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Circular economy potential for climate change mitigation

November 2016

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Acknowledgments

We would like to thank the experts who accepted to participate in the study and provided their inputs on how the future of circular economy in their sector will look like:

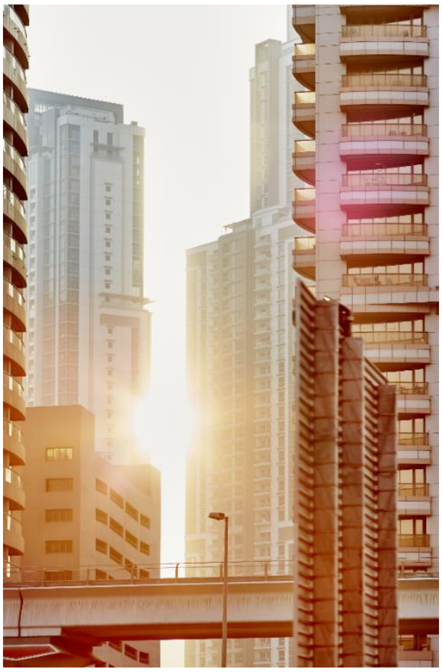
- **Fabrice Bonnifet**, Director of Sustainability & QHSE at Bouygues Group
- **Pascal Eveillard**, Director of Marketing, Strategy & Sustainable Development at Saint Gobain
- **Jean-Philippe Hermine**, Sustainability plan and environmental strategy Director at Renault

We would also like to give our special thanks to **Martin Bruckner**, Research associate at the Vienna University of Economics and Business, who helped us estimate the GHG emissions of the European consumption of goods.

This study wouldn't have been possible without the contribution of the members of the Deloitte Sustainability team: **Florence Didier-Noaro, Olivier Jan, Mathieu Hestin, Augustin Chanoine, Frederic Croison, Fabio Menten, Anton Berwald, and Louise Lecerf**.

Climate and resources: two vital assets threatened by our current economic model

Key messages



Climate and resources: two vital assets threatened by our current economic model

On a planet with finite material resources, a circular economy is a necessity to sustain, not to mention to improve, human life and well-being. Despite the triviality of this statement, our current economy has grown to be strikingly "linear" and wasteful of resources.

This economic model not only threatens the availability of the very resources that enable it, but also generates other impacts on our environment. Among these, climate change, caused by the emission of greenhouse gases, mostly originating from human consumption of fossil fuels, is driving serious concerns, and is high on the international political agenda.

Fossil energy still provides us with essential commodities: heat to warm our households, kinetic energy to transport us fast and over long distances, electricity to power our appliances, and power to dig, extract, melt, refine, and transform raw materials into the manufactured products we use everyday.

Circular economy will contribute to the reduction of GHG emissions

Since circular economy consists in keeping materials and products 'circulating' in the technosphere, it avoids the extraction and production of raw materials, and, to a certain extent, processing and manufacturing steps. It is intuitive to consider that circular economy facilitates cutting down on GHG emissions, by reducing the amount of energy needed by industrial production processes to transform primary raw materials into usable products. But to what extent?

Several recent publications propose to answer this question, but we have found that most of them propose a quite extensive definition of the circular economy (including, for example, energy efficiency measures, or the development of renewable energy sources), which makes it difficult to clearly identify the "material and product loop" effect on GHG emissions reductions.

This study is therefore, to our knowledge, the first of its kind to attempt to answer the following question:

"How much greenhouse gas emissions can we save in the EU through recirculating materials and products?"

In order to answer this question, we adopted a consumption-based (or life-cycle based) approach. Consumption-based emissions relate to the products and services that are consumed in Europe (although not necessarily produced in Europe), taking into account the total emissions necessary to deliver a product and service to the final consumer (raw material extraction, manufacturing, transportation). This approach was enabled through the use of the EXIOBASE input-output tables.

3.2 Gt CO2.eq of emissions are embedded in EU consumption, more than half of which is related to the production of material goods.

Potential savings between 13% and 66% in selected key sectors

Global Greenhouse gases emissions account for approximately 30 to 35 Gt CO_2.eq per year (excluding land use change).

Excluding direct domestic emissions (e.g. burning gasoline in a personal car, or burning fuel in an individual boiler), 3.2 Gt CO_2.eq of emissions, or **~10% of global emissions, are embedded in EU consumption, more than half of which is related to the production of material goods**. The rest is mainly due to household electricity consumption and transportation services.

We assessed the potential for reducing GHG emissions for four highly contributing sectors: food, construction, vehicles, and electrical and electronic equipment (EEE). These four sectors combined account for a third of the total emissions of 3.2Gt.

Individual analysis was carried out for each of these sectors, demonstrating a potential for savings through technically feasible and realistic circular economy strategies, between 13% and 66% (depending on the sector and the level of ambition of the circular economy scenarios).

Recycling and reuse can easily cut by a third the GHG emissions embedded in our products

On average, the potential savings on these four key sectors is around 33%, but the solutions differ:

- Food is a high contributor to our GHG emissions (~470Mt per year). Circular economy strategies include the recirculation of key nutrients (N, P) through their recovery from food waste or waste water. But the highest potential clearly lies in the reduction of food waste (which accounts for about a third of the total food produced). If food waste is cut by 50%, and 30% of nutrients are sourced from organic waste or waste water, the emissions of the sector can be cut by 13%.

- Material intensive industries that rely mostly on metals and plastics can already unleash GHG reductions through large scale, systematic recycling. Emissions embedded in vehicles and electric and electronic equipment can be reduced by 43% and 45% respectively through recycling. But the potential may be significantly increased through product reuse and lifetime extension. Even with relatively conservative assumptions regarding the reuse of products, we demonstrated that the emissions of the electrical and electronic equipment and vehicle industries can be divided by 2 or 3 respectively.
- The construction sector is also very material intensive, but relies on materials like concrete, bricks, wood, for which simple material recovery brings less benefits. In this case, recycling can contribute to a reduction of the total emissions of around 17%, and further product reuse strategies need to be implemented to reach more significant reductions (up to 34% with our assumptions).

Altogether, circular economy may lead to a reduction of approximately 550Mt CO_2 eq.

This represents a 33% reduction of the emissions related to the production of goods consumed in the EU. Keeping global warming below 2°C would require a reduction of around 50% of *total* global emissions (IPCC, 2014) by 2050. **Circular economy therefore has the potential to take us *at least* 3/5th of the way in mitigating emissions related to the production of material goods.**

Further key take-aways of this study are:

- Recycling is paramount to reducing GHG emissions, but is not sufficient to reach the full potential of circular econommy. Reuse and lifetime extension are key strategies towards a less energy and GHG intensive consumption.

- Circular economy strategies are more impactful and may lead to "quick-wins" on material (especially metal and plastics) intensive industries, like automotive and EEE.
- Our assumptions remain "non disruptive", as they take into account a moderate level of reuse; new patterns of production and consumption (including functional economy, sharing economy, etc.) may, under certain conditions, lead to further benefits.

Introduction

The circular economy: our vision

'Circular economy' is progressively becoming an essential model for decision makers in governments and businesses. However, despite this positive momentum, today's economy is still largely linear – and excessively inefficient in terms of use of natural resources and pollution generated. It is not new that this 'take-make-use-dispose' economy will have detrimental consequences in human well-being – see Box 1.

The introduction of measures in order to keep materials 'circulating' in the technosphere for longer is fundamental for a more efficient use of resources and a reduction of the negative impacts of the economy on the environment. These measures (reuse, recycling, remanufacturing, refurbishment, cascading use, etc.), of varying nature, take the form of material and product loops in the chain of consumption as represented in Figure 1. The implementation of these measures requires technological, organisational and social innovations and the best pathway for the transition from a linear model to a circular model of the economy is still to be defined.

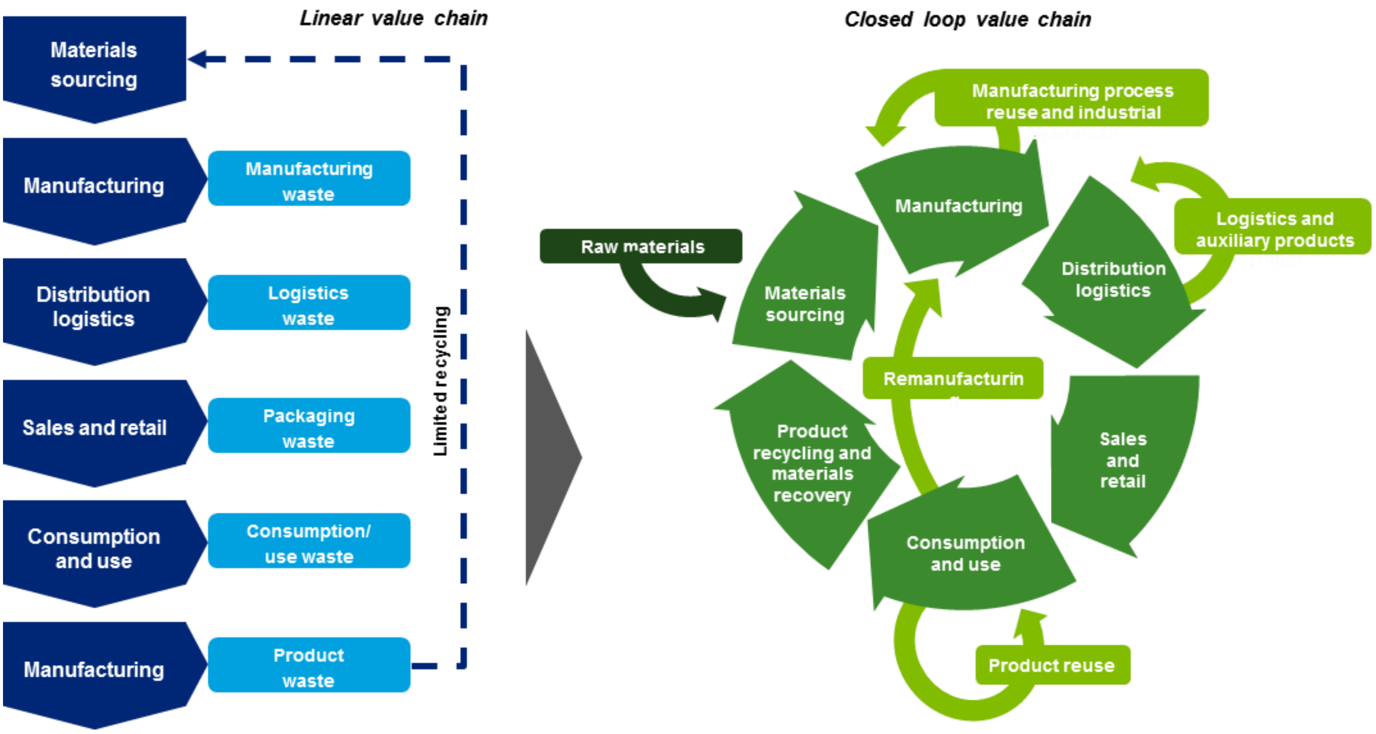


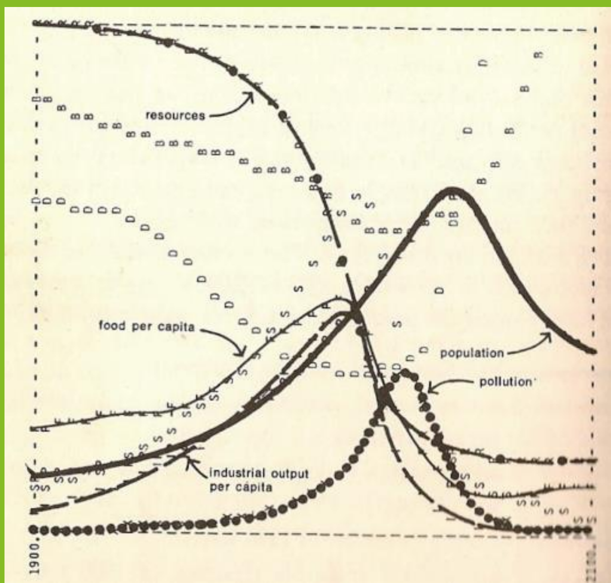
Figure 1: Simplified illustration of a linear and a circular economy

Deloitte has identified seven different types of circular economy business models, which can provide as a useful method for thinking, highlighting different logics and rationales:

- **Cradle to cradle** – A manufacturer designs waste-free products that can be integrated in fully recyclable loops or biodegradable processes;
- **Take-back management** (including reverse logistics) – A manufacturer or retailer takes back the product using reverse logistics streams – the manufacturer is responsible for the product end-of-life;
- **Deposit systems** – A manufacturer or retailer (or groups of) takes back its own products / packaging (or a common product) for reuse and may refund the customer;
- **Repair** – A manufacturer or retailer offers to take a faulty product and return it to good working conditions by replacing or repairing failing components;
- **Refurbishment** (including resale) – A manufacturer or retailer offers to update the appearance of the product by cleaning, changing fabric, painting, refinishing, etc. – as opposed to repair, refurbish is more linked to ‘cosmetic’ changes but definitions might overlap in some cases;
- **Remanufacturing** – A manufacturer disassembles and employs reusable parts on a new product – this practice is generally associated with a guarantee for functionality / performance;
- **Rematerialisation** (including recycling and cascading use) – A manufacturer recovers materials from a given product that has become waste into a reusable material that may be employed for the same purpose or not – when the conversion is into a material of reduced quality, this process is called downcycling.

