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Regulatory barriers for the Circular Economy

Lessons from ten case studies

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Executive Summary

Circular Economy is defined as an economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised". In its 'Circular Economy Package' of December 2015, the EC wants "to help European businesses and consumers to make the transition to a stronger and more circular economy where resources are used in a more sustainable way."

One of the aims of this Package is to 'remove regulatory barriers for the circular economy'. In this project, that already started before the adoption of the Package, ten cases have been selected on their potential for contributing to the circular economy before 2020 if one or more regulatory barriers would be removed. The 10 cases come from different sectors and reflect different circular options, including prevention, reuse and recycling.

The identified regulatory barriers are manifold and cover various directives, legislations and regulations.

Their nature can be summarised in the 6 typifications below:

1. The lack of definitions and the occurrence of gaps in legislation
2. Unclear definitions of targets in legislation, for example in the context of the Waste Framework Directive
3. The definition of hard numerical limits in regulation, for example, considering the REACH and CLP regulation;
4. Lagging or incomplete implementation or enforcement of legislation, notably of the Waste Framework Directive and the Exports and Shipment regulation;
5. Different and conflicting national implementations of a legislation (most notably directives or national action plans), observed in the context of the Waste Framework Directive, Basel Convention and WEEE Directive.
6. legislations that conflict each other because they represent conflicting values, for example with hygiene rules versus food waste.

Especially to aid in resolving the sixth barrier, there is a large need to collect more information in higher resolution on the scale of the challenges and inefficiencies caused by legislation. In many cases the context and application of circulated material is a key determinant of what considerations should be made to serve all values as best as possible. Currently, a one-size-fits-all legislation for whole sectors applies because well-informed locally tailored decisions require information that is simply not present. This incentivices "*better safe than sorry*" legislations.

The internal market for recovered materials or material flows from which they can be recovered must be harmonised to retain value and materials within the European Union. The Union is a net importer of many primary materials, some of them critical for the security of supply of food and energy. Within the Circular Economy paradigm and given the currently available technical options, it is possible to increase the Union's independence. This may also lead to an improved trade balance andincreased employment.

Product design legislations should consider the full-life cycle of the product. This consideration should include a balanced choice of values. The circular economy paradigm promises increased environmental performance which has been observed in many instances in the case studies. Increased performance is possible in terms of reduced greenhouse gas emissions, reduced emissions to soil and groundwater, and reduced resource consumption and consequently reduced impacts of primary resource production. However, trade-offs exist even within environmental performance. Some circular alternatives reduce soil and water emissions but require more energy for processing, thus increasing greenhouse gas emissions if the energy required is not renewably sourced.

Legislation should always aim for the highest possible waste hierarchy option and be flexible enough to stimulate new options for the decoupling of environmental burdens from economic growth as soon as they become available and are economically feasible. In many cases we have encountered favouring (energy) recovery over recycling, recycling over reuse, and so forth.

Although detailed and reliable data are lacking, the case studies make it clear that the economic potential of removing regulatory barriers is significant, ranging from tens of millions to even billions of euros per case. Related effects are also significant on job creation (hundreds of thousands of jobs may be involved), as well as a better environmental performance.

Many of the barriers identified in the cases are already in the focus of policy makers and are being addressed. This does not mean that all barriers can be removed, and certainly not easily: barriers may have been introduced from different, possibly conflicting regulatory perspectives (e.g. public or animal health, environmental protection). Any of these be considered more important than the circular economy perspective. Moreover, the regulatory arrangements can be part of a very complex system that may not be changed easily or may be expensive to change.

Some of the case studies also show that removal of regulatory barriers does not necessarily lead to realisation of the desired circular activity. Economic barriers may remain: e.g. market prices, technology lock-ins, consumer demands and attitude, etc. To ensure the success of circularity it is important that before focusing on the removal of regulatory barriers, a thorough and more holistic assessment of the actual potential for circularity is undertaken.

This goes beyond the issue of existing legislation that hampers circularity. It is an issue at system level: If legislation leads to a suboptimal solution, new legislation can be used to improve the situation, where more value is kept in the value chain and less waste produced. There is no clear recipe yet to achieve a circular economy in Europe by legislation, but, as many stakeholders and sources have stated in the original research done for this project, internalising environmental costs and value of recuperation of materials, combined with extended producer responsibility that stimulates the design for circularity, could very well be part of such a regulatory approach. It can create economic incentives for frontrunners to invest in circular economy processes, innovation and business models. Introducing such a change requires careful implementation, possibly with increasingly strict goals in order to make entrepreneurs invest and constantly innovate. An integrated analysis of regulatory barriers and economic incentives is required in order to develop or support circular economy alternatives of prevention, reuse or high quality recycling. In almost all cases regulatory barriers do not ultimately hinder or prevent more circular solutions but they make it (sometimes unnecessarily) more costly compared to traditional linear approaches.

1 The promise of the circular economy

The circular economy concept is a framework that can be be pursued to move towards an economy in which what is regarded as waste today can enter the economic cycle again as a resource. The concept of a circular economy acknowledges the constraints of natural resources and offers an approach to cope with this to move towards a more economicallly, socially and environmentally sustainable world. The European Commission recognises the valye of the circular economy and adopted a Circular Economy Package (European Commission, 2015) which includes an EU action plan (COM(2015) 614) that targets the whole circle from resource production to secondary raw materials. The proposed EU actions will be introduced in more detail in the next chapter.

The intuition behind the concept of the circular economy dates back to the late 1970s and has been shaped by a number of different schools of thought such as "regenerative design", "industrial ecology" and "cradle to cradle" (Ellen MacArthur Foundation, 2013). The circular concept is linked tightly with the goal of prosperity and reduced dependence on primary resources (Ellen MacArthur Foundation, McKinsey Center for Business and Environment, 2015). The concept is already established in some parts of the economy, however so far these areas constitute niches.

The challenge is to enable a transformation from an established linear system to a circular economic system, by promoting circular options from niches to meanstream practice. While benefits are expected for the economy as a whole as well as for individual business actors and consumers, there are a number of challenges which have to be acknowledged and overcome. Moreover, the transition will be time-intensive and will involve high investments with uncertain returns (IMSA , 2013). In this context, the importance of a suited guiding legal and institutional framework is stressed.

While there are already policies and activities in place to support a circular economy, there is an untapped potential. The focus of this study is therefore on regulatory obstacles. The Policy Studies Institute (2014) identified regulatory instruments to be an area of EU dimension which could present an option to foster the transition towards a Circular Economy. A related study compared selected waste stream directives (Bio Intelligence Service, 2014)[1]. The study finds that there is a potential for a better coherence with the Ressource Efficiency Roadmap as well as with the Raw Materials Initiative. In the following paragraphs first an introduction on what characterizes a circular system in comparison to the currently prevailing linear system will be given. Afterwards the and obstacles transition will be discussed.

The linear economy

The currently prevailing economic system can be characterised as "linear": natural resources are extracted and used to create products which are then consumed and subsequently disposed after usage. After usage, products are regarded as "waste" while even in today's system they contain or even constitute valuable resources. In a system with finite natural resources, i.e. our planet, a linear system reaches its limits at some point. In the context of a growing population and increasing consumption, these limits are approaching even earlier. The limits are set by how much resources we can extract as well as how much "waste" we can emit back into the system.

The costs for negative environmental impacts (negative externalities) are usually not priced (e.g. loss of biodiversity) or priced too low (e.g. CO2 in the EU ETS scheme) (IMSA , 2013). In their report of 2013, the Ellen MacArthur Foundation estimates that in 2010 65 Billion tonnes of raw materials entered the economic system. This figure is expected to grow to 82 Billon tonnes in 2020. At the End-of-Life, the majority of materials (60%) were either incinerated or landfilled. Only 40% of the materials were used in a circular option (recycling or reuse) (Ellen MacArthur Foundation, McKinsey Center for Business and Environment, 2015). Consequently, the circular economy concept is also raised in discussions on resource efficiency. The importance of enhancing a circular economy was identified in one of the policy

[1] The study examines in detail the Packaging and Packaging Waste Directive, the End-of-Life Vehicles Directive, the Batteries Directive, the PCB/PCT Directive and the Sewage Sludge Directive.

recommendations in a study on resource efficiency and its relation to European competitiveness (ECORYS, 2011). The different concepts and strategies on resource efficiency will not be discussed here; there is a great amount of reports and studies related to resource efficiency. These include studies on opportunities to business (AMEC, 2013), on the economic effects of resource efficiency policies (COWI, 2011), on investment related topics (Flachenecker & Rentschler, 2015) and guides to implement resource efficiency measures (Greenovate!, 2012).

The circular option

Moving from this linear economic model to a circular economy entails much more than to recycle as much as possible of the materials contained in products at the end of their usage-phase. It includes among others:

- The elimination of the use of **toxic substances**;
- Strategies that improve the **reuse, remanufacturing, repair** and recycling of products through, for example, an adapted product **design**;
- Strategies to stimulate **new consumption patterns**, for example in the way people buy, use and "dispose" goods. Examples include sharing by consumers as well as businesses.
- The potential and the need to establish **new business models** such as the leasing of materials (leasing to other business) and products (leasing to consumers). This is also important to enable the private sector to operate profitably in the context of a circular economy.

The Ellen MacArthur Foundation identifies three essential principles of a circular economy that subsequently provide four sources of value creation. These are summarised in the table below:

Table 1 Essential principles of a circular economy and value creation in a circular economy

Essential principles of a circular economy	*Sources of value creation*
1. Waste is designed out 2. Differentiation between consumable and durable parts of a product 3. Use of renewable energy	1. Minimizing material usage compared to the linear system and minimal times between phases of usage ("power of the inner circle") 2. Maximize the number of use-circles and time in each circle ("power of circling longer") 3. Diversifying reuse across the value chain ("power of cascaded use") 4. High quality collection and distribution systems ensuring uncontaminated material streams ("power of pure circles")

based on Ellen MacArthur Foundation, 2013

The circular option can thus be summarised as a radical change in the way we operate and organise the way we fulfil our demands with tangible products. It impacts the way we design products, how we use them, how business generates income from providing the products and how we retain the value of those products for as much as possible after their usage-phase.

So far, different studies identified a number of priority areas in terms of materials, products, sectors or waste-streams. The scoping study coordinated by the Policy Studies Institute at the University of Westminster (2014) identified, **priority materials** (agricultural products and waste, wood and paper, plastics, metals and phosphorus) and **priority sectors** (packaging, food, electronic and electrical equipment, transport, furniture, buildings and construction). The Ellen MacArthur Foundation identifies the highest potential for circularity in complex medium-lived products such as (mobile) phones or washing machines. Similarly, the scoping study developed four cases: mobile/smart-phones, food supply chains, high-strength steel and plastics (Policy Studies Institute, 2014). Mobile/smart-phones represent a large market. Currently both the production (Wilhelm, Hutchins, Mars, & Benoit-Norris, 2015) as well as disposal are associated with health, social and environmental effects (Policy Studies Institute, 2014). If phones were easier to dismantle they were easier to reuse and could thereby be used for a longer time. Currently the design of phones – exceptions noted – moves into the opposite direction with components integrated resulting in more difficult dismantling. For washing machines an alternative business model would be to move from selling washing machines to consumers to a world in which high-end-machines would be leased to consumers: This concept is called **servitisation**.

The Ellen MacArthur Foundation assumes servitisation would generate benefits to both producers and consumers and the longevity of the product would be much higher. Finally, food supply chains are currently faced with great losses of material throughout the value chain. Consequently, great gains can be achieved in terms of environmental and economic. In the case study on the use of steel in value-chains, two strategies could be pursued: better product-design to use less steel and the greater use of high-strength steel. The last case study considered in the scoping study is on plastics used in a large variety of applications. Plastics represent on the one hand a possibility to make use of cascading options and on the other hand a possibility to move in the direction of a bio-based economy (Policy Studies Institute, 2014).

From the discussion above it appears that there are at least three requirements for a transition to a circular economy:

1. To enable reuse a standardisation and modularisation of components will be of importance, also to create a product design which allows for easier disassembly.
2. The disposal sector, as it is established today, will have to rethink itself and towards a cleaner collection of products. This goes beyond the discussion on mono-material collection. For example, there might be an emerging market for collecting components and reselling them, which is not the standard today.
3. Business models will have to be re-innovated. There will be a shift from product ownership to product usage.

This transition introduces ample opportunities for consumers, industry and the economy as a whole (Ellen MacArthur Foundation, 2013).

From the economic perspective, substantial net material savings are expected which are associated with lower price volatilities and supply risks. There will also be fewer negative externalities as material will be used for longer and less virgin material will be extracted. In addition there is a potential of increased innovation – comparable to what is observed today in the sector of renewable energy production – and furthermore a potential for economic growth and job creation. Both equilibrium modelling as well as a comparative labour study suggest that for the European economy a circular economy could produce better results (in terms of GDP, employment and welfare) than the current linear economy.

Industry will gain by having lower material input costs. An adapted product design that focuses on a long use-phase can reduce cost of warranties. Industry can also benefit from a closer interaction with their customers by staying connected to their "users".

Consumers also face multiple potential benefits: ownership costs could decrease, the option to have tailored contracts instead of a standard solution could increase their utility of products and they can also profit from secondary benefits if materials are more durable or less toxic (Ellen MacArthur Foundation, McKinsey Center for Business and Environment, 2015).

The Ellen MacArthur Foundation and the McKinsey Center for Business and Environment, 2015 (p. 12) estimate that a transition towards a ciruclar economy would "allow Europe to grow resource productivity by up to 3 percent annually". The primary resource benefit is estimated to be around €0.6 trillion per year by 2030 to Europe's economies. Additional benefits (non-resource and externality benefits) are estimated to be €1.2 trillion which would result in annual total benefits of around €1.8 trillion as compared to today.

Moving from an established linear system to a (more) circular system will only be possible with gradual change over time and with an adaptation of the general institutional framework. The transition involves that all possible framework conditions are reviewed and adapted to pursue the idea of a circular economy from governmental actions such as taxing and incentives, procurement, education (to create awareness and to acquire skills), the legal framework (which will be the focus of this report), to establishing circularity in business practices through standards or voluntary agreements and by adding circularity as criteria in access to finance.

It will be important to establish a practice of setting incentives across disciplines, institutiuons and sectors such that externalities are incorporated in the price of products and services. In interplay with the framework conditions, there is an important role of large corporations as a front runners. They rely on a diverse network of suppliers which the corporations can influence by moving into the direction of a more circular design and demanding that their sourcing suppliers provide products that adhere to their standards. This in turn can create spill-over effects throughout the value chain (Preston, 2012).

In the short-run, good opportunities for companies to "try-out" circularity are to start the introduction in the form of pilots. The transition will benefit from experienced resource scarcity (which is currently not reflected in commodity prices) and from using innovative technologies (such as additive manufacturing, precision farming, digitisation of process sindsutry and so forth). Changes in consumer behaviour towards more sustainable consumption will foster the transition. An example for the latter is the increasing use of car sharing sercvices. A development that is logical considering that a European car is parked 92% of the time (Ellen MacArthur Foundation, McKinsey Center for Business and Environment, 2015).

Though the benefits of a circular economy appear promising, there are a large number of barriers. In this report regulatory barriers will be identified and discussed. In addition, there are many other potential barriers: transition will incur costs and require re-thinking of business models. For example, there is a need to shift investment towards product design and production as well as into skills for remanufacturing. Incumbent players can be expected to be hesitant to take up the challenge. This demonstrates need for a supporting policy framework mentioned above.

A transition requires good management to ensure a consistency of the supported approaches. It includes changing economic incentives including tax-incentives, changing public investment and procurement processes, providing targeted funding, supporting the dissemination of good practices, encourage business-to-business collaboration, and investment into skills.

Moreover, there is a need for raising consumer awareness, among others because of the still limited acceptance of more circular business models among consumers as well as industry (Policy Studies Institute, 2014). Policy makers will need to tailor the choice of instruments to the material streams, as each stream follows its own pattern (ECSIP Consortium, 2013). The velocity, veracity, volume and variety of data will all need to be improved to monitor material flows and the transition towards a circular economy. (The ECSIP Consortium, 2013). Indicators will also help consumers and business alike to make well-infoirmed choice for products that align with the circular economy paradigm.

In short, the transition towards a circular economy involves a massive paradigm shift that requires actions from all parties in the social triangle: governments, industry and civil society. Our study has looked at what the European Commisson can do within reasonable time and effort, using a methodologuy that is described in the next chapter.

2 This project and the circular economy in the European policy context

2.1 Background to the study

Circular economy as an integrated concept in European policy making goes back to the Europe 2020 Flagship initiative of resource efficiency. Actions related to the circular economy however already date from a long time before Europe 2020. They include waste legislation, chemicals policies, the bio-economy strategy, the Ecodesign Directive, the European Resource Efficiency Platform, the Roadmap to a Resource Efficient Europe, and other sector specific policies and measures. Under the resource efficiency flagship, the communication: Towards a circular economy: a zero waste programme for Europe (COM/2014/098final) was published in 2014 as a framework for the circular economy in Europe. Via this Communication, the Commission called for the types of studies such as the one for which this proposal has been developed, underlining the importance of this study. It specifically states that the EC will:

> *"…Further analyse the major market and governance failures which hamper the avoidance and reuse of material waste, taking account of the heterogeneity of material types and their uses, to contribute to an enabling policy framework for resource efficiency at EU level."*

In December 2014, the new Commission Juncker decided to withdraw the pending legislative proposal, as part of the political discontinuity exercise carried out for the first Work Programme of the Juncker Commission. The Commission committed at that time to use its new horizontal working methods to present a new package by the end of 2015 which would cover the full economic cycle drawing on the expertise of all the Commission's services. This was in line with various findings (as summarised in e.g. Accelleratio, 2015) that in order to attain a real circular economy, a system change is necessary with a deep transformation of production chains and consumption patterns, as well as a shift in financial, fiscal and reporting instruments. Such a system change requires parallel actions along the value chain rather than a purely sector and/or product focused approach

This led in December 2015 to the renewal of the policies towards circular economy in a new 'Circular Economy Package' in order to contribute to 'closing the loop' of product lifecycles through greater recycling and reuse, and bring benefits for both the environment and the economy (Press release Circular Economy Package, 2015).

Both the 2014 Communication as well as the Circular Economy Package recognise a number of regulatory and non-regulatory obstacles towards the circular economy relating to access to resources, processes and culture typical of a shift in the economy, such as the lack of skills, investment, information, consumer and business acceptance, coherence and harmonisation. This specific study, that started before the publication of the Circular Economy Package, focuses on the regulatory aspects of the circular economy, the non-regulatory obstacles must be taken into consideration to understand the full context of the study.

2.2 Purpose of the study

The (2014) '*Scoping study identifying potential circular economy actions, priority sectors, material flows & value chains*', identified priority economic sectors for the circular economy and placed them in the EU policy landscape. The six main priority sectors identified in the study were Packaging, Food, Electronic and electrical equipment, Transport, Furniture and Buildings and construction. The study also highlighted a wide range of barriers to the circular economy in general, which can be summarized by the following characteristics:

- Vagueness and lack of clarity in the language of legislations
- Insufficient information and awareness of legislations
- Unintended disincentives created through legislation
- Insufficient framework for implementation of legislations
- Insufficient optimisation resulting from competing priorities

In this study, which is a follow-up of this scoping study, we looked at promising potential markets linked to circular economy, that are closed or under-performing due to regulatory obstacles or regulatory gaps. We:

- Identified concrete value chains, subsectors, economic activities for the circular economy and gathered economic data to underpin the related market potential;
- Identified key areas with the highest potential for economically viable market opportunities and conducted further analysis on regulatory barriers, preventing these markets from full development;
- Identified the regulatory framework for the specific areas and analysed the barriers to circularity and evaluated the functioning of the internal market and potential lost market opportunities related to these barriers;
- Provided ten case studies to analyse the barriers' impacts and the most promising options for resolving them.

2.3 Our approach

The opportunities for increased circularity in the economy vary considerably across different companies, sectors, products and value chains. There are many factors that influence the circular economy potential, and a full analysis would require a prohibitively large amount of study. In line with the Terms of Reference a case study approach was chosen. In order to identify concrete value chains, subsectors, economic activities within agreed priority sectors for the circular economy, and gather economic data to underpin the related market potential we therefore used qualitative scoping procedure to select high-potential sectors and value-chains.

This project started by developing an extensive list of possible circular economy activities that might be hindered by regulatory barriers. This long list was based on a literature study as well as on input from the public consultation on the Circular Economy Package that was held from 28 May to 20 August 2015, which received around 1500 contributions. On this list 62 value chains, subsectors and economic activities were listed with a potential for the circular economy and an indicated regulatory barrier. Based on 4 criteria (European level of the barriers; Ambition of EC to follow up on the results before 2020; Technical and economic feasibility of the area; Excluding energy as a specific topic) the list was reduced to 30 areas remained. For these areas a 'quick-scan' was made:

1. Identifying likelihood and size of potential, including material/value chain mapping of the circular opportunity, value shift analysis and determination of economic system effects
2. Performing a regulatory quick scan, where based on common, high-level obstacles from literature it was assessed which generic obstacles were relevant for each area.
3. A short analysis of main environmental potential benefits which more circularity could provide

4. Based on the quick scans a multicriteria analysis was made, resulting in the selection of 15 cases.

Taking these fifteen cases as a starting point, the project conducted 77 semi-structured interviews with experts mainly from European and international business associations that covered all relevant steps of the value chain (from product design, sourcing of inputs, production to waste collection, treatment up to the final recovery and marketing of (secondary) raw materials. The selection was aimed at a balance between the traditional waste management aspects of collecting and recycling, and upstream aspects (e.g. design for recycling or dismantling) as well as downstream aspects of feeding recycled or refurbished materials back into production processes.

