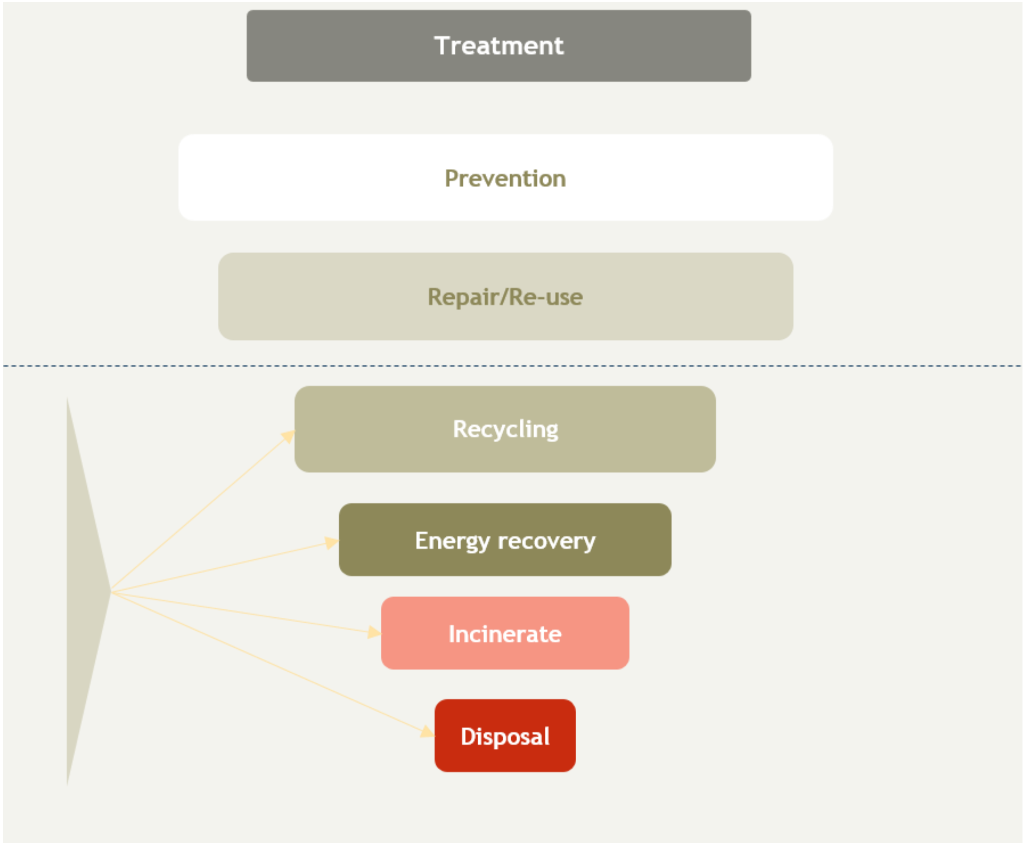
[209] WRAP 2015 Economic growth potential of more circular economies

[210] Waste Market study by Arcadis/Trinomics

better option would be for the waste stream to either enter into combustion for energy recovery or recycling. If we go above the dotted line, we are arguably exiting the waste sector, and entering into the product area, where repair, reuse and prevention are the treatments.

The waste hierarchy also broadly reflects the desired objectives from a climate perspective, as the least preferred option (disposal in landfills and through incineration) increases greenhouse gas emissions, while waste prevention, reuse and recycling reduce greenhouse gas emissions[211].

Figure 4-6 The waste management hierarchy (edited)



The management of several waste streams in the EU works on the principle of 'polluter pays'. This includes the use of extended producer responsibility (EPR) schemes, which require the original producers of the material(s) that eventually become waste to take over (or contribute to the costs of) the collection, treatment, disposal, reuse of their products at their end-of-life stage. This involves the producer or 'polluter' bearing some or all of the cost and responsibility of taking back used goods, sorting them and disposing of or recycling them[212].

[211] http://ec.europa.eu/environment/waste/waste-to-energy.pdf

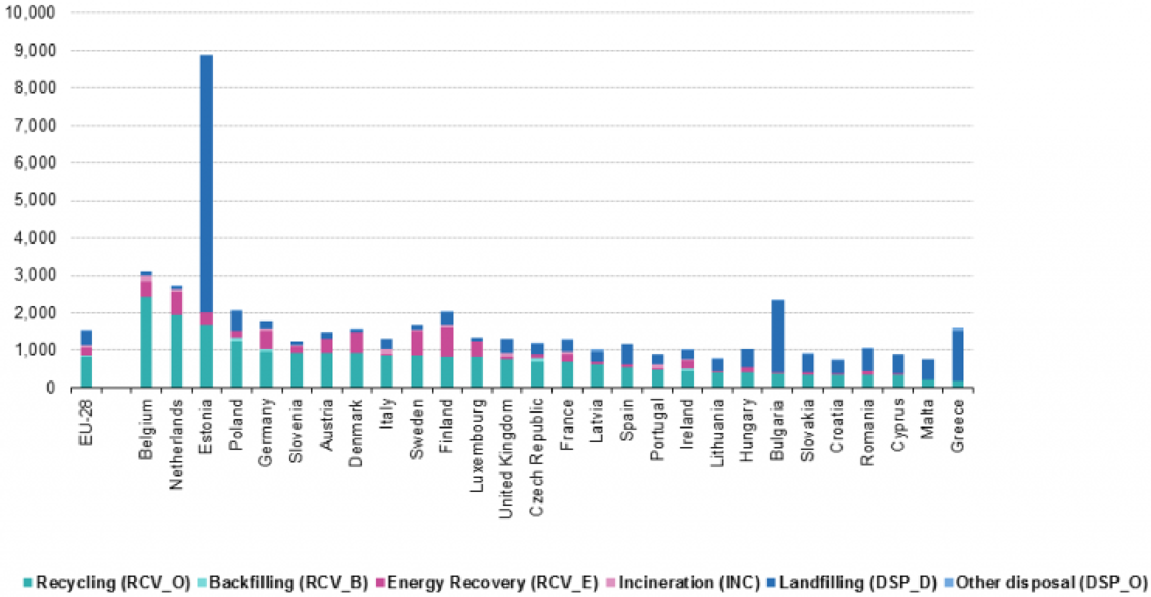
[212] http://ec.europa.eu/environment/waste/pdf/target_review/Guidance%20on%20EPR%20-%20Final%20Report.pdf

The main aim is to increasingly meet the material demand of the economy by using secondary raw materials made of reused, recycled or recovered waste, and preventing the inefficient use of different types of disposal.

Recycling

The recycling rate is a good indicator of progress towards a circular economy. The recycling rate in 2014 for EU28 as a whole was 55% for domestically generated waste or mixed ordinary waste. This amounts to 830 kg per EU citizen[213]. Metal wastes, animal and vegetable waste, as well as paper and cardboard waste, account for more than half of the total amount of recycled waste. Combustion wastes, wood, minerals and glass waste account for about one quarter. In EU countries with waste intensive production, the recycling rate is dependent on the management of each stage of waste in the production chain. Nonetheless, recycling rates range between 78% in Belgium to 10% in Greece[214] (see Figure 4-7).

Figure 4-7 Domestically treated waste by country and by type of treatment 2014, kg/inhabitant (source: eurostat env_wasoper)

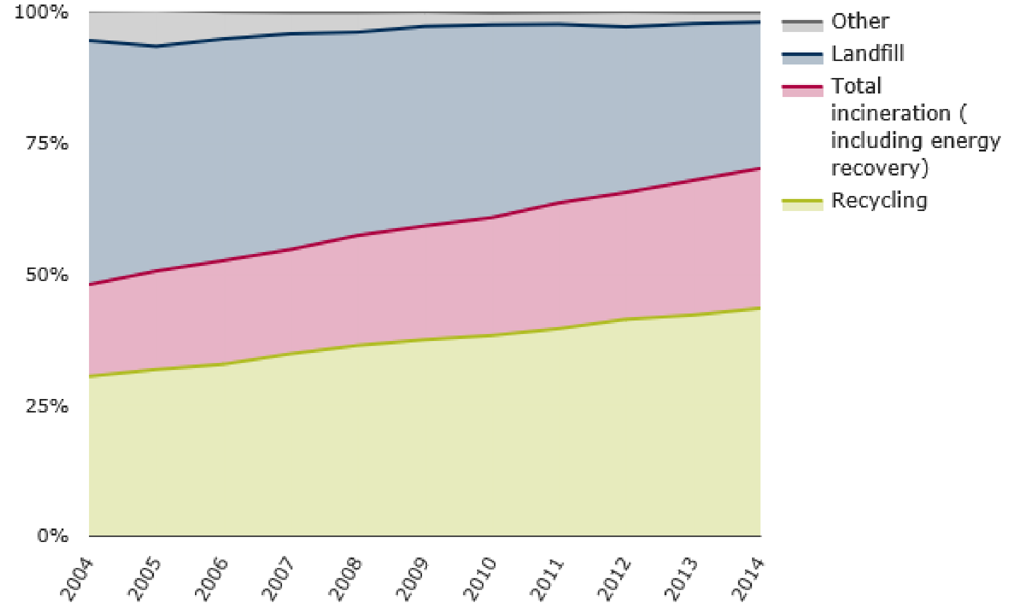


Recycling rates for both municipal waste and packaging waste increased between 2004 and 2014 (see Figure 4-8). Recycling rates for municipal waste increased by 13% between 2004 and 2013, and for packaging waste by 10% between 2005 and 2013. For municipal waste, we again see large differences between European countries and their recycling rates, ranging from 64% in Germany to 10% in Slovakia in 2014.

[213] http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_management_indicators

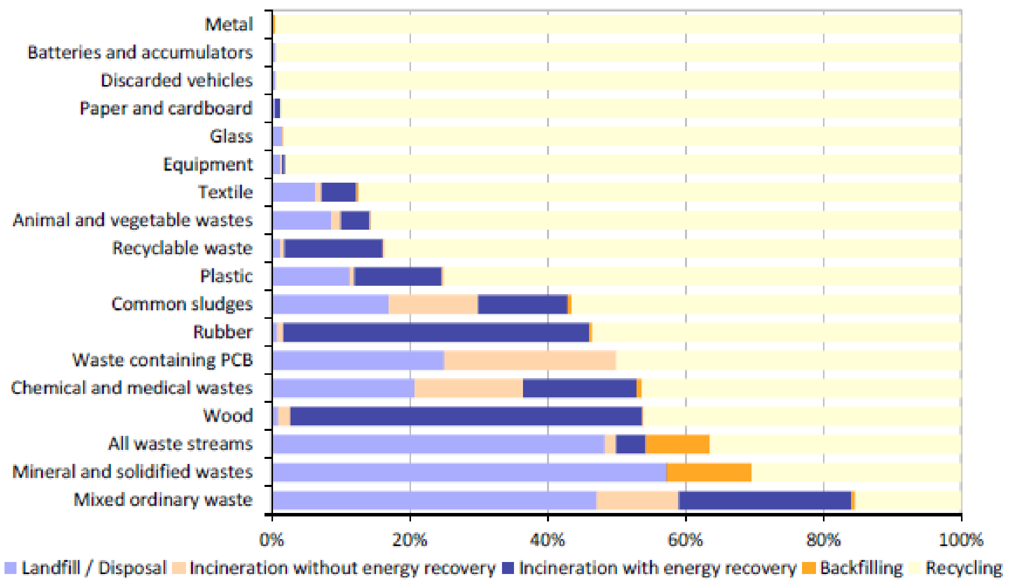
[214] http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_management_indicators

Figure 4-8 Proportion of municipal waste treated by different methods (source: eurostat env_wasmun)



The treatment methods for each waste category vary across the EU. Overall, the majority of waste is landfilled and one third is recycled. Because of its diverse nature, 'mixed ordinary waste' is the least recyclable category[215].

Figure 4-9 Treatment method by waste category in EU28, 2012 (source env_wastrt, 2015)



There have been improvements in recycling rates in the EU. This relates to a combination of EU targets for recycling waste streams introduced in 1994 and 2008 and restrictions on landfilling that were introduced over the same period.

215 http://www.europarl.europa.eu/EPRS/EPRS-Briefing-564398-Understanding-waste-streams-FINAL.pdf

However, there is still room for more action to reach the target of 50% waste to be prepared for reuse or recycling set by the EU Waste Framework Directive [216].

Waste as a resource

Instead of seeing waste as a problem, in the eyes of circular economy it can become a resource. There are many well-known examples of this already in place. Across Europe, kitchen and gardening waste is a large share of municipal solid waste. If this waste is collected separately it has the potential to become an energy source or fertiliser[217]. The EEA found in 2011 that improved management of municipal waste from 1995 to 2008 resulted in much lower greenhouse gas emissions due to lower emissions from landfills and emissions avoided through recycling. If that trend was continued to 2020, and countries fully met the landfill diversion targets from the Landfill Directive then that would make a substantial additional contribution towards to EUs climate change mitigation efforts[218].

Industrial symbiosis

The association between two or more industrial facilities or companies where the wastes or by-products of one become the raw materials of another, otherwise known as industrial symbiosis, brings advantages to both parties. It can be a win-win on both commercial and environmental grounds. Industrial symbiosis reduces raw material and waste disposal costs, new revenue from residues and by-products can be earned, less waste goes to landfill and there is a reduction in carbon emissions. There may also be new business opportunities[219].

Waste-to-energy and recovery

The term waste-to-energy is very broad and covers multiple treatment processes, ranging from incineration to recycling, that result in the production of electricity or heat from waste. These treatment processes have different environmental impacts and thus rank differently in the waste management hierarchy[220]. For example, processes such as anaerobic digestion are regarded in EU waste legislation as a recycling operation, but waste incineration with very little energy recovery is regarded as disposal.

Outlook and potential

What is the circular economy potential in the sector?

There are potentially large gains to be made by moving up the waste hierarchy. As it now stands, there are a variety of regulatory frameworks in place.

[216] https://www.eea.europa.eu/data-and-maps/indicators/waste-recycling-1/assessment

[217] https://www.eea.europa.eu/signals/signals-2014/articles/waste-a-problem-or-a-resource

[218] https://www.eea.europa.eu/signals/signals-2014/articles/waste-a-problem-or-a-resource

[219] http://www.wrap.org.uk/content/what-industrial-symbiosis

[220] http://ec.europa.eu/environment/waste/waste-to-energy.pdf

Therefore, current legislation is not entirely harmonised, hindering a smooth transition towards circular economy[221].

For many products, there is the potential to minimise waste generation throughout the entire value chain, from product design to packaging. This can be done through redesign with waste prevention as a priority. In order to achieve the maximum benefits, there is a need for a joint effort from consumers, producers, policymakers, local authorities and waste treatment facilities. For example, consumers should be willing and able to sort their waste to enable recycling, and the recycling infrastructure should be in place for this to happen[222].

The number of industrial robots in operation has increased recently. In 2013 an estimated 1.2 million robots were in use, and by 2014 this number had risen to 1.5 million. In 2017, it is estimated that a total of 1.9 million robots around the world are in use[223]. While the future impact of robots on jobs could be profound, Hepburn[224] identifies that people are able to learn, adapt and improve in ways which mechanised systems cannot. Machines could reduce costs and improve productivity and efficiency, but they allow for progress and advances[225]. Systems integration of chips or stacked chips with dense memory and fast logic, versatile biosensors, neuromorphic computing and deep machine learning capacity will rapidly improve every day machines, robots and other equipment. This will in turn strengthen the growth of circular economy, by generating mega data, identifying optimisation problems and new needs, thus creating a spiral of innovative solutions for future electronics[226]. One example of this is the creation of NIR spectroscopy for waste, which is a technology form that has been developed to be able to collect and sort waste, such as plastics, more efficiently[227]. More accurate manufacturing approaches, such as 3-D printing also offer the opportunity to reduce waste.

There is great potential to extract biochemicals or recover energy and nutrients from various waste streams. For example, about 70% of the phosphorous in sewage sludge and bio-waste is not recovered. At the same time phosphorous from sewage sludge, meat and bone meal, and biodegradable solid waste in the EU-27 amounts to almost 30% of today's use of synthetic phosphorus

[221] https://www.eea.europa.eu/signals/signals-2014/articles/waste-a-problem-or-a-resource

[222] https://www.eea.europa.eu/signals/signals-2014/articles/waste-a-problem-or-a-resource

[223] James Hagerty, "Meet the New Generation of Robots for Manufacturing," *Wall Street Journal*, June 2, 2015.

[224] Hepburn, C., (2012) Material Efficiency in Economic and Climate Policy Conference on Material efficiency: providing material services with less material production The Royal Society 30th January 2012 – 31st January 2012 https://royalsociety.org/events/2012/materialefficiency/

[225] Hepburn, C., (2012) Material Efficiency in Economic and Climate Policy Conference on Material efficiency: providing material services with less material production The Royal Society 30th January 2012 – 31st January 2012 https://royalsociety.org/events/2012/materialefficiency/

[226] https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Intelligent_Assets_080216.pdf

[227] http://oceanoptics.com/wp-content/uploads/App-Note-Sorting-Plastic-Resins-Using-NIR-Spectroscopy2.pdf

fertiliser. This is important, since more than 95% of the phosphorus consumed in Europe is imported as fertiliser, livestock feed, food, and other organic products[228].

In the built environment, 10-15% of building material is wasted during construction. Waste generated from construction and demolition accounts for almost 30% of all waste generated in the EU, and about 50% of demolition materials are landfilled in some countries while other countries only landfill 6%[229].

Mixed ordinary waste accounts for 10% of total waste arisings but, due to its varying contents, this waste stream is hard to recycle230. However, if the contents were better sorted and thereby placed in the "right bins", mixed ordinary waste would become a smaller waste stream, but would also contribute to waste streams with better recycling rates.

A report231 analysed opportunities and barriers for moving towards a circular economy in the Netherlands. The report estimates the overall annual impact of the circular economy in the Netherlands at €7.3 billion, and 54,000 jobs. The current value of the circular economy for 17 product categories in the metal and electrical sectors is €3.3 billion, and the Netherlands could achieve additional annual market value of €573 million. The use of the 34 most important waste streams already represents value of €3.5 billion. An estimated investment of €4-8 billion in new technologies could create added value of €1 billion a year for the circular economy in bio-refining, bio-gas extraction, and sorting of household waste232.

Regulatory drivers and barriers (political potential)

Barriers

There are a number of waste policy areas that are seen by some as presenting a barrier to the transition to a circular economy. Some of the points raised in a recent study[233] on waste markets include:

- **Lack of harmonisation of waste management requirements through EU legislation**. In the absence of harmonisation in EU legislation, divergence between Member States' requirements on waste management may lead to distortions of waste markets.

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228 https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

229 https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

230 http://www.europarl.europa.eu/EPRS/EPRS-Briefing-564398-Understanding-waste-streams-FINAL.pdf

231 The Netherlands Organisation for Applied Scientific Research (TNO), Ton Bastein, Elsbeth Roelofs, Elmer Rietveld, and Alwin Hoogendoorn, *Opportunities for a circular economy in the Netherlands,* 2013.

232 The Netherlands Organisation for Applied Scientific Research (TNO), Ton Bastein, Elsbeth Roelofs, Elmer Rietveld, and Alwin Hoogendoorn, *Opportunities for a circular economy in the Netherlands,* 2013.

233 Waste Market study by Arcadis/Trinomics

- **Lack of uniform implementation and application of EU waste legislation**. Different interpretation and application of EU legal requirements across Member States may distort the efficient functioning of waste markets.
- **Divergent policy and requirements at national, regional and local levels**. Divergent national, regional and local policy and legislation may create distortions of waste markets between Member States as well as within Member States. A region or local authority may adopt policies or legislation that affect companies from other regions in the same country. It may also affect businesses in other Member States.
- **Obstacles to waste management activities for companies from other Member States**. National, regional and local policy requirements may create obstacles for waste management activities, especially for companies from other Member States.
- **Waste transport obstacles.** Differences in definitions of waste have been seen to cause obstacles to transporting waste.
- **Divergent fiscal policies**. Different Member States adopt different fiscal policies, such as taxes and subsidies, that can have an impact on the efficient functioning of waste markets.
- **Cultural differences**. There appears to be cultural differences across Europe related to the willingness of citizens to sort and recycle waste.