The Limits to Growth

The negative consequences of the linear economy have been brought to light 44 years ago in the Club of Rome’s report “The Limits to Growth” (Meadows, et al., 1972). By using a system dynamics model to simulate the interactions of five parameters (population, food production, industrial production, pollution and consumption of non-renewable natural resources), the authors of this study conclude that a collapse of human population should occur somewhere between the year 2000 and 2100. An additional alarming fact is that the comparison of the results of this model with real data collected between 1972 and 2002 show that we are currently following the “business as usual” pathway – presented on the right.



Business as usual scenario simulation results (Source: Meadows, et al., 1972)

Circular economy and climate change mitigation

Climate change is a growing concern for governments, companies, NGOs and the civil society in general. From 1880 to 2012, the average global temperature increased by 0.85°C. Oceans have warmed, the amounts of snow and ice have diminished and sea level has risen.

Global emissions of carbon dioxide (CO_2) have increased by almost 50% since 1990.

Climate change has huge potential impacts on economy, health and safety, food production and security, and is one of the biggest challenges of the 21st century. GHG emission mitigation alternatives are largely discussed in numerous reports [1,2] . However, these focus on traditional sector-based accounting of direct GHG emissions and are not adapted to capture the potential of circular economy measures for climate change mitigation – for example, in these direct accounting approaches, 'metal industry' would appear as a separate 'industrial' sector and decisions in this sector are not reflected in other sectors, despite the fact that metals are used in a variety of products. For this, a holistic view of economic activities is necessary – looking at the whole value chain of products manufacturing (from cradle to gate).

As life-cycle based approaches develop, circular economy draws progressively more attention as a greenhouse gas (GHG) mitigation option. **There are several reasons why circular economy has a major role to play in the fight against climate change.** First, reducing, reusing and recycling avoid GHG emissions by reducing emissions from traditional waste management strategies (energy recovery, landfill). Second, and most importantly, circular economy strategies help cut GHG emissions by reducing the amount of energy needed by industrial production processes to transform primary raw materials into usable products.

The quantification of circular economy measures potential for GHG emission mitigation is challenging and numerous approaches and estimations are found in a growing body of literature – some examples are presented in Table 1.

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[1] IPCC (2014) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[2] McKinsey & Company (2009) Pathways to a Low Carbon Economy – Version 2 of the Global Greenhouse Gas Abatment Cost Curve.

Table 1: Examples of quantified circular economy impacts on climate change mitigation

Geographical Scope	Circular Economy strategies investigated	GHG emission reduction	Author and year of publication
World	Electric, shared, and autonomous vehicles, food waste reduction, regenerative and healthy food chains, passive houses, urban planning, and renewable energies	17 000 $MtCO_2$eq. in 2030	*Ellen MacArthur Foundation, 2015*
World	Recovery and reuse, lifetime extension, sharing and service model, circular design, digital platforms	7 500 $MtCO_2$eq. in 2030	*Circle Economy, Ecofys, 2016*
Europe	Recycling	176 $MtCO_2$eq. (policy targets) 278 $MtCO_2$eq. (tech. potential)	*BIO for European Commission, 2011*
Europe	Waste Directives Impact Assessment	62 $MtCO_2$eq.	*European Commission SWD(2014) 208*
France	Packaging recycling	2.1 $MtCO_2$eq. in 2013	*CDC Climat for Eco-Emballages, 2015*
Finland, France, The Netherlands, Spain and Sweden	Material efficiency in general ("substituting half of the virgin materials used with recycled materials, and doubling the product-life-time of long-lived consumer products")	Carbon emissions reduced in all countries combined between 3 and 10%, ~75 $MtCO_2$eq. by 2030	*Club of Rome (2015) The Circular Economy and Benefits for Society*

As observed in this table, the scope of strategies included in the circular economy definition varies significantly from one author to another. In the Ellen MacArthur Foundation study, the scope is very large and even energy efficiency measures and the use of renewable energies are included within the circular economy. In other studies, the scope of the circular economy is more restrictive, focusing on only one type of measure such as recycling. However, there is no study, to our knowledge, that estimates the potential for GHG emission mitigation of product and material loops at a large scale (e.g. Europe).

Based on this observed literature gap, the main goal of this study is to estimate the GHG emission benefits from the combination of measures such as recycling, remanufacturing, recovery, repair and reuse. These are the measures that fit within our more precise definition of the circular economy. This means that only non-energetic resources are part of our analysis. Moreover, it was chosen not to focus directly on strategies such as eco-design, industrial symbiosis, collaborative economy (car share, apartment share, etc.): these are very relevant strategies as they are the means favouring an optimised production, use and end-of-life of products, but this study focuses on material and product loops, which are enhanced as a result of these strategies.

Objectives and presentation of the work

As explained in the previous section, the objective of this study was to assess the potential contribution of the circular economy to GHG emissions reductions. This report is structured as follows:

- Identification of the current GHG emissions of product manufacturing and services, across all sectors and countries in Europe with a consumption-based approach.
- Assessment the potential for improving circular economy in selected sectors, through recycling and recovery, repair and reuse, remanufacturing – a focus in four of the sectors with most potential for GHG emission mitigation through circular economy is presented.

Climate change contribution of economic sectors

How to identify the worldwide economic sectors with high life-cycle GHG emissions?

Consensual sources of information such as the IPCC, the Joint Research Centre (JRC) from the European Commission, the International Energy Agency (IEA) and the World Bank generally use production-based data to represent GHG emissions from different economic sectors. Production-based emissions are not sufficient to evaluate the potential of circular economy measures in the most emitting economic sectors. A life cycle perspective is necessary so that possible improvements in all life cycle stages (i.e. from raw materials extraction through manufacturing, distribution, use and end-of life) are taken into account for a given product category.

Life Cycle Assessment (LCA) is related to the general concept of Life Cycle Thinking (LCT) that seeks to "identify possible improvements to goods and services in the form of lower environmental impacts and reduced use of resources across all life cycle stages". Adopting a life cycle perspective guarantees that the environmental effort is concentrated where it gives the largest possible environmental benefits. It also ensures that any potential improvement does not simply shift the environmental burden to another life cycle stage.

LCAs are mostly applied at a product level nowadays (e.g. Environmental Product Declarations, input for product design) – capturing environmental impacts associated to the steps physically linked in the products' life-cycle chain. Results of these micro-level analyses are useful for businesses decision making. At a whole country / world-region policy level, these bottom-up (product level) approaches are more difficult to apply. Since our objective in this study is to quantify the GHG emissions avoided by circular economy measures in Europe (continent level), a top-down LCA approach has been adopted – EXIOBASE , a multi-regional environmentally extended supply and use input-output table (MR EE I/O), was used for calculations (see Box 2 for more details). This allows for an exhaustive view of emissions in one calculation step and avoids errors from the extrapolation of product level LCA results.

What can be referred to as "macro-scale LCA" was, therefore, used for the quantification of consumption-based (or embedded) emissions from different economic sectors. By allocating production-based emissions to final products, one can identify which are the most emitting sectors and where circular economy efforts should be concentrated. Moreover, it is more convenient to analyse the circular economy potential by focusing on relevant strategies by product category than focusing at the waste management sector individually or focus on materials only.

Environmentally extended multi-regional input-output tables

Wassily Leontief received the Nobel prize in Economics in 1973 for the development of the input-output method and for its application to economic problems. An input-output model represents the quantitative interdependencies, in terms of monetary flows, between different economic sectors and regions – it assumes that each industry consumes outputs of various other industries in fixed ratios in order to produce its own unique and distinct output.

More recently, extensions to these purely monetary input-output tables have been developed in order to include environmental accounting systems to these models – see for example the multiple versions of the SEEA project , which have developed water, waste, forest and climate change accounting systems compatible with national accounting.

In this study, the EXIOBASE model has been selected for calculations. It is a database developed through numerous collaborative research projects, with contributions from NTNU, TNO, SERI, Universiteit Leiden, WU, and 2.-0 LCA Consultants. The model, for the base year 2007, has the following characteristics:

- 48 world regions (43 countries and 5 Rest of the World, RoW, regions)
- 163 economic sectors producing 200 products
- The environmental extensions include:
  - 15 types of land use,
  - 172 types of water uses,
  - pollutant flows to air and to water (CO2, CH4, N2O, SOX, NOX, NH3, CO, PM10, PM2.5, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, PAH, PCBs, PCDD, HCB, NVOC, TSP, heavy metals, etc.) – which are compatible with characterization factors for common LCA impact categories (acidification, eutrophication, photochemical oxidation, human toxicity, global warming potential)

Carbon footprint of economic sectors in Europe

The MR EE I/O database was used for the estimation of the embedded GHG emissions from the different economic sectors in Europe. Calculations were done using a Leontief inverse model, which re-allocates environmental impacts from the producer to the consumer. Calculations using this model are relatively simple but involve multiplications of large matrices (9600x9600) and therefore the mathematics software R was employed. The results of this calculation are presented in Figure 2.

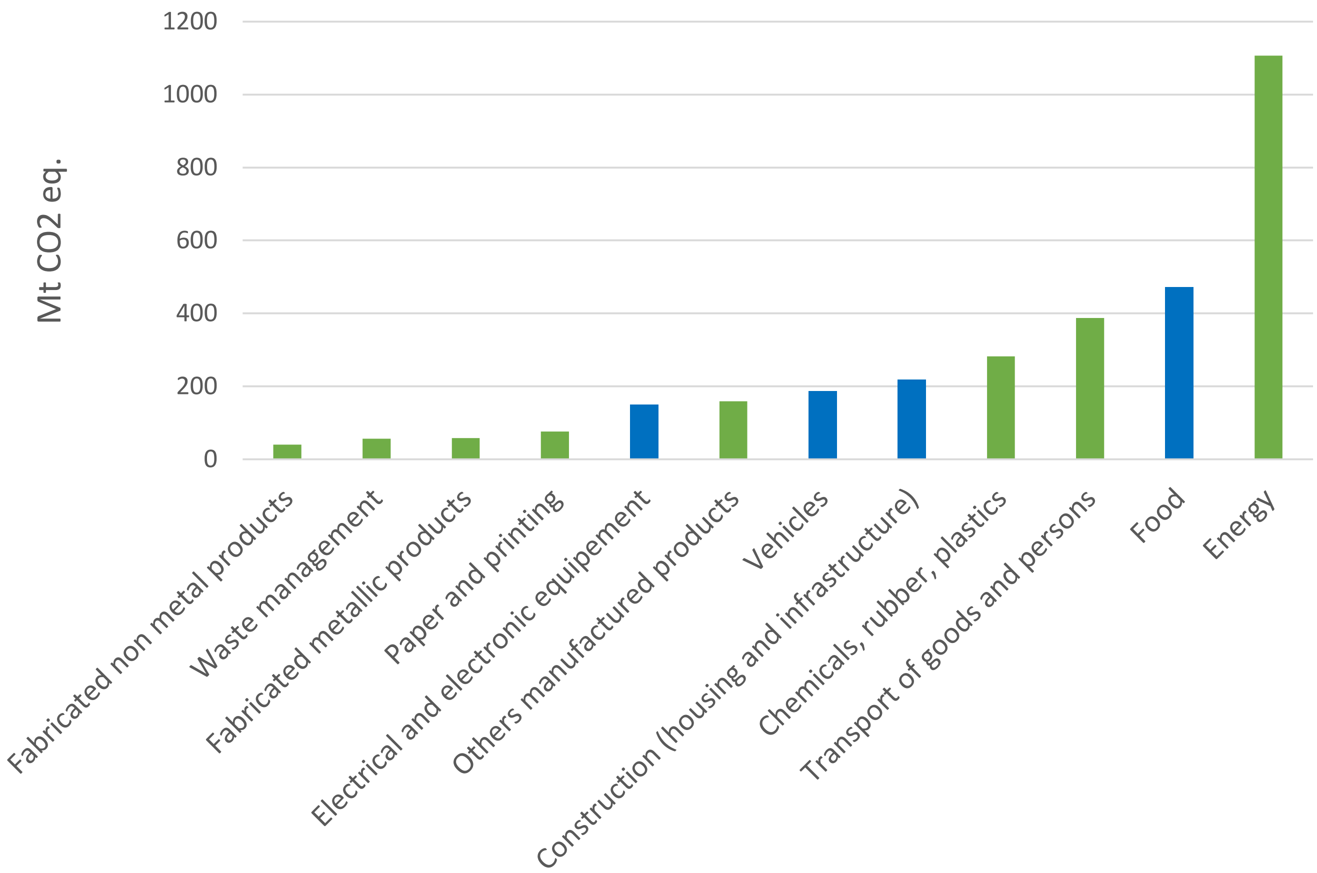

Figure 2: Embedded emissions in different economic sectors in Europe

NB: The sectors in blue are the subject of specific focus in circular economy measures in the next chapter.