Based on the results of the expert interviews, a decision-making matrix was developed in order to identify the ten most relevant regulatory barriers. For this selection process a set of transparent and consistent criteria was developed, allowing a systematic assessment of the different obstacles discussed in the interviews (see chapter 3). Based on the outcomes the following ten cases were selected for further study, in which a circular activity is combined with a specific regulatory barrier.

In the case studies (chapter 4) a description is presented of the circular activity and the economic setting of this circular activity, the regulatory barrier and the potential to overcome this regulatory barrier. Finally, although quite often data were missing for a detailed assessment, an estimate was made of the economic potential of removing the regulatory barriers, and the possible environmental effects related to that.

Based on the findings in the case studies also some more generic conclusions on regulatory barriers for the circular economy were drawn, that were presented in a half-day workshop in Brussels on 21 March 2016, and discussed with approx. 180 participants from industry, research and policy background. Participants were also offered the opportunity to give electronic feedback during and after the workshop. The final conclusions and recommendations are presented in the chapters 5-7.

Further information on the methodology is provided in Appendix A. The full texts of the case studies are provided in Appendix B.

3 Analysis of regulatory barriers

3.1 Scope and approach

The analysis of specific regulatory barriers within this study aimed to identify and analyse key regulatory obstacles that hinder the realization of economic opportunities in a European circular economy as well as initial ideas on potential solutions. In order to understand why such economic opportunities remain blocked and natural resources are still often used inefficiently, this task followed a broad understanding of "regulatory obstacles" that goes beyond the existing legal frame alone and takes into account other influences from institutional settings alongside the value chains of the circular economy. Based on an institutional economics approach this includes an assessment of:

- Formal, mainly legal frameworks, and the governance and implementation thereof;
- Non-legislative obstacles ("the rules of the game") that cause distortions of incentive structures and thus inefficient market allocations;
- The absence or incomplete coverage of specific legislations like common standards or procedures;
- Coherence in crosscutting issues related to the thematic fields or economic sectors, such as inconsistencies between different regulative systems (e.g. waste and raw materials).

Based on a first literature review the assessment took into account that legislations can have a strong influence on innovation[2] (Blind 2012, Prestion 2012, EEA 2014, EMF 2014): They can act as barriers for innovation, but also like in the field of environmental protection foster innovation for new technologies and services. For example the ambitious recycling targets for End-of-Life vehicles or plastic packaging have clearly initiated technological progress in sorting technologies (IMSA 2013, EC 2014). Nevertheless most of the current legislations of importance for this study have the purpose to reduce or control the externalities of economic and societal activities, e.g. in the cases of food waste or discarded electronic products by focussing on ensuring appropriate treatment and disposal instead of prevention and reuse. Therefore many legislations address such externalities by "end-of-pipe" control and measurement. In a way this addresses only the symptoms, rather than the core problems (Bastein 2013, Wilts 2013). The theory behind such legislations is often still a perspective of a linear economy, going from production to disposal. Special emphasis was put on the aspect of "web of constraints": In many cases regulatory obstacles are not created by a single policy, but also by an aggregation of rules that thus cannot be easily "removed" but will require balanced policy mixes.

3.2 Identification of relevant barriers for a circular economy

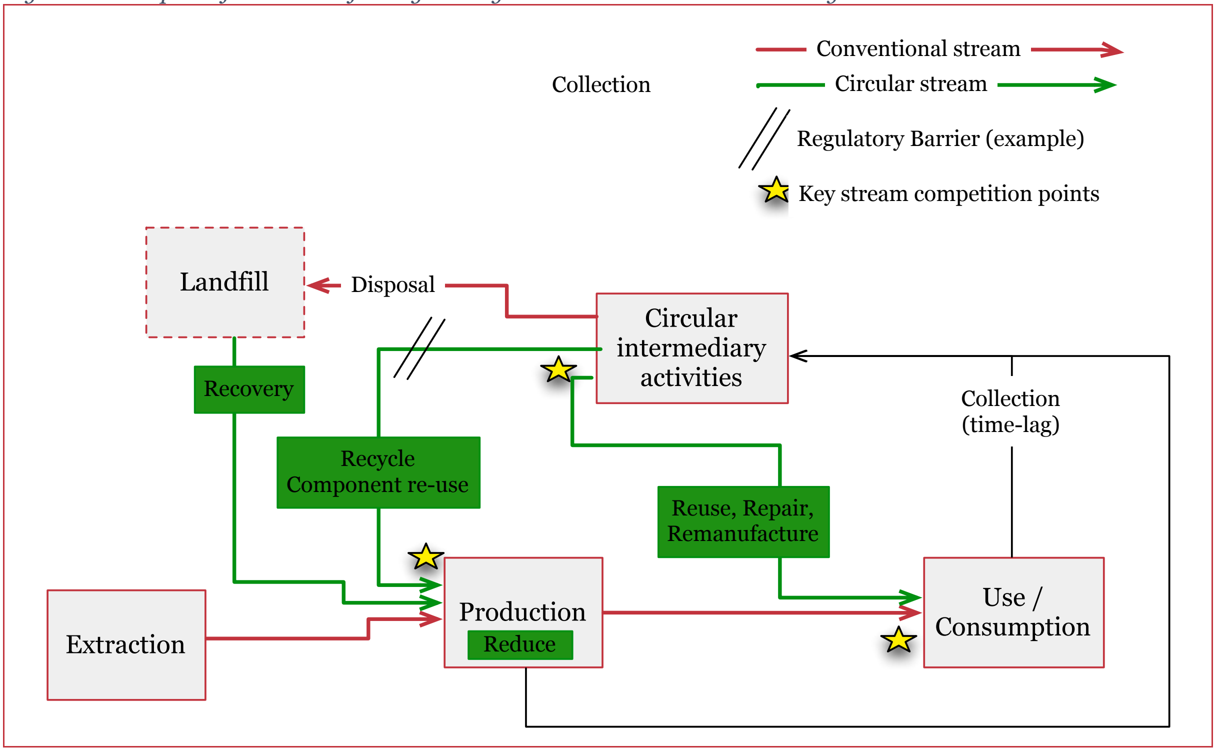
The following figure shows the stylized model of a circular economy that acted as starting point for the identification of regulatory barriers. The analysis aimed to include the full product life cycle and focussed at the interfaces between different steps of the value chain:

- Extraction-Production: existing legislations that lead to the on-going focus on virgin raw materials due to the lack of pricing in of externalities
- Production, internal loops: legislations that make waste generation preferable compared to industrial symbiosis, internal loops or resource efficient production
- Production-use: legislations that hinder closer links between production/ use phase beyond linear models (e.g. with regard to product-service-systems)
- Collection: legislations that fail to feed waste streams into appropriate, high-quality treatment facilities and cause leakages like export, disposal or incineration, e.g. legislation of reliable access to specific waste streams

[2] Knut Blind, 'The Influence of Regulations on Innovation: A Quantitative Assessment for OECD Countries', Research Policy 41, no. 2 (2012): 391–400.

- Production-circular waste management activities: legislations that make products less suitable for reuse or recycling
- Circular waste management activities: legislations that miss to maintain the economic value and imbedded resources of products or at least to achieve technically feasible recovery rates
- Circular waste management activities-production: legislations that hinder the uptake of recycled markets or the development of markets for secondary raw materials

Figure 1 Conceptual framework for regulatory barriers in a circular economy



Within in the interviews with industry experts a broad range of regulatory obstacles for a circular economy has been identified. For this report a total of 60 barriers for the fifteen case studies have been described, depicted in the following table.

Table 2 Regulatory barriers identified in the fifteen case studies in WP 2

Case Studies	Barriers				
Recycling of packaging for food and beverages—plastics and polymers	REACH regulation	Insufficient recycling targets and landfill bans	Missing design for recycling	Lacking extended producer responsibility through container deposits	Missing quality standards ensuring quality of plastics recyclates
Repair of WEEE case study summary	Access for reuse	Quality standards for repairing activities	Design legislations		
Food waste in the hospitality sector	Different implementations of "best before" dates in Europe	Food safety hygiene legislations	Definitions of by-products	VAT charges on donated food	
Manure and fertilizers	Fertilizer regulation	REACH			
Barriers to prevention of packaging waste	Rigid food contact legislation	Monitoring of exported plastics			
Recycling of batteries	Inconsistencies with regard to the calculation of collection rates	Enforcement especially of a) collection legislations and b) bans of hazardous substances	Lacking design requirements for primary batteries		
Remanufacturing of power tools	Lack of regulatory requirements for a remanufacturing-friendly design	Uncertainties with regard to waste definitions and remanufacturing	Liability legislations	International trade legislations	
Recycling of aggregates and limestone	The use of secondary resources based on aggregates and limestone is not very popular due to image problems	Prices of competing regular construction material are extremely low	Ignorance and missing awareness of the importance of recyclable products	Conflicts between the “Waste Framework Directive” and the “Construction Products Regulation”	

Case Studies	Barriers					
Recycling of used lubricating oils	Waste Framework Directive	REACH	Trans boundary shipments	Legislation on separate collection	Mandatory Green Public Procurement	
Solvents recycling	Compliance costs	Waste framework Directive (WFD) & End-of-Waste	REACH	Enforcement of EU regulations and Directives at Member State level		
Recycling of Glass in Packaging in the Food and Beverage Sector	Waste Framework Directive (2008/98/EC)	Packaging and packaging waste Directive (94/62/EC)	Take-back-schemes/EPR	Legislations and access to EU funding	Missing legislation on flat glass	PRN's in the UK
Remanufacturing of Medical Equipment	RoHS	Medical Device Directive				
Recycling of steel	Relation between waste and product Directives	Lacking design for recycling legislations	Interlinkages between national/ European waste legislations and global value chains	Waste shipment regulation		
Recycling of non-ferrous Metals from Consumer Electronics	Export (legal and illegal)	Weight-based targets	Basel Convention	Certification process for international trade (quality treatment)		
Recovery of Palladium from catalytic converters in cars	Regulation on the export of vehicles	Regulation on the End-of-Life of vehicles	Non-transparent value chains			
Recycling of copper	Materials legislation /chemical management	EU Emission Trading Scheme	Interpretation of the waste-shipment-regulation	End-of-Waste criteria	Privileges for public enterprises in some Member States	Design for Repair

Analysing the barriers three different key areas have been identified:

- Key area 1: Collection of waste streams: Several case studies identified regulatory barriers often related to lacking legislations that would allow the collection and pre-treatment of homogenous waste streams. Without specific legislations many waste streams end up as mixed waste where costs for high quality recycling are higher than achievable revenues for recycled materials (e.g. in the field of plastic packaging).
- Key area 2: Uptake of secondary resources: A second type of barriers referred to legislations that hinder the use of recycled materials in production processes. The rationale behind such legislations is often motivated by aspects of health and consumer protection.
- Key area 3: Design for reuse, repair or recycling: And finally many industry representatives reported that design issues are already for quite some time high on the agenda but concrete and enforceable product requirements are still lacking.

The analysis also highlighted a variety of different generic types of barriers: In many cases waste legislations focus on quantities (weight based collection or recycling targets) and not so much on the qualities of recycled materials. Inconsistencies between existing regulations (e.g. related to REACH or End-of-Waste criteria have also been mentioned in a variety of case studies.

Key outcomes of the analysis:

- In many cases a lack of harmonized EU legislations has been identified as major obstacles because without very specific legal obligations incentives for high quality recycling are often lacking, especially with regard to the recent low price levels of primary resources and
- an integrated analysis of regulatory barriers and economic incentives is required in order to develop or support circular economy alternatives of prevention, reuse or high quality recycling. In almost all cases regulatory barriers do not ultimately hinder or prevent more circular solutions but they make it (sometimes unnecessarily) more costly compared to traditional linear approaches. Recycling of plastics can be seen as an illustrative example: despite existing sorting and recycling technologies, plastic is still dominantly down-cycled or incinerated. High-quality recycling is definitely not prevented by regulatory obstacles, but lacking or unclear legislations e.g. with regard to End-of-Waste criteria or quality standards for secondary raw materials create legal uncertainties for the industry that make it rational to continue to focus on primary raw material input.

3.3 Development of a decision making matrix

In order to identify the 10 most relevant regulatory barriers, a "decision making matrix" (DMM) was developed to enable a decision on the selection for the in-depth analysis in WP 3.

The assessment for the DMM included three key assessment criteria:

5. Economic relevance of the barrier: This first criterion was mainly based on the identified potential added value shift in WP 1. It took into account the share of the specific barrier for this current loss of added value
   3 = high economic relevance, 2 = medium, 1 = low
6. Removability of the barrier: The assessment differentiated between barriers that could be removed by the European Commission or that require additional actions on the national or international level. It also analysed already on-going initiatives and specifically focussed on such barriers that could be addressed in the short run or at least in the next 5 years
   3 = easy, win-win opportunity; 2 = doable and 1=almost impossible; strong veto players
7. Potential side effects of removing the barrier: The final criterion assessed a) economic impacts on other markets as well as b) environmental impacts and health risks (e.g. keeping hazardous substances in the loop by closing material loops)
   3 = no potential side effects, 2 = medium potential side effects, 1 = relevant potential side effects

Taking the example of preparing electronic products for reuse illustrates the procedure. The analysis of the case study identified two key barriers that hinder discarded electronic products to be repaired and reused despite significant economic and environmental benefits (see chapter 3): i) lacking requirements with regard to design for repair and specifically disassembly and ii) lacking access to discarded products for reuse organisations.

Improving the design of electronic products could potentially have a significant economic impact and is e.g. mentioned as key issue in the Circular Economy Roadmap (high economic relevance) but at the same time the removability of the barriers can be considered as low: Specific legislations would be required for each product group, legislation should be aligned on an international level and it will cause significant investments into new product design and changed production processes. On the other hand improving access for reuse organisations will clearly have lower economic effects as still only a small part of products can be repaired economically viable. But looking at the removability of the barriers there are already established good practice examples e.g. in Flanders that could be taken up on a European level within the next years.

With regard to potential side effects the assessment took into account inter alia the shift of economic activities outside of Europe, the reduced demand for raw materials that could be substituted by secondary resources or the reduced demand for final products by prevention or reuse. Key aspect for environmental side effects has been the reduction of release to environment through increased re-circulation of hazardous substances in closed material loops. The assessment has been undertaken by the experts of the consortium and discussed with representatives from different DGs within the European Commission. The following table shows the scores for those 10 barriers that came out as most relevant regulatory obstacles for a circular economy (see Annex A for a more detailed description of the methodological approach).

Table 3: Assessment scores for the 10 most relevant regulatory obstacles

Barrier description	*Economic relevance*	*Remova-bility*	*Side effects*	*Total Score*
Legal differentiation between used and End-of-Life cars in order to avoid the illegal shipment of discarded cars	3	2	2	7
Pb limits set by CLP that hinder the recycling of copper using lead as a carrier material	3	2	2	7
Different interpretations of End-of-Waste criteria by Member States causing legal uncertainties for steel recyclers with regard to by-products and REACH	3	1	3	7
Lack of enforceable definitions for the recyclability of electronic products as required in the WEEE Directive, especially with regard to disassembling of batteries	2	3	3	8
ROHS regulations that specifically hinder the remanufacturing of medical equipment	2	3	2	7
Inconsistent calculations of nutrient content between manure based and chemical fertilizers	1	3	3	7
Inconsistent “best before” legislations in the Member States that set incentives for disposing food instead of redistributing it; supported by VAT legislations for donated food	3	3	1	7
Lacking legislations for access to discarded electronic products that would allow the preparation for reuse	2	3	2	7

Lacking implementation of the waste hierarchy that hinders the material recycling of plastics or even favours incineration (e.g. caloric value clause in Germany)	2	3	3	8
Based on problematic product definitions in the Waste Framework Directive only certified waste collectors can deal with secondary construction materials.	3	2	2	7

4 Ten case studies

4.1 Recovery of palladium from catalytic converters in vehicles

4.1.1 Introduction

Palladium is one of the six Platinum Group Metals (PGMs) - platinum, palladium, rhodium, ruthenium, iridium and osmium - which occur together in nature. PGMs are precious metals and are very rare elements in the Earth's crust. Due to their scarcity and their high economic value, PGMs are critical raw materials, which are crucial for the European economy. Palladium, together with other PGMs, is widely used in catalysts in cars where the PGMs act as catalytic converters, enabling the conversion of pollutants from fuel combustion into less harmful substances in order to comply with the emissions regulations of vehicles. In 2010, 51 % of the PGM world gross demand had origin in this sector.

The life cycle of palladium starts with its extraction from natural metal ores. The extracted and purified material is used in the production of catalytic converters, which are used as catalysts in vehicles. The vehicles produced in the EU, either stay within the country where they have been produced and/or within EU, or they are exported to countries outside the EU, where it is no longer possible to track the End-of-Life of the vehicles and in which conditions it takes place. When the vehicles reach their End-of-Life, the converters are typically separated from the vehicle and the palladium as well as the other precious materials are recovered, to be used as secondary material (no losses in the properties) for the production of new catalysts for cars. Due to their high economic value, PGMs are usually not landfilled. The nowadays technically feasible recycling rate ranges around 100 % (European standard). However, due to various material losses (among them losses through exports of actual EoL vehicles), the PGM recovery rate in the EU is only about 60 – 70 % and is therefore able to cover only a small part of the demand for catalytic converters (28 % in 2010). An increased circularity of palladium in the EU could help to increase access to discarded autocatalytic converters for recycling companies and increase rates of palladium recycling.

4.1.2 Regulatory barriers

The recycling of palladium within the European Union faces several barriers, provided in Table 4.

Table 4 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
Legal differentiation between used and End-of-Life vehicles in order to avoid the illegal shipment of discarded vehicles and insufficient regulation on the export of vehicles	Vehicles reaching End-of-Life can be declared as 'used vehicles' and can be exported (legally or illegally). This may lead to losses in materials which could be recycled	Clear definition of EoL of vehicles in the legislation Reversed burden of proof procedures for export of vehicles (e.g. exporter has to prove the usability of the car)
Additional barriers	**Effect**	**Possible (legal) solution**
Non-transparent value chains	Potential losses caused by improper treatment (treatment standards vary between different countries)	Creation of international standards for treatment of catalytic converters Allow only certified actors in the treatment along the value chains Simplify data collection and tracking of cars for more transparent value chains
Classification of catalytic converters in the Basel Convention as hazardous waste	Recyclers have only hardly access to wastes with value in the countries where the legislation is more restricted Different interpretations of the legislation regarding the standards for the transport of wastes / wastes classification	Exclude catalytic converters from Basel Convention or classify them as 'valuable substance to be recycled' Analyse where exactly are the differences on the interpretations / classifications and harmonize them at national level

4.1.3 Economic effects

PGMs are crucial for the European economy, although, they are scarce materials and have supply risks associated. Nowadays, the EU depends on imports of PGMs, including palladium. If the circularity of autocatalytic converters could be increased, the European Union would become less dependent from PGMs imports, as disassembly and recycling facilities would have a better access to autocatalytic converters, which would lead to increased recycling rates of palladium within the EU and therefore to more secondary material available. As the supply of secondary palladium would be higher, less primary material would be necessary to cover the remaining demand. A PGM recovery rate of 100 % in Europe could fulfil the palladium demand by maximum 60 %. The European Union would therefore become more independent from PGMs imports and would lower the risk on the supply.

Currently, 115 million Euro worth of precious metals in autocatalytic converters leave the EU annually through exports of vehicles (in all life stages) to non-EU countries, which do not return to the European Union[3]. If the vehicles would remain within Europe, this value would be managed within EU.

Alternative business models, such as leasing, can contribute to more Extended Producer Responsibility, maintaining the vehicles within EU. This would contribute to more circularity of materials and increase job growth potential and expansion of various industry sectors within the EU.

4.1.4 Non-regulatory barriers and other effects

Further effects of an increased circularity of PGMs within the EU are of environmental as well as social nature. From an environmental perspective, if more EoL autocatalytic converters are maintained within the EU, recycling of PGMs increases and more secondary material can be used. Secondary production was mentioned to have approximately 20 % lower environmental impact than primary production due to the avoidance of mining, therefore saving natural resources[4]. Secondary production was also mentioned to have less energy consumption and therefore also less Greenhouse Gas emissions.

In the case of an increased circular economy, more vehicles are dismantled and recycled in the EU, which allows more transparency regarding their End of Life.

[3] There are also spent catalysts imported in Europe. Data on these imports are not available.