Drivers/Solutions

If the waste market functions in the EU were more efficient, and were not hindered by different restrictions, the waste sector could improve performance[234]. This would likely mean better sorting techniques, more free movement of waste also across borders, more effective treatment and better recycling and recovery rates. The EU has already set in place the Waste Shipment Regulation to help on some of these issues but there are still issues to be solved, which could be aided by:

- Harmonisation in definitions and standardisation to alleviate differences in interpretations.
- Separate levels of waste hierarchy.
- Setting criteria/producing guidance for the design of producer responsibility schemes and amend producer responsibility schemes.
- Setting minimum levels of requirements to be applied in all Member States and standardisation of waste collection system within a country.
- Providing economic incentives and means for financial innovation.
- Developing the raw materials diplomacy.
- Better data, monitoring and advice.
- Improving enforcement.

[234] Waste Market study by Arcadis/Trinomics

- Administrative simplification.
- Supporting EU wide instruments to spur demand for circular economy.
- Innovation pathways on technology and markets.
- Certification schemes for Environmentally Sound Management (ESM) of waste.
- New policy measures enabling the transition towards a circular economy.

Employment implications of the circular economy transition

To get an idea of the future size of circular economy in Europe and thereby the future job potential, it is relevant to have a look at the current situation. A proxy indicator of employment is created by pinpointing employment data from Eurostat at the level of business activity. In total, European employment in repair, waste and recycling is estimated to be around 3.4 million (this includes rental and leasing activities). Of these 3.4 million jobs:

- 1.2 million are in the repair of machinery and equipment sectors
- 0.4 million are in repair of electronics and household goods
- 0.7 million are in the waste collection, treatment and disposal sectors
- 0.3 million are in recovery of sorted materials and wholesale of waste and scrap
- 0.1 million are in retail second hand goods
- 0.6 million are in rental and leasing activities

At the same time, the proportion of employment in circular economy activities in relation to countries' sizes should be taken into account[235].

In the recycling loop and for reuse activities there is a good potential to offer lower skilled jobs to mid-level skilled work forces[236].

A WRAP study[237] suggests three possible scenarios for the expansion of circular economy and the job situation.

The first scenario assumes that no new initiatives will be taken, but the advancement of circular economy activities will be based on the motions already set in place, mostly comprised in the recycling sector. This suggests an increase of around 250,000 jobs (gross) by 2030 in circular economy activities in Europe[238].

The second scenario assumes that current level of initiatives is maintained, with further advancements in the recycling sector, and moderate actions taken in the remanufacturing, repair and reuse of products, as well as servitisation. Based

[235] WRAP 2015 Economic growth potential of more circular economies

[236] WRAP 2015 Economic growth potential of more circular economies

[237] WRAP 2015 Economic growth potential of more circular economies

[238] WRAP 2015 Economic growth potential of more circular economies

on these assumptions, the second scenario estimates a potential of 1.2 million jobs (gross) by 2030 in Europe[239].

The third scenario bases its assumptions on the notion of much more activity in the circular economy with high rates of recycling and advancements in remanufacturing, and still moderate progress in the repair and reuse activities. This scenario suggests that by 2030 a potential of 3 million jobs (gross) could have been created.

Another study[240] summarised selected literature on impacts of the circular economy, and found that for the Netherlands an estimated 54,000 jobs could potentially be created in the circular sector. For Sweden, this number was estimated to be around 100,000 jobs stemming from an expansion of the circular economy, and for EU a total of 2 million jobs could be created due to improvements in resource productivity.

However, based on an outlook from the UK, some are less optimistic about the future job creation stemming from the circular economy[241]. The report highlights the fact that a structural mismatch in worker skills and available jobs might account for around 3% of unemployment rates, where consistent and declining unemployment in some regions and for mid-skilled workers could reflect an addition of new jobs displacing current jobs. Therefore, in the light of circular economy more emphasis should be put on net job creation instead of simply the amount of new jobs without considering what jobs might be lost.

4.3 Modelling inputs (E3ME)

The following circular economy activities trends will have impacts on the waste management sector:

- *Further reducing landfill and waste incineration* (especially incineration with no energy recovery) – it is expected a stagnation then decline in this sub sector.
- *Increased recycling (of all waste streams)* – as a result of trying to meet recycling targets and because of pressure to take waste out of landfill / incineration. This is activity that will lead to activity and employment growth in the waste sector. In the short to medium term it appears that this growth will be labour intensive, but in the medium to long term this may be more mechanised – at the moment it appears that a major increase in mechanisation of waste sorting ('robots') are too expensive in comparison to wages.
- *Reduced total waste arisings* – as a result of improved longevity and reparability of products – it is not certain if this will affect waste sector employment. Although it should notionally reduce waste collection and transport, but the trend to increase recycling should counteract this,

[239] WRAP 2015 Economic growth potential of more circular economies

[240] EMF (2015) "Growth Within: A Circular Economy Vision for a Competitive Europe", EMF, SUN, McKinsey Center for Business and Environment

[241] http://www.green-alliance.org.uk/resources/Employment%20and%20the%20circular%20economy.pdf

because of increased need for stream separation and the increased need to process the waste in order to recycle / recover it.

It's important to note that the above activities are outcomes from circular economy activities in other sectors. Their activities will lead to changes in demand for the waste management sector. The results from E3ME include endogenous responses for the waste sector when we model circular activities in other sectors. The responses cover the waste sector's supply-chains, employment and its investment impacts. However, it's expected that many of the impacts will be close to zero as waste and recycling fall under the same sector classification in E3ME (NACE 38). A positive impact associated with higher recycling are likely to be offset by reduction in landfill and waste management demand.

For the waste management sector, we will only apply specific modelling inputs that are not captured in circular activities in other sectors. For example, waste and recycling have different labour intensities. Waste management is a highly mechanized process that requires a small level of labour input. Recycling, on the other hand, can be much more labour-intensive (collecting, sorting, processing, reselling, etc). We will therefore introduce a change in the sector's labour intensity assumption to reflect more recycling activities and less waste management.

The following are the three inputs specific to the waste management sector that will be included in the modelling

- labour intensity
- changes to sector investment (to reflect more recycling plants)
- additional non-labour operational costs (more expensive to operate than landfill)

Table 4-7 Expected impacts per CE activity – Waste Management Sector

CE activity	Baseline	Moderate	Ambitious	Impact
Reductions in waste from other sectors	No change from current situation	Combination of other sector's moderate ambition inputs	Combination of other sector's ambitious ambition inputs	Reduction in demand for waste management sector (landfill and traditional waste management)
Increase in recycling demand from other sectors	No change from current situation	Combination of other sector's moderate ambition inputs	Combination of other sector's ambitious ambition inputs	Increase in demand for waste management sector (recycling part)
Higher recycling activity within the waste management centre	No change from current situation	Higher labour intensity (4x more labour intensive)[242], Additional 20% investment for recycling plants 20% Higher costs	Higher labour intensity (4x more labour intensive), Additional 40% investment for recycling plants 40% Higher costs	Changes within the waste management sector to reflect higher level of recycling activities and less traditional waste management activities

[242] A good summary of labour intensity of different waste management activities can be found here http://www.gov.scot/Publications/2017/01/5347/8.

5 Electronics Sector

5.1 Overview and scope of the Electronics sector

Scope of the sector

The electronics and electrical equipment sector covers a large number of products using electricity as a medium for storing or conveying information, and as a source of power, respectively.[243] We define **electronics** as those products falling under NACE 26 Computer, electronics and optical products manufacturing. This includes the manufacture of:

- Computers, computer peripherals (e.g. printers, monitors, etc.), communications equipment (telephone and data communications equipment), and similar electronic products, as well as the manufacture of components for such products.
- Consumer electronics (e.g. TV, DVD, CD, video game controls, etc.), measuring, testing and navigating equipment, electromedical equipment (X-ray, MRI, medical lasers, etc.);
- Optimal instruments, microscopes, lenses, cameras and light meters;
- Magnetic and optical media (e.g. blank video tapes, blank optical disks, etc.).[244]

Electrical equipment is defined according to NACE 27 as the manufacture of:

- Products that generate, distribute and use electrical power (e.g. transformers, power switches, control panels, power circuit breakers, etc.);
- Electrical lighting equipment (e.g. electric lighting fixtures, light bulbs, etc.);
- Electric household appliances (e.g. small electric appliances and household goods, water heaters, white goods, etc.);
- Other electrical equipment (e.g. battery chargers, door opening, traffic lights, etc.).[245]

The sector is very broad and not all products and equipment will be covered in the section on circular economy (Section 5.2). That section will focus only on those products and equipment which are discussed within the EU circular economy debate.

[243] On definition of electrical and electronics goods, see http://www.europe-economics.com/publications/the_economic_impact_of_the_domestic_appliances_industry_in_europe_finaol_report.pdf

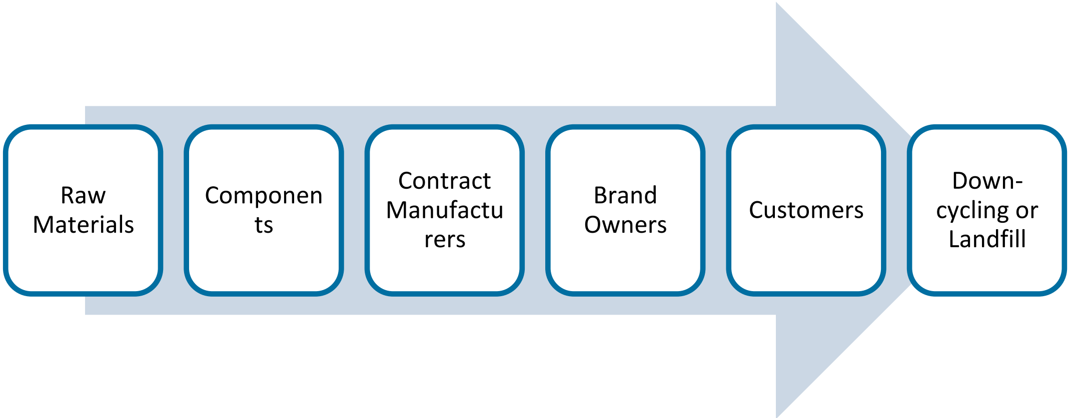
[244] Eurostat Statistics Explained 2016 http://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Manufacture_of_computer,_electronic_and_optical_products_statistics_-_NACE_Rev._2#Context

[245] Eurostat Statistics Explained 2013 http://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Manufacture_of_electrical_equipment_statistics_-_NACE_Rev._2

Supply chains of electronics and electrical equipment

An example of the electronics supply chain can be found in Figure 5-1. This shows that the sector still relies heavily on a linear model, which poses challenges for its transition to the circular economy.

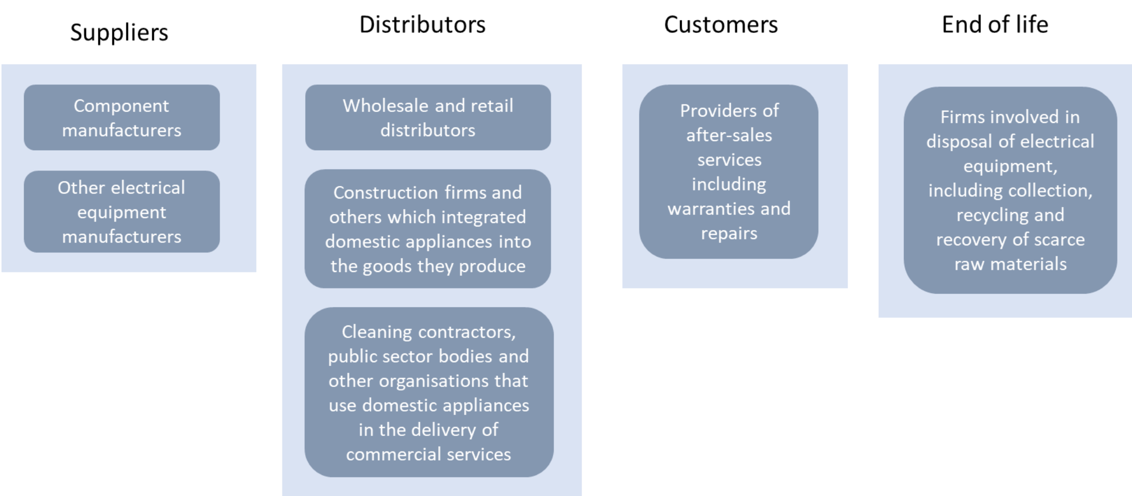
Figure 5-1 Linear model used by the electronics supply chain



Source: based on the presentation of Antea Group (2016)[246]

A study on domestic appliances (part of the electrical equipment sector) described its supply chain as follows (see Figure 5-2) (Europe Economics, 2015).[247] This figure is taken as an example of a supply chain for electrical equipment, but it differs per product.

Figure 5-2 Supply chain of electric domestic appliances



Source: Europe Economics (2015)

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[246] Antea group (2016) Presentation on "The Electronics Supply Chain Can Thrive in the Circular Economy", available at https://www.slideshare.net/AnteaGroupUSA/the-electronics-supply-chain-can-thrive-in-the-circular-economy

[247] Europe Economics (2015), The Economic Impact of the Domestic Appliances Industry in Europe", a report for the European Committee of Domestic Equipment Manufacturers, available at http://www.europe-economics.com/publications/the_economic_impact_of_the_domestic_appliances_industry_in_europe_finaol_report.pdf

Economic characteristics

To estimate the economic relevance of the sector in Europe, we rely predominantly on Eurostat data. Electronics and electrical equipment is covered in the two core sectors – NACE 26 Manufacture of computer, electronic and optimal products, and NACE 27 Manufacture of electrical equipment. Another clear sector of relevance includes NACE 95 Repair of computer and personal and household goods. Key statistics for these three sectors for the EU28 and 2014 (the latest available figures for EU28) can be seen in Table 5-1.

Table 5-1 Key economic indicators for the sector in the EU28, in 2014

Indicator	Manufacturing	Manufacture of computer, electronic and optical products	Manufacture of electrical equipment	% manufacturing	Repair of computers and personal and household goods
Number of enterprises	2.110.000	41.700	48.000	4%	209.739
Turnover or gross premiums written ('000)	7.110.000,0	290.637,5	294.826,5	8%	28.109,2
Production value ('000)	6.510.000	258.955	268.829	8%	22.090
Value added at factor cost ('000)	1.710.000,0	78.096,5	87.155,1	10%	10.861,9
Number of persons employed	29.900.000	1.093.652	1.450.811	9%	414.682
Number of employees	28.200.000,0	1.070.017,0	1.414.779,0	9%	229.749,0
Turnover per person employed ('000)	238	266	203	197%	68
Apparent labour productivity (Gross value added per person employed) ('000)	57	71	60	230%	26
Gross value added per employee ('000)	61	73	62	221%	47

Source: Eurostat (2017) Structural business statistics

This shows that the manufacture of electronics and electrical equipment have similar levels of turnover, value added and employment. The two core sectors cover approximately 10% of value added at factor cost and number of employees in the European manufacturing sector.

However, it should be noted that when looking at the sector from its supply chain perspectives, parts of other sectors should be included in its economic assessment: mining of metal ores, wholesale and retail trade of electronic and electrical equipment and to some extent rental and leasing equipment.

Employment characteristics

Both sectors (Divisions 26 and 27) are relatively stable in employment terms, collectively employing over **2.9 million workers** across the EU-28 (see Table 5-2).

Supply chain perspective

Table 5-2 Number of employees (EU-28), Electronics and electrical equipment and related lifecycle sectors (,000)

NACE_R2/TIME	2012	2013	2014	2015	2016
Manufacture of computer, electronic and optical products	1,510.1	1,552.9	1,537.3	1,510.5	1,531.4
Manufacture of electrical equipment	1,375.7	1,332.6	1,310.3	1,331.6	1,390.5
Mining of metal ores	49.3	59.1	59.6	54.8	58.1
Other mining and quarrying	235.8	224.5	216.6	221.2	217.7
Rental and leasing activities	436.1	447.9	445.4	458.9	489.6
Repair of computers and personal and household goods	508.4	515.0	516.7	500.3	489.0

Source: Eurostat

As with the construction and motor vehicle sectors, there is a link from the mining industries (*mining of metal ores* – Division 7; *other mining* – Division 8) to electronics/electrical equipment manufacturing. However, it is more straightforward to identify the aspects of these small mining sectors that are of relevance to electronics than for the other linked priority sectors:

- Group 7.2 Mining of non-ferrous metal ores (specifically the 'other' class of activity that includes copper, nickel, silver etc.)
- Group 8.9 Other mining and quarrying not elsewhere classified) specifically graphite, quartz etc. – although the class is arguably more closely linked to the construction sector overall)

From a circular economy perspective, there is a strong link to the *rental and leasing* sector (Division 77). This link is distinctive from the similar activities associated with motor vehicles, as it relates specifically to:

- Group 77.2 Renting and leasing of personal and household goods
- Group 77.3 Renting and leasing of other machinery, equipment and tangible goods

All classes of the *repair of computers and personal and household goods* sector (Division 95) are linked to the electronics/electrical lifecycle – even though it encompasses some elements associated with construction and textiles. The repair sector is closely associated with the circular economy, although employment has fallen across the EU28 since 2012 (to **490,000 people** in 2016).

Occupational composition of the core sector

The core sector has a slightly split occupational profile with a greater concentration of professional/associate professional roles and plant, machine operators/elementary occupations than found in other similar sectors; although there are also two large craft-related occupations (see Table 5-3).

Table 5-3 Top jobs – Electronics and electrical equipment

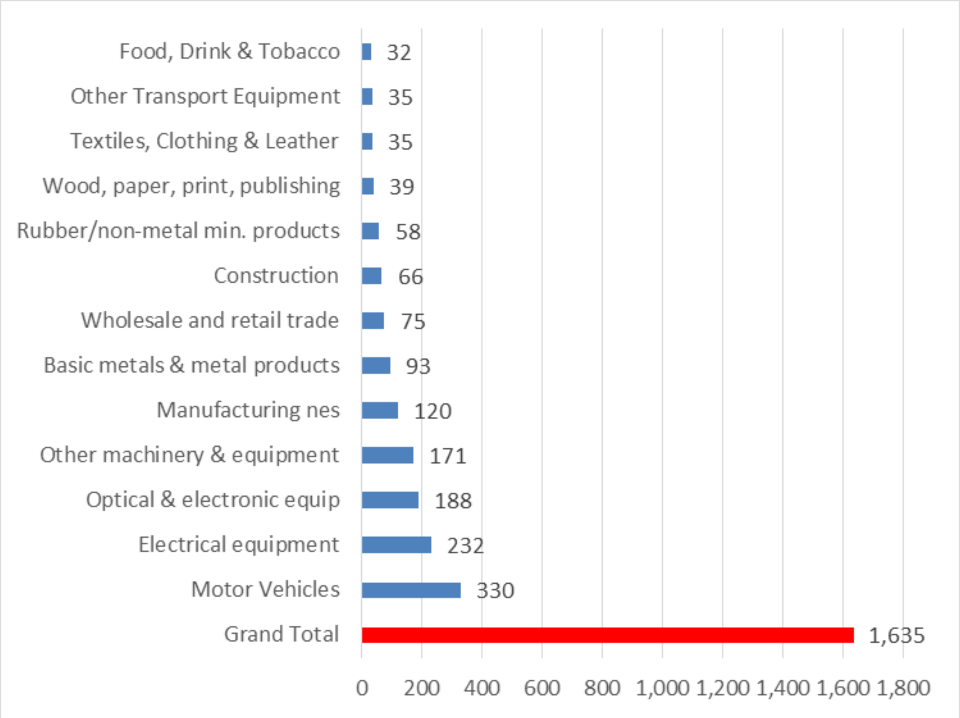
Rank	ISCO Occupational Group (and ranking by volume for manufacturing)	Employment 2015 (,000)	Share of sector employment	Forecast growth (% share) 2015-2025
1	82. Assemblers (#9)	420	14.3%	-1.3%
2	31. Science and engineering associate professionals (#4)	328	11.2%	-0.7%
3	21. Science and engineering professionals (#6)	311	10.6%	1.2%
4	74. Electrical and electronic trades workers (#13)	260	8.9%	-1.7%
5	72. Metal, machinery and related trades workers (#1)	197	6.7%	-1.6%
6	33. Business and administration associate professionals (#7)	168	5.7%	0.2%
7	43. Numerical and material recording clerks (#8)	157	5.4%	-0.8%
8	93. Labourers in mining, construction, manufacturing and transport (#5)	131	4.5%	0.0%
9	24. Business and administration professionals (#14)	125	4.3%	0.6%
10	81. Stationary plant and machine operators (#2)	122	4.2%	1.1%
	Total	2 930	100.0%	-3.0%

Source: Cedefop Forecast (EU-28)

Linking key occupations and skills/competences to other industries

The largest occupational groups, *assemblers*, is shrinking in size and found more commonly in some other manufacturing sectors (see Figure 5-3). As noted in the construction profile, *science and engineering associate professional* employment is relatively evenly spread across the large number of sectors (as are *science and engineering professionals*). As the core electronics/electrical sector is relatively small in overall employment terms, it is possible to suggest that there is potential for inward recruitment of new skills.