How to interpret these results? The sum of the different product contributions is 3.2 Gt CO_2 eq. (about 10% of the worldwide emissions represented in EXIOBASE). These are the emissions embedded in Europe's economic activities – in other words, this corresponds to the final demand footprint for all products and services consumed in Europe. These emissions are mainly associated to fossil fuel consumptions occurring in agriculture, industry and services and it should be noted that these do not include "diffuse" emissions from the combustion of fossil fuels by final consumers (households, public authorities, NGOs). This can be illustrated by the following examples:

- In the 'Energy' category, emissions are linked to the consumption (i.e. combustion) of fossil fuels for the production of electricity, district heating and liquid transport fuels (e.g. amount of oil/natural gas burned in a refinery delivering gasoline, diesel, jet fuel, naphtha and other products). Emissions from a household burning fuel oil for private heating are not included in this category and are not represented in the figure above.
- In the 'Transport of goods and persons' category, emissions are linked to freight, public transportation systems, taxi services, car rentals, commercial flights, etc. Emissions of people driving their own private vehicles, consuming (i.e. burning) gasoline or diesel, are not included in this category and are not represented in the figure as well.

Furthermore, it should be noted that the embedded emissions in all the manufactured product categories ('Vehicles', 'Housing and infrastructures', 'Electric and electronic equipment (EEE)') are strictly those of the life cycle steps from the production of these products and not from the use phase. For example,

- emissions from fuel consumption in vehicles are not allocated to the 'Vehicle' category but are either allocated to the 'Transport of goods and persons' for transport services provided in exchange of a financial transaction or neither accounted for nor represented in Figure 2 for private transport of final consumers;
- a television (included in the 'EEE' category) consumes a certain amount of electricity, the emissions from this electricity production are not allocated to the 'EEE' category – they are allocated to the 'Energy' category.

An important consequence of using a consumption-based approach is that reported emissions are not all taking place in the European territory. If a product consumed in Europe is manufactured in China, the emissions associated to manufacturing are allocated to Europe; and if this same product is manufactured using minerals from Brazil, the emissions associated to the extraction and transportation of these minerals are allocated to Europe as well.

The product categories highlighted in green in Figure 2 are the object of a specific focus on the next sections of this report:

- Food (15% of EU embedded emissions),
- Housing and infrastructure (7% of EU embedded emissions),
- Vehicles (6% of EU embedded emissions),
- EEE (5% of EU embedded emissions).

Two criteria were taken into account for the choice of these sectors / product categories: their contribution to the total emissions and the potential of circular economy measures to be applied in the given sector.

On the contrary, some sectors / product categories have a significant contribution to the total European GHG emissions, but were excluded from further analysis for the reasons explained below.

The 'Energy' sector has the highest embedded emissions and contributes up to 35% to the total presented in Figure 2. Energy efficiency measures (improvements in the conversion of primary energy into final energy optimising resource use) are not in the scope of the circular economy measures analysed in this study. The same reasoning leads to the exclusion of the 'Transport of goods and persons' category from our analysis – the optimisation of power trains for better ratio of distance driven per fuel consumed is not a circular economy measure according to this study.

The 'Chemicals, rubber, plastics' category represents 9% of emissions presented in Figure 2. The largest contributor to this product category is the pharmaceutical / cosmetics industry. This industrial category produces the chemicals that are the most likely to be consumed directly by households or governments (hospitals). Other chemicals, plastics and rubber are most likely intermediate products (used in other industries) and, therefore, the emissions associated to their production appear with a larger contribution

The selected product categories have a strong link with the most basic human needs: alimentation, shelter, transportation and communication

Selected sectors for focus on circular economy measures: Housing and infrastructure (construction), food, electric and electronic equipment, vehicles in other product categories. Circular economy measures are not applied extensively for medication and cosmetics and were not addressed in our study.

The ‘Other manufactured products’ category includes manufactured products produced mainly from renewable resources. It was not chosen for a circular economy focus since the products included in this category are very heterogeneous (e.g. textiles, silk, leather products, tobacco, wood products) with regards to resources consumed, lifetime, etc.

Circular economy measures and potential emissions reduction in a circular economy in high impact sectors

In this section we describe our vision of the circular economy in each of the four sectors selected previously. We then analyse the current practices of the sectors in terms of resource use and management and discuss what could be achieved through circular economy.

Finally, we present the evaluation of the potential emissions reductions which could be achieved through scenarios implementing different circular economy strategies.

Food sector

Key figures

Worldwide GHG emissions from agricultural activities, as calculated by the FAO, are estimated at 5.3 Gt CO_2 eq.[3]. In Europe, the food sector is responsible for 0.47 Gt CO_2 eq. (about 15%) of embedded emissions according to our calculations (Figure 2). These emissions are related to agricultural inputs (fertilisers, pesticides, etc.) production, field emissions (CH_4, N_2O), energy resources use for cultivation (diesel consumed in tractors, electricity consumed at storage infrastructure, etc.), transportation, distribution, paper and plastics for packaging, etc.

One of the biggest levers for reducing food related GHG emissions is to reduce food waste. Globally about a third of the food for human consumption is wasted[4]. This means that about a third of all the GHG emissions in upstream steps of food supply chains are emitted in vain. Moreover, food waste is ethically unjustifiable in a world where almost 1 billion people remain undernourished[5].

[3] FAOSTAT: http://faostat3.fao.org/home/E (Emissions agriculture)
[4] FAO (2015) Global Initiative on food loss and waste reduction (http://www.fao.org/3/a-i4068e.pdf)
[5] FAO (2015) The State of Food Insecurity in the World (http://www.fao.org/3/a-i4646e.pdf)

According to the latest data collection and analysis of the European research project Fusions (Food Use for Social Innovation by Optimising Waste Prevention Strategies)[6], an estimated 88 Mt of food goes to waste each year in EU-28[7] . This equates to 173 kilograms of food waste per person. If in developing countries most of food waste is associated to post harvest losses due to more intense climate conditions and a lack of appropriate infrastructure for storage and logistics; in the EU, most of food waste occurs at **the households and processing** sectors[8].

The global UNDP objective is, by 2030, to halve per capita food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses[9]. The European Commission committed to supporting the Sustainable Development Goal target on food waste in the EU Action Plan for Circular Economy[10].

Circular economy in the food sector
According to the House of Lords report published in April 2014[11], the waste hierarchy as applied to food, translates into 'food us hierarchy', where each successive step down the hierarchy from waste prevention down towards treatment and disposal represents a loss in food value and a less desirable option, as represented below.

Figure 3: Food use hierarchy

The main circular economy strategies for the food sector are:

- **Reducing consumer food waste:** Measures mainly aim at consumer awareness of the issues associated to food waste and provide guidelines for behavioural change.

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[6] http://www.eu-fusions.org/
[7] Stenmarck A., Jensen C., et all, Etimates of European food waste levels (EU FUSIONS), March 2016
[8]Stenmarck A., Jensen C., et all, Etimates of European food waste levels (EU FUSIONS), March 2016
[9] As outlined in the Sustainable Development Goal 12.3.
[10] European Commission (2015), Closing the loop - An EU action plan for the Circular Economy
[11] House of Lords (2014), Counting the Costs of Food Waste : EU Food Waste Prevention

- **Reducing losses in retail:** Many actions can be taken by food retailers – measure food waste; better estimate demand; reduce late cancellations, sell misshaped fruits and vegetables; donate food surplus before the expiration of the "best before" to charities (e.g. a recent French Law[12] encourages retailers to donate rather than throw away food, by obliging them to sign a contract with a charity) etc.
- **Reducing losses in the food supply chain** (agricultural steps – planting, harvesting, etc., storage and transportation): As already mentioned, in Europe, these losses are much lower compared to those in developing countries, with lacking infrastructure and more intense climate conditions. However, food products consumed in Europe may have supply chains in developing countries (imported products). Therefore, optimising logistics and storage are relevant strategies for Europe as well.
- **Reducing losses in the food supply chain** (agricultural steps – planting, harvesting, etc., storage and transportation): As already mentioned, in Europe, these losses are much lower compared to those in developing countries, with lacking infrastructure and more intense climate conditions. However, food products consumed in Europe may have supply chains in developing countries (imported products). Therefore, optimising logistics and storage are relevant strategies for Europe as well.
- **Alternative valorisation of unavoidable food waste:** Animal feed, composting, bio-based materials, energy (anaerobic digestion, incineration with energy recovery). Schemes for food waste collection are essential for a large-scale adoption of these practices.
- **Packaging**: The main strategy is to find the right balance between reduced packaging (low resource use and reduced GHG emissions from transportation) and improved functionalities helping to preserve food as long as possible.
- **Nutrient recycling**: Nitrogen (N), phosphate (P) and potassium (K) are the main nutrient inputs in agriculture.
  - K is relatively abundant and does not require significant energy in processing.
  - P fertilisers are derived from phosphate rock, a mining activity product. About 85 Mt CO2 eq may be allocated to the worldwide production of P fertilisers[13]. A circular economy option for P fertilisers is the return of sewage to agricultural land. This is a controversial measure and the practice varies greatly among EU Member States. While France and the UK recycle to land about 70% of biosolids (sewage sludge – digestate produced by the wastewater industry), in the Netherlands such recycling is prohibited[14]. Experts from the MIT, target a 50% total phosphorus recovery from wastewater by 2025 for the top phosphorus consumers in the world (China, India, the United States, the European Union, and Brazil)[15].
  - Ammonia and other N fertilisers are produced using N2 – which is unlimited in the atmosphere – and hydrogen – which is most effectively produced today from methane. Finding alternative sources

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[12] https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000032036289&categorieLien=id

[13] Own calculation. Estimated from worldwide P fertilizer consumption from FAO (http://www.fao.org/3/a-av252e.pdf) and emission factor from ecoinvent.

[14] Lyberatos G, Sklivaniotis M, Angelakis A (2011) Sewage biosolids management in EU countries: Challenges and perspectives. Fresenius Environmental Bulletin 20(9):2489-2495

[15] MIT (2016) Mission 2016 – The Future of Strategic Natural Resources.

for hydrogen are essential for GHG emission reductions in this industry. A circular economy measure in this sense is the use of natural gas vented/flared from oil wells for the production of N fertiliser. The amount of methane needed for worldwide fertiliser production (90% used for N fertilisers) is equivalent to the amount that is lost in oil wells[16]. Eliminating flaring and venting has the potential to reduce about 350 Mt CO2 eq.[17] but this is not a specific circular economy measure for the food sector. Additionally, N compounds are found in concentrations of 2-4% in compost from manure and agricultural residues – these can be collected and used in agriculture as well.

Emissions of the sector and sources of emissions

Establishing a typical profile of food products is not straightforward compared to more homogeneous sectors such as the automotive and the construction sectors – the food sector comprises agricultural products and manufactured products. In other words, there are numerous food products which are consumed for the production of food products. This is illustrated in the figure below, where three products are detailed:

- Cereal grains – the biggest contributors after onsite emissions are associated to the production of fertilisers (N and P);
- Raw milk – the biggest contributors for raw milk GHG emissions are the production of cereal grains;
- Dairy products – the biggest contributor for dairy products' GHG emissions is raw milk.