[4] Expert estimate by thinkstep experts, based on LCA thinking

4.2 Recycling of copper

4.2.1 Introduction

Copper is an important metal that is used in many different applications. Examples include architecture, energy production and supply, telecommunication, electronics and the usage in pipe systems[5]. While there is only little copper mining in Europe, the sector focusing on smelting and refining is large. In addition, there is a large market producing semi-fabricates. The European Copper Institute estimates the number of people employed directly in the European copper industry to be about 50,000. More people are employed in industries that use the copper as an input material.

Putting the outputs of the European copper industry into numbers, in 2014 the European copper production was about 2.8 Mio tons, which is slightly more than 10% of the world production. About 5.6 Mio tons of semi-fabricates were produced in Europe, which is slightly less than 20% of the world production (European Copper Institute, 2016).

Recycled copper, when recycled in the best quality, cannot be distinguished from primary copper, therefore no problems exist to place recycled copper on the market. Researchers at Fraunhofer ISI estimated in studies for the International Copper Study group that about 50% of the copper used in the EU originates from recycling. The recycling of copper is linked to positive environmental effects: its production requires, for example, up to 80-85% less energy than primary production. Worldwide copper recycling saves per year about 100 Mio MWh of electrical energy and 40 Mio t of CO_2 (European Copper Institute, n.d.).

The recycling of copper, including the collection of scrap, is an established and working system, starting from local collectors, involving a chain of processing, trading and transport, and then being used in the copper production in or outside Europe. The material entering the recycling process today represents the state of the art of years ago. Depending on the application the copper was used in, it takes shorter or longer until the material enters the recycling circle again. Copper that is used in buildings stays there for a long time while copper used in electronics is entering the recycling-circle much faster.

Sometimes lead is used as a carrier material, which can result in lead content in the copper-scrap. Technically this presents no problem to the smelters. However, currently it is discussed to introduce limits for lead content in the CLP-regulation. Toxicity of lead depends, however, on the form in which the metal is presented. Main regulatory barriers and legislations under consideration which may hinder the development of a circular economy in the near future

Table 5 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
The discussed introduction of a maximum content of lead of at max. 0,03% into the CLP regulation	During the work for this study, the interviewees feared that if this threshold would be introduced it would (most likely) lead to a situation in which many recycling processes of copper would have to be classified as recycling of hazardous material, associated with increased process-costs for increased security measures. There was a fear of putting the metal-recycling system at the risk of losing profitability.. The barrier changed during the course of this study and is perceived less severe now. Whether the modification has detrimental effects on a circular usage of resources remains to be seen. It seems that there might be effects on the usage of by-products which might exceed the defined thresholds, however it is not clear at the moment in what direction this will develop (prove of non-leakage, advanced technologies etc.).	During the study the solution was identified to define the legislation such that it differentiates according to which form the lead is present. Meanwhile, a new proposal was voted in the REACH/CLP Committee, which distinguishes between lead as a powder and lead in massive form. The interviewees welcome this distinction in general.

[5] Another application is agriculture, both in plant protection and in animal nutrition. This area will not be the focus of this study.

The geographical focus of the EU Emission Trading Scheme	Having an ETS only in the European area puts the European industry at a disadvantage in comparison to the rest of the world. The emissions will be produced somewhere else.	A possibility, but likely difficult to achieve, would be to extend the scope of the ETS also to outside of the EU. Probably, a “world-ETS” starts with an ETS that includes also those countries (outside the EU) that have a significant industrial sector and thereby capture the countries which are the biggest emitters. It is important that such a system has an effective design.
National implementation of Waste Framework Directive	Different implementations between the Member States leading to a situation in which the classification (as waste or product) of material (in particular important for by-products) can vary between regions/countries and thereby leading to administrative burdens (and costs) and uncertainty for recyclers.	Better consider by-products, for example in the definition of standards and in the usage of these standards. This does not only hold for slag but also for different other materials such as organics, dust, slurry and other solids. Better align/define the product- and the waste-Directives/regulations and ease the application of law. Examples include the use of scientifically validated information, e.g. from REACH in the classification process. Improve the accessibility of REACH to local authorities. Harmonize the different waste codes (e.g. Basel, OECD, EU). When defining/specifying the legislation it is important to keep in mind the idea to support the circular economy. It might be more useful to use realistic targets rather than overambitious targets.
Interpretation and administration of Waste Shipment Regulation	There is a link to the Waste Framework Directive and the classification as waste/product, thus mainly relevant for by-products. The current design of the administration of waste shipment results in high administrative efforts and costs. There are still too high levels of illegal exports. Transit countries can hinder the efficient flow of end-of-life-material-streams.	Ease and improve application and unify interpretation (e.g. by guidelines); keep in mind to support circularity. Streamline the administrative process. Possibly aim for global conventions to establish how materials are classified (comp. Basel convention). Ensuring the implementation of a high quality collection and treatment system to prevent illegal exports.
Missing design for recycling	The trend towards miniaturization and complex product design, for example in electronic devices leads to – in general - a higher number of different materials that are used – in lower concentrations - inside products. This increases the difficulty to recover the different materials and increases the technological requirements of the recovery technologies, which is associated with higher cost of recovery.	Consider ecodesign in product-design regulations. It seems to be useful to include general requirements for a design for recycling in the scope of the ecodesign directive. The specification should be made such that innovations and recycling are supported. At the same time the directive has to be supported such that it gets more attention. It might be useful to follow an approach similar to EMAS and support companies in the move towards a more circular product design by giving companies incentives to do so.
Uncertainty of regulatory application and development	Detrimental effect on investment. High costs to the economic actors.	Pursue a long-term policy-making. Ease application of law, also in terms of making law easier accessible up to the local level, better align different areas of law.
Implementation of the WFD obligation to separately collect scrap	Contamination” of the materials, lower values.	While the obligation for separate metal collection is specified in the WFD, it is more strictly to be pursued by the MSs.

4.2.2 Economic effects

The exact economic effects of the above mentioned barriers are difficult to estimate. In addition to not being specific to the recycling of copper alone, the above-mentioned barriers are mainly associated with cost increases for the recycling companies and therefore mainly concern the profitability of the copper recycling companies. This profitability depends on the internal cost structure of the recycling companies, which is not disclosed. The interviews suggested that the associated costs are likely to affect small recycling companies (SMEs) most.

Earlier in the study there was the fear, that if a general maximum lead content would be introduced into the CLP legislation this would concern – in the extreme case – the whole sector of copper recycling – about more than 2 Mio t copper scrap. Heavy copper scrap is currently priced at around 4000 €/t at the LME. With the distinction between lead in the form of powder and in the massive form, the affected materials will not constitute the majority of copper. It is not clear how much material will be affected and how this will impact their circular usage.

Illegal exports are of importance to the whole economy. On the one hand because value is flowing out of Europe; on the other hand because of probable detrimental environmental effects which will be discussed in the next section. Easing and streamlining administrative procedures for waste shipment would benefit the waste shipping companies but also the respective authorities in charge. With a proper design, it is likely that resources, for example in the form of personnel, could be freed to track illegal shipments. By the nature of the problem, illegal shipments are difficult to quantify. Currently they seem to be increasing (European Environment Agency, 2012). In the case of copper that means that material with a high value is risked being not properly treated and possibly partly "lost". In a coordinated inspection campaign (between 2008-2011) in the context of the project "Enforcement Actions II" it was found that almost a fifth of the inspected shipments were in violation of the European Waste Shipment Regulation, 37% of those were illegal shipments, which is about 7% of the inspected shipments (IMPEL, 2011 cited in European Environment Agency, 2012). These numbers are, however, not necessarily representative and by now older than 5 years.

In addition to the legal barriers, it has to be noted that the financial situation of the copper recycling sector is worse than some years ago as globally prices are decreasing, like also for other metals and commodities. The LME settlement price of "Copper Grade A" is at less than 4100 €/t. Prices have been much higher, for example copper cathodes were priced at more than 6000€/t in 2011. Prices for scrap move with world market prices of copper: they have also been decreasing since 2011. Comparing, for example, the prices of "Scrap heavy" with the LME daily price, the heavy scrap is priced at around 90% of the base metal. Since scrap is priced in different qualities, it is not easy to generalise the price. To illustrate, the prices for "copper wire and tubing" are at around 2600€/t (Feb 2016) (About Money, 2016). In addition, energy and commodity prices are low which supports primary production.

4.2.3 Environmental effects

Recycling facilities in Europe operate with high standards of environmental and health protection, under these preconditions illegal exports may have adverse effects on the environment as well as on human health. A better enforcement of the Waste Shipment Regulation is likely to be beneficial for the environment as well as for the European economy.

The other barriers discussed above mainly impact the profitability of the recycling sector in the EU. If this would result in a lower recycling rate of copper scrap, this is associated with more use of virgin materials, with more energy usage in the production process and with comparatively higher CO_2 emissions. The use of ores always is linked with land-use. The production of recycled copper requires up to 85% less energy than primary production: to extract copper from ores one needs about 95 Mio Btu/t, for recycling copper one needs about 10 Mio Btu/t. In consequence, the production of copper from scrap, as compared to the primary production reduces CO_2 emissions by about 65% (BIR, n.d.).

4.2.4 Non-regulatory barriers and other effects

Table 6 Overview of no regulatory barriers and other effects

Barrier	*Nature of the barrier (e.g. technological)*	*Effect*	*Possible (legal) solution*
Market prices for commodities and energy	Economic/ Financial	Low prices for energy and ores decrease the incentives to recycle	

4.3 Recycling of steel and steel by-products

4.3.1 Introduction

The steel sector is a large sector with high economic importance, in particular because of its importance for value-chains. Steel is a crucial input into a number of industries. Industries that have a particular high demand are the construction, the automotive and the machine construction industry. The value creation of the European steel sector is estimated to be about 57 billion Euros[6] (Stahl-Zentrum, n.d.).

The European production of crude steel was about 169.3 million tons in 2014; about 25% were produced in Germany, which is the largest European steel producer and the 7th largest in the world (BIR, 2015). In general, steel production is associated with CO2 emissions, the exact amounts depend on whether the steel is produced from ores or from scrap and on the applied production technology. Still, the steel sector is the largest industrial emitter of CO2 (Bio Intelligence Service, 2010).

There are two different production processes of steel: the production in so-called “BOFs” (Basic Oxygen Furnaces) which represents the production of crude steel from mainly iron-ores and the production in “EAFs” (Electric Arc Furnaces) which uses mainly scrap as an input into the production system. However, in general both systems can also use the input material that is not the main input factor. The exact proportions are chosen based on economic and process technological considerations. The production of steel from secondary material consumes about 78% less energy and emits about 85% less CO2 than primary production in a blast furnace (BOF) (EuRIC, 2015). Independent of the type of production process, the resulting product (crude steel) cannot be distinguished. In 2014 about 61% of the European steel production (103.2 Mio t) was produced in BOFs , 39% (66.1 Mio t) was produced in EAFs. About 91.3 Mio t of scrap were inputted into the steel production, which is 53.9% of the total crude steel production (BIR, 2015). In 2010 this ratio was at 55.8%.

The production of steel results in a large volume of by-products, on average between 200 and 400kg of by-products per ton of steel, 90% (by mass) of this being slag.

Steel is – in theory – a material that can be re-smelted over and over again without a loss of quality. However, when used in complex products such as composites, recyclability gets more difficult and more expensive (source). Also, the presence of other metals in the used scrap, such as copper, can decrease the quality of the recycled steel.

The recycling of steel, including the collection of scrap, is a very established process, starting at local collectors, involving a chain of processing, trading and transport, and then being used in the European steel production or being exported.

[6] The number is based on the estimation of the German sector as reported on www.stahl-online.de.

4.3.2 Main regulatory barriers

Table 7 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
National implementation of Waste Framework Directive and End-of-waste criteria (council regulation No 333/2011)	Different implementations between the Member States leading to a situation in which the classification (as waste or product) of material (in particular important for by-products) can vary between regions/countries and thereby leading to administrative burdens (and costs) and uncertainty for steel recyclers.	Better consider by-products, for example in the definition of standards and in the usage of these standards. This does not only hold for slag but also for different other materials such as organics, dust, slurry and other solids. Better align/define the product- and the waste-Directives/regulations and ease the application of law. Examples include the use of scientifically validated information, e.g. from REACH in the classification process. Improve the accessibility of REACH to local authorities. Harmonize the different waste codes (e.g. Basel, OECD, EU). When defining/specifying the legislation it is important to keep in mind the idea to support the circular economy. It might be more useful to use realistic targets rather than overambitious targets.
Interpretation and administration of Waste Shipment Regulation	There is a link to the Waste Framework Directive and the classification as waste/product, thus mainly relevant for by-products. The current design of the administration of waste shipment results in high administrative efforts and costs. There are still too high levels of illegal exports. Transit countries can hinder the efficient flow of end-of-life-material-streams.	Improve application and unify interpretation (e.g. by guidelines); keep in mind to support circularity. Streamline the administrative process. Possibly aim for global conventions to establish how materials are classified (comp. Basel convention). Ensure the implementation of a high quality collection and treatment system to prevent illegal exports.
Missing design for recycling	The trend towards miniaturization and complex product design, for example in electronic devices leads to – in general - a higher number of different materials that are used – in lower concentrations - inside products. This increases the difficulty to recover the different materials and increases the technological requirements of the recovery technologies, which is associated with higher cost of recovery. Depending on the material combination the composite cannot be (fully) recovered in the recycling process.	Consider ecodesign in product-design regulations. It seems to be useful to include general requirements for a design for recycling in the scope of the ecodesign directive. The specification should be made such that innovations and recycling are supported, without introducing mandatory LCAs or mandatory recycling content quotas etc. which can be contra productive (hinder innovations, less efficient). It is important to increase the scope of the Ecodesign directive and to promote it, such that it gets more attention from product designers and industry.. It might be useful to follow an approach similar to EMAS and support companies in the move towards a more circular product design by giving companies incentives to do so.
Coherence between European legislations in different areas of law (waste, environment, etc.) as well as with national legislation	Even at national level, there are inconsistencies between legislations. For example, the planned German „Ersatzbaustoffverordnung“ is in conflict with the German Resource Efficiency Strategy ProgRess	It is important to have an integrated analysis and assessment of existing as well as with planned legislation. Analyze the interfaces with waste legislation at Member State level.
Uncertainty of regulatory application and development	Detrimental effect on investment. High compliance costs to the economic actors, in particular for SMEs. This can have detrimental effects for the production of secondary raw materials.	Pursue a long-term policy-making. Ease the application of the legal framework, also for laypersons, also in terms of making law easier accessible up to the local level. Means to achieve this could be to issue guidelines. Better align different areas of law.

4.3.3 Economic effects

It is difficult to estimate the exact economic effect of the above-mentioned barriers. On the one hand most of them are not specific to the recycling of steel, thus the economic effects will be broader than just affecting the steel sector. In the steel sector, the above mentioned barriers are mainly associated with cost increases for the recycling companies and therefore mainly concern the profitability of the steel recycling companies which depends on the internal cost structure of the recycling companies. The interviews suggested that the associated costs are likely to affect small recycling companies most.

A barrier which is discussed more detailed in the case of copper recycling concerns the discussed introduction of a maximum lead content in the CLP legislation; this could also have a negative effect for the steel recycling, although this was not mentioned explicitly by the interviewees. In the extreme case the recycling of steel would be classified as hazardous. As a very rough estimation in 2014 91.3 Mio t of Steel scrap were used in the steel production (see above). Assuming a scrap-price of about 150€/t means that scrap of value up to 13700 Mio € would be classified as hazardous which is associated with respective higher requirements of the production and storage facilities of the actors along the value chain.

In addition to the legal barriers the current world economic situation of the steel market is detrimental to the recycling of steel: The prices of scrap have been decreasing since 2011. Currently they are at about half of the price of 2011. To illustrate: in Germany the prices of "new" steel scrap (type 2/8) were peaking at 350€/t in 2011 and they were at about 150€/t at the beginning of 2016.

Steel is traded globally and prices are established at metal exchanges, thus European products compete with products produced around the globe. Production conditions as well as economic conditions in other economies therefore also influence the European steel sector. The standards of environmental and health protection in the EU are comparatively high and to pursue these is associated with cost to the economic actors and with benefits to the environment.

The economic downturn in China leads to an increased supply on the international market, which leads to reduced prices of steel products. To illustrate this: the exports of China were at about 2/3 of the European steel production (EU: production ~170Mio t, exports China: 112 Mio t) (BIR, 2016). This also leads to difficult conditions in the European sector.

From the interviews it seemed that the current world economic conditions are perceived as being more detrimental to the European steel recycling than the above mentioned legal barriers, which are still being perceived as being of high importance.

4.3.4 Environmental effects

There are two important scenarios to be discussed: the use of less scrap in the world steel production and the shift of steel production. First, when less scrap is used, because it is not profitable to collect it anymore, higher environmental impacts are expected when the scrap is substituted with virgin material, i.e. ores. This is associated with comparatively higher CO2 emissions and mining, which means ultimately more land-use. The Bureau of International Recycling summarizes on its website the positive effects of recycling steel as follows: the recycling of 1t of steel saves (BIR)

- 1,100 kg of iron ore, 630 kg of coal and 55 kg limestone
- Co2 emissions are 58% lower through the use of ferrous scrap
- 642 kWh of energy, (which is about 75% less), 1.8 barrels (287 litres) of oil, 2.3 cubic metres of landfill space.
- Steel recycling uses 90% less virgin materials and 40% less water; it also produces 76% fewer water pollutants, 86% fewer air pollutants and 97% less mining waste

When production is shifted away from Europe this is likely to be associated with higher environmental impacts as the average production standards seem to be higher in Europe and seem to have a lower environmental impact.

4.3.5 Non-regulatory barriers and other effects

Table 8 Overview of no regulatory barriers and other effects

Barrier	*Nature of the barrier (e.g. technological)*	*Effect*	*Possible (legal) solution*
Market prices for commodities and energy	Economic/ Financial	Low prices for energy and ores decrease the incentives to recycle	

4.4 Recycling of batteries in electronic products

4.4.1 Introduction

Batteries and accumulators play an essential role to ensure that many daily-used products, appliances and services work properly, constituting an indispensable energy source in our society. The two value chains analysed in this case study are virgin portable batteries and on the other hand recycled amounts of portable batteries that could then be used as input in industrial production processes, e.g. again for the production of batteries. Over the last years a lot of emphasis has been put on the collection of discarded batteries but nevertheless many Member States still struggle how to achieve the 45% collection rate in 2016 according to the EU Battery Directive. More and more batteries are contained in electronic products and the disassembly is often time consuming and thus costly – despite general legislations in the Battery Directive. This barrier especially affects high quality recycling and recovery of raw materials for which hazardous substances in batteries pose significant threats for the quality of potential secondary raw materials.

4.4.2 Regulatory barriers

According to article 11 of the European Battery Directive 2006/66/ EC, the Member States shall ensure that manufacturers design appliances in such a way that waste batteries and accumulators can be readily removed. Where they cannot be readily removed by the end-user, they shall ensure that manufacturers design appliances in such a way that waste batteries and accumulators can be readily removed by qualified professionals that are independent of the manufacturer. Appliances in which batteries and accumulators are incorporated shall be accompanied by instructions on how those batteries and accumulators can be safely removed by either the end-user or by independent qualified professionals. Where appropriate, the instructions shall also inform the end-user of the types of battery or accumulator incorporated into the appliance. The provisions set out in the first paragraph shall not apply where, for safety, performance, medical or data integrity reasons, continuity of power supply is necessary and a permanent connection between the appliances and the battery or accumulator is required.

The key barrier in this case is the lacking concreteness of these design requirements: The wording in the Directive especially leaves open the question of how "readily removable" should be defined. Recyclers of electronic products report that for an increasing share of products it is not possible to change batteries without destroying the product (EUCOBAT 2014). Especially consumers are not able to take out rechargeable batteries from their electronic devices. This steady incorporation of batteries in products often leads to an unnecessary reduction of product use phases and thus to a waste of raw materials and other natural resources. According to the German EPA this is the case for more than 20 out of 120 electronic product groups, especially for ultrabooks, smartphones, tablet computers, navigation systems and electronic toothbrushes (Odendahl 2014).

According to the German EPA better legislations would have to specify design requirements that allow taking out batteries also in order to improve their recycling routes. The Battery Directive should be revised in a way that ensures the disassembly of batteries from products without necessary destruction of the product already during the use phase. In contrast the electronic products industry states that the global standard IEC 62075 already sufficiently promotes battery removability "either by users or skilled persons" and that proper procedures for the safe removal of the battery, information on the battery types and their location should be available to the user or skilled person.