Figure 5-3 Distribution of Assemblers by sector (Number of jobs – '000)



Source Cedefop

While *electrical and electronic trades workers* is only the fourth largest occupational group – it is a group of increased relevance from a life cycle perspective. In the context of the circular economy, it includes the relevant 3-digit ISCO occupation of *Electronics and telecommunications installers and repairers* (ISCO 742), which can be further segmented to the specific role of 'consumer electronics repair technician'. Table 5-4 shows illustratively that, at this detailed occupational level, there is a strong skills commonality between repairers and roles in other sectors.

Table 5-4 Electronics mechanics and servicers (ISCO 7421): Skills links

Key tasks	Selected essential skills/competences	Skills reusability and links
"Electronics mechanics and servicers fit, maintain, adjust and repair electronic equipment such as commercial and office machines and electronic instruments and control systems. Tasks include - (a) examining and testing machines, instruments, components, control systems and other electronic equipment to identify faults; (b) adjusting, repairing and replacing worn and defective parts and wiring, and maintaining machines, equipment and instruments; (c) reassembling, test operating and	Apply company policies	**Cross-sector:** Found across a wide range of corporate, retails, IT and other sectors
	Provide customer follow-up services	**Cross-sector:** Found in a wide range of sales-related roles
	Repair equipment on site	**Cross-sector:** Links to roles in agriculture (machinery repair)
	Set up consumer electronics	**Sector-specific:** A highly occupationally-specific skill requirement
	Troubleshoot	**Cross-sector:** Also found in a wide variety of construction, manufacturing, energy and transport roles

Key tasks	Selected essential skills/competences	Skills reusability and links
adjusting equipment; (d) installing electronic instruments and control systems; (e) coordinating work with that of engineers, technicians and other maintenance personnel; (f) interpreting test data to diagnose malfunctions and systemic performance problems; (g) installing, adjusting, repairing or replacing electrical and electronic components, assemblies and systems, using hand tools, power tools or soldering irons; (h) connecting components to assemblies such as radio systems, instruments, magnetos, inverters and in-flight refuelling systems; (i) keeping records of maintenance and repair work. ".	Replace defect components	**Cross-sector:** Common to technician and non-electrical repair roles
	Create solutions to problems	**Cross-sector:** An extremely transferable skill requirement from managerial/professional through to craft/trade occupations in many sectors
	Maintain customer service	**Cross-sector:** Similarly wide-ranging applicability, especially in hospitality and retail roles
	Use repair manuals	**Cross-sector:** Common to technician and non-electrical repair roles
	Maintain equipment	**Cross-sector:** Although can by more narrowly defined to relate to specific equipment, the principle skill requirement is essential across agriculture, manufacturing, media/creative and personal service sectors.

Source: ESCO Version 1.0

Resource and environmental characteristics

A study by Ecofys (2017) estimates that the electrical, machinery, metals and manufacturing consumption sector accounts for around 10% of the selected eight key raw materials in the main 11 consumption sectors[248] in terms of tonnage, around 17% of GHG emissions, around 5% of water use and around 8% of land use. See Table 5-5 for comparison with different sectors.

Table 5-5 Overview of 11 consumption sectors and their environmental impacts (relative)

Consumption sectors	Tonnages	GHG	Water	Land use
Agriculture, hunting, forestry and fishing	22%	9%	37%	35%
Mining and quarrying	0%	0%	0%	1%
Food production, beverages and tobacco	18%	16%	28%	20%
Textiles, leather and wearing apparel	2%	2%	2%	2%
Wood, paper and publishing	1%	0%	0%	3%
Petroleum, chemicals and non-metallic mineral products	5%	4%	2%	3%
Transport	1%	1%	1%	1%
Service sectors	17%	15%	18%	17%
Electricity, gas and water	1%	1%	1%	1%
Construction	23%	36%	5%	9%
Electrical, machinery, metals and manufacturing	10%	17%	5%	8%

Source: Ecofys (2017)

This shows that the sector's environmental impact is relatively moderate in comparison to some other sectors, e.g. agriculture, food production or construction.

[248] The eight key raw materials are: steel, aluminium, plastic, cement, glass, wood, primary crops, cattle.

The direct environmental impacts of electronics and electrical equipment occur at different life cycle stages of the specific product in this sector. As described above, there are a large variety of products in this sector, hence the impacts may differ.

In general, the following could be concluded:

- **Extraction phase/ raw materials** – relevant for the upstream industries supplying materials for the electronics and electrical equipment sector. The most relevant materials are metals (copper, lithium, tin, silver, gold, nickel and aluminium), plastics and chemicals.
- **Manufacturing components and products** – energy consumption during the manufacturing process and the use of chemicals are the most important environmental impacts.
- **Logistics** – energy consumption needed during transportation of materials and products.
- **Use phase** – this seems to be the most important phase for environmental impacts, such as GHG emissions coming from energy consumption during the use phase. The lifetime of electric and electronic equipment is about five years, however, the products are in general underutilised, with less than 50% of their potential being used (Ellen McArthur Foundation, Growth Within, 2015).
- **Recovery and reuse** – a relatively large potential for domestic appliances (Ecofys, 2017).
- **End of life** – this phase is very significant in Europe as WEEE is expected to grow to more than 12 million tonnes by 2020. Moreover, disassembly and recycling of these products is complex. One of the key features of this sector is that a large part of e-waste gets recycled outside of Europe. There is no control over how such e-waste is recycled, and as a result valuable materials and components (e.g. from mobile phones) are not properly processed, and as such are lost.

Table 5-6 Overview of environmental impacts in the electronics industry

Products	Raw materials	Manufacturing	Use	End of life
Computers, microchips, printed circuit boards	Half a computer is composed of metals, a circuit board uses a substantial amount of copper, copper uses a significant amount of water, use of chemicals, plastics, minerals, ceramics	Energy consumption (e.g. 41.1MJ/chip) Use of (hazardous) chemicals, upstream impacts of making chemicals Soldering with a mix of lead and tin – high environmental impact For its fabrication, a 2-gram microchip necessitates 1600 grams of petroleum, 72 grams of	Energy consumption to power the devices Use of complementary products – e.g. DVDs, USBs, paper	Complex disassembly Hazardous materials Proliferation of electronics in waste stream

	chemicals, 32,000 grams of water, 700 grams of elemental gases.[249]

Source: Table prepared based on Dartmouth College presentation[250], Investopedia article (2015)[251]

Key factors shaping the future development

One of the key drivers of the future development in the sector is energy and environmental legislation, such as eco-design that currently mainly tackles energy efficiency of products, the Waste Electrical and Electronic Equipment (WEEE) Directive (DIRECTIVE 2012/19/EU), and the Restrictions of Hazardous Substances (RoHS) Directive (EC, 2012) from the environmental side.[252] The WEEE directive tackles the recycling, recovery and reuse of such products, while the RoHS Directive tackles the use of hazardous substances in these products.

5.2 Circular economy in the electronics and electrical equipment sector

How circular is the sector?

Electronics and electrical equipment sector (NACE 26-27) is an important sector for circular economy as it:

- ✓ Requires the use of raw materials (virgin or secondary), in particular metals and critical raw materials, which are often not produced in the EU (and therefore constitute critical materials), not well recycled or substituted, and of chemicals, which can be hazardous.
- ✓ Waste of Electrical and Electronic Equipment (WEEE) is an important waste stream in Europe.
- ✓ Offers opportunities for innovative business models, such as rental and leasing activities – to cover the optimisation of the use phase of these products by renting and sharing activities.
- ✓ Offers opportunities for the repair sector to cover the remanufacturing and refurbishing of these products (covered largely by NACE 95).

According to the International Electronics Manufacturing Initiative (iNEMI), individual companies in the electronics industry have begun to take steps toward a circular economy in this sector, but the electronics industry as a

[249] Dartmouth College, Environmental issues in the electronics industry, course presentation, available at https://engineering.dartmouth.edu/~d30345d/courses/engs171/ElectronicsIndustry.pdf

[250] Dartmouth College, Environmental issues in the electronics industry, course presentation, available at https://engineering.dartmouth.edu/~d30345d/courses/engs171/ElectronicsIndustry.pdf

[251] Investopedia (2015), What commodities are the main inputs for the electronics sector?, available at http://www.investopedia.com/ask/answers/042015/what-commodities-are-main-inputs-electronics-sector.asp

[252] European Commission (2012), Functioning of the market for electric and electronic consumer goods. Available at http://ec.europa.eu/consumers/archive/consumer_research/market_studies/docs/report_electric_and_electronic_goods_market_2012_en.pdf

whole has not undertaken the steps towards closing the loop for recycling and reuse.[253]

The main challenges in the sector can be summarised as follows:

- The lack of an economically viable reuse and recycling infrastructure given the rapidly evolving product design and material content. Separation of electronic products and materials is challenging as the products contain integrated components (such as printed circuit boards) that are made from multiple materials moulded into a single function, and there is often no cost-efficient way to extract the embedded raw materials without degrading the product (Ellen MacArthur Foundation, 2014).[254]
- The relatively low value of the materials in waste electrical and electronic equipment.[255] There are significant losses along the collection and treatment chain and, with today's infrastructure, design-for-recycling does not pay for the producers (iNEMI; EllenMacArthur Foundation, 2014). Currently, three dollars' worth of precious metals (gold, silver and palladium) is all that can be extracted from a mobile phone that, when brand new, contains raw materials worth a total of US$16 (EllenMacArthur Foundation, 2014). As a result, the supply chain is not incentivized to reuse and recycle.
- The need to start with product design as it impacts the ability to reuse and recycle. But this might have a negative impact on the lifetime of a product (iNEMI).

Figure 5-4 illustrates the potential venues for circularity in the sector, including circular supplies, returning by-products, re-/ upcycling, reselling, remanufacturing as well as sharing/ repairing. The frontrunners in the sector are already busy with implementing such a circular value chain. Nevertheless, the focus is still on recycling (as driven by the WEEE Directive).

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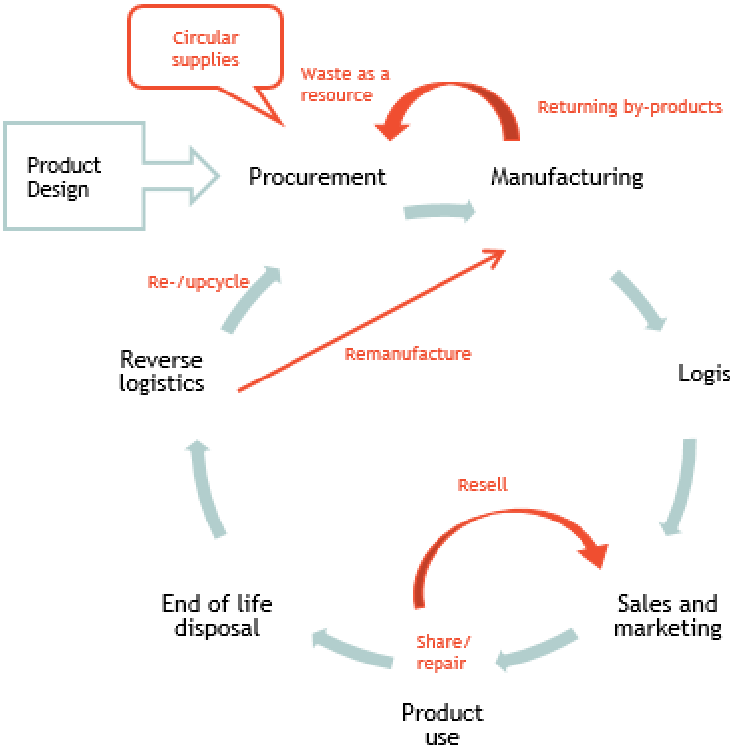
[253] International Electronics Manufacturing Initiative (iNEMI), available at http://www.inemi.org/blog/circular_economy

[254] Ellen MacArthur Foundation (2014), Towards the Circular Economy: Accelerating the scale up across global supply chains, Vol. 3, Company report

[255] See also UNEP (2011) Decoupling Natural Resource Use and Environmental Impacts from Economic Growth, A Report of the Working Group on Decoupling to the International Resource Panel, UNEP

Figure 5-4 Circularity in the electronics and electronic equipment value chain



Source: Trinomics based on Accenture (2014) Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth, Accenture

Currently, the trend in the sector is to focus on reverse logistics and the end-of-life phase of products as the main actions to improve circularity. In general, according to sector stakeholders interviewed during the sector study for the Dutch Ministry of Infrastructure and Environment (Trinomics, 2015):

- The technology needed to make the sector more circular is already there, but its current use is not optimal yet.
- Different products in the sector require different strategies, depending on the life-time, cost and usage of the product.
- Computer electronic devises and mobile phones, for example, have a relatively high turnover of buyers and users, compared to for example, white goods and larger machinery.[256]

The Trinomics study (2015) also assessed the level of development (Technology Readiness Level) and market uptake of a variety of circular economy activities in the Dutch electronics and electrical equipment sector. As a known frontrunner in this field, this might still be far beyond from what other EU Member States are doing. Table 5-7 summarises the results from this study.

[256] Trinomics (2015), Technological innovations and financial instruments for a circular economy, Final report for the Ministry of Infrastructure and Environment

Table 5-7 Circular economy innovations in the electronics and electrical equipment sector in the Netherlands

Circular economy activity & level of development	Exploratory phase (research)	Starting up/ low uptake (demonstration)	Developed (commercialisation)
IT and telecommunications			
Modular design of technologies	✓✓	✓	
End-of-life reparation or recycling	✓✓	✓✓	✓
In-use and user-led reparation using open source modular parts	✓		
Extended lifetime	✓		
'Fair' products (with social value)	✓✓	✓	
Adaptable telephones ('lego' telephones)	✓✓	✓	
Consumer goods			
Use of recycled plastic in domestic appliances			✓✓
Ecodesign			✓✓
Lighting systems			
Use of smart meters and sensors			✓✓
Circular business models			
Selling services instead of products – e.g. lighting performance contracts	✓✓	✓	
From owning to sharing – sharing/ leasing platforms (electrical products, machinery, medical technologies)	✓✓	✓✓	✓
Circular logistics/ end of life			
Trade and return systems			✓✓
Collection and reparation of old models		✓✓	✓✓
Improved recycling technologies	✓✓	✓✓	✓✓

Source: adapted by Trinomics based on findings from Trinomics (2015)

The table above shows that today, circular economy activities in the electronics and electrical equipment sector focus mainly on circular logistics and recycling, and energy efficiency improvements in the design phase. One other rising activity is sharing and leasing business models, where companies experiment with P2P renting of electronics and electrical products. However, the markets for these are very low scale and immature.

It also shows that circular design is in its infancy and that there are not enough incentives in the industry to adopt such practices as the business model is still relatively linear, where profits depend on the sales and fast turnover of new products. In addition, the majority of production happens outside of Europe, which makes it difficult to influence the design stage.

The innovative business models such as selling a service or sharing/ renting models where the consumer does not become an owner of the product are being developed. However, the relatively low price of certain electronic products and electrical equipment does not create enough incentives for people to 'share' rather than buy. But this trend is increasing for more expensive products, such as machinery or medical equipment.

What is the circular economy potential in the sector?

Based on the understanding of this sector and its challenges in its transition to a circular economy, the potential to improve circularity in the sector seems very large. There is still great potential to close the loop, i.e. improve recycling, recovery, remanufacture and reuse. The challenges to do so were outlined in the previous section. Some progress has been made in recent years with respect to increasing the yield of the current sheltering-based recycling processes to extract the embedded raw materials (Ellen MacArthur Foundation, 2014). Other trends in the sector include:

- Trace and return systems – mostly in the ICT and telecommunications sector, innovative solutions of how to support greater collection of electronic products, and reduce e-waste. For example, in the Netherlands Vodafone offers a service where clients can receive some remuneration (an average price of 85 euro) for returning their old telephones (VBDO (2014).[257]
- Improved technologies for recycling – there are several research projects in this field on topics such as how to better extract and recycle polymers and metals from electronic products (e.g. REWARD, MAGNETRONIC-REC projects funded under the CIP Eco-innovation programme.).

The studies and stakeholders (see for overview Arcadis & Trinomics, 2016)[258] mention that there are large amounts of materials and by-products that are being wasted and lost due to for example, (illegal) WEEE shipments outside of Europe for recycling. Eurometaux in their interview mentioned that approximately 38% of end of life products are illegally exported out of Europe, out of which around 25% are metals as WEEE (Arcadis & Trinomics, 2016). As a result, a lot of material is lost and/ or not treated properly. The industry itself needs to close the loop but also consumer behaviour will need to change. Waste will need to be reused, repaired or remanufactured.

There is also moderate potential to improve the utilisation of electronic and electrical products, i.e. using them more optimally during the product's lifetime (more than 50% of their potential use) through e.g. sharing/ renting, and/ or by extending their life time. However, this potential seems largely theoretical as it mostly depends on consumer behaviour and the choices they make, as well as the availability of safeguards and insurances for shared products. For example, there are sharing/ renting platforms for goods, including domestic electrical appliances (e.g. Peerby) but the size of these is very small as people are not ready to share/ rent between each other.[259] Companies selling white goods are also exploring these opportunities – for example, Philips is offering

[257] VBDO (2014) Vodafone Nederland 2014 circulaire economie, https://www.vodafone.nl/_assets/downloads/algemeen/vbdo_vodafone_stakeholder_nl.pdf

[258] Arcadis & Trinomics (2016) The efficient functioning of waste markets in the EU: legislative and policy options, Final report for DG Environment, European Commission, available at http://ec.europa.eu/environment/waste/studies/pdf/waste_market_study.pdf

[259] European Commission (2017) Environmental impact of the collaborative economy – final report – ongoing project

performance lighting contracts instead of selling light bulbs[260], and Gorenje is exploring renting out its washing machines instead of selling them (Gorenje's goRENT project)[261]. Sharing and renting out personal items such as computers and mobile phones has also not been taken up yet, as consumers like to own these items. According to the Sustainability manager for Vodafone Netherlands, there is a personal attachment to the mobile that makes customers not want to sell it – only around 10% of customers wanted to take advantage of the 'return deal' in 2015 – i.e. to bring back their phone in return for around 85 euros (Trinomics, 2015).[262] These business models need to be economically viable (why would a consumer pay each time he/she does laundry rather than buying their own washing machines?) and/ or need to be backed up by insurance products for such products (FLOW2, a sharing platform in the Netherlands mentioned the lack of insurance for shared/ rented products by peers as a bottleneck to scaling up these business models (Trinomics, 2015)).

With regard to extending the lifetime of a product, supporting legislation is in place, for example the WEEE directive, EU Ecodesign directive and other initiatives such as the Integrated Product Policy, Eco-innovation Action Plan and the EU Action Plan for the Circular Economy.

Improving circularity of the product design is another area for potential that still needs to be further explored and developed. There are several circular economy trends in the sector but some of them have opposing impacts. For example, increasing complex product design decreases the amount of needed materials and increases functionality, while at the same time this complex design decreases the ability to recycle and repair as parts are glued together and integrated. (EEA, 2017).[263] Another trend is modular design, e.g. there has been an introduction of modular phones, such as Fairphone, Phoneblocks, and adjustable phones, such as ARA Project: ' Lego Phones' – started at Motorola and currently part of Google's secret Advanced Technology and Projects (ATAP) division)[264] (EEA, 2017). Modularity has an impact of increasing the lifetime of products as parts can be repaired and remanufactured. On the other hand, such services and parts need to be available (EEA, 2017). Another challenge is that the majority of electronics and electrical equipment are manufactured outside of Europe (Trinomics, 2015).