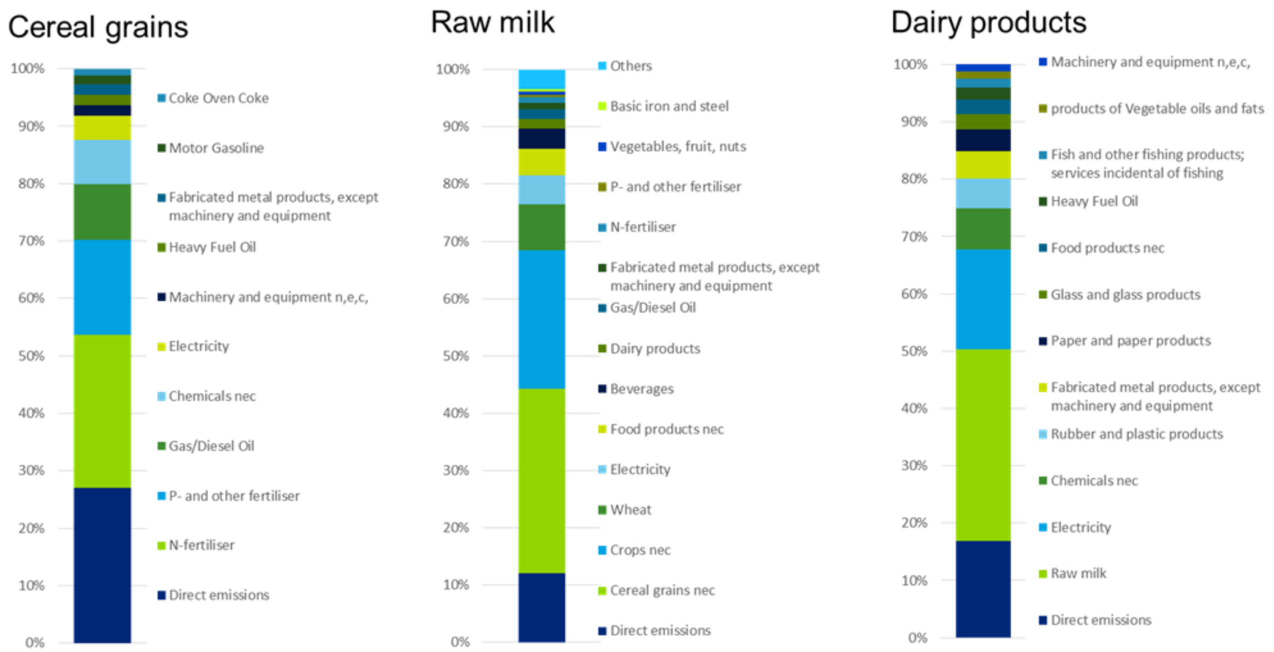

Figure 4: Examples of food product GHG emission profiles

Potential emissions reductions in a circular economy

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[16] *Dawson, CJ, Hilton, J. Fertiliser availability in a resource-limited world: Production and recycling of nitrogen and phosphorus. Food Policy 36(Supplement 1):14-14*

[17] *World Bank – Retrieved from: http://www.worldbank.org/en/programs/zero-routine-flaring-by-2030#2*

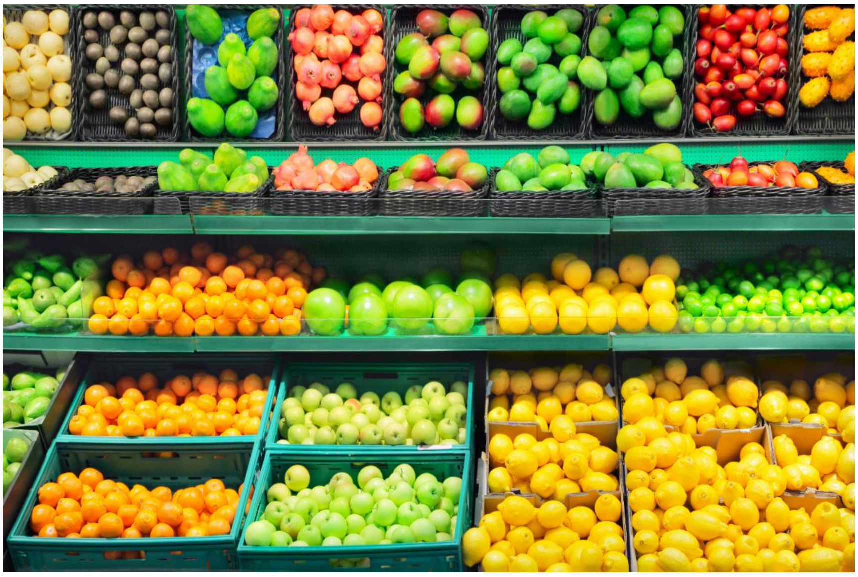
The UN Sustainable Development Goals include a specific food waste reduction target: *"by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses".* According to a recent FAO study[18], achieving this target would reduce worldwide emissions associated to food waste between 33% and 38%.

In our calculations (Figure 2), embedded emissions of the European food sector amount to 471 MtCO_2eq. We assume that one third of these emissions are linked to food waste: 157 MtCO_2 eq. Therefore, by applying circular economy measures and achieving the target of a 50% reduction of per capita food waste, between 52 and 60 MtCO_2eq[19]. can be avoided in Europe.

An extra 3 to 4 MtCO_2eq. reduction can be achieved from recycling nutrients from organic waste: phosphorous mainly returning sewage to agricultural land and nitrogen from composting. This figure is estimated based on:

- The GHG emissions from fertiliser production embedded in products consumed in Europe: 12.7 MtCO2eq. – we assume that all the fertilisers are used in the food sector;
- A recent communication from the European Commission[20], which estimates that bio-waste could substitute up to 30% of inorganic fertilisers (today, only 5% of bio-waste is *recycled* and used as fertilisers).

In summary, these circular economy measures could reduce emissions from the food sector between 55 and 64 MtCO_2eq. – 12 to 14% approximately.



[18] FAO (2015) Food wastage footprint and climate change
[19] 33% to 38% of 157 Mt
[20] http://europa.eu/rapid/press-release_MEMO-16-826_en.htm

Construction sector

Key figures

The construction sector is a significant consumer of resources. More than 30-50% of total material use in Europe goes to housing[21]. The EU27 consumed between 1.200 - 1.800 Mt of construction materials per annum for new buildings and refurbishment between 2003 and 2011[22].

Concrete, aggregate materials (sand, gravel and crushed stone) and bricks make up to 90% (by weight) of all materials used. Over half of the world's steel is used in construction[23].

821 Mt of construction and demolition waste (CDW) was generated in the EU28 in 2012 that is around 33% of all waste generated in the EU[24].

The level of recycling and material recovery of CDW varies greatly across the EU. The recovery rates achieved by MS these last years are displayed in

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[21] EEA (2010) SOER 2010 Material resources and waste, quoted by EC (2014) Resource efficiency in the building sector

[22] Ecorys (2014) Resource efficiency in the building sector

[23] WSD, quoted by the World Steel Association, Presentation of Edwin Basson, 19 April 2012: https://www.worldsteel.org/dms/internetDocumentList/downloads/media-centre/SBB_Green-Steel-Strategies/document/SBB%20Green%20Steel%20Strategies.pdf

[24] Calculation from Eurostat waste statistics. In 2012, the total waste generated in the EU-28 by all economic activities and households amounted to 2 514 million tonnes.

Figure 5. Although these figures show that high recovery rates are achievable (with a handful of Member states performing higher than 80% or event 90%), comparability is still hindered by unclear inclusion of certain "downcycling" operations such as backfilling, data quality, etc. Moreover, these general recovery rates tend to reflect the performance achieved on inert materials (concrete, bricks, etc.) which represent, by far, the largest quantities. The situation for other building materials (glass, plastics, metals, etc.) may be very different from this global picture.

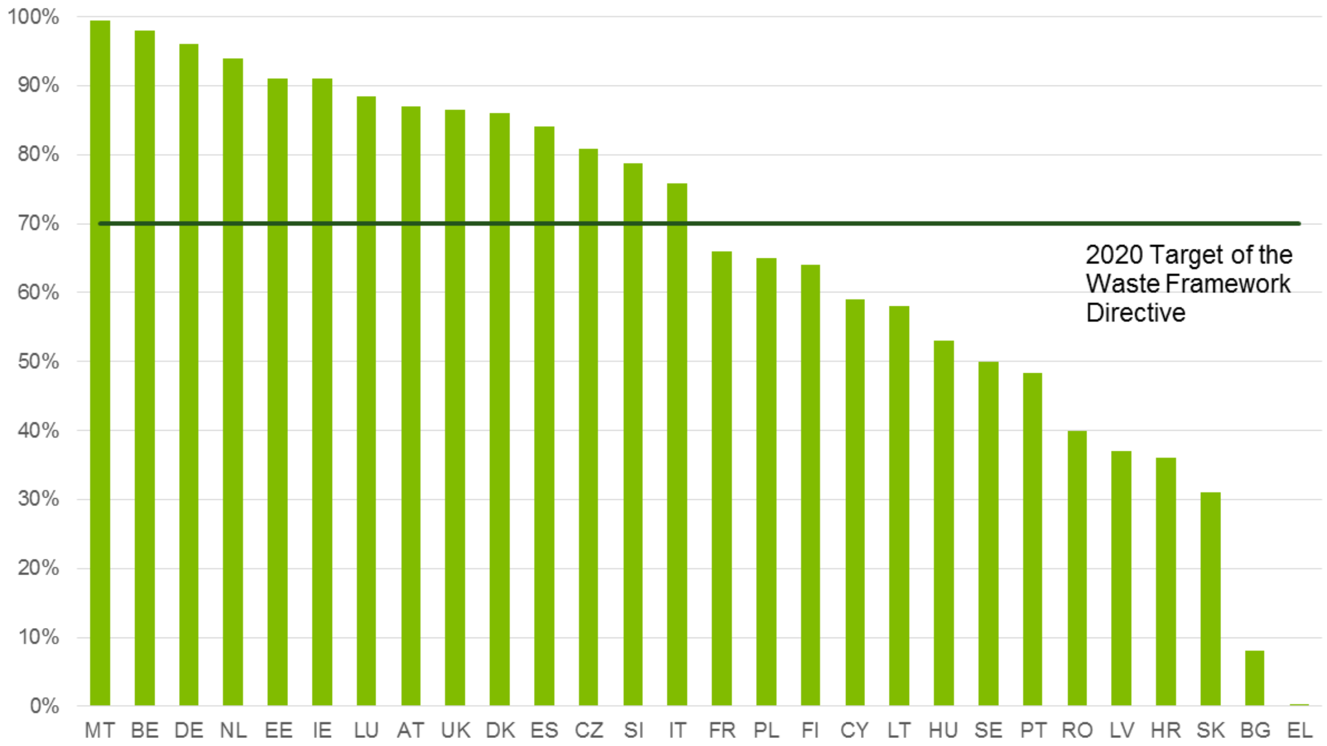

Figure 5: 2012 CDW recovery rates calculated using all available national information

Circular economy in the construction sector

Circular economy in the construction sector encompasses a wide range of initiatives, as illustrated in Figure 6.