Table 9 Overview of regulatory barriers

Main Barrier	*Affected department (s)*	*Effect*	*Possible (legal) solution*
Lack of enforceable definitions for the the recyclability of electronic products as required in the WEEE directive, especially with regard to disassembling of batteries	Product design	Lowered incentives for high quality recycling	Specified design requirements
Implementation of bans for hazardous substances in batteries	Recycling	Lowered incentives for high quality recycling	Stricter monitoring especially of imported batteries, better labelling

4.4.3 Economic and environmental impacts

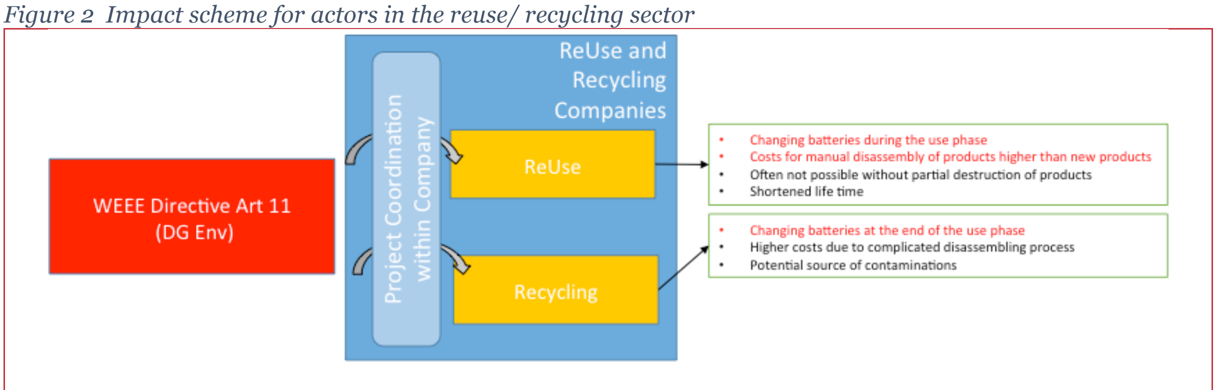
The following figure illustrates the main impacts from the regulatory barrier for circular economy identified in this case. Unclear and not enforceable legislations of recyclability especially with regard to the removability of batteries have two key impacts on reuse and recycling of electronic devices:

- During the use phase difficulties to change batteries makes reuse more costly and often not economically viable compared to the purchase of new products
- At the end of the use phase, difficulties to dismantle the product and to disassemble the batteries can cause contaminations of secondary resources in the recycling process (especially taking into account lacking enforcement of hazardous substances bans)

Removing the barrier by adopting the Battery Directive will lead to significant necessary investments into new product designs and changes of production processes. As outlined above this might lead to a situation where industry may need to stop sales of already produced products, withdraw them from the distribution chain and redesign existing and viable products. In the longer run there will be economic benefits from lower disassembly costs that based on the price difference between virgin and secondary materials might be estimated in a range of 5 to 10% compared to linear alternatives (so around 50 – 100 million Euros per year).

Also environmental impacts of removing the barrier are ambiguous: On the one hand stricter end-user removability requirements will clearly lead to increasing product life spans; increased reuse and better recycling of several resource intensive raw materials. On the other hand it might also cause either bulkier products with increased battery and appliance volume and weight, or to a reduced battery capacity. For various electronic devices such design changes might have a negative impact on the functionality, handling and usability as well as on the environment due increased resource requirements.

Figure 2 Impact scheme for actors in the reuse/ recycling sector



4.5 Remanufacturing of medical equipment

4.5.1 Introduction

Medical imaging devices such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) are widely refurbished because of their high value and their design for repair and refurbishment. Globally MRI, CT and X-Ray devices account for up to 75% of refurbished products, so medical imaging devices make the biggest share of refurbished products and are therefore in the scope of this study. The devices are built to last 15-20 years but are often not completely utilized in their first life cycle. Refurbishment can therefore extend the overall time of the equipment. The main manufacturers are Siemens, GE, Philips, Toshiba and Hitachi. The OEM's also refurbish their products in a closed-loop system. The refurbishment business is global, however, the main markets for refurbished medical equipment are the EU and the US (approx. 90% of shipments of used medical devices and parts for reuse go to the US and Europe). Before 2014, 30 % of refurbished equipment sold in the EU was sourced from outside the EU. The refurbishment of medical equipment accounted for a global revenue of approx. 480M€ in 2012. Approximately all the refurbished systems are sold in the US (48%) and EU (26%). In 2013 refurbished medical equipment worth around 130M€ was sold in the EU. The Compound Annual Growth Rate is estimated to be 12.5 % from 2014 to 2019.

Due to the specific properties needed for medical imaging, those devices often contain hazardous materials such as lead, cadmium, and hexavalent chromium. High standards of End-of-Life treatment of these substances can avoid the risk for patients and the environment. The Good Refurbishment Practice (GRP) industry standard supports this.

The value chain of medical imaging devices is mainly controlled by the OEM's. Third parties are involved in some activities such as logistics and brokerage. The OEM's produce the devices and sell them to the customers (hospitals, clinics). Once the customers need new products they contact the OEM's and can purchase new or refurbished equipment. Public hospitals that fall under the public procurement law have to make proposals to which the companies make offers. Those offers can be new or refurbished medical equipment. Used medical equipment is taken back by the OEM's to be remanufactured, if the equipment was used in foreign countries it has to be imported. A quality assessment of the used parts and equipment is done to ensure the quality of refurbished equipment, a new warranty is given after refurbishment. Functioning spare parts of used equipment can be used for refurbishment or to manufacture new products. At the end of their life, the products are treated as EEE waste and are recycled at quality facilities under high standards, so that the material can be reused. Most materials are valuable and even plastic parts can be used for their calorific value.

4.5.2 Regulatory barriers

The remanufacturing of medical equipment within the European Union faces several regulatory barriers, which are provided in Table 10.

Table 10 Overview of regulatory barriers

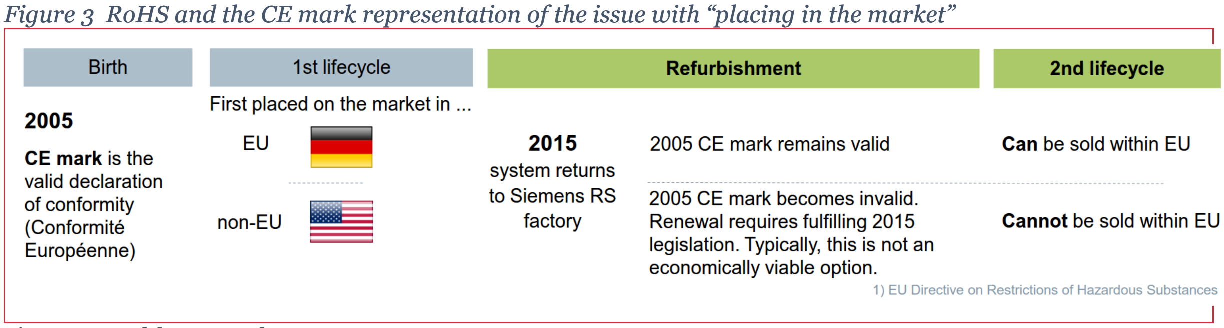
Main Barrier	*Effect*	*Possible (legal) solution*
RoHS	Restricted access to used parts/products; Difficulties with selling refurbished equipment on EU market; Uncertainty about future restrictions	Exclude refurbished products from RoHS and allow the use of used spare parts for new products independent of the origin[7]; Include exemptions for medical devices in the legal text of RoHS; Harmonize definitions throughout all legislations; Link the term "placing on the market" with the CE-marking only;

[7] An alternative might be reviewing it to "placing on the market for the first time". This would mean that in future, refurbished medical devices should have to meet all the requirements at the time when this medical device was originally CE-marked (e.g. RoHS) - but not those requirements which are valid at the time the refurbished medical device is placed on the European market. Therefore the optimal r solution is to link the "placing on the market" with the CE marking only.

		If imaging devices are considered "large-scale fixed installations" then RoHS would not apply (Article 2.4e); Add a new article to RoHS because exemptions are only temporary, have to be adapted and renewed
Additional barriers	*Effect*	*Possible (legal) solution*
Other substance regulations (REACH) in the future	Restricted access to used parts/products; Difficulties with selling refurbished equipment on EU market; Uncertainty about future restrictions	Exclude Refurbishment of medical devices
Medical Device Directive	Limited access to used parts/product	Link the term "placing on the market" with the CE-marking only
Interpretation of the Blue Guide	Limited access to used parts/product	Link the term "placing on the market" with the CE-marking only
Trade agreements/barriers	Limited access to used parts/product; Products cannot be sold to other countries	Include circular economy in Free Trade Agreement
WEEE legislation	It is more and more difficult to get equipment back	– Ensure that used medical devices for refurbishment and refurbished devices are not treated as waste – eliminate the administrative burden
The definition of the terms refurbishment / remanufacturing and waste / used equipment should be reviewed harmonized	Uncertainty, lack of common understanding	Good Refurbishment Practice (GRP) as currently developed; must be applicable in EU; Define a new class of pre-owned systems

The main barrier in terms of refurbishment and reuse, RoHS, acts as an obstacle by limiting the access to used equipment and parts as approximately 30 % of the equipment is sourced outside of the EU. Equipment that was "placed on the market" before RoHS was introduced has to be RoHS-compliant when entering the EU market after refurbishment. In the context of that, the interpretation of the term "placing on the market" according to the Blue Guide causes issues. If two identical products were sold, one in the EU and one outside of the EU and both were CE-marked at that time, the product sold outside the EU cannot be taken back for refurbishment because it then has to be RoHS-compliant. **Error! Reference source not found.** illustrates with an example this issue from the first life of the product and the instances after refurbishment in the subsequent lives of the product, when the product has been placed in the European and American market in the first place.

Figure 3 RoHS and the CE mark representation of the issue with "placing in the market"



Siemens Healthcare GmbH, 2016

In regards to economic effects, EU producers of medical equipment reported losses of 30 % revenue cuts, caused by limited access to used, but functional parts of medical equipment, which were exported outside the EU. This limited access for producers is caused by the current RoHS regulation, which hinders the return of outsourced used medical equipment into the EU.

The current medical equipment refurbishing market in the EU is rather low, regarding that it was estimated to be approximately 3 % of the total revenue for imaging devices. By overcoming the RoHS barrier, remanufacturing business could expand and therefore lead to increased job creation potential in the remanufacturing sector. In addition, India, China and Brazil could contribute to higher global remanufacturing rates as their potential to increase refurbishment of medical equipment was estimated to be about 50-100 %.

Additionally, the implementation of the RoHS regulation was mentioned to be costly, and is, together with the revenue losses, influencing the financial situation of manufacturing and refurbishing companies. Therefore, this money is missing for other fields and could cause possible missing investments. For example, these resources can be instead used for research and development of the sector. The global expenditure for the RoHS compliance is estimated in about 2 billion Euros since 2006.

Currently, medical equipment parts worth of 0.5-1 million Euros cannot be remanufactured (due to the limited access to outsourced used medical equipment and parts) and have to be introduced into a less efficient End-of-Life option. If manufacturing would be increased in a circular economy scenario, these losses through less efficient End-of-Life options could be avoided.

Refurbished equipment can be sold up to 20 % cheaper than new medical devices, which is representing 100 to 150 million Euros, which could be saved for hospitals and clinics every year.

4.5.2.1 Non-regulatory barriers and other effects

From an environmental and resource efficiency perspective, reuse and remanufacturing (if efficiency of the product is not compromised) are preferred over any other End-of-Life option of a product (e.g., recycling, landfill). Limited access to used parts and equipment, caused by the current RoHS regulation, is therefore hindering refurbishment and reuse. The remanufacturing of medical equipment allows the conservation of embodied energy of materials. This is in hand with the avoided CO_2 emissions from the materials primary production, leading to less exploitation of natural resources.

4.6 Minerals recycling from manure

4.6.1 Introduction

Manure from livestock, most notably cattle, poultry and pigs contains large fractions of nutrients such as nitrogen (N), phosphorus (P) and potassium (K). The age-old practice of recycling manure on land to fertilise crops in accordance with crop requirements makes best use of the nutrients in livestock manure. With increasing intensity of livestock husbandry, the volume of the manure produced increases and this has led, because of the amounts of manure in some locations, to applications in excess of crop requirements. This has unacceptable environmental impacts such as increase in nitrates levels in waters, eutrophication and increased greenhouse gas emissions with consequences on for human health and for ecosystem services. When a farmer produces livestock manure, in excess of the crop requirements on his/her holding it must be exported to alternative spreadlands and it is then in **direct competition with chemical and mineral fertilisers** that are industrially produced. Their nutrient content and mix can be better tuned than animal manure and is often preferred by farmers not involved with animals. Therefore, the livestock farmer has produced an excess of manure that cannot be effectively used on his/her holding. It is regarded as waste if it is not used to fertilise crops and has to be disposed of and as such the minerals contained in it get lost or at least inefficiently used. This is a problem because:

- Mineral fertilisers are energy intensive to produce and,
- For what concerns phosphorus, there is a finite supply that is sourced from a small set of countries, mostly outside the EU. This makes the EU dependent on imports of materials that are essential for food production.

Many technological options exist for treating manure, usually the derived products are spread on land or incinerated, in some cases landfilled. Manure functions as a fertiliser for food and feed crops. The crops produced serve as feed for livestock and the cycle starts again. The challenges in this cycle are in manure-derived product quality, legal classification as waste (where it is not used to meet crop nutrient requirements) or animal by-product, and treatment costs.

4.6.2 Regulatory barriers

Treatment of manure into derived products faces several barriers, identified in the table below:

Table 11 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
The fertiliser regulation does not cover organic fertilisers	There is no European market for manure-derived fertilisers, while diverging national interpretations emerge.	Extend the fertiliser regulation to organic fertiliser so a European market develops for manure derived products
The Animal By-Product regulation does not take into account sanitising effects of various manure processing methods	The derived products remain labelled as C2 material for which stringent labelling and sanitation legislations apply	Research sanitation effects of various manure processing activities and certify them accordingly
The Waste Framework Directive labels AD as a recovery operation instead of recycling operation	Incineration stands on equal footing with AD.	Define AD as a recycling operation
There are no End-of-Waste criteria for manure derived products	Manure and derived products retain waste classification and face subsequent barriers in material acceptance.	Develop EoW criteria for manure derived products
REACH applies for manure derivates but not for manure, because manure processing is a waste processing activity.	Increased costs for manure derived products compared to raw manure	Assess suitability of REACH framework for manure derived products

Technopolis

4.6.3 Economic effects

Attribution of damages incurred due to specific regulatory barriers is not possible. However, the barriers do incentivise inefficient application of manure as fertiliser. Using calculations on the value contained in manure, estimates of value lost due to inefficient manure application can be made. References for the sources are included in the full case study.

Table 12 Overview of economic effects

	Nitrogen	*Phosphorus*	*Total*
Fertiliser value	€543/ton	€333/ton	-
Nutrient content in manure[8]	7.5 Mton	4.7 Mton	12.2 Mton
Total value in manure	€4.1 billion	€1.6 billion	€5.7 billion

Assuming that 20% of fertiliser value is lost by disposing of manure as waste instead of extracting nutrients for targeted fertilisation, the damage would amount to €1.14 billion euros or €57 m per percent annually.

4.6.4 Non-regulatory barriers and other effects

The most prominent non-regulatory barriers for manure processing and nutrient recovery are listed below. Organic fertilisers or nutrients extracted from manure have a higher price than inorganic fertilisers. This high price is not regarded as justified by all crop farmers because they may not be aware of additional benefits from organic fertilisers. Also, some risks are perceived in the material: because of its natural origin, a flawless consistency cannot be guaranteed. This relates also to the technology that is still in development. This technical and legal uncertainty around manure-derived products in turn scares off investors.

Table 13 Overview of no regulatory barriers and other effects

Barrier	*Nature of the barrier*	*Effect*	*Possible (legal) solution*
Additional beneficial effects of organic fertiliser not acknowledged or known	Awareness	Higher price of manure derived products is not seen as justified	Research and communicate effects of manure derived products
Quality inconsistencies and impurities of manure derived products through immature technology and the nature of the product	Technological	No market or reduced price for manure derived products	Improve technology, review appropriateness of quality and purity demands for organic fertilisers
Manure processing towards higher quality fertilising materials is more expensive than manure spreading or inorganic fertiliser production	Economical	There is a limited demand for manure derived products	Increase cost efficiency by technological learning
Legal uncertainty around manure derived products scares off investors	Financial	Reduced investments in manure treatment technology development and operations	Create rigid regulatory framework for the European market

Nutrient recovery and manure processing are labour intensive. Interviewees report that 70,000 people are employed at 17,000 biogas installations, amounting to some 4 people per installation on average. A similar number has been found in a technology and economics survey on manure treatment options.

[8] (Pleso, 2002)

The interviewee mentioned above said that employment in the sector could triple in the next decade to 210,000 people employed, although note has to be taken that the biogas installations must process more than manure alone to be economically viable.

The survey mentioned also reports that some 19,000 installations treat 8% of manure. To treat 100%, some 240,000 installations would be needed. A lower limit of 1 Full Time Equivalent (FTE) per installation may be feasible if construction and maintenance is included. This means that a figure of some 200,000 people employed is not unreasonable. Considering the desire and potential for mixed approaches for manure and other bio-wastes, the figure cannot be solely attributed to manure treatment alone. Since manure is a voluminous product, local (possibly clustered) treatment is preferred to reduce transport movements. This increases the chances for SMEs to be involved.

4.7 Food waste in the hospitality sector

4.7.1 Introduction

This cases study focuses on food that is wasted in the hospitality sector and the ways in which this amount can be reduced. The hospitality sector is a collection of multiple types of food providers, including businesses like restaurants and cafeterias but also public institutions like schools and hospitals that provide food to their "customers".

In general, there is a lot of food "loss" or "waste" in the food supply chain, 89 million ton annually in the EU. There is a clear difference in definition of "loss" and "waste". Food "loss" is defined as food mass that gets extracted out of the food chain all the way up to, but excluding, retailers and consumers. Food "waste" specifically covers food mass that gets lost in the end of the food chain, mainly related to behaviour of retailers, food providers and consumers. In this case study the focus will be on part of the food that is wasted.

4.7.2 The product and its value chain

In general, the available amount of data on food waste in Europe is low in quality and volume. Data on food waste is for instance not (yet) collected by Eurostat in a central methodological way. However, a general overview of food waste in the hospitality sector can be given. In Europe 89 million ton per capita per year is wasted. 17 million ton of this can be attributed to the hospitality sector per year. Of this 17 million ton, 2.7 million ton per year is avoidable through legislations. As calculated in the case in appendix B.7, the price of food may be estimated at €1.57/kg. This results in €4.239 billion that is wasted in avoidable food waste.

Several end-of life options exist. (1) Food donations to charities. However, the hospitality sector is a small contributor to these donations, partly due to the lacking infrastructure and the small time span for delivering already prepared food. (2) Converting waste to animal feed. Despite the commercial return, it is hindered by Regulation 1069/2009 to avoid cannibalism for safety reasons (e.g. TSE), and the extra work stemming separation. (3) Anaerobic digestion (AD). For this option, separation and lacking collection infrastructure are again hindering (4) Composting.

4.7.3 Regulatory barriers

In this case a total of four regulatory barriers are identified. These barriers are categorized in two sub-categories; legislations posing as barrier to the prevention of food waste and legislations posing as barrier for the reuse of food.

4.7.3.1 Legislations posing as barrier to the prevention of food waste

Hygiene rules and best before dates

Many respondents mentioned that the too strict hygiene rules are causing food waste. These hygiene rules stem from the Hazard Analysis and Critical Control Points in the European regulation (EG) 852/2004 on food stuff hygiene (HACCP). This HACCP is translated into a national hygiene code. The regulation states that Member States can design hygiene rules as long as they are based on HACCP

Examples of these hygiene regulations are Regulation (EU) No 1169/2011, which determined the best before dates on food packaging and Regulation (EC) No 589/2008 which sets the best before dates for eggs. Regulation (EU) No 1169/2011 causes confusion on the edibility of the food and often still-edible food is thrown away. Regulation (EC) No 589/2008 does not consider storing conditions such as the prolonged edibility of refrigerated eggs. Another barrier stems from the presentation rules at buffets. Some foods, like tomatoes, are often still edible but are now thrown away. Yet this presentation rules stems from national legislation.

Possible solutions: The rules for presentation time can also be viewed as an European problem if regarded as a lack of legislation and a harmonized rule on presentation time could be implemented. The best-before-dates could be tailored to the storing conditions of products and Annex X of Regulation (EU) No 1169/2011 which contains a list with products exempt from the best before dates, could be extended.

If the solutions lead to waste reduction, this will save costs in the hospitality sector, as they need fewer resources. However, as the hospitality sector will buy less products form the wholesale markets, the wholesale market would lose income.

Lacking legislations on portion sizes

Food that has been served cannot be used twice. Currently portions tend to be too large and not all the food gets eaten. This is a big source of food waste with associated costs, although the consumer pays for the waste.

A solution could be getting restaurants to address their food waste and options to reduce it and serving smaller portions, and, at the same time educating the consumer to accept smaller portions and order less. The local government could play a role in assisting the education of both guests and restaurants.

Consumers might find eating out less attractive this way and consequently those restaurants in the hospitality sector that reduce their portion size might lose customers. On the other side these restaurants might obtain a reduction in costs, both by using fewer resources and having less waste.