This assessment of the circular economy potential in the electronics/ electrical equipment industry is in line with the estimate made by Ellen MacArthur Foundation in their report 'Growth within', where looping has a high potential,

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[260] http://www.theguardian.com/sustainable-business/intelligent-lighting-designing-responsible-consumption; http://www.lighting.philips.com/main/experience/inspiration/cases#page=1&filters=Country%2FNetherlands%2C

[261] ResCoM project, case study Gorenje http://www.rescoms.eu/case-studies/gorenje

[262] Interview done for Trinomics (2015), Technological innovations and financial instruments for a circular economy, Final report for the Ministry of Infrastructure and Environment

[263] EEA (2017), Circular by design – products in the circular economy

[264] Project Ara, news https://www.cnet.com/news/google-project-ara-hands-on-rafa-camargo-interview-modular-phones/

optimising and sharing a medium potential, and virtualising and exchanging also a medium potential (Ellen MacArthur, 2015).

In their report "Circular advantage: Innovative business models and technologies to create value in a world without limits to growth" (2014), Accenture outlines several business models that could drive the transition to a circular economy for consumer electronics.[265] These business models include:

- ✓ Resource recovery model, i.e. to recover useful resources/ energy out of disposed products or by-products. This model is in line with closing the loop, mentioned above as an action with high potential in the sector.
- ✓ Product life extension model, i.e. extending the working lifecycle of products and components by repairing, upgrading and reselling. This model is in line with the improved utilisation of a product during its lifetime. As electronics are relatively expensive, while the raw material value is very low, sometimes less than 1% of the product price (for example, the price of a new computer is on average around €1100 while the raw material value is only €8.60[266]), there is a great potential for reparation and reuse.
- ✓ Performance based service model, i.e. a service rather than a product is sold, where ownership of the asset remains in the hands of the seller rather than the buyer. This model is in line with improving the utilisation of a product during its lifetime.
- ✓ Ownership of assets is retained by the producer – this corresponds to the circular business model based on sharing platforms (enabling increased utilisation rate of products by making shared use possible) and product as a service (offering product access and retain ownership).[267]
- Warranties are offered on remanufactured/ refurbished items – this would support further utilisation of consumer electronics and electrical equipment and move up on the hierarchy towards keeping the products in use. Examples of such activities include medical equipment being refurbished in healthcare (e.g. Philips Diamond Select programme[268]).

Together with the development of digital technologies, e.g. mobile, M2M, cloud, social, big data analytics,[269] which are crucial in moving beyond sale

[265] Accenture (2014) Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth, Accenture
[266] UNEP (2011) Decoupling Natural Resource Use and Environmental Impacts from Economic Growth, A Report of the Working Group on Decoupling to the International Resource Panel, UNEP
[267] See Accenture (2014) Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth, Accenture, at http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Circular-Advantage-Innovative-Business-Models-Technologies-Value-Growth.pdf
[268] Philips Diamond Select https://www.usa.philips.com/healthcare/articles/refurbished-systems-diamond-select
[269] See Accenture (2014) Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth, Accenture

transaction and dematerialisation, there is a great potential for circular economy in the sector.

Barriers to circular economy

To what extent the identified circular economy potential will be realised in the sector depends on a number of factors, such as regulatory drivers and barriers, as well as the involvement of the complete supply chain, including consumers. Consumers need to be aware of measures such as sharing of products, and the recycling of materials (Ecofys, 2017).

Regulatory drivers and barriers (political potential)

At EU level, the 2017 Commission Work Programme confirms the full commitment to ensure the timely implementation of the Circular Economy Action Plan. The following is a summary of key policies/ legislation that are driving the sector (and other sectors) into a more circular economy path:

- *Circular design* - the Ecodesign Working Plan 2016-2019 was adopted on 30 November 2016 as part of the Clean Energy for All Europeans package.[270] In this working plan, the Commission further explores the possibility to establish product requirements relevant for the circular economy such as durability, reparability, upgradeability, design for disassembly, information, and ease of reuse and recycling. The Commission will also launch a specific study on ICT products, including smart phones, with a view to their possible inclusion in the ecodesign working plan.[271] In parallel, the Commission has developed mandatory product design and marking requirements to make it easier and safer to dismantle, reuse and recycle electronic displays (e.g. computer monitors, televisions and electronic displays integrated in other products). The draft Regulation[272] includes requirements that facilitate recycling such as avoidance of welding or gluing of certain components (e.g. printed circuit boards, capacitors, batteries and internal power supplies), marking of plastic parts and the presence of cadmium and mercury.
- *Reverse logistics* – promotion of non-toxic material cycles and the uptake of secondary raw materials.[273] The Commission is also adopting a proposal[274] to make a targeted amendment to the Directive restricting the use of hazardous substances in electrical and electronic equipment ('RoHS Directive'). The draft directive, by triggering the substitution of certain hazardous substances in electrical and electronic equipment, enhances the possibility and economic profitability of recycling waste of that equipment.
- *Use phase* - On 9 December 2015, the Commission adopted a legislative proposal on online sales of goods.[275] The proposal aims to strengthen guarantees for consumers to better protect them against defective products and contributes to the durability and reparability of products, and promotes repair more strongly. This is highly relevant not only for

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[270] COM(2016) 773 final.

[271] http://ec.europa.eu/environment/circular-economy/implementation_report.pdf

[272] Draft Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for electronic displays

[273] http://ec.europa.eu/environment/circular-economy/implementation_report.pdf

[274] COM(2017)38

[275] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A20 15 %3A63 5 %3AFIN

electronic goods and electrical equipment and the attempt to increase their utilisation rate via sharing/ renting, but for other products as well. The amendments to the RoHS Directive mentioned above would also keep electrical and electronic equipment in use for longer and as such postpone their end of life and disposal. This avoids additional generation of waste, including hazardous waste. It is estimated that the measure will prevent the creation of more than 3000 tonnes of hazardous waste per year in the EU.[276] The extended lifetime of electrical and electronic equipment would also lead to additional savings of energy and raw materials.

The main barriers identified refer to:

- Definition of waste and by-products in the EU legislation – some definitions prevent certain by-products and 'wastes' to re-enter the supply chain (Arcadis & Trinomics, 2016).
- Lack of a business case to recycle and recover materials from old products.
- For some materials, such as plastic, recycled material does not have the qualities to be used as 'virgin' material.
- Lack of insurance products, guarantees and related legislation to regulate renting/ sharing of electronic products and offer more protection/ security to the owners.

Circular economy outlook

Based on the identified regulatory drivers and barriers, the circular economy outlook in the sector shows trends towards improvements along the supply chain – design, manufacturing, reverse logistics, remanufacturing, reuse, extending the lifetime of products, P2P renting/ sharing and recycling. However, the barriers also lead to assumptions that the full potential will not be reached by 2030.

In general, it is assumed that the existing WEEE recovery, preparation for reuse and recycling targets as of 15 August 2018 will be increased by 5% by 2030. This is a pure assumption as targets are set in the WEEE Directive 'as of 15 August 2018', and there is no evidence of potential/ aspirational targets for 2030. Hence, we propose to estimate the potential of increasing WEEE recovery, preparation for reuse and recycling targets if they were increased by 5% (in each of the six categories) (see

Table 5-8 Recovery and recycling/ preparing for reuse targets according to Directive 2012/19/EC (WEEE Directive) and our assumptions for moderate and ambitious scenarios

		Baseline (WEEE Directive) targets		Moderate (+5%)		Ambitious (+10%)	
		Recovery	Recycling / preparing for reuse	Recovery	Recycling / preparing for reuse	Recovery	Recycling / preparing for reuse
1	Temperature exchange equipment	85%	80%	90%	85%	95%	90%
2	Screens, monitors, and equipment containing screens having a surface greater than 100 cm²	80%	70%	85%	75%	90%	80%
3	Lamps	n.a.	80%	n.a.	85%	n.a.	90%
4	Large equipment (any external	85%	80%	90%	85%	95%	90%

[276] SWD(2017)22 and SWD(2017)23

	dimension more than 50 cm)						
5	Small equipment (no external dimension more than 50 cm)	75%	55%	80%	60%	85%	65%
6	Small IT and telecommunication equipment (no external dimension more than 50 cm)	75%	55%	80%	60%	85%	65%

Source for Baseline: WEEE Directive Annex V, Moderate + ambitious targets = pure assumptions

Circular design, i.e. modular design and the use of non-toxic materials/ and material efficiency will increase e.g. due to new or recent policies, revision of existing relevant legislation or market drivers, remanufacture and repair will become more economical due to implemented policies on extending lifetime for products, funding programmes, and better regulatory framework supporting renting/ sharing of products. This in turn would decrease the amount of products becoming waste and the need for new products, and as such the need for virgin materials.

Fully enabling secondary market operations and increasing spare part availability for certain electrical and electronic equipment will have a positive economic impact by bringing market opportunities to the repair industries and secondary selling.[277]

Extending lifetime for products will similarly create opportunities to the repair sector, as well as maintenance and rental services. A study for the European Parliament (2016) has estimated that a 1% increase in added value of these three sectors will generate 6.3 billion EUR.[278]

The expected impacts per CE activity by 2030 are summarized in Table 5-14 below. The circular economy outlook corresponds to the moderate uptake scenario.

5.3 Modelling inputs (E3ME)

Sections above have highlighted the key priority CE actions in this sector:

a) Reverse logistics - Remanufacture, reuse – high potential

b) End of life - recycle – high potential

c) Circular design – design for sharing, modular design, better use of materials (metals mostly) and chemicals, eco-design – medium potential

d) Optimising use – P2P sharing, extending the lifetime of products – theoretically medium potential

e) Decreasing energy consumption during the use phase – refers mostly to energy efficiency. Considered out of scope of this project.

We propose to model these activities as follows (open for discussion):

[277] http://ec.europa.eu/environment/circular-economy/implementation_report.pdf

[278] European Parliament (2016), A longer lifetime for products: benefits for consumers and companies, Study for the IMCO Committee, available at http://www.europarl.europa.eu/RegData/etudes/STUD/2016/579000/IPOL_STU(2016)579000_EN.pdf

Baseline scenario assumes the implementation of current legislation and of current policies in place by December 2014, consistent with the modelling baselineThis includes WEEE legislation (from 2012) and its targets, Eco-design (focus on energy efficiency) (from 2009), and RoHS (from 2011) as the most relevant pieces of legislation. The modelling baseline follows 2030 projections in PRIMES, which assumes the existing legislation, up to December 2014, is incorporated in these projections. Recast WEEE targets on recycling, recovery and preparation for reuse will apply in the baseline (the targets set as of 15 August 2018 in the recast WEEE). No change implies that currently the needed CE policy is not in place or does not create sufficient incentives for CE uptake for that CE activity. This is the case for extended lifetime of products, P2P sharing, better use of materials, circular design and remanufacture (see sections on regulatory drivers above).

Moderate scenario assumes a higher uptake of all CE activities due to e.g. market drivers or regulatory drivers (implemented legislation/ policies). This means that it is assumed that WEEE targets will be revised and increased, circular design, remanufacture, P2P sharing and extended lifetime of products will be moderately taken up.

Ambitious scenario assumes an ever higher uptake of all CE activities, where the CE potential discussed in section above will be reached. This means that CE activities in the sector will be mainstreamed along the supply chain, and not only taken up by a small number of frontrunners.

Developing modelling inputs for the CE activities in the sector

a) Reverse logistics – reuse, recovery

b) End of life, recovery

To model reverse logistics in the electronics sector, we tried to estimate the reduction in metal and plastics demand from electronics, as metals and plastics are two of the three main materials arising from the WEEE, besides glass, where ferrous metals account for approximately 50%, non-ferrous metals for 5% and plastics for 20-25% of the WEEE arising.[279] Unfortunately, we did not find estimates for the proportion of glass in WEEE.

Eurostat reports these data on volumes of WEEE (latest available for EU28 are for 2014):

Table 5-9 Statistics on WEEE

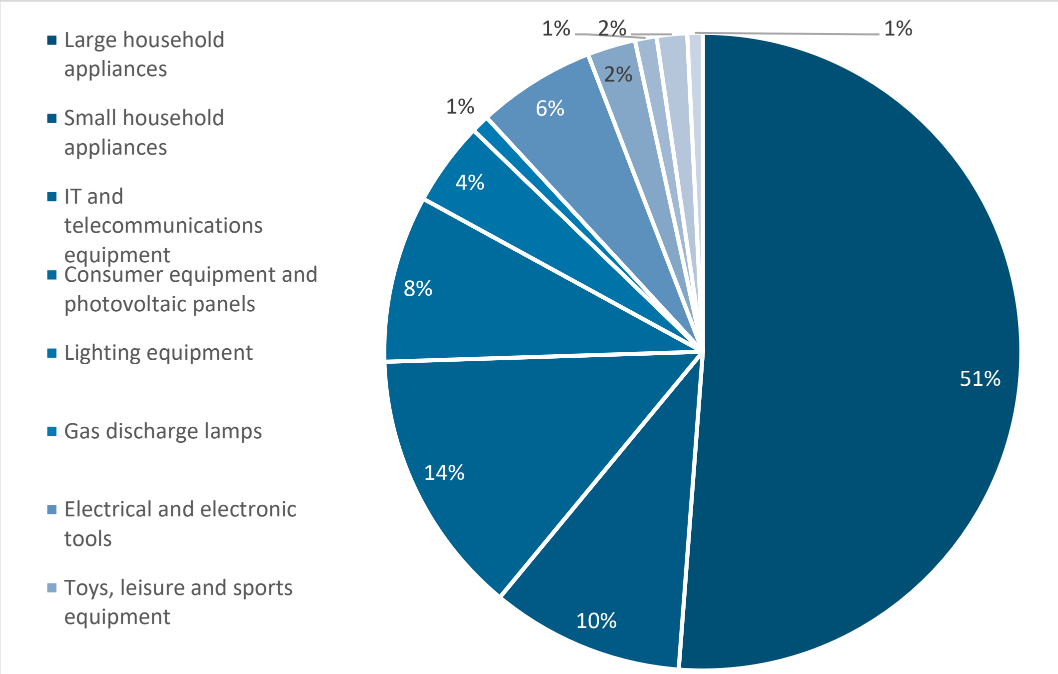
Total WEEE waste	2014
	tonne
Put on the market	9.260.953
Total collected	3.483.352
collected from households	3.151.139
Collected from other sources	332.213
Total waste treatment	3.427.156
Total recovery	3.099.477
Total recycling and reuse	2.845.996

Source: Eurostat

Furthermore, taking into account the different categories of WEEE, their relative share is the following:

[279] SEC(2008) 2933 EC SWD Impact Assessment of recast WEEE Directive

Figure 5-5 Products put on the market, 2014 (% tonnes)



Source: Eurostat

Different product categories have different recycling and reuse rates in the WEEE Directive, and we assume those to be the recycling and reuse (RR) rates in the baseline, while for the moderate and ambitious scenarios we assume the following higher recycling and reuse rates for the different product groups:

Table 5-10 Assumed recycling and reuse rates for different product groups

Product category	% tonnes put on the market	Baseline (RR rate)	Moderate (RR rate)	Ambitious (RR rate)
Large household appliances	51%	80%	90%	95%
IT and telecommunications equipment	14%	55%	60%	65%
Small household appliances	10%	55%	60%	65%
Consumer equipment and photovoltaic panels	8%	70%	80%	85%
Electrical and electronic tools	6%	80%	85%	90%
Coverage of the WEEE market	89%			

Note: the RR rate for electronic and electrical tools is assumed to be the same as for large equipment

With these five product categories, we are covering 89% of the EEE put on the market in terms of tonnes. This is of course due to the fact that large household appliances are also heavier, but include also more material in terms of tonnage.

Table 5-11 Calculation of % of recycled or reused tonnes of EEE tonnes put on the market under different collection rates and scenarios

	Baseline scenario	Moderate scenario	Ambitious scenario
	% tonnes RR of EEE tonnes put on the market		

Product category	100% collection rate	65% collection rate	100% collection rate	65% collection rate	100% collection rate	65% collection rate
Large household appliances	41%	27%	46%	30%	48%	31%
IT and telecommunications equipment	8%	5%	8%	5%	9%	6%
Small household appliances	6%	4%	6%	4%	7%	4%
Consumer equipment and photovoltaic panels	6%	4%	6%	4%	7%	4%
Electrical and electronic tools	5%	3%	5%	3%	5%	4%
Total (coverage cca 89% of the WEEE market)	64%	42%	72%	47%	76%	50%

Note: WEEE Directive specifies collection target as of 2019 65% of EEE put on the market. The 100% collection rate is calculated as the % share of the product category put on the market in tonnes multiplied by the assumed recycling and reuse rate. The 65% collection rate is calculated as 65% of the 100% collection rate. The numbers might not add up due to rounding up.

The WEEE Directive specifies that as of 2019, 65% of EEE put on the market will be collected. In our scenarios we use this target, but we also investigate the impact of a potential 100% collection rate by 2030. The results show the % of recycled or reused tonnes of EEE tonnes put on the market for each product category under the two collection rates and three scenarios. For example, large household appliances, which cover 51% of the tonnes of EEE put on the market, and assuming 80% recycling and reuse rate will lead to around 27% of recycled/ reused tonnes of EEE tonnes put on the market under the 65% collection rate in the baseline.

The total coverage of the WEEE market will also differ based the scenario and the collection rate, with the highest coverage of WEEE recycled and reused in the ambitious scenario (with highest RR rate) at 100% collection rate.

Knowing the % of recycled or reused tonnes of EEE put on the market and the material composition of WEEE, we can calculate the % tonnes of a certain material in the recycled/ reused WEEE out of the total tonnes of EEE put on the market under the different collection rates and scenarios.

Table 5-12 Estimation of the decrease in materials – metals and plastics

Material	Material composition of WEEE	% tonnes material in the recycled and reused WEEE out of total EEE tonnes put on the market (100% collection rate)			% tonnes material in the recycled and reused WEEE out of total EEE tonnes put on the market (65% collection rate)		
		Baseline	Moderate	Ambitious	Baseline	Moderate	Ambitious
Ferrous metals	50%	32%	36%	38%	21%	23%	25%
Non-ferrous metals	5%	3%	4%	4%	2%	2%	2%
Plastics	20-25%	13-16%	14-18%	15-19%	8-10%	9-12%	10-12%

Source: own estimation

For example, if we achieve the recycling and reuse targets by 2030, there will be 36% tonnes of ferrous metals in the recycled and reused WEEE out of total EEE tonnes put on the market, assuming 100% collection rate in the moderate scenario. This will decrease to 23% if we assume 65% collection rate of EEE put on the market (in accordance with the WEEE Directive as of 2019). Comparing with the % calculated for the baseline using the WEEE targets, we could imply that the demand for 'virgin' ferrous metals will decrease by 4% in the moderate scenario under 100% collection rate and by 6% in the ambitious scenario.

c) Circular design for sharing

d) Optimising use

To model sharing of electronic goods, and as such optimising their use and decreasing the need for new products, we base our modelling inputs developed as part of another study for DG Environment on "Environmental potential of the collaborative economy".[280] In this study we developed modelling inputs for a Peerby case to show the reduction in electronics demand from consumers and the revenues generated by sharing platforms such as Peerby. All these numbers are potential savings compared to the baseline.

Table 5-13 Modelling assumptions of sharing electronic goods

Modelling input	Moderate scenario assumptions	Ambitious scenario assumptions
Reduction in electronics demand from consumers	Numbers are potential savings compared to Baseline. - Households appliances 2.5% - Audio-visual, photographic and information processing equipment 1.75%	Numbers are potential savings compared to Baseline. - Households appliances 5% Audio-visual, photographic and information processing equipment 3.5%
Payment to sharing platform e.g. Peerby	25% fee of the above spending	25% fee of the above spending

[280] Trinomics (2017), Environmental potential of the collaborative economy, conducted together with Cambridge Econometrics, VITO and VVA. Still ongoing, reference to be updated once published.