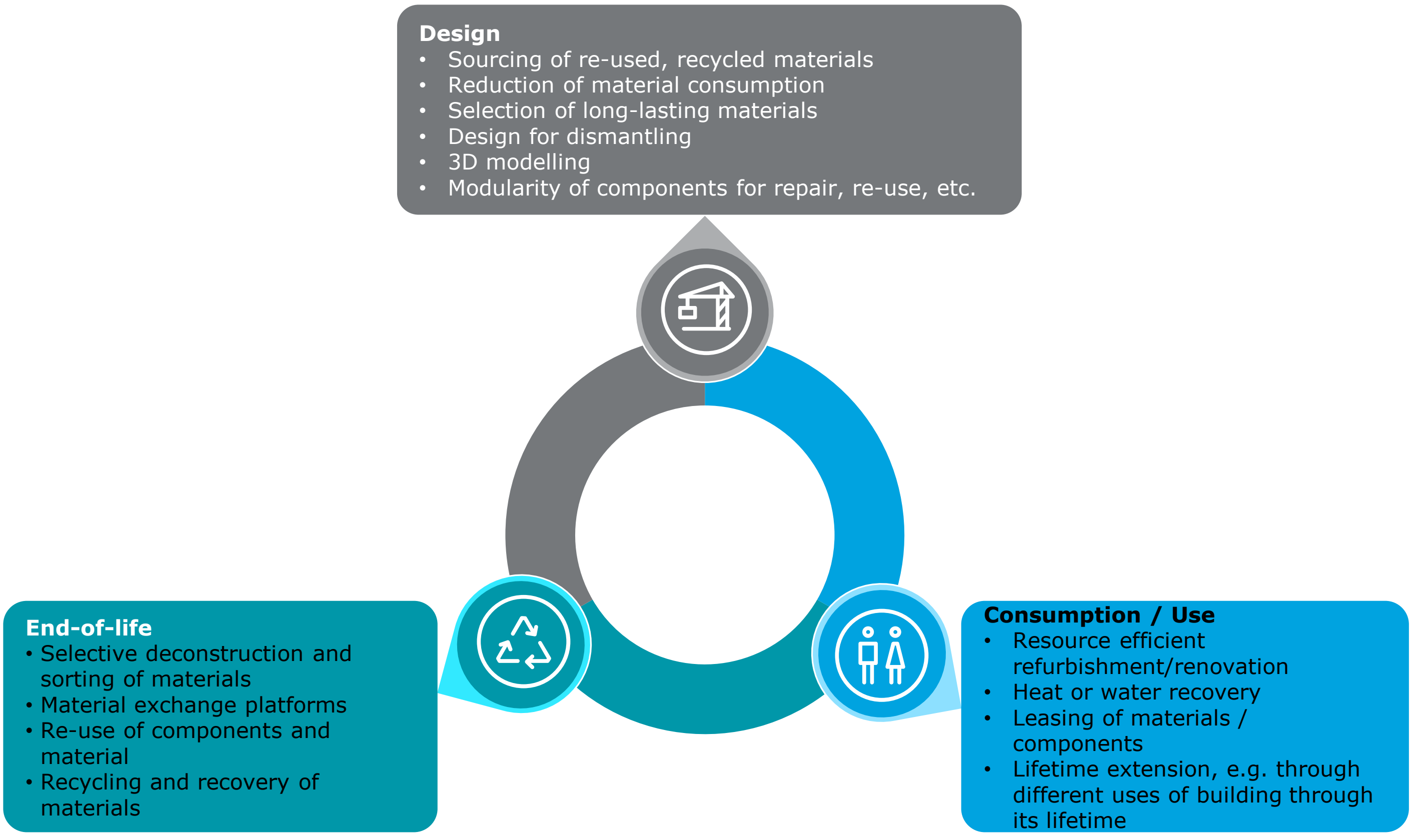

Figure 6: Circular economy in the construction sector

The present study focuses on the strategies creating material loops (reuse and recycling activities).

Companies in the sector develop new solutions to increase the reuse and recycling of CDW. 3D modelling (BIM (Building Information Modelling) technology) will make it possible to scan a building and locate reusable materials before deconstruction (Bouygues construction for example is investing in the technology[25]), material exchange platforms are emerging (such as Soldating, for the barter of soil[26]) and buildings are increasingly modular (ex: the Brummen Town Hall in the Netherlands is designed to be entirely dismantled). In addition, construction companies may keep the ownership of materials in the future, thus ensuring they are recovered at the end-of-life of the buildings.

Emissions of the sector and sources of emissions

According to our calculations, the construction sector in the EU emitted 220 Mt CO_2 eq. in 2007. Production of concrete contributed to 30 % of the total emissions. Figure 7 below shows how the emissions of the sector are broken down between the embedded emissions of the construction materials consumed, the energy supply of the sector, its direct emissions, and other less important contributors. The emissions from the energy supply and the direct emissions of the sector, which correspond to the emissions due to the electricity production and the emissions from the supply and combustion of fossil fuel during the construction process respectively, contribute 20% of

"We are now able to create buildings with positive energy. The carbon footprint of the sector has been greatly reduced. Yet, two issues remain: the impacts of people travels from-to buildings and the grey energy from materials."

Fabrice Bonnifet
Bouygues Group

[25] http://www.bimgeneration.com/
[26] https://soldating.fr/

the total emissions. The embedded emissions of the tools used for construction such as vehicles are also accounted, and included in machinery and equipment.

It is estimated that today 30% of concrete waste is recovered as aggregates for road construction or backfilling in the EU while a small part is recycled into aggregates for concrete production. Concrete could yet be re-used as precast elements (concrete blocks). On the other hand, steel is recycled up to 98% in the EU[27].

In 2010, 20% of construction plastic waste in was recycled, and 36% incinerated with energy recovery in the EU[28]. 70% of plastics used in the construction sector would yet be recoverable[29]. Bricks can also be reused or recycled e.g. as aggregates in concrete or to fill roads.

Finally, wood waste is today recycled into derived timber products (30% of wood waste) or recovered for energy (34%). Glass is mostly recovered with other materials as aggregates.

[27] Interview with Bouygues
[28] PlasticsEurope (2010) Analysis of recovery of plastic waste in the building and construction sector
[29] Life Project APRICOD (Assessing the Potential of Plastics Recycling in the Construction and Demolition activities), Guide "Towards Sustainable Plastic Construction and Demolition Waste Management in Europe"

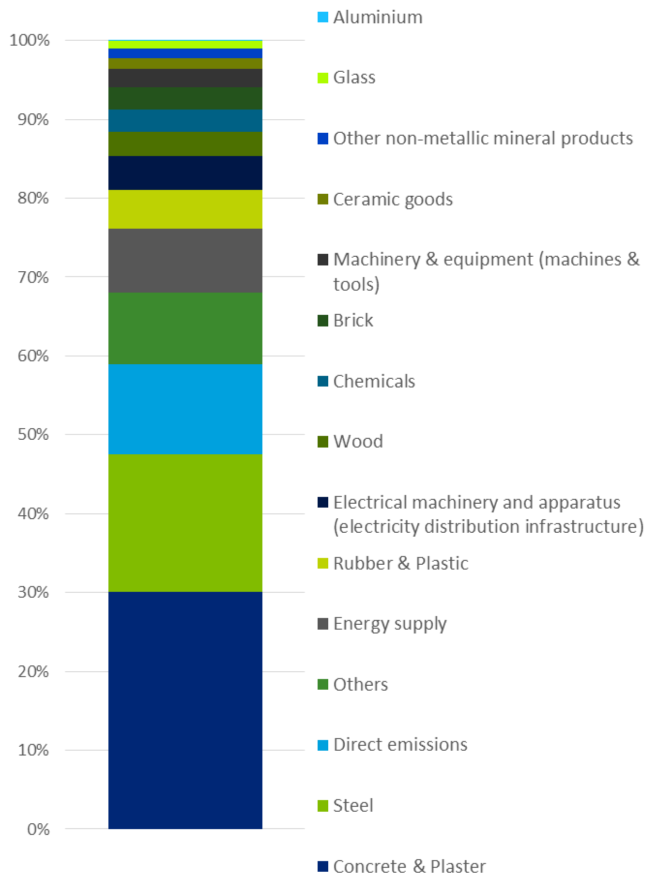

Figure 7: Breakdown of GHG emissions for the construction sector in Europe

Potential emissions reductions in a circular economy

Two potential scenarios have been studied to reduce the emissions of the sector:

- Scenario 1 considers a significant increase in the integration of recycled materials used for the construction of buildings. Apart from recycled concrete that cannot be used extensively into new concrete (recycled aggregate can be integrated up to 30% without altering the structure of concrete), the integration rate of recycled materials is assumed to reach 60% to 95% depending on the material. The recycled content of a few materials is however considered as unchanged because they are difficult to recycle for their original purpose (bricks, ceramic goods, chemicals). Overall, the average recycled content increases from 22% to 70% in this scenario.
- Scenario 2 focuses on an increased reuse of materials, while integrating the same amount of recycled materials as in scenario 1. It is assumed that steel and aluminium can be reused up to 50%. A more conservative assumption has been applied to other materials (reuse rate of 30%).

Scenario 1 leads to a reduction in emissions of -17%, while scenario 2 would achieve a -32% reduction.

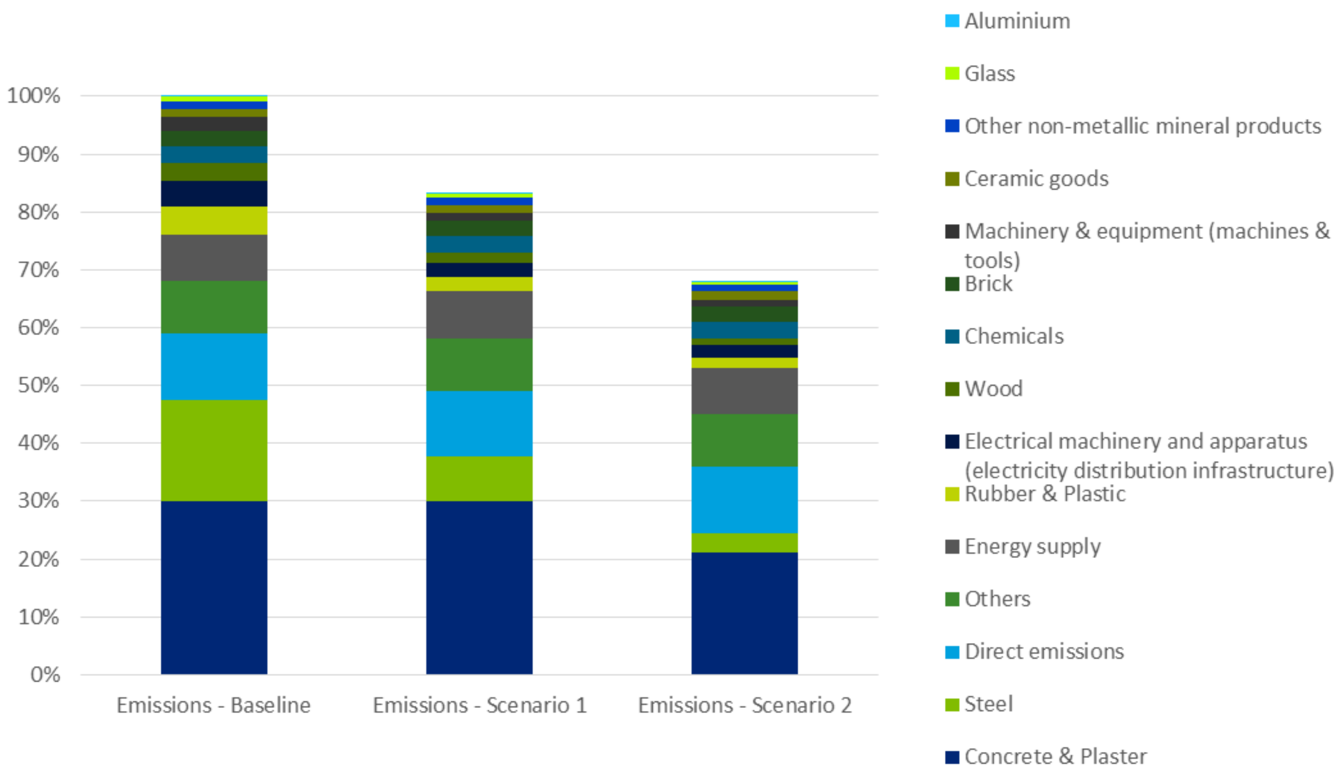

Figure 8: Reductions in GHG emissions achieved in scenarios 1 and 2

The re-use of materials in construction is highly relevant because the properties of some materials make it difficult to recycle them (e.g. concrete cannot be recycled into concrete without the addition of cement). Even for easily recyclable materials (such as steel), reuse further avoids emissions related to the recycling process. However, large scale reuse is currently hindered by the difficulty for reused parts comply with quality standards. In addition to reusing and recycling the materials as much as possible, a more ambitious strategy would also focus on decreasing the environmental impacts of concrete (for example by reducing the use of cement through better planning or substitution with lower impact materials, e.g. wood) and the direct emissions of the sector, through energy efficiency measures. It is also necessary to limit backfilling, which is today a common practice to dispose of CDW in the EU. The extensive lack of trust in recycled products (quality issues), coupled with very low raw material prices and low/free landfill costs, leads to a highly uncompetitive market for recycled CDW materials today. A strong legislative framework (including a limitation of backfilling, an introduction of mandatory selective demolition, etc.) would increase CDW recovery.