4.7.3.2 Regulatory barrier for the reuse of food

Value added tax

Council Directive 2006/112/EC places an extra tax on food donations, which has to be paid by the donor. This is problematic because it makes disposal cheaper than donating food and caterers are more inclined to discard the food instead of donating. A possible solution might be adopting the 'Good Samaritan law' throughout Europe. In this way the hospitality sector won't have to pay for their donations, so food banks would receive more donations and can more easily reach their goals. This would mean that people in need would gain more access to food. Tax income would however shrink, but since due to the VAT donations are currently this is only a marginal effect.

Liability of food donors

Many of the respondents believe donation will incur extra costs on the hospitality sector, as a special insurance against liability is needed. Insurance costs are a negative economic incentive and furthermore potential brand damage makes discarding food more attractive than donation. Respondents mention that food banks are defined as food business operators. Food operators are responsible for their role in the chain. According to article 7 of the Council Directive 85/374/EEC, the producer in the case of food donation is not liable. A solution would thus be to categorize caterers as producers. However, there is not a clear distinction between a producer and a food business, which are liable. If this is clarified and solved, people in need will gain easier access to food.

4.7.4 Economic effects

4.7.4.1 Regulatory barriers for the prevention of food waste.

Table 14 Overview of regulatory barriers for prevention

Barriers for prevention	*Effect*	*Possible (legal) solution*
Hygiene rules and best before dates. Regulation (EU) No 1169/2011, Regulation (EC) No 589/2008, Regulation (EC) No 1881/2006,	Unnecessary food is thrown away, placing a unnecessary economic burden on the hospitality sector.	Taylor best-before dates and Hygiene rules per product.

Lacking legislations portion sizes.	Over preparation of food and unnecessary waste.	Set standards for portion sizes

There are costs associated with discarding food that could have been prevented, but we have been unable to reasonably estimate a figure. The fraction of preventable food waste consists of food waste through portion size mismatches and food waste through best before dates and hygiene rules. An estimation of the allocation of food waste to either of these categories and subsequently the preventability of food waste within them was not possible, especially since they are also related: with buffets, one can argue that too much is prepared (portion size) and/or that the allowed serving timeis inappropriate.

4.7.4.2 Regulatory barriers for the reuse of food.

Table 15 Overview of the regulatory barriers for reuse

Barriers for reuse	effect	Possible (legal) solution
VAT on food donations: Council directive 2006/112/EC	A negative economic incentive is placed on food donations, leading food being discarded.	Adopt the Good Samaritan law throughout Europe.
Liability of food donors. Regulation(EC) no 178/2002. Council Directive 85/374/EEC .	Negative economic incentive on food donations; food is discarded instead of donated.	Define the hospitality sector as a producer.

Current legislation puts a negative economic incentive on the food donations. Economic effect: 79% of the food waste in the hospitality sector cannot be avoided through legislations, but, food can also be reused in order to prevent it from becoming discarded as “waste”. For this 79% a significant proportion can be reused by charities in order to feed people in need, which it seems is hindered by a regulatory barrier. This 79% would result in 10 million ton of food. How much food of this total 10 million tons can be directly passed to food banks is unknown. So even when assuming that: 1) one third of the food can be used by charities, and 2) that also one third is collectable in urban regions, the potential is great. This would result in 1.1 million ton food that can be collected. Yet due to a lack of data and practical issues as collection it is not clear how much of this number can actually be donated.

4.7.5 Other effects

It is not resource efficient to discard food instead of reusing it. Through discarding materials are lost. Besides being economically wasteful, production of food requires resource extraction.

Aside from the environmental concerns stemming from the extra needed production, it is morally questionable to discard still edible food, while it could also be transferred to people in need.

4.8 Preparation for reuse of electronic products

4.8.1 Introduction

The role of reuse and preparation for reuse in a circular economy has been significantly strengthened by the five-step waste hierarchy; these concepts are inter alia mentioned by the Roadmap for a Resource Efficient Europe as two of the key strategies to increase resource efficiency in Europe. Reusing products or components enables to maintain the natural and financial resources that have imbedded into them during the production process. Against this background reuse, repair or remanufacturing are core elements of the "inner circles" of a circular economy. Over the past few decades, repair and reuse of used products has been stabile on a rather low level (Poppe 2014) - mainly due to the increasing complexity of products along with shorter innovation cycles leading to a rapid loss in value of products. However, just recently the interest in reuse has increased significantly – together with innovative approaches and new business models to overcome "linear product systems of produce-use-throw away".

Directive 2008/98/EC, Article 11.1 of the European Parliament and of the Council of 19 November 2008 - the Waste Framework Directive states that Member States *"shall take measures, as appropriate, to promote the reuse of products and preparing for reuse activities, notably by encouraging the establishment and support of reuse and repair networks, the use of economic instruments, procurement criteria, quantitative objectives or other measures."*

Reuse is of special relevance for electric and electronic equipment (EEE), ranging from electric household appliances such as washing machines, fridges and lamps to electronic equipment such as computers, mobile phones, electronic toys and smoke detectors. The use of EEE is an integral part of modern Europe, both in the private and in the working sphere. Electric and electronic equipment are a quickly growing consumption area. In 2011, EU-27 consumers spent on average 5.6 % of their budget on EEE, up from 2.3 % in 1995. The total market size of electronic products in Europe is estimated at about 640 billion Euros (Produktion 2014).

Against this background waste electrical and electronic products (WEEE) is one of the fastest growing fractions of municipal solid waste. Considering the multitude of actors and products, the rapid changes of technology, product design and related material composition, as well as the rather opaque life cycle chains, WEEE is also one of the most complex waste fractions in terms of its highly heterogeneous mix of materials with low or zero recovery rates for many raw materials. The alternative of reusing second hand products would prevent losses of these raw materials but its relevance is difficult to estimate. According to Eurostat the recent overall reuse rate can be estimated at a maximum of 1% of collected WEEE and differs significantly between the Member States as well as product groups.

4.8.2 Regulatory barriers

Regarding the access to waste streams article 6, paragraph 2 WEEE Directive states that "In order to maximize preparing for reuse, Member States shall promote that, prior to any further transfer, collection schemes or facilities provide, where appropriate, for the separation at the collection points of WEEE that is to be prepared for reuse from other separately collected WEEE, in particular by granting access for personnel from reuse centres". Nevertheless reuse organisations are restricted from accessing collection points. To be able to access high quality goods for reuse the organisations need to close contracts with local authorities or other responsible collecting institutions. Especially for small organisations this can be already a difficult challenge, as it requires approaching and convincing the local decision makers to change their process. On the other side it is also important to only allow reliable organisations to access materials for reuse, as also a strong informal market is active in this field all over Europe. The main change required for reuse is the separate collection at waste centres; many places have already adopted this and provide specific containers where products can be placed, if they are still functioning well. In some cases organisations involved in reuse also face barriers to access materials due to required licensing as waste management company allowed to process waste (in German "Erstbehandler"), even though the organisations do not intend to process waste, but just prepare the products for reuse. In this case the technical requirements are challenging and costly for often rather small companies that just want to repair products that are legally classified as waste but don´t cause direct harms to the environment or human health.

Regarding access for reuse some solutions was mentioned in Flanders. Here collaboration between reuse centres and take-back schemes for extended producer responsibility was found. First both parties felt in this collaboration as in a “forced marriage”; nevertheless both parties now see already the benefits of the collaboration. In Flanders the members of the regional reuse network Komosie now have better access to high quality products, which can be resold, in their shops, while the take-back scheme reduces its cost for treatment. Though it is expected that the reused products lifetime is only extended for a little bit further, but at a later point still have to be recycled.

Additional barriers identified in this study relate to the issue of ecodesign: Article 4 WEEE Directive states that Member States shall take appropriate measures so that the ecodesign requirements facilitating reuse and treatment of WEEE. Nevertheless these regulatory requirements are not precise enough to control access to the European market so that Europe is experiencing a “flood of cheaper and poorly designed products on the market” (Rreuse 2012). This barrier of design legislation was confirmed in the interviews with reuse centres. For them it has become more and more difficult to repair white goods, the older products were much easier to repair for the centre, but now with increasing electronic systems in place the preparation for reuse becomes much more challenging. Also it is reported that the construction of many products moved from system that use screws and bolds that could be replaced to adhesive bindings that cannot be removed quickly. Therefore many of the centres think about stopping reuse activities with white goods and focus on smaller electric items, like smartphones, tablets, and laptops, which require less storage space.

Table 16 Overview of regulatory barriers

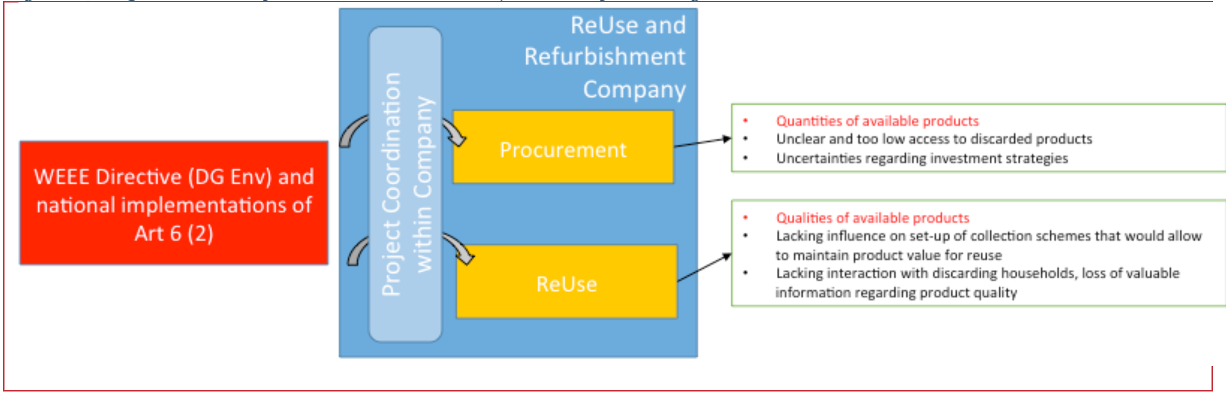
Main Barrier	*Affected department (s)*	*Effect*	*Possible (legal) solution*
Lacking legislations for access to discarded electronic products that would allow preparation for reuse	Repair and second hand sales	Reduced amount of inputs	Priority access and enforcement of mandatory testing for reuse or reparability
Additional barriers (other barriers mentioned as important): Implementable design legislations for reparability	**Product design**	**Non-repairable products**	**Concretisation of so far too vague design requirements**

4.8.3 Economic and environmental impacts

The following figure illustrates the main impacts from the regulatory barrier for circular economy identified in this case. Lacking legislations for the access to discarded products has two key impacts on reuse as one of the key circular activities:

- impact on quantities: only very low amounts of products are prepared for reuse
- impact on qualities: collection schemes are set up in a way that leads to the loss of information concerning product qualities. This leads to high transaction costs (e.g. testing of products for functionality) and threatens the economic viability of the business model

Figure 4 Impact scheme for actors in the reuse/ remanufacturing sector



Solving the existing regulatory barriers could lead to a significant increase of the reuse sector by a factor of 2-10 based on frontrunner experiences like in Flanders or Austria and significant economic potentials for the EU. Taking into account cost savings of around 30-50% compared to new products (even considering on-going technical improvements and additional functionalities), increasing the market share for second-hand products to 2% could lead to direct cost savings of up to 3 billion Euro.

Supporting reuse seems especially beneficial with regard to potential job creation: Estimations based on the reuse network in Flanders show that for 10,000 tonnes of waste products and materials, 1 job can be created if incinerated, 6 jobs if landfilled, 36 jobs if recycled, and up to 296 if refurbished and reused. A recent study by the European Environment Bureau cited by RREUSE (2015) suggests that with ambitious reuse targets, 300,000 jobs could be created in Europe just in this sector.

4.9 Recycling of plastics

4.9.1 Introduction

Plastics are valuable materials used in a wide range of applications in everyday life. Since 1950, global as well as European plastic production has been continuously growing. In 2012, Europe had a share of 20 % in the global plastics production, representing 57 million tonnes of produced plastics. Today, Asia, especially China, is the biggest growing market worldwide. The global plastic packaging market was 78.4 mega tons in 2013, corresponding to a value of about US$ 260 billion in 2013. Plastics packaging for food and beverages represent the biggest application market share of plastics packaging (65 %). Parallel with a steadily increasing plastics packaging production, the amount of post-consumer plastics has been consequently growing as well. In 2012, European countries produced 25.2 million tonnes of plastics waste. With a share of 62.2 %, packaging consisting of different plastics such as Polyethylene (PE), Polypropylene (PP) and Polystyrene (PS) is the dominant fraction.

Besides reuse, refurbishing and remanufacturing, recycling is one of the options for increasing the circularity of materials. Although, only a small share of plastics waste is currently recycled. In 2012, only 26 % of the total post-consumer plastics waste (including plastics packaging for food and beverages) was recycled, meaning that the largest share was either incinerated for energy recovery (36 %) or sent to landfill (38 %). Only half of the collected and recycled plastics waste was managed in European facilities, the rest was exported, mainly to China. This leads to an actual post-consumer plastics waste recycling quote of only 13 % in Europe. This rate is far away from a resource efficient "circular economy" scenario.

Plastics are derived from organic materials that can either be fossil or renewable resources. Since organic substances, especially crude oil, consist of a complex mixture of compounds, they have to be processed in order to extract the useful components for plastics production. The two major processes used are polymerisation and polycondensation, both requiring specific catalysts. Three different types of plastics can be produced: thermoplasts, duroplasts and elastomers. Thermoplasts can be recycled and used many times; they are the most common polymers in use. The plastics are used in a huge field of applications, in this study the packaging plastics for food and beverage are considered, since they represent the biggest share in produced plastics waste in Europe. After their use phase, the packaging plastics are collected and separated for either incineration, deposition or recycling.

4.9.2 Regulatory barriers

The recycling of packaging plastics within the European Union faces several regulatory barriers, which are summarized in Table 17.

Table 17 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
Lacking implementation of the waste hierarchy (Directive 2008/98/EC on waste - Waste Framework Directive - WFD)	A large part of post-consumer plastics waste ends up in energy recovery and landfilling instead of being recycled	Ban landfilling of plastics Identify main sources of insufficiencies / inefficiencies in collection systems in EU[9] Establish clear requirements / standards for collection systems in EU (e.g. mechanisms to separate plastics to recycle and incinerate)
Additional barriers	*Effect*	*Possible (legal) solution*
Insufficiencies in collection systems of recyclable material	Plastic waste is collected at low rates and once collected,	Insufficiencies in collection systems within the EU need to be identified and harmonized in order to increase the

[9] Before making any changes on the legislation, the sources of insufficiencies/inefficiencies need to be identified. Drafted legislation could give the legal framework for the implementation of a better and more efficient collection system by defining mandatory collection targets, incentivize collection of specific material flows, etc.

	the separation process is complex	amount as well as the quality of material collected for recycling
Missing guidance for ecodesign	Lower recycling rates because of plastics designs which are challenging to sort / treat (e.g. multi-layer plastics)	Holistic perspective throughout the whole life cycle of the plastics
Insufficient recycling targets and lacking descriptions of actions in legislation	Target setting in Waste Framework Directive 2008/98/EC does not specifically address packaging plastics (household) Collections rates for materials with low quantities on the market (e.g. bio plastics) are considered low (0.1 %) Focus of legislation is too much on recycling; waste prevention is even more important and sometimes overseen	Consider the entire life cycle of a material and use technical studies with comparisons of options to support policy decision making. Consider also the materials with low shares on the market
Potential lack of technical practicability (the new Circular Economy package from the European Commission states, that in case it is not technologically feasible, the waste does not have to be collected and recycled)	This is mentioned as an aspect that leaves room for different interpretations and could lead to a lack of motivation with the argument of 'lack of technical practicality'	As solutions, there have been mentioned incentives for MS with regard to the recycling of wastes of plastics with lower shares in the market and the development and explanation of mechanisms

4.9.3 Economic effects

For a future possible circular economy scenario of 80 % recycling rate of packaging plastics in Europe, 700 million Euro could be saved through increasing the use of secondary material, which is approximately 10 % cheaper than primary material (based on the average prices for primary and secondary PE, PP and PS for 2013).

Investment costs to increase circular economy in the field of packaging plastics was estimated in the range of billions of Euros. In general, if more plastic packaging would be recycled in European recycling facilities, less plastics waste would end up in incineration facilities or in landfills. Especially recyclers would benefit, as their market share could be increased. Increasing circularity has been mentioned as having a positive impact on the job growth potential with 10 times more jobs generated per tonne of waste than sending waste to incineration or landfill. Also new jobs in the field of Research and Development (R&D) would be created in order to create new technologies for the recycling of multi-layer packaging plastics as well as flexible packaging.

Plastic recyclers, and also plastic incinerators, could benefit from a more stable input of plastics in terms of quality and quantity. This builds trust on investments for improving facilities and allows better prediction of the amounts of energy generated.

4.9.4 Non-regulatory barriers and other effects

The most prominent non-regulatory barriers for packaging plastics are summarized in Table 18.

Table 18 Overview of technological, economical and value barriers

Barrier	*Nature of the barrier (e.g. technological)*	*Affected department*	*Effect*	*Possible (legal) solution*

Challenges on eco-design of products	Technological	Design / production	Production of flexible packaging solutions using only one material it is not standard	Development of new designs which allow having flexible packaging made out of only one material
Insufficient recognition and handling of different types of plastics by the sorting technologies	Technological	Sorting	Higher levels of contamination of the streams to recycle	Technological developments (R&D)
Insufficient technology to recycle some types of plastics (e.g. flexible packaging, multi-layer plastics)	Technological	Recycling	Recycling is not possible	Technological developments (R&D)
Recycling is expensive and cannot be financially uphold by itself	Economic	Recycling	Less recycling, more incineration and deposition	Extended Producer Responsibility (e.g. Green Dot system)

The insufficient recognition and handling of different types of plastics and insufficient recycling technologies for some types of plastics are regarded to represent main technological barriers. To overcome these barriers, more research is needed.

Another non-regulatory barrier mentioned is the high costs for collection, sorting and recycling of plastics. The recycling of plastics cannot be financially uphold by itself as for example the collected plastics waste is of lower value than the collection process itself.

From an environmental perspective, recycling is always better than landfilling.

Although, not only recycling should be the focus, but also the overall life-cycle should be considered in order to evaluate environmental and economic benefits.

For example, flexible packaging has been controversial, generating discussions among the different stakeholders. It is frequently regarded as a not beneficial approach, because it is only hardly recyclable, being typically incinerated after its use phase. Supporters of flexible packaging point out, that material savings can help to prevent waste generation, leading to less resource exploitation.

This leads to the conclusion that not only the recycling should be in the focus of a sustainable and resource efficient European Union, but that the whole life-cycle of a product should be considered in order to evaluate its environmental and economic benefit.

4.10 Secondary construction materials

4.10.1 Introduction

The focus of this case study lies on the recycling of construction aggregates used in buildings. In this topic, there are strong country variations. First, the main determinants of the amount of Construction and Demolition Waste (CDW), building traditions, geography/geology and economic activity in the sector vary across the EU Member States. These determinants have market implications such as the amount of supply and demand of recycled as well as virgin aggregates. Second, the national legislations in member states regarding CDW management are country-specific as well as the particular definitions of CDW. Hence, these two factors make it difficult to make generalizations for the European Union as a whole in the scope of this study. That becomes also quite visible when the situation in the various member states is analysed statistically. According to a study released by Deloitte the usage of CDW in the various member states varies between 15% and almost 100%.[10] Accordingly, to maintain a certain consistency within a quite heterogeneous European context, the analysis has a slight focus on one country, namely Germany. Based on the focus on Germany differences to other EU member states are drawn. The decision to use Germany as a blue print was taken since Germany shows a fairly high recycling quota for CDW. Accordingly, any regulatory barrier should show stronger impacts than on those member states with little usage of CDW.

In comparison to the European average of around 62% percent, the recycling rate of CDW in countries like Germany and the Netherlands is quite high (96,4%) but when considering the destination of the flows of the recycled material, most of the secondary aggregates are used in civil engineering. In buildings the secondary aggregates are hardly used.[11] Hence, this case study addresses the (regulative) barriers determining the low recycling-rate of aggregates in buildings.

If recycled CDW is not used, aggregates are generated from raw materials, that are extracted by blasting or excavation in the quarry. This process is often criticised as a wasting of resources and has s strong impact on the landscape. In Germany, for instance, around four hectares of grit are removed each day. Across, Europe around 3 billion tonnes of aggregates (crushed stone, sand & gravel) are produced a year at 24,000 quarries and pits. Hence, generally it is expected that an increase of the recycling of aggregates will lower the use of primary materials. Moreover, critics argue that the geographical distances between the sources and the locations where the materials are used increases environmental pressures. As quarries are located at the countryside but building material is typically used in urban agglomerations, large amounts of materials have to be transported over (long) distances. On the other hand, there are actors criticising that the secondary material is often not easy to access because it is subject to fluctuations and shortages in the supply of old buildings. So supply of aggregates from demolition seems to be frequently short.[12]

The recycling process of aggregates instead already starts with the construction of the building as the constructor should anticipate the demolition process in distant future to ease recyclability. Hence, the high recycling level of some countries can be explained by the composition of the recycled waste. Soils and stones cannot be used for recycled aggregates and are mostly used as filling for mining sites in the stone and soil-industries. After the actual demolition of the mineral material, the demolition waste is either delivered to a processing plant or treated by mobile sorters and crushers close to the demolition site. The material gets separated from non-recyclable material, crushed and strained and sometimes washed too. The recycled product is then delivered to a concrete producer who is mixing the pure concrete with the recycled product.