Table 5-14 Expected impacts per circular economy activity

CE activity	Baseline	Moderate	Ambitious	Impact
Reuse	Recast WEEE as of 2018 prepared for reuse targets (55-80% depending on WEEE)	Increase of the relevant WEEE preparing for reuse targets by 5%	Increase of the relevant WEEE preparing for reuse targets by 10%	Decrease the amount of virgin and secondary materials, less waste, increase income to repair sector
Recovery	Recast WEEE as of 2018 targets recovery (70-85%)	Increase of the relevant WEEE recovery targets by 5%	Increase of the relevant WEEE recovery targets by 10%	Less raw materials, less waste
Remanufacture	No change[281]	Lower prices – less spending on new products, reduced raw materials, energy consumption, CO2 emissions, landfill	Remanufacture uptake higher (potential tripled by 2030)[282]	Less raw materials, less waste, less buy of manufacture
Recycling	Recast WEEE as of 2018 recycling targets (50-80%)	Increase of the relevant WEEE recycling targets by 5%	Increase of the relevant WEEE recycling targets by 10%	Decrease the amount of virgin material, less waste (some shift from electronic manufacturing buy from recycling and less from raw materials) but also less incentives for reuse
Circular design	No change (Eco-design)	Some opposing impacts: complex design (lower demand for materials but lower potential for reuse and recycling) – probably negative overall impact. Modular design (More remanufacture, repair, extend lifetime, less waste) – probably positive	Some opposing impacts: complex design (lower demand for materials but lower potential for reuse and recycling) – probably negative overall impact. Modular design (More remanufacture, repair, extend lifetime, less waste) – probably positive	Less new products due to modular design, increase income to repair sector

[281] current (2016) total estimate EUR 30bn in the EU, employing 190000 people - http://www.circle-economy.com/european-remanufacturing-industry-estimated-at-e30bn-with-potential-to-triple-by-2030/#.WbKRA7puKUk

[282] http://www.circle-economy.com/european-remanufacturing-industry-estimated-at-e30bn-with-potential-to-triple-by-2030/#.WbKRA7puKUk

CE activity	Baseline	Moderate	Ambitious	Impact
Better use of materials	No change (WEEE + RoHS)	Shift of manufacturing buy from virgin materials to recycled materials	Higher shift of manufacturing buy from virgin materials to recycled materials	Different type of materials and chemicals used in manufacturing, less virgin raw materials
P2P sharing	No change	Uptake of P2P renting (case study Peerby)	Uptake of P2P renting (case study Peerby)	Optimising product use, less buy of new products, less waste, increased income to renting sector, and secondary selling
Extended lifetime of products	No change	Increased income for repair, maintenance and rental services, R&D, less income for manufacturing and waste but it might decrease product lifespan of others – impact unclear	Higher increased income for repair, maintenance, rental and R&D sectors, less income for manufacturing and waste but it might decrease product lifespan of others – impact unclear	Optimising product use, less buy of new products, less waste, less materials, more income to maintenance, repair and rental services, decrease product lifespan of others.

6 Motor Vehicles Sector

In this sector profile, we analyse the potential and the impact of the circular economy for the motor vehicle sector, in particular in relation to employment, by:

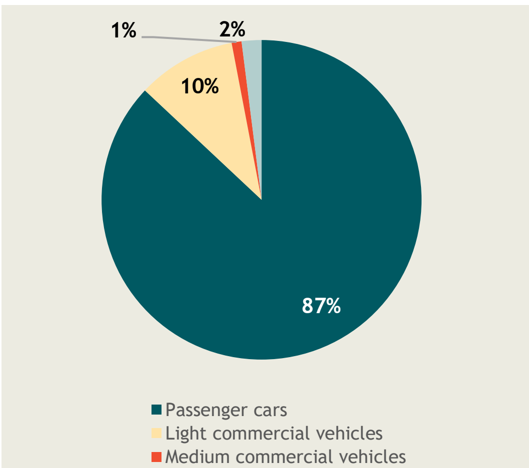
- Presenting an overview of the relevant economic, environmental and employment characteristics of the motor vehicles sector in the EU
- Discussing the economic and employment implications of the circular economy for the sector, including an outlook towards 2030
- Translating these implications and circular economy outlook towards concrete modelling input for the E3ME model so that the economic and employment impacts of the circular economy in this sector can be estimated in more detail

6.1 Overview and scope of the Motor Vehicles sector

Introduction to the sector

This sector profile focuses on the implications of the circular economy for the 'motor vehicles' sector as defined by statistical NACE code 29. This sector is assessed from a *life-cycle perspective*, though, as the circular economy can present opportunities before, during and after production. As the circular economy is by definition also a cross-sectoral concept, we also take important *supply chain links* with the motor vehicles sector into account. Therefore, we analyse the sector from the moment resources are extracted and processed to deliver materials to the producers of parts and components and the companies assembling the vehicles (*production phase*). After the vehicles are produced and distributed (*distribution phase*), we specifically analyse the *use* phase of motor vehicles and identify what happens when the vehicles are discarded (*End-Of-Life phase*). A schematic overview of the sector from a life-cycle and supply chain perspective is presented in Figure 6-2 overleaf (this overview will be used in the remainder of this section to explain the characteristics of the sector).

Figure 6-1 EU motor vehicle production, 2014

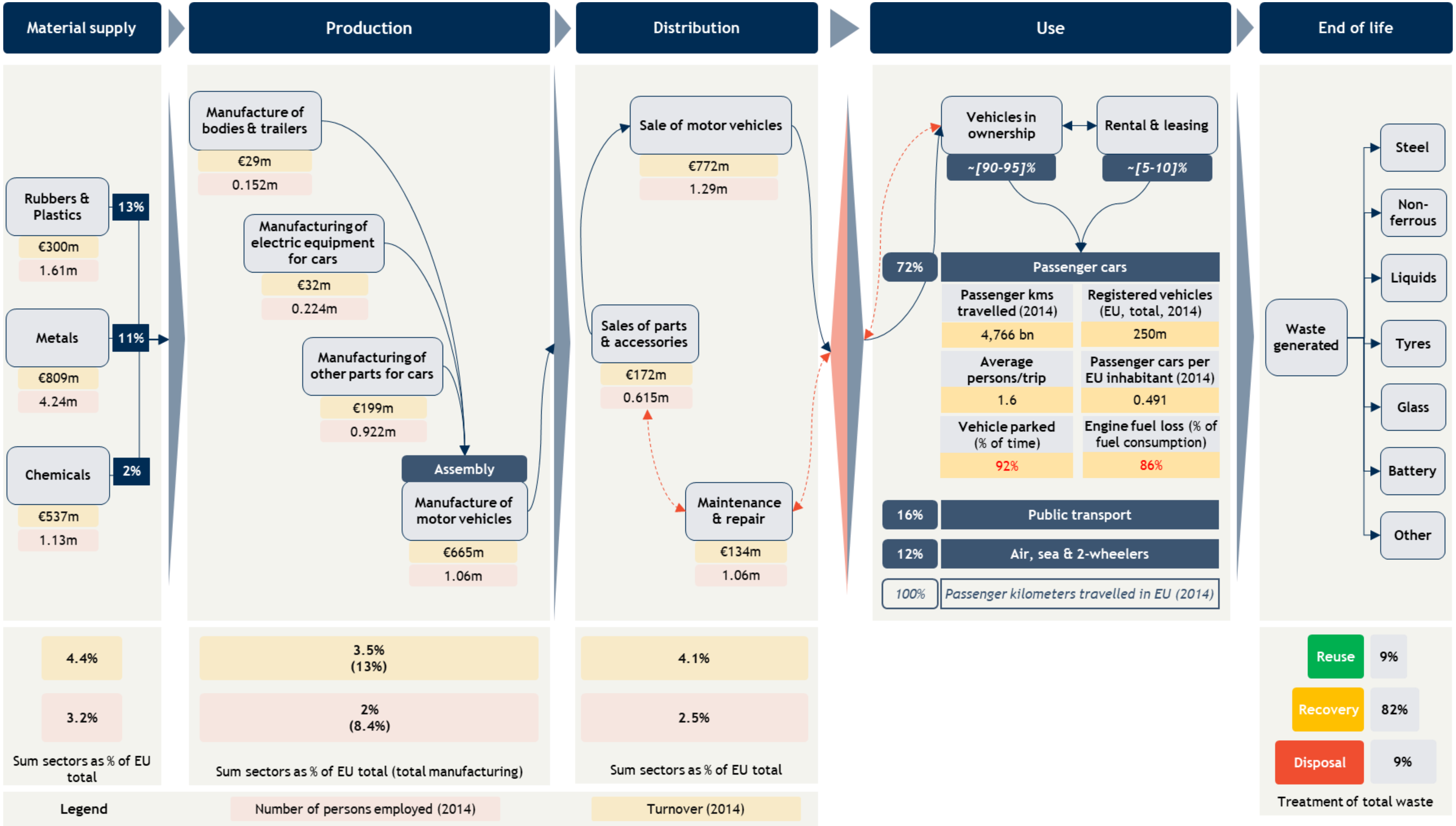


Source: ACEA, 2015, The Automobile Industry Pocket Guide 2015/2106

Moreover, even though this sector profile covers (for statistical reasons)[283] the 'motor vehicles' sector as a whole, the analysis in this profile focuses on production and use of **passenger cars** in the EU since these represent the vast majority of the motor vehicle fleet and annual production in the EU (see Figure 6-1). We might therefore also use the term 'automotive sector' interchangeably with the motor vehicles sector.

[283] The highest level of sector disaggregation in the E3ME model is the 'manufacture of motor vehicles' sector

Figure 6-2 Life-cycle overview of the motor vehicles sector



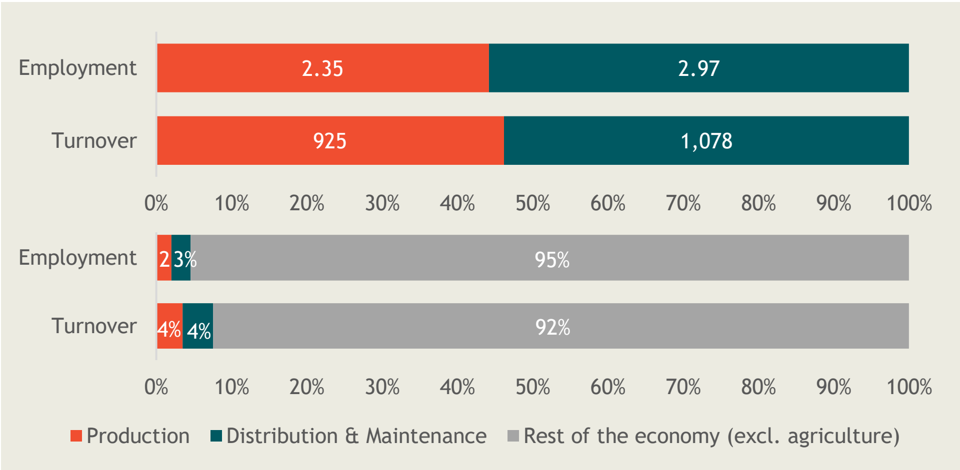
Note: All data from represent 2014

Sources: Own elaboration, based on data from Eurostat's Structural Business Statistics (Turnover & Employment), EU Statistical Pocketbook 2016 – *EU Transport in Figures*, Eurostat's *wastegen* data and EllenMacArthur Foundation (2013), *Growth Wtithin: A circular economy vision for a competitive Europe*

Economic characteristics

It is important to describe the supply chain linkages from the motor vehicles sector to other relevant related sectors and illustrate the level of economic activity in the different segments of the automotive supply chain in order to understand what effect potential circular actions might have in the sector. Directly related sectors to the manufacturing of motor vehicles are the manufacture of (electrical) parts and equipment for cars as well as bodies, which provide the most important inputs to the final production of motor vehicles. These in turn depend on – amongst others – (processed) raw material inputs. After production, passenger cars are sold either through leasing schemes or in full ownership to EU citizens. In 2014, there were approximately 250 million passenger cars on the road, approximately one car per two EU citizens[284]. After its average service life of 9.7 years[285] (including maintenance and repair), parts and components of the End-Of-Life (EOL) vehicle are reused, recovered (recycled) and disposed of. Some **5.4 million people were employed** in the 'manufacturing of motor vehicles' sector and its most directly related economic sectors in the production and distribution & maintenance phases in 2014, which **jointly generated €2 billion turnover** in the same year (see Figure 6-3). Compared to the rest of the EU business economy (excluding agriculture, forestry and fisheries), this represented jointly 5% of total EU employment and 8% of total EU employment. In the following paragraphs, we discuss the detailed economic characteristics for each of the life-cycle phase individually.

Figure 6-3 Employment and value added in the motor vehicles production & distribution sectors, millions, EU-28, 2014



Source: Eurostat Structural Business Statistics

Note: 'Production' = NACE 29 and 'Distribution & Maintenance' = NACE 45

1) Materials supply

From a supply chain perspective, the most important goods and services supplied to the transport equipment are automotive parts and components (included in phase 2 production). As illustrated in Table 6-1,some 39% of total costs for intermediate products and services needed to produce transport equipment in the EU, consist of products and services from *within* the transport equipment sector itself. Central to the notion of the circular economy,

[284] EU Statistical Pocketbook 2016 – EU Transport in Figures

[285] ACEA, 2015, *The Automobile Industry Pocket Guide 2015-2016*

though, is the preservation of value embedded in material and resource flows for as long as possible. From that resource perspective, (processed) resource inputs from *metals* (15% of total costs of intermediate inputs), *rubbers and plastics* (5%) and *chemical products* (2%) are important as inputs for the transport equipment sector. These industries, in turn, depend in various degrees on sales to the transport equipment sector in the EU (as illustrated in Figure 6-2): the rubbers & plastics sector supplies 12.5% of its total output to the transport equipment sector as intermediate inputs, the metals sector some 11% of its total output and the chemicals sector some 1.5% of its total output[286]. The total turnover in each of these sectors was smaller than the turnover in the sectors related to the production and distribution & maintenance of motor vehicles (rubbers & plastics = 32% of total production turnover, metals = 87% and chemicals 58% based on turnover figures of 2014).

Table 6-1 Intermediate goods and services needed for production in the transport equipment sector

Cost share of intermediate inputs by sector in total costs for intermediate inputs in the transport equipment sector	
Sector	%
Transport Equipment	39%
[redacted]	
Electrical and Optical Equipment	6%
Renting of Machinery & Equipment and Other Business Activities	6%
Wholesale Trade and Commission Trade (except motor vehicles)	5%
Machinery, Nec	5%
[redacted]	
Retail Trade (except motor vehicles)	3%
Financial Intermediation	2%
[redacted]	
Inland Transport	2%
Electricity, Gas and Water Supply	1%
Other	9%
Total	**100%**

Source: Own calculations, based on World Input-Output Database (WIOD) 2011

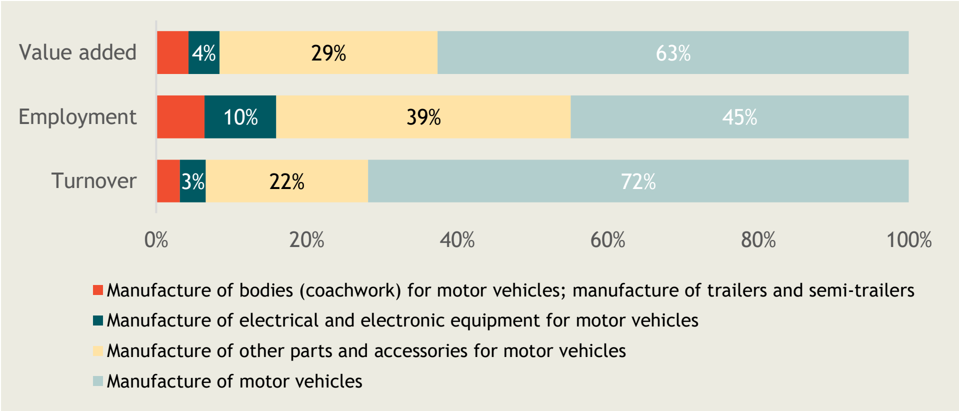
2) Production of motor vehicles

Motor vehicles are produced by assembling various parts and components. Next to the manufacturing of motor vehicles sector (assembly, final stage), we distinguish between the manufacture of bodies, electrical and electronic equipment and other parts and accessories. The majority of turnover, value added and employment is generated by the manufacturing of other parts and accessories and the assembly sectors (see Figure 6-4). However, the manufacturing of electrical and electronic equipment for motor vehicles employs a relatively large share of total workers employed in the sector (10% of the total employment versus 4% of the total value added). More about the labour intensity in these sectors can be found in the employment characteristics section. Over time, the turnover in the sector has steadily

[286] Figures calculated from the World Input Output Database (WIOD) 2011 – wiod.org

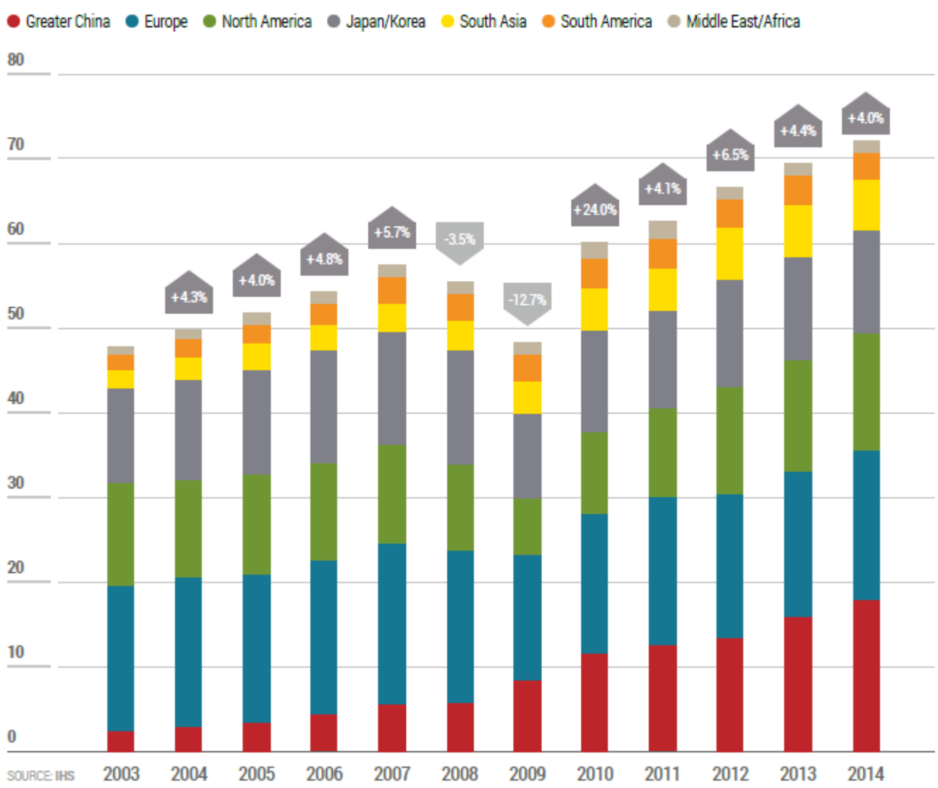
grown (see Figure 6-4 and Figure 6-5). Most of the turnover in the sector in 2014 was generated in Germany (45%), followed by France (11%) and the UK (9%)[287]. Globally, Europe produces approximately 18m new passenger cars per year, which is more than North America and equal to China (see Figure 6-5). Since the year 2000, the production of passenger cars in China has increased sharply, from approximately 2m in 2003 to 18m in 20154. Europe's market share has stayed relatively constant in the same period.