Given the growing pressure on resources, it makes sense for the construction sector to take advantage of the buildings dismantled today to recover valuable materials. This would require the professionalisation of deconstruction activities, for example through the use of 3D scanning technologies.

Automotive sector

Key figures

In 2013, 16.2 million of motor vehicles were produced in the EU27, accounting for 19% of worldwide production. 281.4 million vehicles were in use in 2012 (246.3 million passenger cars), that is 487 per 1,000 inhabitants, and 13.6 million units were newly registered in the EU27 in 2013[30].

In 2010, vehicles were composed of: 61% metals (steel, aluminum, copper, magnesium, etc.), 16% plastics, 6% rubber and 18% of others components[31]. Other components include paints, textile, glass, fluids and precious metals (Platinum, Palladium, Rhodium). The composition of vehicles is becoming more and more complex, and this trend will continue with the development of electric cars. Closing loops for critical commodity materials will thus be an issue.

In 2012, more than 6.3 million end-of-life vehicles were collected in the EU28, representing 6.3 Mt of waste.

A reuse and recycling rate of 86% has been achieved in 2012 in the EU28, thus reaching the objective of the ELV directive set for 2015 (85%). ELV have traditionally been highly recycled due to the share of metals in vehicles which are easily recycled. However, other materials have been less recycled, and overall the re-use potential of materials has not been exploited. Only 10% of spare parts used in the aftermarket consist of remanufactured parts and almost none are used in new vehicle production.

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[30] ACEA, the European Automobile Manufacturers Association

[31] "Plastics. The Future for Automakers and Chemical Companies", A.T Kearney, 2012

Circular economy in the automotive sector

Circular economy in the automotive industry comes from more refurbishment, remanufacturing and recycling. These strategies aim at increasing material efficiency, by ensuring resources are used in loops (reintegrated in the value chain) instead of landfilled at their end-of-life. New business models can also indirectly favor the reuse and recycling of materials, for example the leasing of cars or components (e.g. batteries which stay the ownership of the car manufacturer and can be reconditioned and reused). These have not been directly assessed but it is considered that these strategies will help reach the targets set in the analysed scenarios. Other strategies focus on the intensification of usage (car sharing for instance). It can decrease the consumption of vehicles with the same usage pattern, and favor reuse and remanufacturing (because these vehicles reach their end-of-life earlier and their components are more recent).

The figure below illustrates the wide variety of circular economy strategies that can be implemented in the automotive sector.

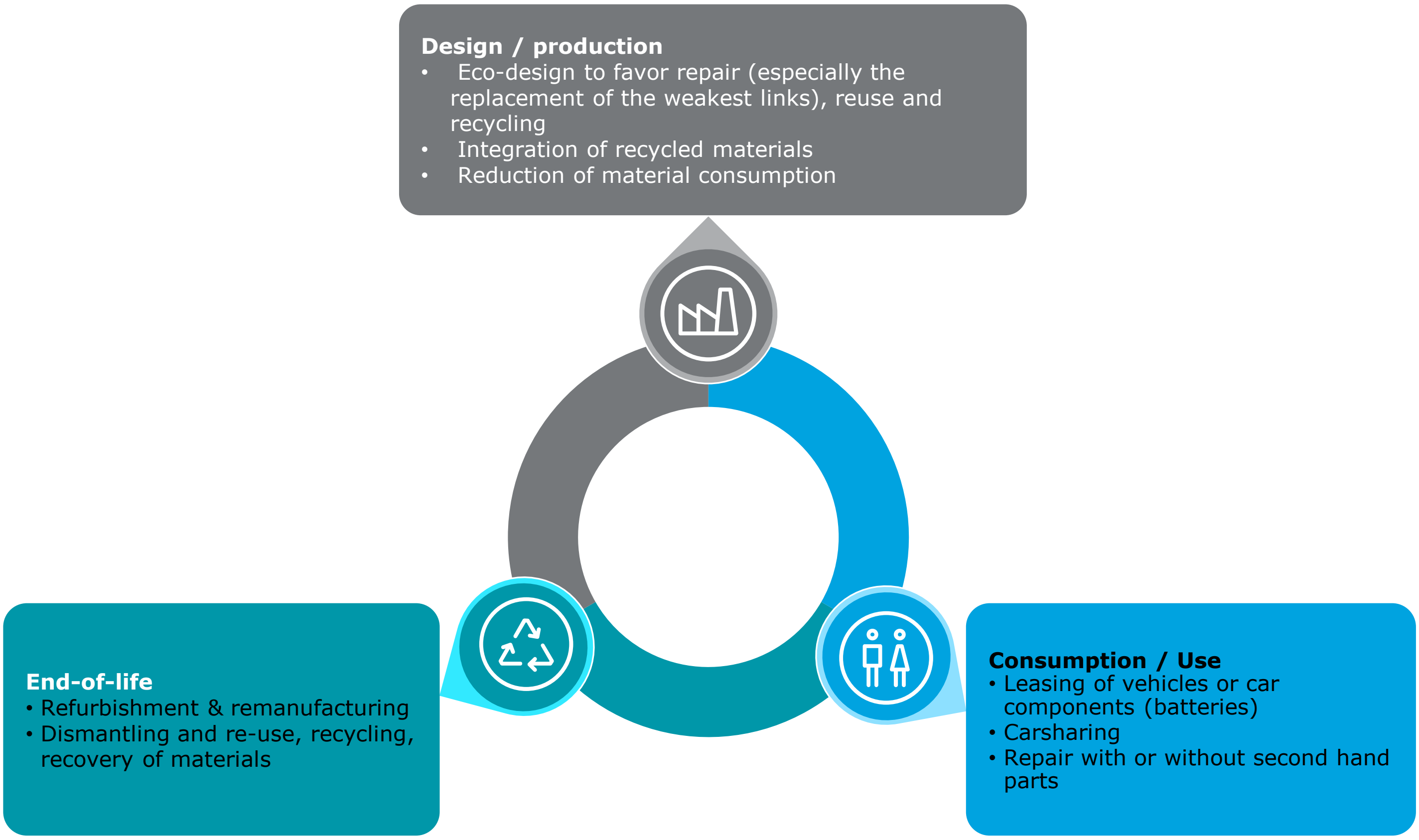


Figure 9: Circular economy in the automotive sector

80% of the GHG emissions of vehicles occur during the use phase because of the combustion of fuel[32]. Efforts from the industry have therefore been focused on decreasing these emissions. Some car manufacturers are yet investing in circular economy. Renault's remanufacturing plant in Choisy-le-Roi reengineers different mechanical subassemblies, from water pumps to engines. It demonstrated reductions of 80% for energy, 88% for water and 77% for waste from remanufacturing rather than making new components. Ford partnered with the aluminum producer Novelis to ensure the aluminum used in its F-150 truck is recycled and used in closed loops. Manufacturers are encouraged to favor dismantling as new vehicles put on the market must be recoverable at 95% minimum of their mass[33] and many manufacturers set objectives to integrate recycled materials in their new cars.

"The different circular economy strategies in the automotive industry are compatible: vehicles between 0-5 years can be repaired or maintained with refurbished parts, vehicles from 5 to 15 can be repaired or maintained with reused parts coming from end-of-life vehicles. Any part of a vehicle can be dismantled to be reused if there is a demand. In France, the market for reused parts could be at least doubled."

Jean-Philippe Hermine
Renault

Emissions of the sector and sources of emissions

According to our calculations, the production of vehicles sold in the EU emitted 186 Mt CO_2 eq. in 2007. The production of steel contributed to 38% of the total emissions.

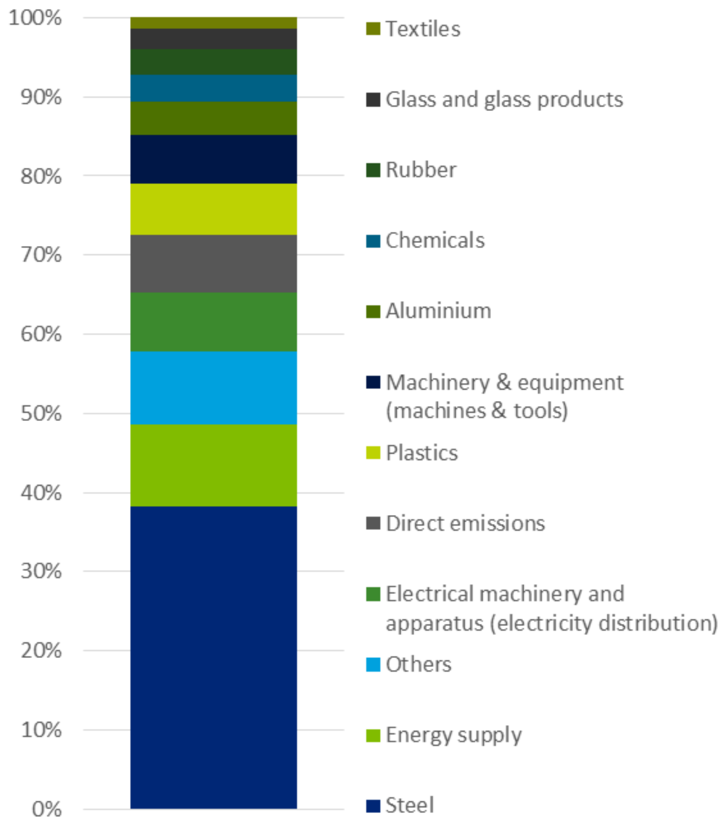


Figure 10: Breakdown of GHG emissions for the automotive sector in Europe

It is estimated that around 5% of ferrous metals used in the automotive industry is reused in the EU today, and 94% is recycled. Reuse of steel

[32] European Commision (2008) Environmental Improvement of Passenger Cars
[33] Directive 2005/64/EC on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability

components is desirable. The reuse of an average car engine would save 1 050kg CO_2 eq. and the reuse of a door 225kg CO_2 eq[34].

10% of aluminum used in cars is also reused and 88% recycled. Reuse of aluminum alloy wheels, transmission, gearboxes could increase. The reuse of a transmission would prevent the emission of 950kg CO_2 eq[34].

Plastic, glass, rubber and textiles are today little reused and recycled. This would be mostly due to their low market value rather than the technical feasibility of reuse and recycling.

Potential emissions reductions in a circular economy

The Ellen MacArthur foundation has been recommending to:

- Improve vehicle design in order to enable the replacement of the 'weakest link' components(engine and suspension, bumpers, wheels, battery and fluids) and to allow for a second usage period of the vehicle at full performance;
- Establish professional refurbishing systems, and capture economies of scale in the reverse supply chain.

The present study aims at assessing the benefits of increasing the reuse of components and extending the lifetime of vehicles as suggested by the Ellen MacArthur Foundation, but also the recycling of materials which is the strategy most pursued today.

The figure below illustrates the impacts of these two potential strategies to reduce the emissions of the sector, analysed through the two following scenarios:

- Scenario 1 considers a significant increase in the integration of recycled materials in automotive and automotive parts put on the market. It is assumed that vehicles today include recycled metals (25% of the car metal content)[35] and some recycled plastic (15%)[36]. In scenario 1, the recycled content of cars increases up to 100% for metals, up to 70% for plastics and 80% for glass. The recycling of rubber for the production of new tyres has been neglected. There is high uncertainty regarding the feasibility of the process of "devulcanisation" at a large scale (where recycled compounds are mixed with virgin materials to produce new rubber) and, eventually, its environmental benefits. Similarly, while textiles from ELV could be recycled into insulation materials, it is, at this stage, less realistic to assume that recycled textiles will be integrated in the production of new vehicles, due to the high diversity of textiles used.
- Scenario 2 considers the development of the reuse and repair market: spare parts are reused and the lifetime of vehicles increases by 50%. The reuse of components for the production of new car is limited because of rapid technology changes in the automotive sector. Therefore we assumed that spare parts will be used mainly for repair. Among the total material put on the market for car production and

[34] Quantis, AGECO (2013) Environmental and Socioeconomic Life Cycle Assessment of the Quebec Auto Parts Recycling Sector
[35] Worldsteel association
[36] Content of recycled plastics in Dacia and Renault vehicles, Rapport annuel 2014 sur la filière VHU en France, ADEME

repair, we assumed that 10% could be reused components. This rate is higher for tires (hypothesis of 30%) as 20% of all tires put on the market today would already be reconditioned tires. In addition, the recycled content rates of scenario 1 were applied in scenario 2 as well.