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[10] Christian Fischer and Mads Werge, 2008, EU as a Recycling Society Present recycling levels of Municipal Waste and Construction & Demolition Waste in the EU, ETC/SCP working paper 2/2009. The data problem is also addresses by Deloitte, 2015, Study on Data for a Raw Material System Analysis: Roadmap and Test of the Fully Operational MSA for Raw Materials, p 36.

[11] The use of secondary materials in buildings could be referred to upcycling, as opposed to down cycling in civil engineering.

[12] See Christian Fischer and Mads Werge, 2008, p

4.10.2 Regulatory barriers

Overall, in the case of aggregates in buildings, no major barrier could be identified. In several members states there exists either a shortage in supply of recycled aggregates in civil engineering or incentives to use secondary aggregates are not given by the market. Therefore, primary resources have to be used in any case and it seems to be ecologically and economically more efficient, to use primary material rather for housing than for civil engineering. Unfortunately, there were no European-wide data available regarding the demand and supply for civil engineering. However, even so member states show little sensitivity to regulatory barriers to the usage of recycled aggregates, a major problem is still given by the missing definition of the environmental characteristics going along with EN12620. Our inquiries show that the European Commission has not defined binding environmental characteristics (discharge of dangerous substances) CDW aggregates have to meet. Accordingly, the definition is given into the hands of the member states, which show quite some diversity in their definitions.

Table 19 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
EN 12620 does not regulate environmentally relevant characteristics of the aggregates so that national rules apply which can lead to increased bureaucratic costs	Use of secondary products is hampered	European committee TC 351 „Construction Products: Assessment of the release of dangerous substances" should create environmental classes for ecological characteristics of aggregates to be used in buildings. These environmental classes can be used as an indication what ingredients are allowed for what kind of usage in every member state.

Technopolis

4.10.3 Economic effects

Attribution of economic effects incurred due to the specific regulatory barrier is not possible because the effects of this barrier may be diverging in the particular countries and depend on the particular legislation for the environmental parameters. In Germany for instance – due to the specific legal framework - there is an excessive bureaucratic burden. Companies producing the secondary aggregates need a building approval from the German Institute for Structural Engineering, which is **costly**, takes **time** and **damages the reputation** of recycled construction material. Furthermore, transfer of of the recycled aggregates to other EU member states sees barriers since the material in some countries is perceived as waste whilst other define it as products. Based on the classification of the recycled aggregates the cost of transporting it to other member states differ significantly.

4.10.4 Non-regulatory barriers and other effects

In this case the only regulatory barrier identified - the absence of environmental characteristics for aggregates for concrete in norm EN12620 – is, is according to interviewees, hardly of any economic importance. That is due to the following reasons:

First: According to information gathered in the interviews the European Commission works already on the barrier and has set up an according committee. Accordingly, the major challenge to the committee is to identify environmental characteristics (discharge of dangerous substances) that find approval in all member states to reduce cost by transfer recycled aggregates from one member state to another. Since the definition of environmental characteristics is currently provided by the member states a harmonisation of those environmental characteristics among the member states would provide more competition in Europe as well as reduce the cost of transferring secondary aggregates from one member state to another.

Second, in several member states the supply and demand of recycled materials do not match, which underpins the argument that no strong barriers can be identified in this case. More specifically, the supply of recycled materials from buildings is not even enough to fully cover the demand for road construction according to two interviewees. Given the fact that experts argue that for construction in civil engineering recycled aggregates due to their baring properties have proved superior behaviour than primary materials a shift of recycled materials from civil engineering to building would have several disadvantages:

- More primary material, which does not have the desired qualities (f.i. baring properties), would have to be used in civil engineering. In comparison to the usage in civil engineering primary material provides advantages in the use in building constructions (f.i. no limitation on inner construction usage).
- At the same time, secondary material to be used in buildings would have to undergo a more sophisticated recycling process. This process is likely to require more resources and energy than the process for recycling for civil engineering and is likely to reduce the available material due to higher quality requirements (so more material may go to be landfilled).

And as mentioned before, the overall supply of recycled materials is not sufficient to meet demand for (primary and) secondary materials. Therefore, there would be no reduction of primary material use, but merely a shift towards an (economically and possibly also ecologically) less efficient use. Thus, a strong and relevant (regulatory) barrier cannot be identified in this case.

Nevertheless, this does not mean that the use of aggregates in buildings should be generally avoided as in future, supply and demand of secondary aggregates may change. Hence, pilot projects using recycled aggregates in buildings as it is already happening, were considered as a good way to raise awareness among the relevant stakeholders with the topic and to pave the way for future developments especially because several respondents referred to a general image problem of recycled aggregates. Hence, an additional barrier is the low demand for secondary aggregates by constructors, which may be caused by a simple preference for virgin materials combined with insecurities towards the quality of the recycled material. In that sense, some interviewees were also strongly in favour of giving more responsibility to the public sector and its procurement, which should operate as a role model or forerunner. Hence, civil infrastructures should use in general more secondary raw materials in their buildings. Moreover, the use of recycled material should get more attention in engineering education and training.

5 Removing regulatory barriers: the potential for the circular economy

5.1 General overview, main aspects and legislation

As illustrated by the ten case studies analysed, circular economy is hampered by various legislation mechanisms. The regulatory barriers are manifold and are summarized in the table below.

Table 20 Overview of different types of barriers and according legislations

Aspect	Legislation
Lack of definitions / gaps	• End-of-Life (EoL) of Vehicles • Battery Directive • Animal by-product regulation
Targets definitions	• Waste Framework Directive
Values definition	• REACH • CLP (Classification, Labelling and Packaging) Regulation - Regulation (EC) No 1272/2008
Lack of implementation / enforcement	• Waste Framework Directive (e.g. Waste hierarchy implementation) • Exports and Shipment regulation
Different national interpretations / implementation of regulation	• Waste Framework Directive • Basel Convention • WEEE Directive • Fertiliser directive
Conflicting options in legislation	• Hygiene rules / 'best before' dates • VAT Directive • RoHS

Many of the barriers identified are already in the focus of policy makers and are being addressed. However, simply removing the regulatory barriers might not be enough to manage this challenge. Firstly because a simple "removal" is a too simplistic approach for these complex issues. When it comes to the level of contamination allowed for example, one cannot simply remove the limit on allowed contaminations. Rather, a new limit will have to be chosen.

Secondly, economic barriers such as market prices, dominance of existing technologies, consumer demands, prohibitive business smodels, should also be considered. When revising the existing legislation, it is important to consider potential uncertainties for stakeholders involved because continuity and predictability in legislations are very important; and potential conflicts between legislations to avoid hampering investments in capacity and technology development.

5.2 Analysis of economic impacts on possible 'new markets'

The circular economy paradigm provides economic benefits in the analysed cases. The relevant economic aspects of the circular economy option depend on each individual case. After all, the cases show a great variety in context, value chain aspects, the number and kind of legislations involed, and so forth. Confidentiality and variety in the economic data (in terms of quality as well as availability) make it challenging to consolidate the information and find a 'common denominator' to all the case studies analysed. Most cases thus have a clear potential for a circular alternative but the costs and benefits vary in nature over each case. More important than providing single values for the different markets (which are in any case not comparable) is understanding the trends to identify the potential future developments.

As an estimation, it is possible to say that the orders of magnitude of the economic impacts for all cases are tens of millions or even billions of Euros per year. For each of the cases where it was possible to derive an estimate, the figures are given below:

Table 21 Overview of economic impacts related to individual case studies

Case	Cost-price ratio (compared with linear economy activity)	Opportunity costs (All figures annual)
Recycling of palladium	Secondary production is expected to be 15 % cheaper than primary	Estimated €115 mi. of precious metals in catalytic converters leave the EU
Redistribution of food	Not identified	Avoidable waste in the hospitality sector estimated to more than €4 billion
Recovery of nutrients from manure	Manure processing and nutrient extraction are more costly than direct spreading on land. The exact difference depends on the methods applied and the regulatory context	Not identified
Recycling of plastics	Up to 10% - due to use of secondary material	€700 million for packaging plastics
Remanufacturing of medical equipment	Up to 20% price reduction for refurbished equipment. This presents 100-500 million € price reduction per year	Loss of 30% of revenue cuts or potential business losses in EU
Recycling of batteries	1:1 - due to use of secondary material	€50 – €100 million
Re-use of electronic equipment	Approximately 30% - due to use of secondary material	2% increase of second-hand products could lead to direct cost savings of up to 3 billion €

For the **food** case, in the hospitality sector alone, the avoidable waste has been estimated in more than € 4 billion per year. For the **palladium** case, one of the interviewed companies estimated the amount of precious metals in catalytic converters leaving Europe in €115 million per year. Since palladium is a rare metal, its price doesn't reflect only the production cost (production of secondary palladium is expected to be at least 15 % lower), but also its scarcity, therefore no influence on the market prices is expected if the circularity is increased. Regarding the **manure** case, value losses amount to €2.3 billion per year. For the **plastics** case, savings of €700 million per year are estimated for a scenario of an 80 % recycling quote for packaging plastics. The secondary material is about 10 % cheaper than the virgin material, although this depends strongly on mineral oil prices. About the **medical equipment** case, up to 20 % price reduction for refurbished equipment is expected, which is representing a cost saving of €100-€500 million per year. Business losses are estimated to be in the range of 30 % and additional indirect costs are expected to be in the amount of €50 million for RoHS implementation. For what concerns the **batteries** case, business losses are mentioned to be significant. For the **reuse of electronic equipment**, business losses in the range of at least €300.000 (for one individual company) are estimated and a cost-price ratio of approximately 30% expected (reuse would be 30% cheaper).

5.3 Growth creation and employment potential of policy interventions

The growth creation potential in the EU as a consequence of removing the regulatory barriers for circular economy in the cases is complex to estimate, but indications have been given by the interviewees.

The order of magnitude of jobs created could be estimated in the range of several hundred thousand newly created jobs. For example for the **manure** case, an advanced nutrient recovery can help to reduce import dependency on phosphates and improve the food security. The job creation in this field ranges about 70.000 and some assume that it could be even tripled. An assumption of job creation potential of 100.000 is reasonable in this field. For the **plastics** case, the recycling is estimated to create about 10 times more jobs per ton of plastics waste than sending the waste to landfill or incineration. Considering the **reuse of electronic equipment**, there is a potential for job creation in the reuse and refurbishment of discarded products. About the **batteries** case, due to necessary investments, growth creation potential exists, but has to be considered in a mid- to long-term perspective. For the **food** wastes case, jobs could be created in the field of collection and processing. Considering the **steel** and **copper** recycling cases, these sectors have established recycling processes as state-of-the-art, so the potential is to ensure that these can operate under their high standards. The main potential is in the increase of the circular use of by-products of the copper/steel production and recycling. In addition, there is a potential in extracting more valuable contents of (some of) the by-products.

The increase of circularity within the European Union leads to an increase of job potential in the activities involved, this might however have a negative influence on the job potential in the field of the extraction of competing materials. For example, as it was mentioned in the context of the **steel** and **copper** cases, it is likely that while the recycling sector benefits if the by-products are processed to be used in the construction sector (e.g. substitution of stone), the incumbent producers of the materials which could be substituted might have losses in their business that is not easily quantified.

It is safe to conclude that preparation for reuse, repair, re-manufacturing and refurbishing are typically more labour intensive than recycling. In the fields where technological development is needed, R&D (Research & Development) jobs will have to be created in order to explore new technological solutions. This is for example the case for new technologies concerning the sorting of **plastics** in their End-of-Life and new plastic packaging designs. As another example, it is worth mentioning the potential improvements regarding the design of products containing **electronic components**, where the modularity can contribute to increase their lifetime and potential for reuse.

5.4 Impact on innovation

Legislation can also be seen as a driver for innovation: it is often necessary to develop new products, processes, and/or business and organisation models to comply with legislation. For example for the **plastics** case, the sorting and recycling process equipment is not yet completely developed from a technological perspective. The main challenges in this field are sorting different kinds of plastics such as flexible and multi-layer packaging and bioplastics. However, in some cases, the innovation in (eco-) design for the use-phase can be even more important than the innovation in end-of-life options of a product. For example regarding the design of products with **electronic components**, where increased modularity could improve the reuse. Another example is the design of packaging **plastics**, where flexible but non-recyclable plastics could help to save material such as foodstuffs and to prevent waste generation. For the **batteries** case, it could be expected that specific legislations which would support the disassembly of batteries from the products, would not only have effects on the design of new products but could also support the development of battery recycling technologies since more batteries could be extracted out of the product for recycling, increasing the input for disassembly and recycling plants.

In order to promote innovation for circular economy options driven by legislations, careful implementation with dynamic goals that reflect the current state of the art is required. Otherwise, the defined goals could become a barrier for the next generation of options as they are “not needed”.

In addition to obsolete legislation, unpredictable legislation is also seen as a barrier for innovation. It causes uncertainties for potential investors as well as long-term technology developers. This can lead to missing investments, as for example for the **copper** and **steel** cases, where this aspect has been mentioned by the interviewees. For the **manure** case, unclear and non-harmonised legislations and definitions hamper investments in R&D as well as in processing capacity. Thus, continuity and predictability in legislations is an important factor for the promotion of innovations.

Also, in some cases, the costly implementation of legislation is seen as a factor that indirectly hampers innovation, since the money spent is no longer available for further Research & Development activities. For example, in the **medical equipment** case, these expenses amount to about 2 billion € are spent for RoHS compliance.

Lastly, there is a need for investments in R&D for new sectors, activities, and products where eco-design is considered. For example for **electronic equipment**, new facilities have to be established in order to process and test the reused and refurbished electronic equipment.

5.5 Winners and losers

By increasing circularity, economic growth and resource consumption can be decoupled. This decreases the dependency on primary resources that often originate from outside the EU. In the case of critical raw materials (e.g. palladium), this is particularly relevant, as there is a risk of supply to be considered - see chapter 5.6. Another relevant aspect is that with higher recycling rates in Europe (compared to exports of certain wastes), higher amounts of materials are treated according to EU standards. Lastly, stimulating a circular economy in Europe stimulates expenses on labour within the EU and simultaneously decreases expenses on material imports. This has a positive effect on the trade balance. These considerations imply the presence of winners and losers.

"Winners" could be, for example: producers that invest in reparability and design, new service-oriented business models (e.g. leasing), reuse centres, refurbishment business and recyclers. Industry sectorsthat need to adapt in order to avoid becoming "losers" could be, for example: producers which do not consider the EoL and (eco-) design of their products; producers which produce products that can be replaced by secondary materials; linear concepts of selling products; WEEE recyclers (in the specific case of re-use); incineration and landfill operators; and those operating legally doubtful practices with imports and exports of used goods such as electronics and vehicles (mentioned in the context of recycling palladium from vehicles in End-of-Life).

Of special importance in this aspect are the SMEs (Small and Medium-sized Enterprises), as they are regarded to be more agile and frequently highly competent, which may allow them to provide the needed solutions faster than big corporations. High flexibility is therefore advantageous, but bigger companies with a high market share also have benefits for the transition of companies to a more circular business model by profiting from economies of scale.

Table 22 Overview of the classification of winners and losers in a circular economy scenario

Winners	Losers
• Producers: invest in reparability • Producers: invest in design • New service-oriented business models (e.g. leasing) • Reuse centres • Refurbishment business • Recyclers	• Producers: not consider EoL, (eco)design • Producers: products which can be replaced by secondary materials • Linear concepts of selling products • WEEE recyclers • Incineration and landfill • "Shady players"

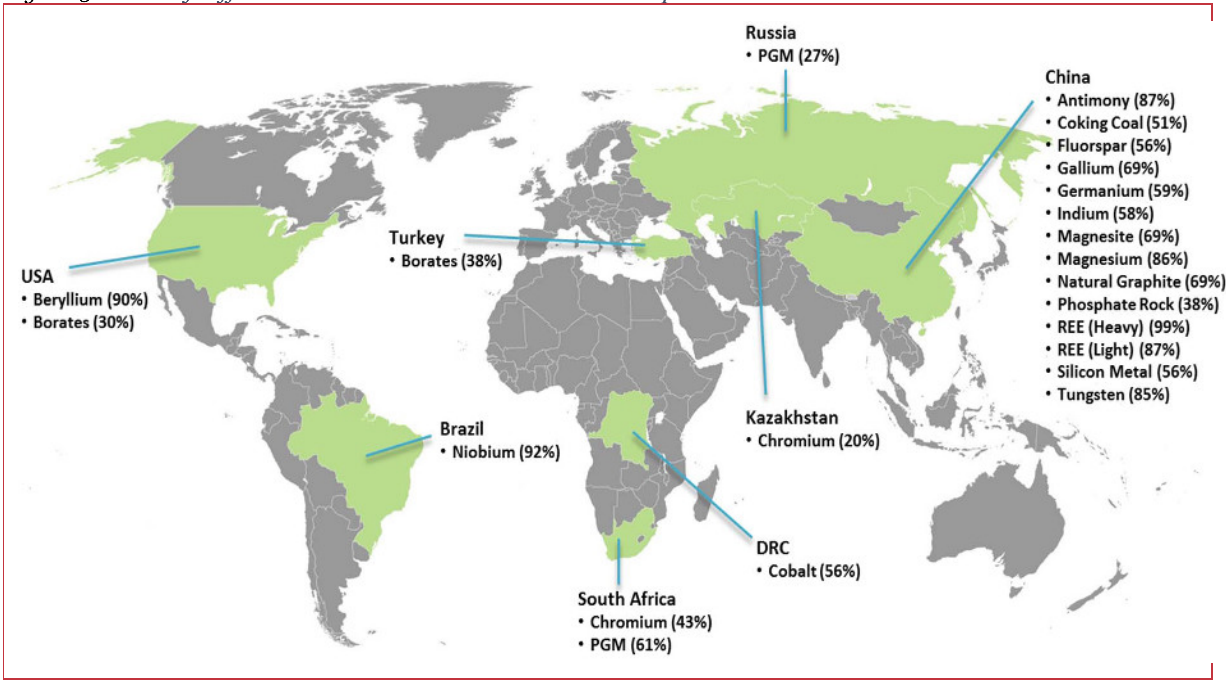
For the **copper** and **steel** cases, there is a market potential for slag (out of primary and secondary production) which can be used as a material in the construction sector. This substitutional use of slag is competing with the "stone producers" and other incumbents who might lose if the application of slag develops. For the **palladium** case, if the transparency is increased, there is a potential to reduce the number of "shady players". For the **manure** case, increased treatment can reduce the demand for mining-based fertilisers and stimulate the market for biobased-fertilisers. The import dependency can be reduced and food security increased. However, the increased treatment of manure could also increase costs for farmers. For the **plastics** case, there are new markets to be considered, including the flexible packaging, as well as the bioplastics, in which there are many SMEs involved. For the **medical equipment** case, OEMs operate as both producer and remanufacturer. For them, alternative business models like for example medical equipment leasing could emerge. More efforts in developing the alternative business modelss in this field will assure better control over hazardous substances. For the **batteries** case, it is expected that winners will be battery recyclers and high-quality WEEE recyclers, which benefit from better quality input materials and lower disassembly costs. In the short-term, producers will have to make investments in product design changes, but they could benefit from lower End-of-Life costs in the long-term. For the reuse of **electronic equipment**, it is expected that winners will be reuse centres ("third labour market"), producers that invested into repairable products and new service-oriented business models that would benefit from professional reuse infrastructures. Companies with traditional concepts of selling products and WEEE recyclers, may face challenges since the increased reuse of products is preventing waste and therefore lowers recycling of these products.

5.6 International competitiveness

The international competitiveness issue depends on the geographical position of actors in the value and these considerations are therefore only relevant to cases with parts of the value chain outside Europe. The **aggregates** and **food** waste cases are therefore not relevant for international competitiveness, as the issues are managed locally. Other cases such as **metals** and **plastics** are relevant for the international competitiveness due to their extensive international value chains.

Many raw materials are extracted outside Europe because of their occurrence. This is especially important for critical raw materials. In 2013, the European Commission assessed 54 raw materials, which are important for the European economy. The European Commission defined 20 of them as “critical raw materials”, which are in addition to their economic value characterized by a high supply-risk. Platinum Group Metals, such as for example palladium, belong to the critical raw materials. China is the largest producer of the 54 assessed raw materials as well as of the 20 EU critical raw materials. A number of other countries have dominant supplies of specific raw materials, such as the USA (beryllium) and Brazil (niobium). The EU primary supply across all 54 candidate materials is estimated to be around 9% of the EU consumption. In the case of the 20 critical raw materials, supplies from EU sources are even more limited. [European Commission 2015[13]]. The figure below shows the share of different countries in critical raw material production for the critical raw materials.