Figure 6-4 Turnover and employment in the manufacturing of motor vehicles sector



Source: Eurostat, Structural Business Statistics

Figure 6-5 World passenger car production, million units, % change 2003 to 2014



Source: ACEA, 2015, The Automobile Industry Pocket Guide 2015-2016

[287] Eurostat, Structural Business Statistics (2014, most recent data)

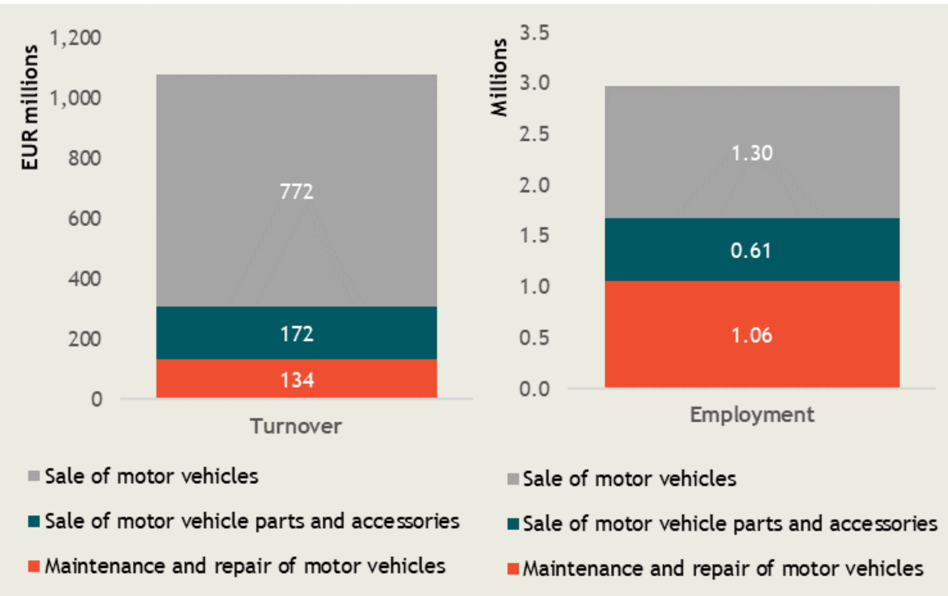
3) Distribution & use

The distribution and retailing segment of the automotive value chain has traditionally been a very important part of the sector, determining the strength of the value chain. The segment is defined by the activities relating to the sale as well as pre-sale and post-sale services, such as maintenance and repair of vehicles. Roughly speaking, there are two types of entities involved in this segment of the market: (i) new car authorised dealers that often work with franchise agreements with car manufacturers to supply and maintain cars and (ii) independent businesses that repair and service cars. This segment can be further grouped into three subsectors as shown in Figure 6-2:

1. Sale of motor vehicles
2. Sale of motor vehicle parts and accessories
3. Maintenance and repair of motor vehicles

As illustrated in Figure 6-3, the segment is economically important as it contributes to more than half of turnover and employment in the value chain. Moreover, in terms of companies, this segment hosts by far the majority of active companies in the automotive supply chain: 57% of all 811,128 companies active in the production and distribution of motor vehicles in 2014 are companies active in ‘maintenance and repair, another 26% of all companies are dealers selling cars and another 14% companies selling parts and accessories[288]. Jointly, automotive companies active in this segment of the market represent 98% of all businesses active in the sector. The sale of motor vehicles generates the largest turnover in the segment (€772m in 2014). At the same time, the maintenance and repair segment generates the lowest share of turnover, while employing the largest share of employees in the segment (see Figure 6-6).

Figure 6-6 EU turnover and employment in the distribution segment, 2014

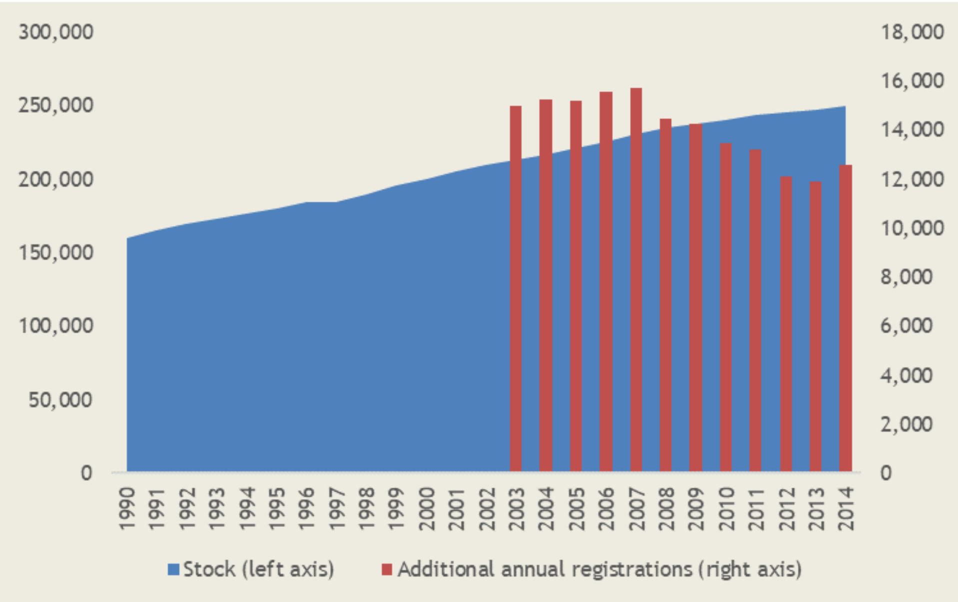


Source: Eurostat, Structural Business Statistics

[288] Analysis based on Eurostat Structural Business Statistics data

The distribution segment is also the segment that will likely be subject to significant change in the near future.[289] Strong competition in the market, digitalisation and an increasing number of clients that conduct their buying process online is challenging the large network of car dealerships in the EU. Still, according to the most recent EU-wide data available (see Figure 6-7), the stock of cars in the EU is still growing and the number of additional car registrations (sales) is on the rise again after strong decreases in sales during the crisis-years of 2008-2013. In 2014, there were nearly 250 million passenger cars on the road, amounting to an average of 0.49 cars per inhabitant in the EU (conversely, almost 1 car per two persons in the EU)[290]. The largest share of sales of new passenger cars in the EU is directly to clients who become full owners of the vehicle, either in cash or on credit. Some 5-10% of new car sales are sold via leasing contracts either to consumers directly (private lease) or to leasing companies[291].

Figure 6-7 Stock of registered cars and annual registrations in the EU



Source: Own illustration based on EU Statistical Pocketbook 2016 – EU Transport in Figures

Passenger cars are important for the mobility of Europeans. Some 72% of all kilometres travelled by Europeans in 2014 was in passenger cars. Of the remainder, some 16% is travelled by public transport facilities and another 12% by air and sea transport modes.[292] Europeans also spend a significant amount of their disposable income on the purchase and operation of passenger cars: In 2015, some 10% of the average annual EU household budget was destined for passenger cars[293]. At the same time, on average[294]:

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[289] McKinsey & Company, 2014, *Advanced Industries – Innovating Automotive Retail*

[290] EU Statistical Pocketbook 2016 – EU Transport in Figures

[291] NextContinent SAS, 2016, *Automotive Finance Study 2016*

[292] EU Statistical Pocketbook 2016 – EU Transport in Figures

[293] Eurostat, Final consumption expenditure of households by consumption purpose [nama_10_co3_p3]

[294] EllenMacArthur Foundation,2013, *Growth Wtithin: A circular economy vision for a competitive Europe* and https://www.eea.europa.eu/data-and-maps/indicators/occupancy-rates-of-passenger-vehicles/occupancy-rates-of-passenger-vehicles-1

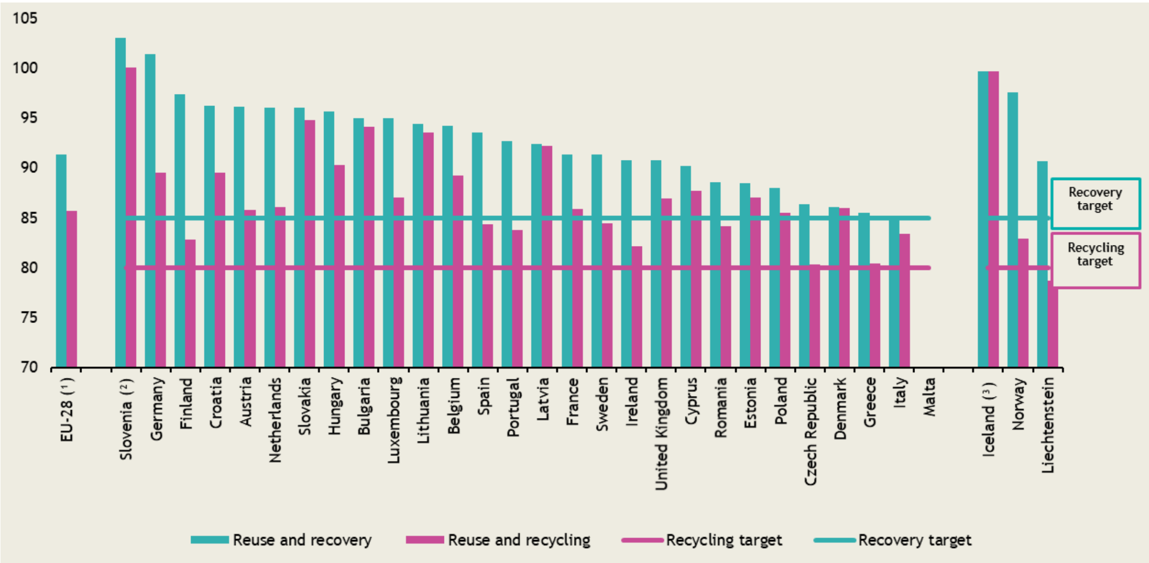
- The EU car is not in use for 92% of the time (parked)
- When in use, on average 1.6 seats in the car are occupied, *and*
- Engine losses and idling amount to 86% of fuel consumption.

These facts illustrate that the utilisation of passenger cars is not exploited to its maximum potential. Section 6.2 further elaborates this point. Due to increased innovation and regulation, the quality of cars produced continues to increase, leading to a continuously increasing average age of the EU vehicle fleet. In 2014, the average age of a car on European roads was 9.7 years, up from 8.4 years in 2006 (+16%).

4) End of Life

After its average useful life, cars are deregistered and become End-Of-Life (EOL) vehicles. In the EU, the number of EOL vehicles was in the years between 2007-2014 most often between 6 and 7 million (only in 2009 it was 9 million)[295]. Compared to the number of new vehicles produced every year (Figure 6-7), this is approximately 50%. In the EU, the Directive 2000/53/EC on End of Life vehicles regulates the management and treatment of EOL by aiming to control the generation and disposal of waste from cars and promoting recycling and reuse of EOL and their components. The Directive includes recycling targets for different phases, notably a 95%/85% target for 'reuse and recovery' and 'reuse and recycling' of the total components of the car. Disposal and landfilling of materials is therefore allowed for up to 5% of the weight of a car. The Directive stipulates that costs for waste collection and treatment should be borne by the producers of cars through an Extended Producer Responsibility (EPR) scheme[296]. Figure 6-8 shows that all EU countries met the 2014-recovery and recycling targets set by the Directive and that on average approximately 80% of EOL vehicles were recycled and 85% recovered (including energy recovery).

Figure 6-8 Reuse and recycling performance per Member State, 2014



Source: Eurostat (online data code: env_waselv)

[295] Eurostat, *End of Life vehicle statistics*, database: env_waselvt

[296] EUR-LEX Europa, Directive 2000/53/EC on end-of-life vehicles

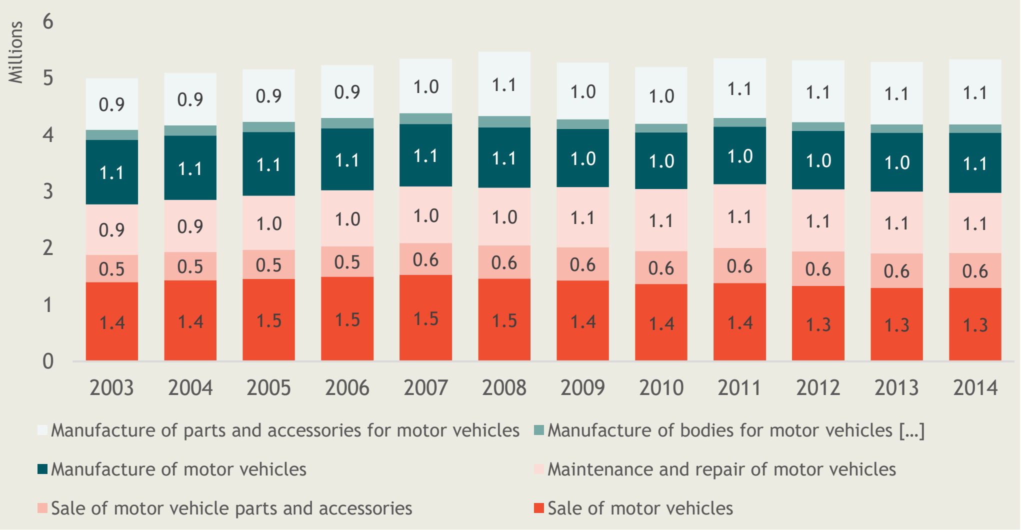
A closer look at the data also shows that from the 80% reused and recycled, approximately 9% of the materials were directly reused without processing. Still some 9% of the total weight of ELVs were disposed of in 2014. This share is expected to decline to 5% in the coming years due to the increased targets since 2015.

Employment characteristics

As explained in the previous subsection, the manufacturing and distribution of motor vehicles sectors in the EU directly employed more than 5 million workers in the EU in 2014. These were approximately evenly split between jobs in the distribution segment and the manufacturing segment. Beyond the manufacturing of motor vehicle segment are sectors that for example produce seating, lighting, batteries and tyres, which depend strongly on the production of cars. According to Cambridge Econometrics, Element Energy & Ricardo-AEA, total employment related to car manufacturing might add up to 10 million in the EU.[297]

Figure 6-9 shows the more detailed distribution of the total number of employees in the sector for the ten years for which data are available in Eurostat. The share of workers employed in the distribution segment has grown slightly, both in absolute terms as well as relatively with respect to the rest of the manufacturing sector in these years. The relative split of employment across the various manufacturing and distribution sub-sectors has remained relatively stable in the years from 2003-2014. The only relevant effect is that both in the distribution segment and the manufacturing segment, the employment in sales and manufacturing of parts and components has increased. In the distribution segment, the total number of jobs in the 'sale of new cars' segment (the dealers) has steadily gone down, whereas jobs in maintenance and repair have increased. This is in line with the fact that vehicle stock in the EU continues to grow and the sale of new cars flattens out (see previous subsection).

Figure 6-9 Employment related to the automotive sector in the EU, 2014

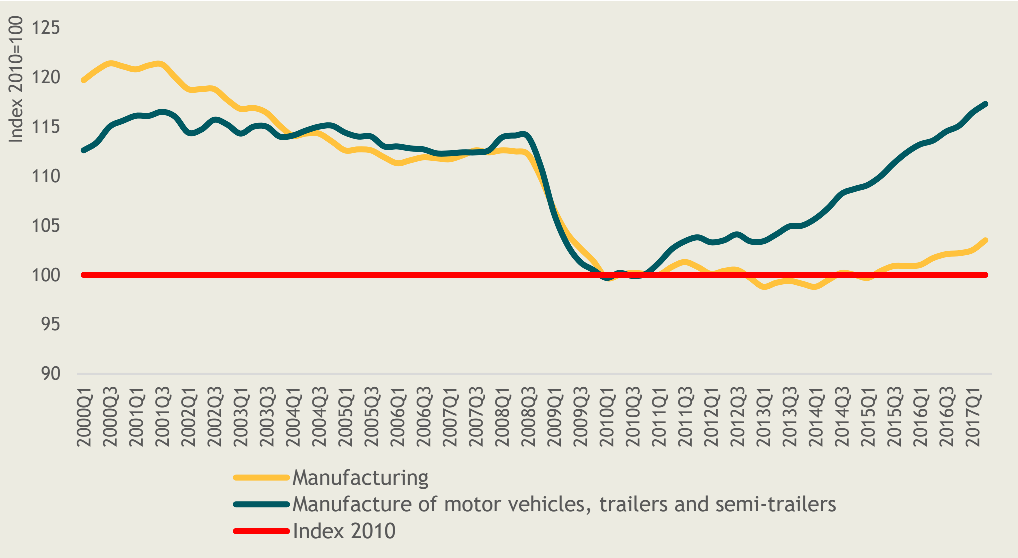


Source: Eurostat, Structural Business Statistics

[297] Cambridge Econometrics, Element Energy & Ricardo-AEA, 2013, *Fuelling Europe's Future,* available at: https://www.camecon.com/how/our-work/fuelling-europes-future/

From a more long-term perspective, we note that total employment in the manufacturing segment of the automotive value chain is currently back at the level it was between 2000 and 2008. During the crisis in 2009, many workers were laid off, just like in the remainder of the manufacturing sector in the EU (see Figure 6-10). However, the remainder of the manufacturing sector has not yet returned to pre-crisis employment levels and employment in the entire manufacturing sector was only 4% higher in 2017 than in 2010.

Figure 6-10 Labour input in motor vehicles and manufacturing sector 2000-2017



Source: Eurostat

Occupations in the motor vehicle sector

It is important to know more about the *type of jobs* in the sector, next to the *volume of jobs* that was discussed above. The type of jobs (or occupations) namely represent more a combination of skillsets that workers in the sector possess. This is relevant to know for the employment implications of the circular economy in the sector as circular actions might force the workers to change their tasks and routines in the job. The occupations present in the sector are presented in Table 6-2 below (based on the ISCO classification mapped to the Cedefop 41-industry definition of motor manufacturing).. Eight 2-digit occupational groups represent three quarters (76.3%) of motor vehicle jobs. A large share of the workers in the sector are *Metal, machinery and related trades* workers (18.4%) and *Assemblers* (13.9%). Due to increased automation and increased efficiency in the sector, the number of these type of workers needed in the motor vehicle sector is expected to decline between by 4.8% and 2.8% respectively between 2015 and 2025. Though for other relevant occupations in the sector, total employment is expected to increase strongly, such as for science and engineering professionals. In the aggregate, these data also show that total employment **in the manufacturing of motor vehicles sector is expected to increase towards 2025, by 4%.** It is important to note that these projections are based on historic trends and on a continuation of the business as usual. The implications of the circular economy actions in the sector specifically are discussed in the next section.

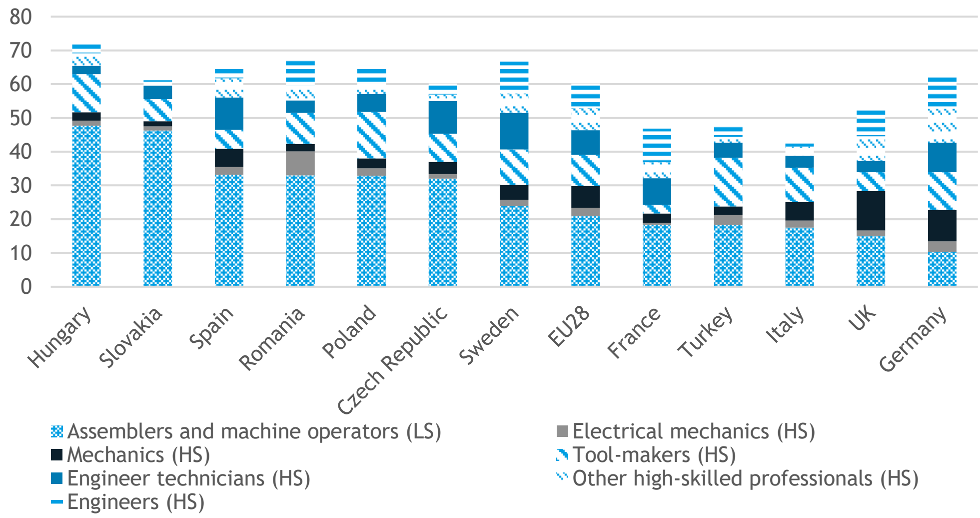
Table 6-2 Top jobs – Motor vehicle

Rank	ISCO Occupational Group (and ranking by volume for manufacturing)	Employment 2015 (,000)	Share of sector employment	Forecast growth (% share) 2015-2025
1	72. Metal, machinery and related trades workers (#1)	435	18.%	-4.8%
2	82. Assemblers (#9)	330	13.9%	-2.8%
3	31. Science and engineering associate professionals (#4)	278	11.7%	-0.1%
4	21. Science and engineering professionals (#6)	227	9.6%	3.1%
5	81. Stationary plant and machine operators (#2)	189	8.0%	2.2%
6	93. Labourers in mining, construction, manufacturing and transport (#5)	143	6.1%	1.5%
7	43. Numerical and material recording clerks (#8)	117	4.9%	-0.6%
8	33. Business and administration associate professionals (#7)	88	3.7%	0.2%
9	75. Food processing, wood working, garment and other craft and related trades (#3)	73	3.1%	-0.2%
10	24. Business and administration professionals (#14)	70	3.0%	0.8%
	Total	**2 369**	**100%**	**4.1%**

Source: Cedefop Forecast (EU-28)

Especially, the occupations that resemble more sophisticated tasks are expected to gain importance in terms of employment shares in the sector: *Science and engineering professionals (3.1%)* and *stationary plant and machine operations (2.2%).* These predictions indicate that the sector is expected to further innovate and focus on research and development, as well as increasingly use robots and automation in its production processes, using 'stationary' staff.