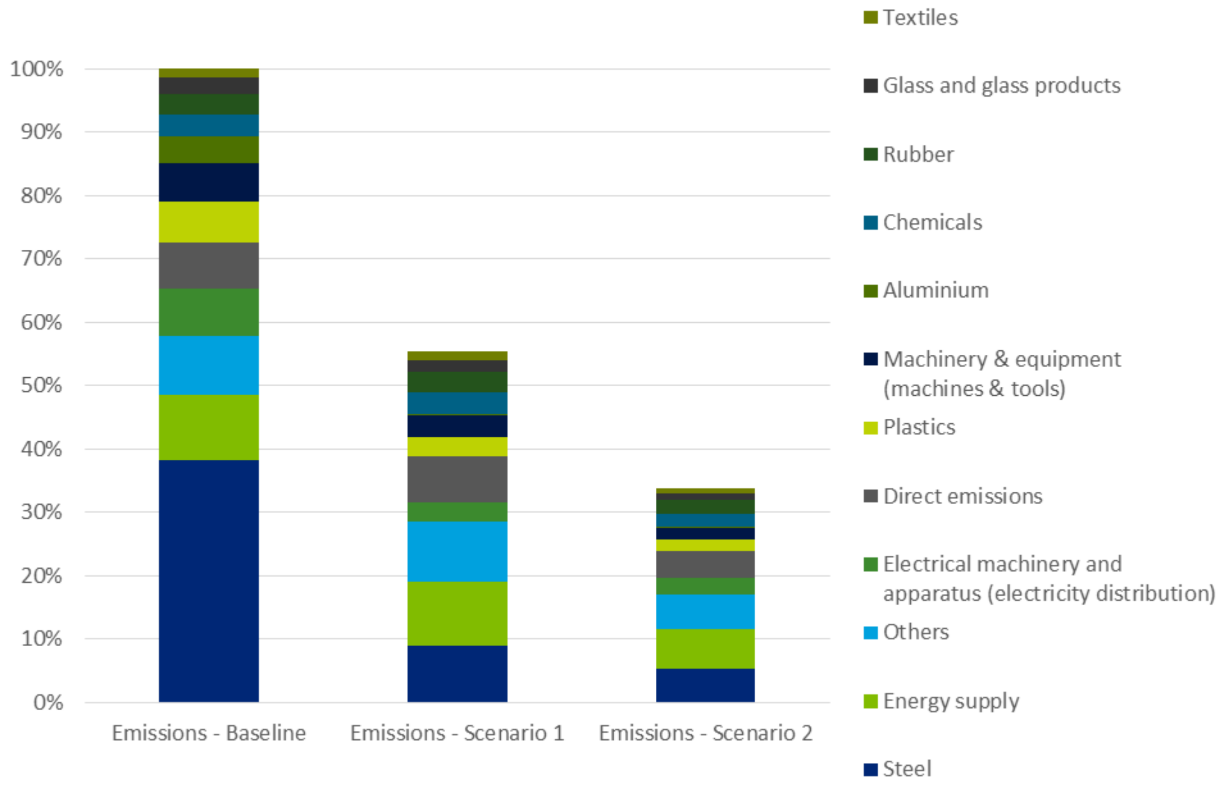
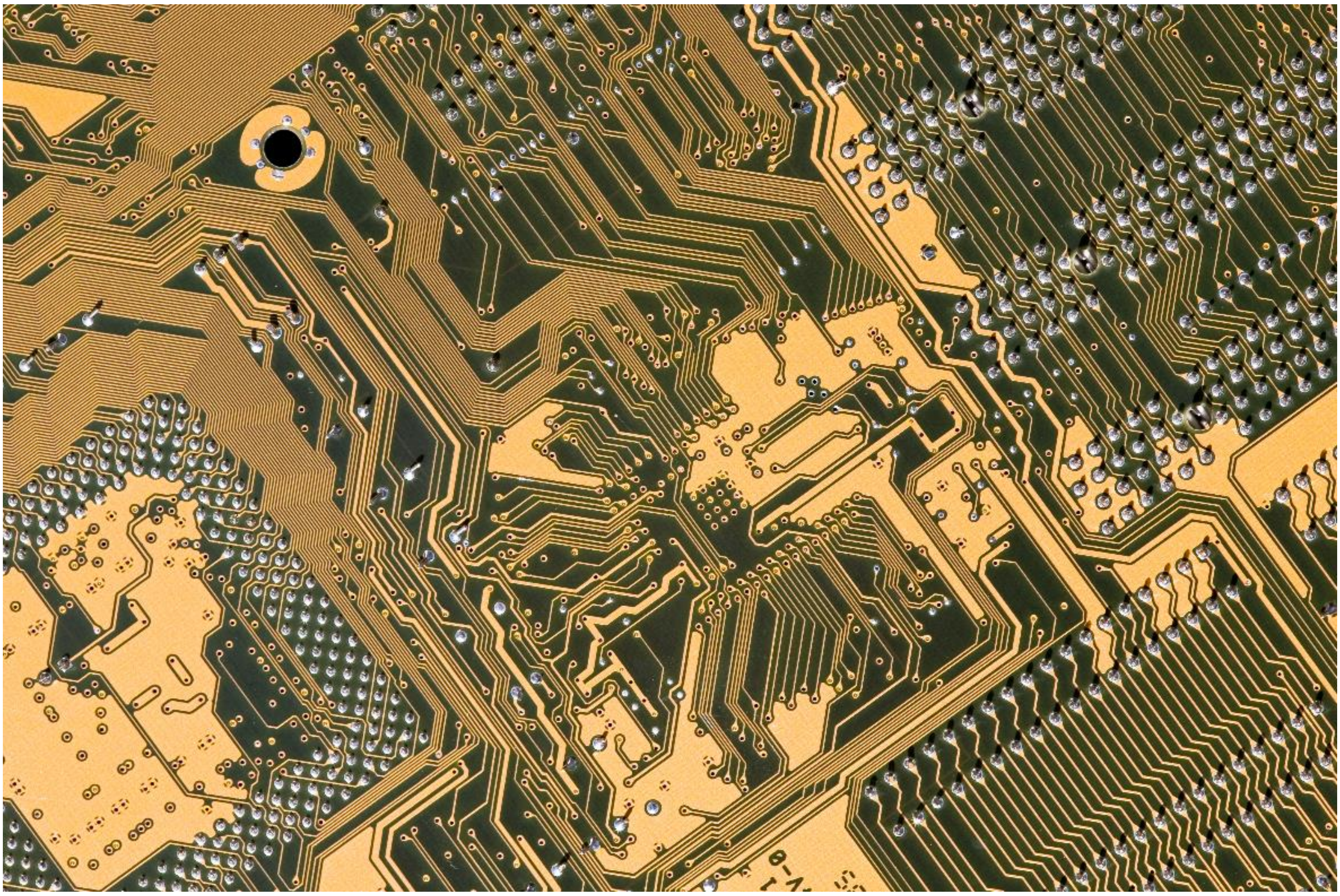


Figure 11: Reductions in GHG emissions achieved in scenarios 1 and 2

Increasing the recycling of materials could decrease by 45% the emissions of the sector. They could be divided by 3 by focusing on the reuse of components and repair activities to extend the lifetime of vehicles. A combination of both strategies is thus a potential objective to move to a circular economy.

Some actions that could be put in place to reach these objectives are the following:

- To eco-design vehicles in order to facilitate the reuse and recycling of parts;
- To implement a system to systematically dismantle the reusable parts of a vehicle;
- To ensure the traceability of parts and materials to enable their reuse in closed loops;
- To find economic outlets for materials retrieved from used cars;
- To invest in R&D, training of stakeholders, alternatives in transport modes, etc.



Electrical and Electronic Equipment (EEE)

Key figures

The Electrical and Electronic Equipment (EEE) sector covers a wide diversity of products including large equipment (washing machine, dryers, dishwashers, etc.), small equipment (microwaves, cameras, speakers, toothbrushes, hair dryers, etc.), temperature exchange equipment (fridges, freezers, etc.), lamps, screen, monitors, ICT equipment (printers, phones, computers, etc.). In 2012, the total weight of EEE put on the European market reached 9.1 Mt[37], all categories considered. Large household appliances were the dominant product category (in weight) in all the EU Member States followed by IT and telecommunication equipment in most EU Member States.

Waste of electrical and electronic equipment (WEEE) is a fast increasing waste stream in the EU, growing at 3-5% per year, with some 9 Mt generated in 2012, and expected to grow to more than 12 Mt by 2020[38].

However, in 2012, only roughly 3.5 Mt out of 9 Mt (or 6.9 kg/inhabitant) of WEEE was officially collected in the 28 EU MS. Of these waste collected and

[37] Eurostat, Waste statistics - electrical and electronic equipment,
[38] http://ec.europa.eu/environment/waste/weee/index_en.htm (accessed in March 2015).

treated, 2.6 Mt were recovered (2.4 Mt recycled and 0.2 Mt sent to energy recovery).

The majority of materials contained in EEE can be recycled as long as there are efficient separation processes. Type and quantity of recovered materials are closely linked to the composition of WEEE treated: the material composition of EEE products varies substantially from one WEEE category to another, as shown in the following table:

Table 2: Simplified average composition of EEE

	Categories of the new WEEE Directive introduced (in Annex III and IV)					
Simplified Composition	**Cat.1**	**Cat.2**	**Cat.3**	**Cat.4**	**Cat. 5**	**Cat. 6**
Iron	57%	25%	0%	54%	46%	4%
Copper	5%	3%	0%	2%	9%	45%
Aluminium	3%	3%	12%	8%	4%	0%
Plastics	25%	25%	11%	10%	26%	36%
Glass	0%	30%	67%	2%	0%	13%
Silver	< 0,5%	< 0,5%	0%	< 0,5%	< 0,5%	< 0,5%
Gold	< 0,5%	< 0,5%	0%	< 0,5%	< 0,5%	< 0,5%
Palladium	0%	< 0,5%	0%	0%	< 0,5%	< 0,5%
Other	10%	14%	10%	24%	15%	2%

NB: Cat.1 includes "Temperature exchange equipment", Cat. 2 "Screens and monitors", Cat. 3 "Lamps", Cat. 4 "Large equipment", Cat. 5 "Small equipment" and Cat. 6 "Small IT and telecommunication equipment with an external dimension of no more than 50 cm"

Reuse and preparing for reuse[39] has been identified as a key strategy for a circular economy and has recently been strengthened by the new Circular Economy package: for the EEE sector, the potential for reuse is high. Statistics on repair and reuse of EEE remain scarce but the global demand for repair services in the field of EEE continues to be high while the number of professionals in the repair sector is decreasing. According to a survey by Flash Eurobarometer[40], the potential market demand in Europe for quality second hand electronic goods is high, showing that 50% of people in Europe would be willing to buy a second hand appliance. A study carried out by WRAP indicates that 23% of electrical and electronic equipment disposed of in the UK are economically viable for resale, with half of these requiring minor repairs and half in full working order[41]. The German Environment Agency estimates that in 2012 one third of the replaced household appliances were still functioning. In the meantime policies tend to better integrate the reuse of EEE: in Spain for example, a new Royal Decree requires 2% of large household appliances and 3% of IT equipment to be

[39] « Preparing for reuse » means **checking, cleaning or repairing** recovery operations, by which products or components of products that have become waste are prepared so that they will be re-used without any other pre-processing
[40] Flash Eurobarometer, Attitudes of Europeans towards resource efficiency, 2011
[41] WRAP (2011) Realising the Reuse Value of Household WEEE.

prepared for re-use from 2017. The targets will rise to 3% and 4% respectively from 2018.

By extending the lifespan of products, reuse has the potential to reduce overall life cycle impacts by increasing the timescale over which production and end-of-life impacts are amortized. However, considering the issue of energy consumption in the use phase, it may be preferable in certain conditions to replace an old appliance with a recent, much more energy-efficient product rather than extending its lifetime by repairing it.

Circular economy in the EEE sector

Circular economy strategies in the EEE sector correspond to a large range of actions seeking to improve the environmental performance and promote greater circularity in EEE value chains.

As far as the public sector is concerned, several EU policies are already related to the circularity of EEE such as the WEEE Directive and the Ecodesign Directive and the European Commission is currently seeking to improve the overall consistency of EU legislation with the circular economy concept through the Circular Economy Package.