Figure 5 Share of different countries in critical raw material production



Source: European Commission 2015

[13] European Commission 2015, www.ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm

The case studies for **Palladium** and **electronic waste** relate to this issue.

For the **medical equipment** case, the global potential of the market is hindered, as other countries like China and India are not willing to lower their restrictions on refurbished medical devices.

Besides the costs and price related aspects, it is also important to highlight other competitive advantages. For example, the fact that some materials are recycled within Europe, may contribute to reduce the risk of supply (e.g. critical materials) and ensure that the standards for the End-of-Life of these materials are met. For example, in the **palladium** case, it would be of importance to keep the catalytic converters within Europe. For the **manure** case, benefits of an increased competitiveness would be the reduction of phosphates imports and increase of the food chain self-sufficiency.

Another aspect to increase competitiveness is to avoid material losses to less transparent EoL processes. Within this point, several suggestions can be made to improve the situation:

- Improving the control over imported and exported materials could help to reduce material losses caused illegal and/or unmonitored by exports of materials or products containing them
- The employment of leasing schemes for various products or servitisation is as another option to increase circularity. When the producer remains the owner *and* is responsible for maintenance their incentive is to maximise a product's lifetime and repairability. They are also incentivised to keep track of leased products in order to retrieve them for further treatment which limits illegal exports
- Extended Producer Responsibilty (EPR) could be applied to more products in
- Revising the 'End-of-Waste' criteria and definitions in the regulation. This would be relevant for example for plastics, where approximately 50 % of the generated plastics waste in the EU is exported outside of the EU, mainly to China. As a result, no clear tracking of the EoL plastics is possible. It is reported, that the definition of 'End-of-Waste' favours the export of post-consumer plastics and therefore lowers its recycling rate within Europe. Changes in requirements to classify a waste as 'End-of-Waste' could therefore help to avoid the exports of the plastics outside the European Union. For the palladium case, lacking definition of EoL-vehicles was seen as major issue, as it allows vehicles, which reach or already have reached their EoL, to be exported outside of the EU. As a possible solution, a revision of the EoL criteria of vehicles in the End-of-Life Vehicles Directive is suggested.

5.7 Impacts on available substitution materials

Demand drives the supply of primary and secondary materials and depends on their prices. The supply of secondary material is typically not sufficient to cover demand, therefore it is necessary to bring additional primary material into the market.

If secondary material is cheaper than primary material and the properties meet the needs for a certain application, the demand for secondary material is higher and this is the preferred option. This is for example the case for some secondary metals, since their market price is generally lower than the price of primary metals.

Rare metals (e.g. **palladium**) these maintain the same properties after recycling and their prices reflect not only the properties, but also the scarcity. Therefore, there are no differences expected in the prices of secondary materials in the market.

If a secondary material is more expensive than the equivalent primary, this will reduce demand for the secondary material. For example, recycling **plastics** may be more expensive then producing them from primary resources, depending on the oil price, the application field and the quality demanded.

To manage situations where the demand of secondary materials is lower or absent, the first option shall be to try to develop options that allow recycling materials in the same quality for similar applications and if this is not possible, consider application in different markets.

Alternative markets are not only relevant for recycled materials, but also for by-products of production processes. For example, slag as a by-product from **copper** and **steel** production can be used as a substitute for construction materials and processed **manure** can be used for substituting mining based inorganic fertilizers.

5.8 Analysis of environmental aspects

In general, it can be stated that a more circular economy is typically connected with better environmental performance due to reduced emissions, reduced energy consumption and reduced exploitation of natural resources. Many different examples of environmental benefits have been mentioned in the different cases.

For example, in the case of **plastics**, increased recycling leads to a reduction of primary material input and therefore lowers the exploitation of finite fossil resources. As more secondary material is kept in the cycle, less plastics waste is released in the environment which leads to reduced littering and ocean debris. Additionally, production of secondary plastics is less energy consuming than of primary plastics, reducing CO_2 emissions.

If the recycling of **copper** is put at risk, this increases the need to use more primary material and more "copper waste" has to be managed. Copper production from scrap is much less energy- and CO_2 intensive than primary production. Regarding the **steel** case, recycling steel has the benefit of avoiding the mining of primary materials. Steel production from scrap is much less energy- and CO_2 intensive than primary production. However currently the amount of steel in use is growing, considering also how much is kept in construction for a long period. For the **palladium** case, secondary production is assumed to have approximately 20 % lower environmental impact in terms of carbon footprint through the avoidance of mining. More recycling of palladium leads to less exploitation of resources and less energy consumption.

For the **aggregates** case, shorter transporting distances to recycling companies are advantageous from the environmental and economic perspectives. For the **manure** case, the manure treatment reduces the carbon footprint and the eutrophication potential, depending on application rates and local conditions. For the **food** waste case, if less food has to be produced, this is always advantageous, as there will be less pressure on the environment. Benefits include reduced water consumption, emissions from cattle, fertiliser demand and related emissions, and emissions caused by decaying food.

About the reuse of **electronic equipment**, for most of the products, significant resource savings will arise from extended product use phases. Exemptions are for example washing machines older than 10 years that have not benefited from energy efficiency improvements in the last decade. For the **medical equipment** case, the situation is similar: from an environmental and resource efficiency perspective, if the efficiency of the products is not compromised, reuse and remanufacturing of equipment are the preferred End-of-Life options.

For the **batteries** case, positive environmental impacts can be expected from lower direct impacts by batteries in mixed waste streams as well as indirect benefits by improved recovery rates for several materials.

Table 23 Overview of mentioned reduction of environmental impacts for all cases

Effects mentioned	**Case-studies**
Reduction of energy and CO_2	Plastics, copper, steel, palladium, aggregates, manure
Reduction of needed water	Food (less watering of forage crops)
Less exploitation of natural resources	Plastics, copper, steel, palladium, electronic equipment
Less release of harmful substances into the environment	Plastics, lead compounds

When considering environmental impacts one cannot only focus on the end-of-life impact of solutions: the life-cycle performance is cannot be ignored. Ecodesign can help minimizing environmental impacts. Flexible, non-recyclable **plastics** packaging design could for example help to reduce generated waste and save primary material thus reducing impacts of resource exrtaction. Also the use phase has to be considered, especially in the cases of energy consuming products, where the use phase dominates the life cycle of the products and the energy efficiency is a key parameter to consider – within the cases, this is mainly true for the case of **electronic** products and **medical equipment** case.

Information about the environmental impact of a product should be provided in order to create transparency. There are already many initiatives in this direction, including labelling of products. One for the most recent on-going activities that is promising is for example the Product Environmental Footprint initiative (PEF).

5.9 Analysis on time/feasibility of solutions

The majority of the proposed solutions can only be implemented in a longer-term perspective, namely more than 5 years. Only a few solutions have a horizon of 1-2 years for implementation. The identified solutions range from easy to implement to very challenging, considering aspects such as the number of stakeholders and actors involved, the level of implementation (national, EU and international), the effort required for enforcement, and the interplay of said legislation with other legislations. In the latter case, some political choices may have to be revisited when considering a trade-off in consumer or environment protection and resource efficiency.

Only few examples were identified where the implementation could take place in a time frame of 1-2 years and are considered as relatively easy to implement:

1. Enforcement of waste shipment and export regulation;
2. Defining CLP regulation – thresholds of lead content;
3. Enforcement of RoHS and Battery Directive;
4. National implementation of the WEEE Directive prioritize access and enforcement of mandatory testing for reuse or reparability, which is already implemented in some EU Member States or regions;

6 Other observations

The circular economy concept requires a paradigm shift that impacts systems, processes and stakeholders across government, industry and civil society. A system change is necessary which implies a deep transformation of production chains and consumption patterns, as well as a shift in financial, fiscal and reporting and governance instruments. Such a system change requires parallel actions along the value chain rather than a sector or product focused approaches (Accelleratio, 2015). The Circular Economy Package proposed by the Comission in 2015 contains various elements of this approach, including the removal of barriers at EU level.

The evidence from the cases suggests that removing the identified barriers can have significant positive economic effects in terms of value retained and employment generated. These effects remain subject to large uncertainties because, in many cases, also other (esp. economic) barriers remain. Furthermore, in comparison with the full promise for the circular economy as sketched by e.g. the Ellen McArthur Foundation and McKinsey, the effects appear to be limited. This may be in part because the case studies were chosen (amongst others) on their potential to contribute to the circular economy before 2020. Another important factor is that many of the cases focus on circular processes quite low in the waste hierarchy, mainly recycling and recovery. For materials with a high intrinsic value these are already well-established processes with strong economic players involved and already a well-developed set of legislations. Additional routing of resources to these processors are subsequently not expected to have as disruptive effects as the implementation of new business models or currently underexploited circular activities have.

For materials with a low intrinsic value the costs of collection and processing are generally higher than the commodity value of the secondary material. This means that, even in the case where there are no regulatory barriers at all, the market does not demand secondary materials because of the price difference. In these instances, material recycling is no suitable option unless market prices are adapted or consumption targets for secondary materials are introduced. Other options for increased circularity of these materials include upcycling, reuse and prevention of usage. This requires stronger incentives than currently encountered in the cases that were studied.

These incentives for processing end-of-life products through options higher in the waste hierarchy could also be used for more valuable materials or products, because the material recycling processes that are realised generally capture only a fraction of the value that the products have (or have had) from which the materials are made (e.g. a computer costs around €500, while the materials include have a recycling value of only tens of euros).

This goes beyond the issue of existing legislation that hampers circularity. It is an issue at systems level: the regulatory system leads to a suboptimal solution from a policy point of view. **New legislations** might be used to improve the situation, where more value is kept in the value chain and less waste produced. There is no clear recipe yet to realise this, but, as many interviewees during this project have stated, **internalising environmental costs and value of recuperation** of strategic materials and **extended producer responsibility** (stimulating the design for circularity) could very well be part of such a regulatory approach and create economic incentives for frontrunners to invest in circular economy processes, innovation and business models. To stimulate the investments from entrepreneurs, a clear long-term strategy for regulatory revision needs to be developed to reduce uncertainties. This requires careful implementation, possibly with dynamic goals. Otherwise new legislation can become a barrier for next generation of circular options that will be made possible by innovation and changing market circumstances.

7 Conclusions and recommendations

The ten cases studies confirm that the realisation of a Circular economy is hampered by legislation. Though many barriers were encountered, their nature can be summarised in the 6 typifications below:

- **The lack of definitions** and the occurrence of gaps in legislation
- **Unclear definitions of targets** in legislation, for example in the context of the Waste Framework Directive
- **The definition of hard numerical limits** in legislation, for example, considering the REACH (Registration, Evaluation, Authorization and Restriction of Chemicals), CLP (Classification, Labelling and Packaging) Regulation – Regulation (EC) No 1272/2008;
- **Lagging or incomplete implementation or enforcement** of legislation, notably of the Waste Framework Directive and the Exports and Shipment regulation;
- **Different and conflicting national implementations** of a legislation (most notably directives or national action plans), observed in the context of the Waste Framework Directive, Basel Convention and WEEE Directive.
- **Legislations that conflict each other because they represent conflicting values**, for example with hygiene rules versus food waste, national implementations of the VAT Directive vs. donations of otherwise wasted food, stringent material contamination limits versus the usage and uptake of secondary materials, livestock contamination risk versus nutrient recovery, and the RoHS (Restriction of Hazardous Substances Directive).

Especially to aid in resolving the sixth barrier, there is a large need to **collect more information in higher resolution on the scale of the challenges and inefficiencies** caused by legislation. In many cases the context and application of circulated material is a key determinant of what considerations should be made to serve all values as best as possible. Currently, a one-size-fits-all legislation for whole sectors applies because **well-informed locally tailored decisions require information that is simply not present.** This incentivices *"better safe than sorry"* legislations. Improved information availability can inform policymakers to make better informed choices for the values they protect, tailored to the specific context. The availability of statistical and quantitative information has also negatively affected the ability of the researchers involved in this study to asses the scale of the regulatory barriers. Lacking statistical data, reluctance of companies to share data more conceptual difficulties to assess economic scenarios once a regulatory barrier is removed, have made it impossible to make exact estimates of the economic value that can be obtained. However the case studies do make it clear that the economic potential is significant, ranging from tens of millions to even billions of euros per case. Related are significant effects on job creation (hundreds of thousands of jobs may be involved).

The internal market for recovered materials or material flows from which they can be recovered must be harmonised to retain value and materials within the European Union. The Union is a net importer of many primary materials, some of them **critical for the security of supply of food and energy**. Within the Circular Economy paradigm and given the currently available technical options, it is possible to **increase the Union's independence**. This also leads to an improved **trade balance** andincreased **employment**.

Product design legislations should consider the full-life cycle of the product. This consideration should include a balanced choice of values.. The circular economy paradigm promises increased environmental performance which has been observed in many instances in the case studies. Increased performance is possible in terms of reduced greenhouse gas emissions, reduced emissions to soil and groundwater, and reduced resource consumption and consequently reduced impacts of primary resource production. However, trade-offs exist even within environmental performance. Some circular alternatives reduce soil and water emissions but require more energy for processing, thus increasing greenhouse gas emissions if the energy required is not renewably sourced.

Legislation should always **aim for the highest possible waste hierarchy option and be flexible** enough to **stimulate new, better options** as soon as they become available and are economically feasible. In many cases we have encountered favouring (energy) recovery over recycling, recycling over reuse, and so forth.

Resolution of regulatory barriers for the circular economy should be accompanied by complementing interventions. The case studies show that barriers remain in economics through unpriced externalities, technology lock-ins and consumer and producer attitudes. The study shows that the circular economy paradigm cannot be reached by legislators alone with a single silver bullet. It is imperative that there is a continuous dialogue between government, industry and civil society. The many stakeholders from all three of these institutions that were consulted during the study showed sincere motivation to alleviate the extensive problems caused by our consumption patterns within a linear economy. Policymakers need to harness this willpower and facilitate by creating the right conditions for action by industry and civil society.

To do so, one can view the recommendations shown below that were aggregated from all the cases and refer to the specific case to get more in-depth knowledge on how to proceed and whom to contact.

Recommendation	*Palladium*	*Copper*	*Steel*	*Batteries*	*Medical*	*Manure*	*Food*	*electronics*	*Plastics*	*Construction*
Formulate clearer definitions for the End of Life criteria to limit grey-area trade flows	√			√				√		
Stimulate and relieve barriers for intra-European trade of valuable resources currently classified as waste to enable economies of scale for recovery operations	√					√				
Allow deviations in one-size-fits-all legislation for specific materials in specific apolications, possibly in pilot settings for a limited time with intense monitoring		√	√		√	√				
Make material contamination limits of secondary materials specific to the purpose of application		√	√						√	
Enforce the ban on landfilling of materials for which a recycling alternative is available						√			√	
Restrict recovery operations, trade and handling of materials only to certified operators	√			√				√		
Increase and harmonise data collection efforts to monitor material flows; to assist enforcement of legislation; to assist circular economy options impact assessments	√	√	√	√	√	√	√	√	√	√
Extend eco-design requirements to include end-of-life options for products, including considerations for "fitness for remanufacturing"				√	√			√		
Resolve conflicting national implementations of directives and harmonise national action plans to stimulate the internal market for secondary materials	√					√				√
Review legislation to always aim for the highest possible processing method as implied by the waste-hierarchy.				√		√	√	√	√	
Review and design legislation to reflect current technically possible circular options, and make them flexible enough to allow for expected circular options				√	√	√		√		

Appendix A Project Methodology

A.1 Purpose of the study

In this study we looked at promising potential markets linked to circular economy, that are closed or under-performing due to regulatory obstacles or regulatory gaps. We:

- Identified concrete value chains, subsectors, economic activities for the circular economy and gathered economic data to underpin the related market potential;
- Identified key areas with the highest potential for economically viable market opportunities and conducted further analysis on regulatory barriers, preventing these markets from full development;
- Identified the regulatory framework for the specific areas and analysed the barriers to circularity and evaluated the functioning of the internal market and potential lost market opportunities related to these barriers;
- Provided ten case studies to analyse the barriers' impacts and the most promising options for resolving them.

A.2 Our approach

A.2.1 Identification of concrete value chains, subsectors, economic activities

The opportunities for increased circularity in the economy vary considerably across different firms, sectors, products and value chains. There are many factors that influence the circular economy potential, and as such a full analysis of all sectors on all factors would require a prohibitively large amount of study. In order to identify concrete value chains, subsectors, economic activities within agreed priority sectors for the circular economy, and gather economic data to underpin the related market potential we therefore used a **qualitative scoping procedure** to select high-potential sectors and value-chains.

This project started by developing a long list of possible circular economy activities that are hindered by regulatory barriers. This long list was based on a literature study as well as on input from the public consultation on the Circular Economy Package that was held from 28 May to 20 August 2015, which received around 1500 contributions. On this list 67 value chains, subsectors and economic activities were listed with a potential for the circular economy and an indicated regulatory barrier.

These activities are stated in Table 24

Table 24 Value chains, subsectors and activities relevant for the circular economy

sector	*product/activity*		*sector*	*product/activity*
Agriculture	Fibre recycling		Electronics	Remanufacturing of medical equipment
Agriculture	Recycling phosphorus/nitrate from manure		Electronics	Remanufacturing (of batteries in power tools
Automotive	Recycling of aluminium from cars		Electronics	Repair of power tools
Automotive	Reuse of rubber tyres		Electronics	Machine washing as a service
Automotive	Recycling dark polymers from cars		Metal products	Recycling of coated metal discards
Automotive	Car glass recycling		Metal products	Recycling of water in metal product industry
Automotive	Steel recycling from cars		Metal products	Recycling of steel in metal product industry
Automotive	Recovery of rare earths from batteries and motors		Metal products	Recovery of milling/cutting/lubrication liquids
Automotive	Recovery of Palladium from catalytic converters		Food supply chains	Recovery of energy/nutrients from food discards

sector	*product/activity*	*sector*	*product/activity*
Aviation	Remanufacturing of aeroplane bodyparts	Food supply chains	Reccyling of nitrogen
Carpets	Recycling of carpets	Food supply chains	Prevention of packaging waste
Clothing	Various circular options for cotton	Food supply chains	Reuse of process water
Clothing	Various circular options for polymers	Food supply chains	Prevention of food discards
Clothing	Various circular options for shoes	Furniture	Remanufacturing of furniture
Commodities	Recycling of biobased/biodegradable plastics	Hospitality	Prevention of food discards
Commodities	Reuse of ferromolybdenum slags	Hospitality	Recycling of vegetable oils
Commodities	Recycling of oxo-degradable plastics	Packaging	Prevention of paper&pulp waste
Commodities	Reuse of water in pulp&paper industry	Packaging	Prevention of plastic waste
Commodities	Recycling of copper	Packaging	Prevention of wood waste
Commodities	Recycling of non-ferrous metals	Packaging	Recycling of metals
Commodities	Recycling of paper and pulp	Packaging	Recycling of glass
Commodities	Recycling of steel	Packaging	Recycling of paper&pulp
Construction	Remanufacturing of air conditioning equipment	Packaging	Recycling of plastics
Construction	Recycling of mineral wool	Publishing/printing	Reduction of paper waste by ICT
Construction	Recycling of aggregates and limestone	Solvents	Recycling of solvents
Construction	Recycling of photovoltaic panels	Waste	Recycling of batteries
Construction	Reccyling of steel	Waste	Prevention of non-packaging plastics
Construction	Remanufacturing of wood parts	Waste	Options for treatment of sewage sludge
Consumer electronics	Recycling of rare earths from WEEE	Waste	Recycling of flat glass
Consumer electronics	Prevention of dark plastics in telephones	Waste	Recycling of lubricating oils
Consumer electronics	Recycling of rare earths from telephones	Waste	Recycling of compostable materials from gardens
Consumer electronics	Recycling of non-ferrous metals	Waste	Repair of WEEE
Consumer electronics	Recovery of rare earths	Waste	Recycling of paper and pulp
Consumer electronics	Repair of consumer electronics		

A.2.2 Identification of potential interesting cases

All 67 activities/sectors were given a qualitative score (1-5 or 1-3) by the project team on the quality of the regulatory evidence base. In a discussion with the steering committee for the project some activities were combined, energy as a specific topic was excluded and the term at which a legislation could be adapted was included in the criterion for regulatory evidence base (the sooner the better). Based on the assessment a long list of 30 areas remained (the green sectors/activities in the table above).

These 30 cases were vetted following extensive desk research, with the main objective of establishing cases with adequate information on identifiable circular activities, regulatory barriers, and economic data.

The **assessment of regulatory barriers** was carried out in a number of steps. Cases were reviewed to ensure that a clear regulatory barrier could be identified. While several cases presented detailed accounts of market-related or technical barriers to further development for use in a circular economy, it was crucial that clear regulatory barriers could be identified to support subsequent analysis.

The selection took into account **feasibility of removing identified barriers**; the cases were assessed in terms of identified activities for removing regulatory barriers. In some cases, there were clear regulatory reform proposals, often linked to specific European regulations, while in others the activities were limited to political or industry-led discussion on the potential for addressing barriers.