Figure 6-11: Employment shares in the automotive sector per country



Source: Cambridge Econometrics, Element Energy & Ricardo-AEA, 2013, *Fuelling Europe's Future*

More detailed data from a study for the European Climate Foundation[298] corroborates the findings that a large share of employment in the automotive

[298] Cambridge Econometrics, Element Energy & Ricardo-AEA, 2013, *Fuelling Europe's Future*

sector relates to low-skilled production line workers. Figure 6-11 also clearly illustrates that the employment shares in the sector vary significantly across the EU. Countries which host the headquarters of major European car manufacturers – like Germany and France – focus on the knowledge-intensive production activities and employ a large share of graduate occupations in the sector, such as engineering, and low shares in occupations which require less skills like *assemblers and machine operators*. The reverse is true for countries in Southern and Eastern Europe where most of the production and assembly lines are located. The share of engineers in sectoral employment there can be as low as 2% (Italy), but where the share of *assemblers and machine operation*s (low-skilled), can account for almost half of total sectoral employment (Hungary).

Table 6-2 and Figure 6-11 show that the occupations which are expected to experience job losses towards 2035, are currently also the most important in volume. For some countries where such occupations constitute a large share of employment in the sector, such as in Southern and Eastern Europe, this could imply an overall decrease of employment in the sector as employment in assembling occupations constitutes an important share of employment in relation to skill intensive occupations. In Hungary for instance, there are 10 times more assembling occupations than engineering jobs.

Given the transformation the sector is already undergoing (due to the rise of electric and autonomous vehicles), the task descriptions of the traditional occupations in the sector might change regardless of the circular economy. Table 6-3 illustrates this for a motor vehicle mechanic, by illustrating which of his/her typical skills are sector-specific and which are cross-sector relevant. Overall, a large share of his/her skills seem to be transferable to other sectors, making mechanics and repairers occupations somewhat resilient to change in the sector.

Table 6-3 Motor vehicle mechanics and repairers (ISCO 7231): Skills links

Key tasks	Selected essential skills/competences	Skills reusability and links
"Tasks include - (a) detecting and diagnosing faults in engines and parts; (b) fitting, examining, testing and servicing motor vehicle and motorcycle engines; (c) replacing engine components or complete engines; (d) fitting, examining, adjusting, dismantling, rebuilding and replacing defective parts of motor vehicles; (e) installing or adjusting motors and brakes, and adjusting steering or other parts of motor vehicles; (f) installing, adjusting, servicing and replacing mechatronics components of motor vehicles;	Perform manual work autonomously	**Sector-specific:** Although links to roles in other transport industries
	Repair vehicle electrical systems	**Sector-specific:** Narrowly focused on certain technician repair roles
	Use traditional toolbox tools	**Cross-sector:** Applies to other removal and handyman occupations outside of the motor vehicle sector
	Perform technical tasks with great care	**Cross-sector:** Applies to roles relating to medical devices
	Think analytically	**Cross-sector:** Widely-applicable skill found in a range of mathematically-related roles across numerous sectors

Key tasks	Selected essential skills/competences	Skills reusability and links
(g) performing scheduled maintenance services, such as oil changes, lubrications and engine tune-ups, to achieve smoother running of vehicles and ensure compliance with pollution regulations; (h) reassembling engines and parts after being repaired.		(pharmaceuticals, transport, public service roles)
	Apply health and safety standards	**Cross-sector:** Found across a wide range of manufacturing-related roles, as well as in transport and retail, among other sectors

Source: ESCO Version 1.0

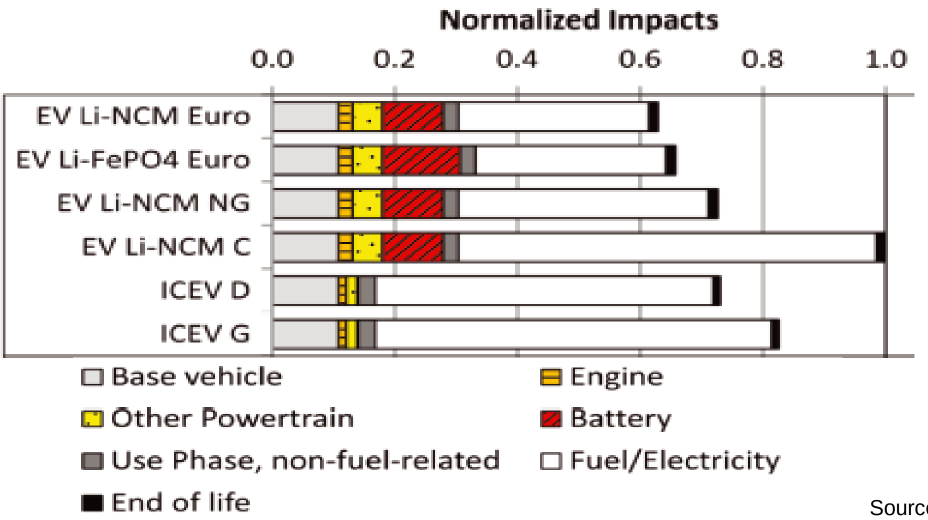
Resource and environmental characteristics

During its entire lifetime, a car has an environmental and resource impact – from the moment it is constructed (due to raw materials extraction and the environmental effects associated with production facilities), to its energy use during the use phase and in the End-Of-Life stage when a car is deconstructed for waste treatment. Life Cycle Assessments (LCAs) are tools that calculate the environmental impacts of a product (in this case a car) across all its life cycle stages and allows you to compare the relative environmental impacts across all life cycle stages.

Figure 6-12 shows the environmental impact of six types of passenger cars in terms of Green House Gas (GHG) emissions for all its relevant life cycle stages. The six types of cars differ with respect to their powertrain: Electric Vehicles (EV) and the ‘regular’ Internal Combustion Engine Vehicles (ICEV) that use gasoline and diesel as energy sources. The figure already shows that most of the environmental impacts of passenger cars is created during its use phase from burning fuel or using electricity (the white bars). This is much larger than the combined environmental impacts from the production of the car, especially for ICEVs: basic vehicle, engine, other powertrain and battery. That is why it is also important to remember that the environmental impact of an electric vehicle depends on the type of fuels used to generate electricity in the country. The figure shows how two different types of electric vehicles (based on their battery type - Li-NCM and FePO4) can have a different environmental impact depending on the energy source used to generate the electricity: the European average electricity mix (Euro), natural gas (NG) or coal (C). The environmental impact during the production phase is mainly due to the extraction of minerals and other materials. Currently, these are mostly ferrous metals (62.2%), plastics (12.2%), aluminium (7.0%), non-ferrous metals (1.3%) and copper (1%).[299] As the figure shows, in the production phase, EVs have a substantially larger global warming potential than in ICEVs. Even though the engine is only marginally worse, the battery and other powertrains cause significant environmental impact (due to the resources needed, especially for batteries, such as rare earths and metals).

[299] Messagie, Macharis & Van Mierlo, 2013, *Key outcomes from life cycle assessment of vehicles, a state of the art literature review*

Figure 6-12: Global Warming Potential (GHG emissions) EVs vs. ICEs



Source: Hawkings, 2012, *Comparative environmental life cycle assessment of conventional and electric vehicles*

Indeed, the use phase is the key phase in analysing the environmental impact of cars since the effects outweigh the global warming potential of the production phase in all cases. The strong environmental advantages of EVs compared to ICEVs are evident: except for the EV which is powered by coal, the global warming potential in the use phase is much lower for all EVs than for ICEVs. The reduction in the global warming potential which can be achieved by EVs is estimated to be between 10% to 27% compared to ICEVs.

The environmental impact of the EOL phase is very small compared to the first two phases and they do not differ substantially between cars. Moreover, as shown in Figure 6-2, 9% of the materials are reused in the production of new products and more than 80% recycled or recovered.

Key factors shaping the future development of the sector

We continue to travel more and more in the EU. Indeed, demand for passenger transport continues to grow in the EU, albeit at a low rate. In the period 2000-2015 the number of kilometres travelled per capita in the EU28 increased with an average rate of 0.5% p.a. and the number of kilometres travelled by car per capita also increased by 0.5% per year[300]. Demand for transport is expected to continue growing by 0.9% p.a. in the period 2015-2030 and 0.6% p.a. in the period 2030-2050. We therefore are expected to continue travelling more, though the rate of increase is likely to flatten out towards 2050. The largest part of the growth in this sector is expected to occur in rail travel, but even more in air travel (see Table 6-4).

Still, car ownership has grown faster than car travelling, by 19.5% in the period 2000-2013 (1.4% p.a.), with the strongest growth in Eastern Europe and almost stable car ownership in large western European countries like Germany, France and the UK[301]. When looking at these historical trends it is

[300] EC (2016). EU Reference scenario 2016 - Energy, transport and GHG emissions – trends to 2050.

[301] EEA (2017) URL:

likely that car sales will continue to grow in the future, mainly due to further predicted growth of car ownership in Eastern European countries. For the short term this is quite a realistic assumption, but there are some disruptive trends including car sharing and the rise of autonomous cars, which makes future growth in car sales uncertain.

Table 6-4 Annual historical and forecasted growth of per capita travelling (person-kms) in the EU28 by transport mode.

Transport mode	2000-2015	2015-2030	2030-2050
Total transport	**0.5%**	**0.9%**	**0.6%**
Public road transport	-0.3%	0.5%	0.4%
Private cars and motor cycles	0.5%	0.7%	0.4%
Rail	0.9%	1.5%	1.1%
Aviation	1.6%	2.2%	1.5%

Data source: EU Reference scenario 2016 - Energy, transport and GHG emissions.

The motor vehicles industry is currently undergoing dramatic changes as many of the large carmakers have started to transform their businesses away from ICEs to electric drivetrains instead (hereafter referred to as electric vehicles or EVs). Although the share of EVs of total car sales in Europe is still marginal, the market is expanding rapidly and expected to grow further as governments introduce policies to replace ICEs with more efficient and less polluting cars. In 2016, 1.3% of the light duty vehicle sales consisted of plug-in hybrids (PHEVs). The total fleet of electric vehicles in Europe grew to about 17.1 million units in the same year[302]. The share of battery electric vehicles (BEVs) in total EV sales is, however, still relatively small.

Some predict that within a decade the complete market for new passenger cars will shift to EVs. ING expects that the price for ICEs and BEVs will break even between 2023 and 2028 and that by 2035, 100% of new car sales will be battery electric vehicles[303]. Others expect that ICEs will remain dominant until 2035 if the international community does not implement ambitious climate policies and until 2025 if transport policies will be implemented that aim to achieve the 2ºC warming target[304]. Additionally, this study expects that fuel cell EVs, which are fuelled by hydrogen, will gain importance, especially for larger vehicles.

Next to the advent of EVs, autonomous vehicles are on the rise. Many large technology companies including Google, Apple and UBER are investing in this autonomous car technology, as well as some car manufacturers such as Tesla. Tesla already equips all its cars with an autopilot today and the company expects to release a car with autonomy level 5, where the driver can sleep in the car while driving, by 2019[305]. Market forecasts by McKinsey estimate that by 2030, 15% of the new cars sold might be autonomous[306].

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302 URL: http://www.ev-volumes.com/country/total-euefta-plug-in-vehicle-volumes-2/, retrieved on: 7-9-2017

303 ING (2017) Breakthrough of electric vehicle threatens European car industry.

304 McKinsey & Amsterdam Round Tables (2014) EVolution – Electric vehicles in Europe – gearing up for a new phase?

305 URL: https://electrek.co/2017/04/29/elon-musk-tesla-plan-level-5-full-autonomous-driving/ Last retrieved on: 07-09-2017

306 McKinsey, 2016, Automotive revolution –perspective towards 2030.

Both effects will be described in more detail in the next section as they represent both an ongoing trend affecting the sector as well as circular economy actions.

6.2 Circular economy in the motor vehicles sector

This section deals with the question: What does the circular economy mean for the motor vehicles sector? For this purpose, it is worth recalling the definition of the circular economy: *An economy that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, based on three principles:* [307]

1. Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows;
2. Optimise resource yields by circulating products, components, and materials in use at the highest utility at all times […];
3. Foster system effectiveness by revealing and designing out negative externalities

In the same report, the Ellen MacArthur Foundation defined six **circular** (business) **actions** that would contribute to realising such a circular economy:

1. **Regenerate** – Shift to renewable energy and materials; reclaim and retain health of ecosystems
2. **Share** – Keep product loop speed low and maximise utilisation of products by sharing their use among peers;
3. **Optimise** – Increase performance and efficiency of a product; optimise the supply chain by removing waste; leverage big data and automate
4. **Loop –** Keep components and materials in closed loops and prioritise inner loops (sharing, repairing/maintaining, remanufacture);
5. **Virtualise –** Deliver services virtually
6. **Exchange –** Replace old materials with advanced renewable materials; choose new products/services and apply new technologies.

What do these circular actions imply for the motor vehicles sector?

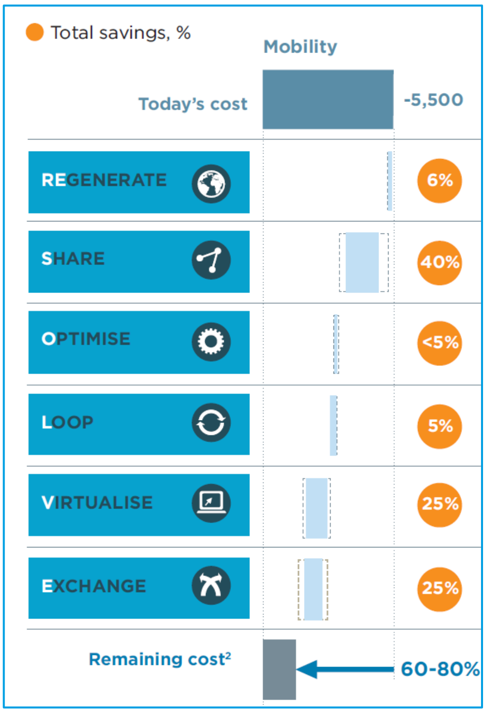
Implications of the circular economy for the motor vehicles sector

The Ellen MacArthur Foundation quantified the maximum potential of these circular actions for the future of mobility for Europeans in 2050. The results are summarised in Figure 6-13. The largest economic potential (in terms of cost savings for consumers) lie in the **Sharing, Virtualising** and **Exchanging** actions. The next sub-section will discuss these in more detail. It is worth noting that the other actions of **regenerate**, **optimise** and **loop** are not predicted to create a significant effect for consumers. As described in Section 6.1 of this chapter, the motor vehicle industry has been improving its productivity for decades already through more efficient production processes, adoption of robotic production and automated production.

[307] EllenMacArthur Foundation, 2015, *Growth Within: A circular vision for a competitive Europe*

The additional scope for optimising the supply chain (Optimise) is therefore minimal. Moreover, a large share of the raw materials needed for the production of cars are ferrous metals, which are already recycled to a large extent. The sector met its recycling and recovery targets of 80/85% in all EU Member States in 2014, indicating the already high rate of recycling in the sector. Therefore, the potential of maintaining more material value from reuse and recycling (loop) is also limited in scope, also assuming it is especially hard to increase recycling rates much further than 90%. Therefore, we conclude that the sector is already rather circular from the looping perspective of the circular economy (involving the end of life and the production phase). We therefore conclude that the largest potential from the circular economy stems most significantly from increasing the utilisation and impact of cars during the use phase in various ways.

Figure 6-13 Circular Economy potential



What is the circular economy potential in the sector?

As illustrated above (Figure 6-13), the Ellen MacArthur Foundation indeed identifies that the following actions resemble the most significant potential of the circular economy:

1. Sharing car use as well as rides (**Share**)
2. Electrification of the vehicle fleet (**Regenerate** and **Exchange**)
3. Autonomous (driverless) driving (**Virtualise**)
4. Materials evolution (**Exchange**)

Sharing

Section 1 of this chapter already described that currently the average car in the EU is parked 92% of the time and that on average carries 1.5 persons per trip, while most cars have a capacity of 4 seats. In recent years, thanks to increased digital connectivity of Europeans and increasing innovation of online solutions, internet platforms have arisen that started to exploit this potential through mostly two business models: car-sharing and ride-sharing. Car-sharing companies offer on-demand, short-term rentals of cars, often with very flexible drop-off and pick-up points. Examples are ZipCar, Autolib, DriveNow and Car2Go. Peer-to-peer sharing of cars already owned by individuals is also upcoming through initiatives such as SnappCar. These business models achieve much higher utilisation rates of cars and allow travellers to get rid of their own car. Ride-sharing businesses on the other hand intermediate between car drivers that offer space in their car on pre-announced routes they drive and travellers to these destinations. This provides travellers with another option for travel alongside their own car or public transport. Both schemes can create significant economic gains for travellers in the EU as infrequent travellers would only pay for car use when needed and ride-sharers can share the costs of the car use.

Electrification

The second important circular economy action in the sector is the switch to electric vehicles (EVs), instead of 'regular' cars based on internal combustion engines (ICEs). The transition from ICEs to EVs will also seriously affect the economics of the automotive industry. First, the switch from ICE to BEV drastically reduces the complexity of the powertrain and thereby the number of components required. ICE powertrains contain around 1,400 components, whereas a battery EV powertrain only contains around 200 components. Maintenance costs of electric vehicles could therefore also decrease compared to ICE cars, by as much as 50-70%[308], leading overall to an expected decline in total cost of ownership for consumers when the production of EVs still declines a little further (as expected).

The switch to EVs also has some substantial environmental impacts. Currently, EV batteries contain a relatively large variety of metals including relatively rare elements such as cobalt[309]. While this technology remains in its current state, then large growth of the EV market and thereby growth in battery demand might negatively affect the resource impact of the automotive industry. However, technological innovation as well as a switch from batteries to hydrogen storage might alleviate these worries. Apart from resource use, EVs can play an important role in reducing air pollution as there are no local tailpipe emissions. This is important as the air pollution levels in many European cities are far above the norms, thus posing serious public health risks[310]. Road traffic is a significant contributor to this air pollution. In case of high shares of renewable sources in electricity production, EVs can also play a role in reducing the greenhouse gas emissions of the transport sector. Lastly, electric powertrains are twice as efficient as ICEs, so need less energy input per km than ICEs and therefore also save emission per km[311].

It is important to note that the business case for EVs is in recent years strongly improving, which makes it more likely that a significant uptake of EVs will take place without much (policy) intervention. This trend was therefore already mentioned in the baseline trends affecting the development of this sector. An active circular economy policy could, however, further increase the uptake of EVs, by for further strengthening emission targets in the sector for example.

Autonomous driving

Another ongoing trend in the automotive sector is the development of fully autonomous cars: cars that are able to drive without the driver using software. Many automotive incumbents as well as Uber, Google and Tesla are rapidly making progress in building and testing cars that are able to operate independently using the current infrastructure. By itself, autonomous cars do

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308 EllenMacArthur Foundation, 2015, *Growth Within: A circular vision for a competitive Europe*

309 Richa I., Babbitt, C.W., Gaustad, G., Wang X (2014), A future perspective on lithium-ion battery waste flows from electric vehicles, *Resources, Conservation and Recycling*, **83**, pp. 63-76,

310 EEA (2016) Air quality in Europe — 2016 report.

311 Cambridge Econometrics, Element Energy & Ricardo-AEA, 2013, *Fuelling Europe's Future*

not make mobility much cheaper, but they are more fuel-efficient, reducing energy use during driving and also reducing congestion as the space between cars could be reduced significantly.[312] The most significant impact of autonomous cars, however, is mostly in their role in clever multi-modal transport systems that are based on mobility on-demand, reducing the need for car ownership significantly. Moreover, they make ride-sharing and car-sharing business (much) more potent, increasing the environmental and economic potential these business models have. Additionally, the move towards autonomous vehicles is currently driven from within the industry itself, without much regulatory push. This circular action therefore also does not depend much on a regulatory push. Still, regulatory barriers regarding privacy controls and liability could be a barrier to a potential future uptake.