Besides, some actors of the private sector have developed strategies to promote and implement the principle of the circular economy. The figure below illustrates the variety of circular economy strategies that can be implemented in the EEE sector.

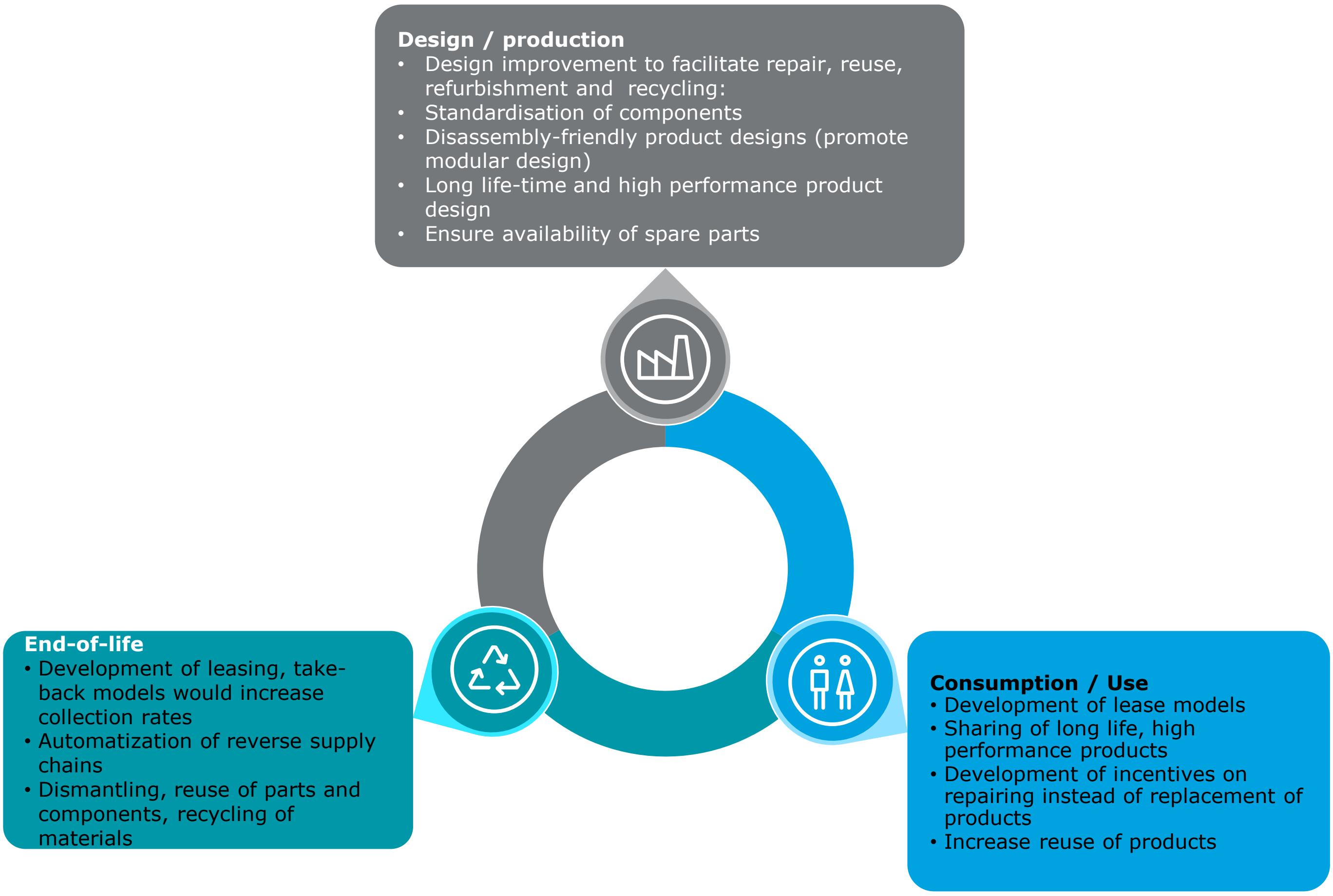


Figure 12: Circular economy in the EEE sector

Emissions of the sector and sources of emissions

In this study, the impact of the EEE sector on GHG emissions has been estimated for the year 2007: the EEE sector in the EU emitted 150 Mt CO_2 eq. According to the emission profile obtained for the EEE sector and presented in Figure 13, the consumption of steel, aluminium and copper products is the main contributor to the GHG emissions of the sector with more than 60% of the total emissions.

The consumption of steel alone by the sector represents the majority of the emissions of the sector with 50% of the emissions. As shown in the table below, steel and metals are major inputs in most of EEE products with average incorporation rates between 30% and 60%, except for lamps (category 3) and small IT appliances (category 6).

Electricity consumption within the sector is responsible for 13% of the emissions: a large part of the electricity is consumed for the production of some high-tech components such as printed wiring boards. Furthermore, the production of these key components for the EEE sector is often performed in countries supplied with highly carbon-intensive electricity.

Consumption of aluminium and aluminimum-made products represents 7% of the emissions of the sector (same contribution for rubber and plastics and rubber and plastic products).

Direct emissions, i.e. on-site emissions of EEE production / assembly facilities, represent 5% of the total emissions.

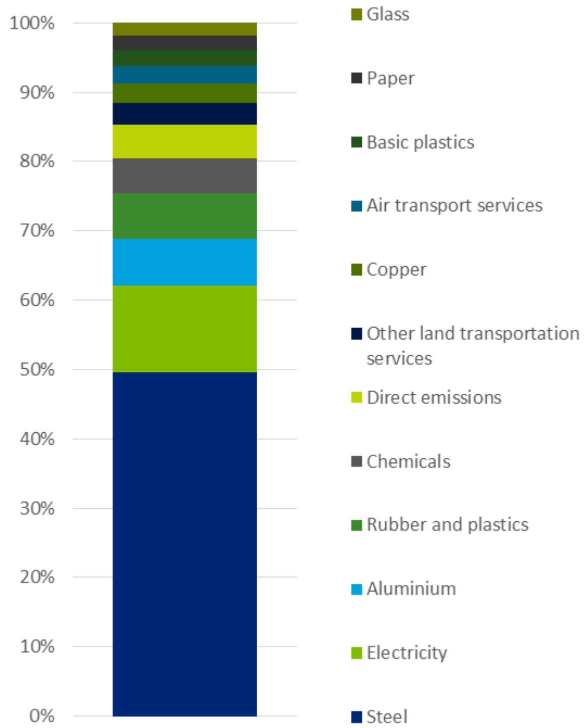


Figure 13: Breakdown of GHG emissions for the EEE sector in Europe

Potential emissions reductions in a circular economy

In this section, two scenarios of potential circular economy strategies in the EEE sector are investigated. For each scenario, three drivers for a more circular economy are selected:

- Increase of the recycled content of materials,
- Increase of the lifetime of products (e.g. through reuse).

The baseline scenario considers current European average values for the recycled content for steel, aluminium, glass[42], rubber and plastics[43] and copper[44]:

- Steel: 50%
- Aluminium: 37%
- Rubber and plastics: 11%
- Copper: 45%
- Glass: 45%

The current reuse rate of EEE is assumed to be 2% of the total EEE flow.

[42] Gala A.B. et al., Introducing a new method for calculating the environmental credits of end-of-life material recovery in attributional LCA, 2015 for steel, aluminium and glass

[43] For plastics, we assumed the average recycled content of PET in Europe for all plastics (from www.epbp.org), but this value may vary depending on the nature of plastics.

[44] For copper : from copperalliance.org.uk

Scenario 1 considers a significant increase of the recycled content for steel, aluminium, rubber and plastics, copper and glass: the majority of these materials are currently or theoretically recyclable materials. Hence we can assume that it would be feasible to design EEE parts based on almost 100% of secondary materials. The share of reused EEE is the same as in the baseline scenario: we assume that no specific effort is being done to support or drive the reuse of EEE.

In scenario 2, the same assumptions have been considered for the integration of recycled material for steel, aluminium, copper, plastics and glass. However we assume in this scenario that the efforts made to support the reuse of EEE lead to 30% of EEE reused by 2030, in comparison with only 2% of reused EEE in the baseline scenario.

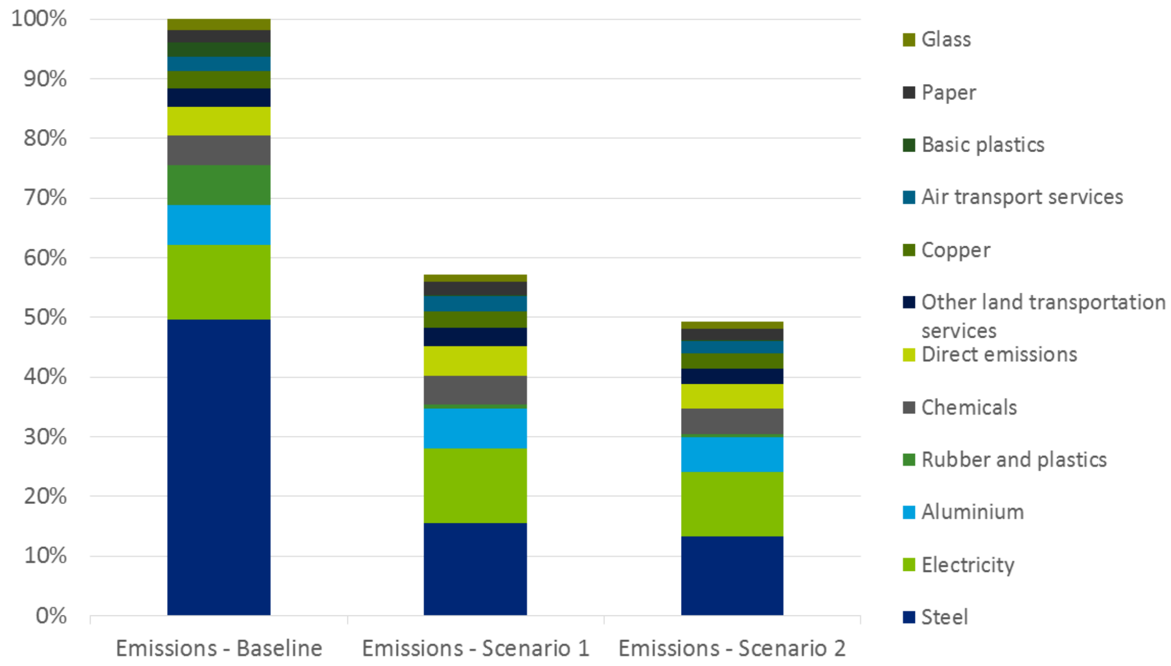


Figure 14: Reductions in GHG emissions achieved in scenarios 1 and 2

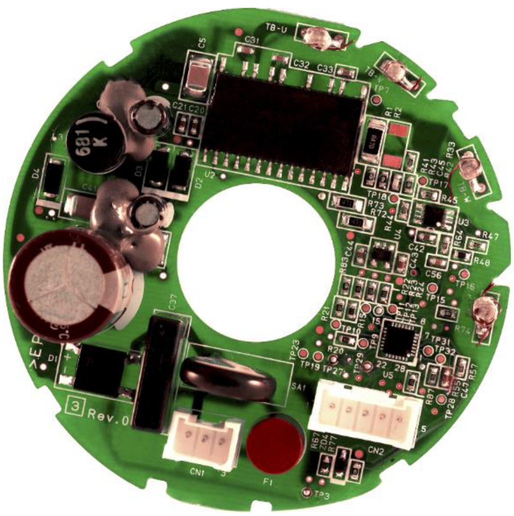
Emissions of the EEE sector could decrease by 43% by focusing on the recycled content of materials in EEE and could be divided by two if minimal efforts were made on the increase of the reuse of EEE (and hence on the extension of the lifespan of EEE). Further reuse and lifetime extension could lead to much higher reductions.

A combination of both strategies is thus a potential objective to move to a circular economy in the EEE sector.

This would require to implement appropriate strategies aiming, for example:

- To improve the design of EEE in order to facilitate the reuse and recycling of the different components of a product;
- To support and develop reuse and repair of EEE;
- To overcome technical or economic barriers for the integration of recycled material in EEE products.

Other actions that have not been investigated in this study could help improving the global performance of the EEE sector such as reducing the on-site direct emissions of EEE factories and reducing the electricity consumption of the EEE sector.



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