Material evolution

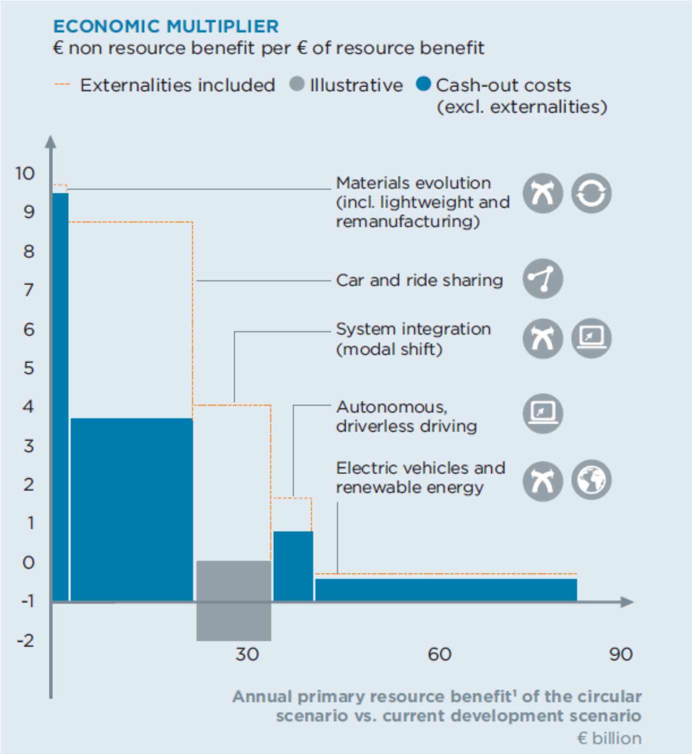
Lastly, evolution in the type and weight of materials used for the production of passenger vehicles can help to keep the value of materials maintained for longer. Lighter cars mean less emissions during the use phase and can also extend the life-time of a car. Audi has for example reduced the steel and iron content in the new A6 by 5% compared to the previous model and increased the use of light metals[313]. Moreover, a further increase in the remanufacturing and reuse of parts and components of EOL vehicles can be achieved (compared to the average of 8% now, see Figure 6-2), which would keep material value longer and can also achieve economic gains.

Altogether, these circular actions can create significant environmental and economic opportunities, through savings on the costs of mobility. At the same time, some of these gains cannot be fully attributed to the circular economy actions as there is already an endogenous level of sharing, electrification, autonomous vehicle development and material evolution ongoing in the sector. The Ellen MacArthur Foundation recognises this and quantifies the environmental and economic potential of an ambitious uptake of the four levers described above by 2050 (see Figure 6-14). In their scenario, all cars sold by 2050 would for example be autonomous and 50% of rides would be shared. The scenario also assumes a significant system-optimisation of mobility modes, so that public transport is used more intensively and cars are only used on-demand for mostly end-of-mile purposes. Such levels of ambition would likely only be reached with (significant) regulatory support.

[312] Ellen MacArthur Foundation, 2015, *Growth Within: A circular vision for a competitive Europe*

[313] Audi, 2017, Audi A6 Life Cycle Assessment, available at: https://www.audi.com/content/dam/com/EN/corporate-responsibility/product/audi_a6_life_cycle_assessment.pdf

Figure 6-14 Economic and environmental impacts of the circular economy for mobility



Source: Ellen MacArthur Foundation, 2015, Growth Within: A circular vision for a competitive Europe

Figure 6-14 shows that the bulk of the environmental gains (x-axis, width of the bars) would be reached through electrification of the vehicle fleet (more than 50% of environmental gains). The most significant economic gains (from costs savings on mobility, y-axis height of the bars) would be reached from material evolution and sharing schemes. This ambitious scenario also takes into account the fact that due to reduced costs for mobility, for example through electric vehicles, consumers will also be triggered to 'consume' (drive) more, which would offset the economic and environmental gains. This is called the **rebound effect**. Goodwin et al[314] estimate the rebound effect in the transport sector to be 50% as they find that a 10% reduction in the price of travel leads to a 5% increase in volume of travel. When assessing the economic and environmental impacts of efficiency improvements due to the circular economy, it is important to take this offsetting rebound effect into account.

Circular economy outlook

What will a circular economy in the motor vehicles sector look like towards 2030? As described in Section 6.1 of this chapter, the automotive industry is already undergoing quite significant changes, such as the rise of electric and autonomous vehicles and the increasing popularity of car sharing. These developments will, apart from any circular economy policy instruments, bring about some environmental benefits, such as reduced emissions of air pollutants and greenhouse gases. Furthermore, optimisation of the utilization rate of cars might reduce the total number of cars that is needed to provide car users with the mobility they need. This will save raw materials, parking space and demand for broader roads. On the other hand, automation of cars might

[314] Phil Goodwin, Joyce Dargay and Mark Hanly, Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review (2004), Transport Reviews, Vol. 24, No. 3, 275–292

reduce the costs or car use, which, in absence of policy intervention, will result in more car travel. Therefore, it is essential that these cars will run on sustainable energy sources, because otherwise a large part of the environmental benefits resulting from autonomous changes in the sector will be offset by increased car travelling.

Without further policy intervention we already expect that 13 percent of the car fleet will be fully electric by 2030 and that 12.5% of all the cars sold in 2030 will be autonomous (Table 6-5). The use of car-sharing and ride-sharing will increase as the transaction costs for these models come down further and it offers people cheap access to car travel. Therefore, we expect car-sharing to grow by 10% p.a. to 9.3m users in 2030, and a doubling in ride-sharing users between now and 2030 (Table 6-5). Increased uptake of car-sharing will reduce car ownership, but we assume in this scenario that most travellers will prefer to own a car and assume a reduction in car ownership of 10%. On-demand mobility solutions will only develop moderately. Transport by means of private cars will thus remain the most important transport mode.

In an ambitious circular economy scenario, the mobility sector will change more dramatically than what is expected based on the current developments. In this scenario the whole mobility system will change, where travellers have a wide range of modalities to choose from and interconnection between different transport modes is improved. Here one could think of car and bike sharing stations at train stations and other important spots in cities. Also, automation of vehicles will blur the lines between personal means of transport, public transport and taxi services as intelligent ICT systems might change the timetable based system towards more demand-driven models. The fact that UBER invests massively in autonomous cars already reflects this development and Tesla has announced to move into this market as well[315].

In such an ambitious circular economy scenario, we expect car sharing to grow by 20% p.a. to a total of 29m users in 2030 and the number of ride-sharing users will increase fourfold to 120m users in 2030 (Table 6-5)[316]. This strong growth in car-sharing and ridesharing, combined with the advent of multimodal mobility options will lead to dramatic (50%) reduction in car ownership for the participants in car-sharing schemes (guesstimate), as good access to flexible mobility is now also possible without a private car. In the ambitious case stricter policies regarding emission norms for cars are also assumed, which leads to higher shares of BEVs and FCEVs at the cost of hybrid vehicles (Table 6-5).

Table 6-5 Assumptions for different development scenarios on carsharing, ridesharing and the penetration of EV technologies and autonomous vehicles.

Business model		Baseline scenario	Moderate growth	Ambitious growth
Car-sharing	Users	2.7 million	9.3 million users (10% p.a.)	29 million users (20% p.a.)
	Cars/person	0.491 cars per person[317]	0.442 cars p/person	0.246 cars p/person

[315] URL: https://electrek.co/2017/05/01/tesla-network-elon-musk-autonomous-ride-sharing-vision/ Last retrieved on: 07-09-2017
[316] These estimates are based on calculations made in the ongoing study for DG Environment on the *Environmental Potential of the Collaborative Economy (forthcoming)*
[317] EURF (2016). Road statistics yearbook 2016.

Business model		Baseline scenario	Moderate growth	Ambitious growth
			(-10% in car ownership)	(-50% in car ownership)
	Person-kilometers	(11,000)*70%	(11,000)*70%	(11,000)*70%
	Total person-kms	**20.8bn**	**71.6 bn**	**223 bn**
	Total vehicle-kms[318]	**13.5 bn**	**46.5 bn**	**145 bn**
Ride-sharing	Users	30 million users[319]	60 million users	120 million users
	No. of trips	1.33 rides pp/year	1.33 rides pp/year	1.33 rides pp/year
	Person/trip	2.8	2.8	2.8
	Avg. trip length	360 km[320]	360 km	360 km
	Total person-kms	**40.2 bn**	**80.4 bn**	**160.9 bn**
	Total vehicle-kms	**14.4 bn**	**28.7 bn**	**57.5 bn**
Total sharing	**Person-kilometers**	**61 bn**	**152 bn**	**384 bn**
	Vehicle-kilometers	**27.9 bn**	**75.2 bn**	**202.5 bn**
	As % of person-kms driven by car[321]	**1%**	**2.7%**	**6.7%**
	As % of vehicle-kms	**0.8%**	**2.0%**	**5.5%**
Electric vehicles	**Share of EVs in total car sales**[322]			
	HEV	31%	32%	25%
	PHEV	5%	21%	30%
	BEV	2%	13%	21%
	FCEVs	0%	5%	11%
Autonomous vehicles	**As a % of total cars in EU car fleet**[323]	0%	12.5%	25%

Employment implications of the CE transition

The transition towards a circular economy can result in significant impacts on employment in the motor vehicle as well as related sectors. We distinguish three dimensions of impacts:

1. The volume effect
2. The skill effect
3. The learning and cross-sectoral effect

Volume effect

[318] Assuming the standard 1.54 persons per ride as in the baseline for all scenarios
[319] Estimate based on total number of 40m users worldwide: https://www.forbes.com/sites/rawnshah/2016/02/21/driving-ridesharing-success-at-blablacar-with-online-community/#26c5b1073b51
[320] BlaBlacar (2017**).** Average trip length of Blablacar trips in the UK. URL: https://www.blablacar.co.uk/blablalife/going-places/womens-day-at-blablacar
[321] These self-derived estimates are in line with the predications made by the EllenMacArthur Foundation (2015), who predict car- and ride-sharing schemes to represent 5% of person-kms in 2030
[322] McKinsey & Amsterdam Round Tables (2014) EVolution – Electric vehicles in Europe – gearing up for a new phase? & PRIMES reference scenario (for baseline)
[323] EllenMacArthur Foundation, 2015, Growth Within: A circular vision for a competitive Europe

Holding everything else equal, the increase in utilisation of cars during the use phase from car-sharing schemes, will reduce the need for new cars in the future. The key driver of the volume effect is the increase in the utilisation rate of cars due to an increase in car sharing (1) and car usage (i.e. decreasing the time that a car is parked). As this action will cause a single car to be used more often and to carry more passengers, individuals will need fewer cars and the overall demand for cars will decrease. Reduced demand for new vehicles, will reduce output in the sector and consequently also lower input. This potential circular action was not included in the forecast made by CEDEFOP in Table 6-2, in which industry employment is expected to grow by 4% towards 2025.

The technological transformation towards EVs will have similar effects. The labour requirement for BEV production is much lower than that for ICE vehicles[324]. They also require far less vehicle maintenance compared to conventional vehicles. Thus, employment in this segment of the industry could decline due to reduced demand for the products.

Material evolution and autonomous cars are in themselves not expected to create a significant impact on the volume of employment in the sector, whereas the system optimisation of transport modes could also reduce the need for cars and thus negatively affect the volume of occupations.

Skill effect

Besides the absolute decline in the demand for new cars, the technological CE evolutions towards EVs (circular action 2) and autonomous cars (circular action 3) also alters the required skills in the production and maintenance of cars.

The rise of EVs and the development of autonomous vehicles will only reinforce the current trend of the rising demand for high-skilled labour (like software developers and engineers) and lower the relative demand for low-skilled labour. The production and assembling of new cars involves more skills compared to the production of conventional cars. For example, due to the risk of exposure to high voltage electricity[325].

Thus, the current decreasing trend in low-skilled employment in the automotive industry (such as assembling) is expected to intensify because of the CE transition.

Learning and cross-sectional effect

The skill effect on itself is not necessarily a threat to low-skilled employees. If employees can learn the new set of skills which is required in the CE automotive industry they will not be effected. Moreover, if employees whose job in the car industry is dissolved can easily find employment in a different sector, the negative sectoral employment effects remain moderate.

Yet, several caveats to learn arise from the technological consequences of the transition towards CE. To start with, some employees could face difficulties in mastering the new techniques and skills. Moreover, employers could be reluctant to provide this training to employees close to retirement age as this could be considered too expensive.

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[324] ING (2017) Breakthrough of electric vehicle threatens European car industry.

[325] Cambridge Econometrics, Element Energy & Ricardo-AEA, 2013, *Fuelling Europe's Future*

Moreover, whereas high-skilled employees in the car industry possess a set of skills which can be applied across different sectors, the set of skills for low-skilled workers is more industry specific (see Table 6-3). This implies that potential job losses would harm this segment of the industry even harder.

Thus, there are several labour market risks in the transition towards CE. First, the volume effect could lower overall employment in the sector. Second, due to the skill effect and the learning and cross-sectoral effect, CE could have negative consequences for low-skilled workers within the industry.

6.3 Modelling inputs (E3ME)

As explained in section 6.2, circular economy actions have a large potential to transform the motor vehicles sector and the entire mobility system in the EU. Currently, approximately 75% of passenger kilometres travelled are made in passenger vehicles, which are largely driven by ICEs. Important developments are already ongoing and will transform the sector, such as sharing, electrification and autonomous vehicles. These trends are in line with the circular economy mindset. We expect particularly the uptake of electric vehicles to further increase without many circular economy policies. The **baseline** scenario for the world in 2030 therefore assumes an increase in penetration of electric vehicles but not much additional impacts from the circular economy. The **moderate** circular economy scenario assumes a world with further uptake of sharing, autonomous vehicles and electric vehicles as well as efficiency improvements from the ‘evolution in materials’ circular economy lever. The **ambitious s**cenario for 2030 is the most circular scenario in which electric vehicles, sharing, autonomous vehicles and evolution in materials would have even higher uptake rates in line with what would be realistic to expect when policies would be designed for large efficiency improvements in the entire transport system. The detailed assumptions and calculations for the size of the changes for the two scenarios were presented in Table 6-5. The full adoption of a multi-model transport system based on on-demand mobility where the passenger car would only be used in sharing style for ‘last-mile’ solutions (as presented in the EllenMacArthur study[326]) is however considered too ambitious for 2030 and therefore not considered for the next modelling step.

Table 6-6 shows for these assumed scenarios which effects from the circular economy are expected and how these circular economy transformations are proposed to be modelled in the E3ME model.

[326] EllenMacArthur Foundation, 2015, Growth Within: A circular vision for a competitive Europe

Table 6-6 Overview scenarios and modelling inputs

#	CE action	Modelling implication			E3ME modelling input	
		Dimension	*What?*		*Moderate scenario*	*Ambitious scenario*
1	**Sharing** [Car-sharing and ride-sharing at 2.5-5% of car kms in 2030]	Economic	Decrease in cost of mobility by car	Households can save costs by sharing models on expenditure to drive a passenger car	Spending on purchase and operation of vehicles down by **5 & 5% respectively** [a]	Spending on purchase and operation of vehicles down by **10% & 10% respectively** [a]
		Energy	Less energy use due to fewer vehicle kms	Fewer vehicle kilometres due to (i) increase in utilization of cars from 1.54 to 2.8 persons per ride by 2030 for users expected to participate in *ride-sharing* and (ii) 30% less person-kms driven by car-sharing users	Savings from ride-sharing and car-sharing business model amount to **86bn less vehicle kms in 2030** compared to the baseline (*30.7 ktoe/bn pkm = **2623 ktoe less energy** used by passenger cars **= 1.5% less energy used by cars in 2030)**	Savings from ride-sharing and car-sharing business model amount to **194bn less vehicle kms in 2030** compared to the baseline (*30.7 ktoe/bn pkm = **5949 ktoe less energy** used by passenger cars **= 3.4% less energy used by cars in 2030)**
		Environmental	Less emissions from fewer vehicle kms	*Included in the E3ME model through the reduction in energy use [1.5-3.4% less]*		
2	**Electric vehicles** [14% of car kms in 2030]	Economic	Lower cost of car ownership	Households can save costs by driving electric vehicles due to their predicted lower cost of maintenance and operation	Reduce household expenditure 'operation of vehicles' **30% gross by 2030, 15% net** (including rebound from cheaper driving)[b]	Reduce household expenditure 'operation of vehicles' **50% gross by 2030, 25% net** (including rebound from cheaper driving)[b]
			Rebound in volume due to lower costs	Due to the lower costs of car-ownership and operation, people start driving more by an estimated 50% (based on	*Included in the above*	

#	CE action	Modelling implication: Dimension	Modelling implication: What?		E3ME modelling input: Moderate scenario	E3ME modelling input: Ambitious scenario
				elasticity of 5% for 10% price decrease)[327]		
		Energy	EV engines are more energy-efficient, thus lower energy use by the sector	EV engines are 50% more efficient than ICE thus energy demand decreases	Energy used by cars decreases by 50% for the 14% of passenger car kms in 2030[c] that will be electric (=total reduction of 7% in total energy use by cars**) (=reduction of 7920 ktoe = 5% of total energy demand by cars in 2030)**	
		Environment	Reduced emissions of fleet	EV engines emissions during use phase are approximately equal to emissions from electricity production	14% of passenger car kilometers using the emissions factor of [electricity production] instead of [car transport]	
3	**Autonomous vehicles** [12.5% – 25% of passenger car kms autonomous]	Economic	Supports cost-savings through 'sharing' business model		*Autonomous vehicles mostly used in sharing-car schemes and thus they are a tool to reach the impact potential of sharing schemes covered by point #1 above*	
		Energy	Moderately lower energy use due to more efficient driving			
		Environment	Lower emissions due to moderately lower fuel use			
4	**Evolution in materials** [Increased use of remanufactured and reused materials and use of lighter materials in production]	Economic	1. Increased use of remanufactured and reused materials lowers cost of production 2. Use of lighter materials lowers fuel costs (cost of operation)		1. **2.5% lower cost on 'purchase of cars'** (assuming cost reductions are passed through)[d] 2. **5% lower fuel cost** ('operation of car')[d]	**1. 5% lower cost on 'purchase of cars'** (assuming cost reductions are passed through)[d] **2. 10% lower fuel cost** ('operation of car')[d]
		Energy	Lighter materials lowers fuel use		*Included automatically through lower fuel cost*	
		Environment	1. Lower raw material input 2. Lighter materials lower emissions during use phase		1. Reduction in use of ferrous metals by **2.5%** 2. Not included separately in the modelling, but	1. Reduction in use of ferrous metals by **5%** 2. Not included separately in the modelling, but through

[327] Phil Goodwin, Joyce Dargay and Mark Hanly, Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review (2004), Transport Reviews, Vol. 24, No. 3, 275–292

#	CE action	Modelling implication			E3ME modelling input	
		Dimension	***What?***		***Moderate scenario***	***Ambitious scenario***
					through the above fuel cost reduction	the above fuel cost reduction
5	**System-level integration**	*Development towards 2030 too uncertain to model*				
	Total	Economic	Cost of car ownership and mobility decreases		Purchase of vehicles: **-7.5%** Cost of operation: **-25%**	Purchase of vehicles: **-15%** Cost of operation: **-40%**
		Energy	Less energy input passenger cars	- Less vehicle kms (sharing) - Higher efficiency EVs - Less weight	Reduction in energy use by cars by **6.5%** (compared to ktoe energy use in baseline)	Reduction in energy use by cars by **8.4%** (compared to baseline)
		Environment	1) Less emissions from less energy use 2) Less raw material input in production	1) – Less energy use cars - Lighter materials cars 2) From lever 4	1) Automatically from energy effect above 2) Reduction in use of ferrous metals by **2.5%** in sector	1) Automatically from energy effect above 2) Reduction in use of ferrous metals by **5%**

a = €300 savings per car-sharing user per year / average EU HH expenditures on 'operation of vehicle' and 'purchase of vehicles'
b = EllenMacArthur Foundation, 2015, pp. 56
c = Cambridge Econometrics, Element Energy & Ricardo-AEA, 2013, Fuelling Europe's Future
d = author's guesstimate

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