The desk study outlined the **economic potential** of cases, examining a number of dimensions that are relevant for determining the economic impact of regulatory barriers. Economic system effects were derived from examining the value added of sectors combined with the structures of the value chains within each relevant sector. This includes the presence of economic operators in Europe, industrial leaders, or emerging industries within the value chains of the sectors examined. In some sectors, European actors are leading players within various points of the value chain and any changes would be felt primarily in Europe, while in other cases the value chain is effectively globalised or predominantly based outside Europe. While it is difficult to estimate the precise impact of regulatory barriers, a value chain analysis was used to determine whether or not impacts – ranging from very positive to very negative – are felt in or outside Europe.

The analysis of economic impacts was determined in part by the **availability of data**. In some cases, estimates could be derived based on prices and volumes. These estimates could then be compared to trends in sector or industry based on scenarios of medium-term competitiveness of the industry compared to the competing alternative. In other cases, qualitative assessments were provided that illustrated the direction of the impact, whether the impact was positive or negative, or whether the burden fell primarily on Europe versus the impact in other regions. A scale was applied (3-1), with complete or near complete economic data scoring a 3 and a lack of data scoring a 1. If qualitative statements on the direction of the impact – positive or negative – were provided, then a score of 2 was assigned. The selection process also looked at the type of cases and categorised the selections based whether the focus of the circular activity was on a product or an activity.

We then sought to obtain a distribution of cases that covered a range of circular economy activities, types of regulatory barriers, and case type. To this end a multi-criteria approach was used, with cases selected to reflect the range of the potential issues related to regulatory barriers in developing circular economy approaches across sectors.

Based on the criteria, a selected of cases was made based on a follow up discussion with authors. The process resulted in a list of fifteen cases identified for further analysis (see Table 25).

Table 25 List of Selected Cases

Case Name	*Circular Activity*	*Regulatory Barrier**
Recycling of phosphorous and nitrogen from manure	Recovery	Waste management-production (2)
Recycling (resmelting) of steel	Recycle	Collection (1), Production (2)
Recycling of aggregates and limestone (cement) in building industry	Recycle	Production-Use (1) Production (2) Waste management (2)
Recycling of non-ferrous metals from consumer electronics	Recycle	Extraction/Production (2) Collection (2) Waste management (2)
Remanufacturing of medical equipment	Re-manufacture	Extraction/Production (1)
Remanufacturing of power tools (esp. batteries)	Re-manufacture	Production-Use (1) Waste management (1) Waste management-production (1)
Prevention of plastic/metals use in packaging in the food supply chains (consumers)	Prevention	Production-Use (1) Collection (1) Production-waste management Waste management-production (1)
Prevention of waste from biotic materials in hospitality sector	Prevention	Production-Use (2) Collection (2)
Recycling of metals in packaging in the food and beverage sector	Recycle	Collection (2) Waste management (2) Waste management/production (2)
Recycling of glass in packaging in the food and beverage sector	Recycle	Collection (2) Waste management (2) Production-waste management (2)
Recycling of polymers/plastics in packaging in the food and beverage sector	Recycle	Production-Use (2) Collection (2) Production-waste management (2) Waste management (2) Waste management-production (2)
Recycling of solvents from manufacturing processes	Recycle	Production-use (2) Collection (2) Production-waste management (2)
Recycling of batteries (post-consumer)	Recycle	Production-Use (2) Collection (2)
Repair of WEEE	Repair and maintain	Production-Use (2) Collection (2) Production-waste management (2) Waste management (2) Waste management-production (2)
Recycling used lubricating oils	Recycle	Collection (2) Waste management (2)

*(1) Yes, the barrier was identified, (2) Yes, the barrier was identified and initiatives or plans to remove it exist.

A.2.3 Analysis of existing and potential regulatory obstacles: selection of 10 cases

Taking these fifteen cases as a starting point, the project conducted 77 semi-structured interviews with experts mainly from European and international business associations that covered all relevant steps of the value chain (from product design, sourcing of inputs, production to waste collection, treatment up to the final recovery and marketing of (secondary) raw materials. The selection was aimed at a balance between the traditional waste management aspects of collecting and recycling, and upstream aspects (e.g. design for recycling or dismantling) as well as downstream aspects of feeding recycled or refurbished materials back into production processes.

Based on the results of the expert interviews, a decision-making matrix was developed based on which the ten most relevant regulatory barriers have been identified. The assessment for the DMM included three key assessment criteria:

1. Economic relevance of the barrier: This first criterion was mainly based on the identified potential added value shift in WP 1. It took into account the share of the specific barrier for this current loss of added value
   3 = high economic relevance, 2 = medium, 1 = low
8. Removability of the barrier: The assessment differentiated between barriers that could be removed by the European Commission or that require additional actions on the national or international level. It also analysed already on-going initiatives and specifically focussed on such barriers that could be addressed in the short run or at least in the next 5 years
   3 = easy, win-win opportunity; 2 = doable and 1=almost impossible; strong veto players
9. Potential side effects of removing the barrier: The final criterion assessed a) economic impacts on other markets as well as b) environmental impacts and health risks (e.g. keeping hazardous substances in the loop by closing material loops)

   3 = no potential side effects, 2 = medium, 1 = none

Taking the example of preparing electronic products for reuse illustrates the procedure. The analysis of the case study identified two key barriers that hinder discarded electronic products to be repaired and reused despite significant economic and environmental benefits (see chapter 3): i) lacking requirements with regard to design for repair and specifically disassembly and ii) lacking access to discarded products for reuse organisations:

Improving the design of electronic products could potentially have a significant economic impact and is e.g. mentioned as key issue in the Circular Economy Roadmap (high economic relevance) but at the same time the removability of the barriers can be considered as low: Specific regulations would be required for each product group, legislation should be aligned on an international level and it will cause significant investments into new product design and changed production processes. On the other hand, improving access for reuse organisations will clearly have lower economic effects as still only a small part of products can be repaired economically viable. But looking at the removability of the barriers there are already established good practice examples e.g. in Flanders that could be taken up on a European level within the next years.

With regard to potential side effects the assessment took into account inter alia the shift of economic activities outside of Europe, the reduced demand for raw materials that could be substituted by secondary resources or the reduced demand for final products by prevention or reuse. Key aspect for environmental side effects has been the increased circulation of hazardous substances by closing material loops. The assessment has been undertaken by the experts of the consortium and discussed with representatives from different DGs within the European Commission. The following table shows the scores for those 10 barriers that came out as most relevant regulatory obstacles for a circular economy.

Table 26: Assessment scores for the 10 most relevant regulatory obstacles

Barrier description	*Economic relevance*	*Removability*	*Side effects*	*Total Score*
Legal differentiation between used and end-of-life cars in order to avoid the illegal shipment of discarded cars	3	2	2	7
Pb limits set by REACH that hinder the recycling of copper using lead as a carrier material	3	2	2	7
Different interpretations of end-of-waste criteria by member states causing legal uncertainties for steel recyclers with regard to by-products and REACH	3	1	3	7
Lack of enforceable definitions for the recyclability of electronic products as required in the WEEE directive, especially with regard to disassembling of batteries	2	3	3	8
ROHS regulations that specifically hinder the remanufacturing of medical equipment	2	3	2	7
Inconsistent calculations of nutrient content between manure based and chemical fertilizers	1	3	3	7
Inconsistent "best before" legislations in the member states that set incentives for disposing food instead of redistributing it; supported by VAT legislations for donated food	3	3	1	7
Lacking legislations for access to discarded electronic products that would allow the preparation for reuse	2	3	2	7
Lacking implementation of the waste hierarchy that hinders the material recycling of plastics or even favours incineration (e.g. caloric value clause in Germany)	2	3	3	8
Based on problematic product definitions in the Waste Framework Directive only certified waste collectors can deal with secondary construction materials.	3	2	2	7

A.2.4 Drafting of case studies

The 10 case studies all describe a circular activity and the economic setting of this circular activity, the regulatory barrier and the potential to overcome this regulatory barrier. Finally, although quite often data were missing for a detailed assessment, an estimate is made of the economic potential of removing the regulatory barriers, and the possible environmental effects related to that. Sources for the case studies are literature/internet data and additional interviews (with entrepreneurs, relevant EC staff and where relevant other stakeholders

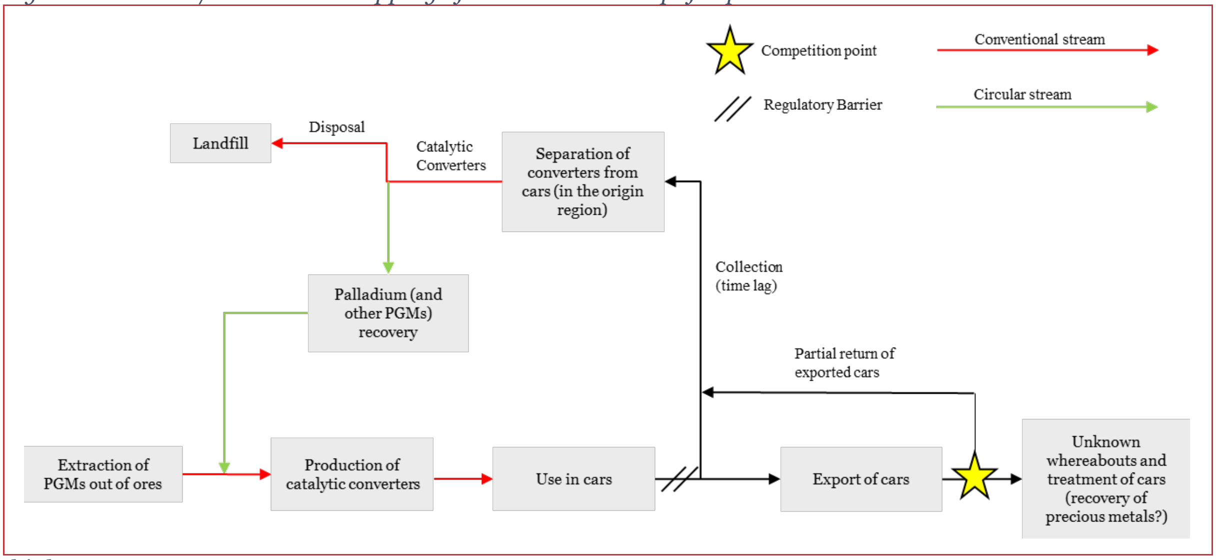
Based on the findings in the case studies also some more generic conclusions on regulatory barriers for the circular economy were drawn, that were presented in a half-day workshop in Brussels on 21 March 2016, and discussed with approx. 180 participants from industry, research and policy background. Participants were also offered the opportunity to give electronic feedback during and after the workshop. The final conclusions and recommendations are presented in the chapters 5-7.

Appendix B Case Studies

B.1 Recovery of palladium from catalytic converters in vehicles

B.1.1 The product and its value chain

Figure 6 Material/value chain mapping of the circular concept for palladium



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Description of the product/activity

Palladium is one of the six Platinum Group Metals (PGMs) – platinum, palladium, rhodium, ruthenium, iridium and osmium –, which occur together in nature. PGMs are precious metals and are very rare elements in the Earth's crust. Palladium and platinum are the main products and the most relevant metals in the PGM mix in terms of economic value and amounts. (The environmental profile of platinum group metals (PGMs) - IPA Factsheet)

Palladium is widely used in autocatalysts as catalytic converter. In 2010, 51 % of the PGM world gross demand had origin in this sector. Autocatalysts consist of a cylinder coated with a solution of chemicals and a combination of platinum, rhodium and/or palladium. The PGMs act as catalytic converters, enabling the conversion of pollutants from fuel combustion into less harmful substances. Without the PGMs, this reaction could not take place. The chemical elimination of pollutants is necessary in order to comply with the emissions legislations of vehicles. (Autocatalysts and platinum group metals (PGMs) - IPA Factsheet).

Value chain and life cycle of the product/activity

As shown in Figure 6, the life cycle of palladium starts with its extraction from natural metal ores. The extracted and purified material is used in the production of catalytic converters, which are used as autocatalysts in vehicles.

The vehicles produced in the EU either stay within EU -when they reach their End-of-Life there is specific legislation which covers their treatment -, or they are exported to countries outside the EU -it is not possible to track the End-of-Life of the vehicles and in which conditions it takes place.

When the vehicles reach their End-of-Life (EoL), the converters are typically separated and the palladium, as well as the other precious materials, are recovered to be used as secondary material for the production of new autocatalysts. Due to various losses, the recovery of PGMs in EU is only able to cover only a small part of the demand for catalytic converters (28 % of gross demand for the same application in 2010). The further demand is fulfilled by primary material.

Per step in chain: actors and their relation with connected actors

- Design and production

It has been reported that nowadays two types of converters are used: ceramic converters with a share of 90% and metallic converters with a share of 10% in the market. In the first case, the precious metals are recovered by smelting the converter in smelting works. In metallic converters, the precious metals are in direct contact with the carrier metal. Therefore, there is a need for mechanical processes to recover the PGMs from the metal, since it is difficult to separate the metals in the smelting processes. This makes the recycling of metallic converters more expensive and more complex.

- End-of-life options of product

When a vehicle reaches its End-of-Life, the converters are separated from the vehicle and the precious metals are extracted. The extracted PGMs are usually not deposited but recovered and recycled for further use in new autocatalysts due to their high economic value and their scarcity.

However, the actual recycling rate in the European Union is only about 60 – 70 % due to material losses during the life cycle of the product. For example, during the utilisation phase of catalytic converters in the vehicles, losses can occur through possible damages of the catalyst. Another factor leading to PGM material losses is regarded to be the export of used vehicles to places, where it is not possible to track their End-of-Life, which could result in higher losses. Other losses were mentioned to have origin in the pyrometallurgical treatment during the recycling process (although those are rather small), non-transparent trade chains and losses during dismantling processes of the vehicles. It was reported, that in Europe, the remaining PGM material can technically be recycled to nearly 100 %. Outside of Europe there are also many countries where the recycling standards are even higher than in Europe, but there is no clear track about where the vehicles have their End-of-Life.

It would be possible to reduce the losses and increase the recycling rate of PGMs through improving the efficiencies of the individual processes. Suggestions to improve the situation include shorter and more transparent streams with reliable industrial actors and elimination of shady players (for example not-certified scrap dealers) in the recycling chain. It is also suggested to increase the standards on the recycling processes.

- Collection system

The quality and quantity of collection of vehicles in Europe is regarded to be mainly influenced by the exports of vehicles which are often not returned to European recycling facilities and for which the location is hard to track. For example, according to the German Federal Office for motor vehicles, 3 million vehicles are removed yearly from the car register in Germany. Only 400.000 to 500.000 End-of-Life vehicles are returned to German disassembly facilities, resulting in 2.5 million missing vehicles located elsewhere (not tracked). The typical composition of European automotive catalytic converters is 1 kg platinum, 1 kg palladium and 250 g rhodium per ton. The gap on the values of registered vehicles and the returned vehicles is influenced by the export of vehicles, which becomes even more relevant when these are getting closer to their End-of-Life (or might even have already reached it) but are declared as used. This allows their export, since used vehicles are considered a commodity and not a waste. When a vehicle is declared to be at its End-of-Life, it is no longer possible to export it to outside of the EU: it is subject to the European End-of-Life Vehicle Directive 2000/53/EG. The lack of a clear definition of End-of-Life vehicles and the resulting losses of materials considered the main barrier to the recycling of palladium identified in this case.

The tracking and local collection of vehicles could help to prevent the losses and increase the collection efficiency. Additionally, applying the Extended Producer Responsibility could help to change the perspective and see the End-of-Life vehicles not only as additional costs, but also as source of resources.

- Market aspects

When vehicles have reached their End-of-Life, they are usually sent to disassembly facilities where their parts are dismantled. Various companies then contact the disassembly facilities in order to buy the catalytic converters, which are typically sold to the best price offered. The recycling companies contract smelting facilities that recover and store the precious materials. However, a constant supply of secondary material cannot be guaranteed, as there are fluctuations due to the already mentioned losses. Nevertheless, given the scarcity of the PGMs, there is a demand for secondary resources.

The demand for vehicles in Europe was around 16 million (according to the number of registered vehicles in Europe) and worldwide was around 65 million (according to the number of registered vehicles worldwide) in 2014. Considering the average of the past 10 years, the vehicles demand based on the number of personal registrations is estimated to be approximately around 22 %. (Organisation Internationale des Constructeurs d'Automobiles (OICA)., 2014) These numbers can be used to estimate the palladium demand in Europe.

The annual volume of the linear market for palladium from autocatalytic converters is estimated to be approximately 102 tons worldwide and approximately 22 tons in the EU (considering the vehicles demand information in Europe, which is 22 %). The annual volume of the circular market for palladium from autocatalytic converters is estimated to be approximately 28 tons worldwide (considering that approximately 28 % of demand in the car industry has origin in secondary resources) and approximately 6 tons in the EU (considering the vehicles demand information in Europe)

The total economic value of the current linear market for palladium used in autocatalytic converters is estimated about 663 million to 2.6 billion Euro worldwide and between 143 and 561 million Euro in the EU. The total value of the current circular market is estimated to range between 182 million and 714 million Euro worldwide and between 39 and 153 million Euro in the EU.

- Quality aspects

Secondary palladium, like all the other PGMs, has equivalent quality as primary material – it does not lose its properties in the recycling process.

The energy demand for recycling the PGMs is assumed to be lower than the energy demand for producing PGMs from primary sources, since mining can be avoided and the concentration of precious metals in the vehicles wastes is about 400 times higher than in ores.

Table 27 Primary / secondary material streams and volumes

Type	*Value + Unit*	*Comment*
Total primary production	Worldwide approx. 102 tons of palladium only for the application of catalytic converters (considering that 51 % is used in autocatalysts production) In the EU, approx. 22 tons for automotive sector (considering the car demand information in EU, which is 22 %)	200 tonnes palladium (400 tonnes PGM) annually worldwide for all applications
Total secondary production	Worldwide approx. 28 tons of palladium only for automotive sector (considering that approx. 28 % of demand in the car industry has origin in secondary sources) In the EU, approx. 6 tons (considering the car demand information in Europe)	Approx. 56 tons of palladium annually worldwide for all applications
Total demand	16 million vehicles registered in Europe (2014), 65 million vehicles registered worldwide (2014)	Vehicles demand (22 % of worldwide demand, averaged over 10 years) in Europe can be used to estimate the palladium demand in Europe
Recyclability (how much sec. material can be incorporated)	95 - 98 %	98 % secondary material can be incorporated in new converters

Type	*Value + Unit*	*Comment*
Potential max. secondary supply	60 %	For an increase to 100 % recovery, the demand for palladium would be fulfilled by in maximum 60 %
EU share of prim. /sec. production	50 – 70% recycling of palladium in EU	After various losses during the converter life cycle, losses about 30 to 50 % can occur

Table 28 Indicative economic values / trends

Type	***Value + Unit***	***Comment***
Current price situation (materials, please indicate country/region of reference)	Price for monolith: 50.000 – 70.000 Euro, depending on price level of platinum, palladium and rhodium Market price of secondary PGM is the same as for primary, the real prices for secondary PGM are much lower 17.700 Euros per kg, the price of palladium suffers volatility	Market prices for primary and secondary PGMs are the same, the highest share of the added value goes to the scrap dealer
Expected cost-price ratio (due to use of sec. material instead of primary)	Real prices for secondary PGM are lower	Assuming that production of palladium has 50 % less costs and 30 % increase off supply → 15 % price reduction
Revenue cuts or potential business losses caused by existing legislative barriers	No information available	–
Cost of non-action	115 million Euro worth of precious metals in autocatalytic converters leave the EU annually	–
Additional indirect costs caused by legislative barriers (human resources, external consulting, research, …)	No information available	–
Investment costs to increase circularity	No information available	–
Any other identified costs	No information available	–
Environmental impact (e.g. higher cost due to higher emissions)	If secondary materials are used: • Less energy consumption Less consumption of natural resources Secondary production was estimated to have approximately 20 % lower environmental impact than primary production due to avoidance of mining	–

B.1.2 Regulatory barriers

Within the previous work in this project, the main barrier identified was the lack of a clear definition of End-of-Life of vehicles, which is also related to the regulation on the exports of vehicles.

Table 29 Overview of regulatory barriers

Main Barrier	***Affected department (s)***	***Effect***	***Possible (legal) solution***
Legal differentiation between used and End-of-Life vehicles in order to avoid the illegal shipment of discarded vehicles and insufficient legislation on the export of vehicles	Procurement Operations business (recycling of PGM)	Vehicles reaching End-of-Life can be declared as 'used vehicles' and can be exported (legally or illegally). This may lead to losses in materials which could be recycled	Clear definition of EoL of vehicles in the regulation Reversed burden of proof procedures for export of vehicles (e.g. exporter has to prove the usability of the car)
Additional barriers (other barriers mentioned as important)	**Affected department (s)**	**Effect**	**Possible (legal) solution**
Non-transparent value chains	Procurement Operations business (recycling of PGM)	Potential losses caused by improper treatment (treatment standards vary between different countries)	Creation of international standards for treatment of catalytic converters Allow only certified actors in the treatment along the value chains Simplify data collection and tracking of cars for more transparent value chains
Classification of catalytic converters in the Basel Convention as hazardous waste	Procurement Operations business (recycling of PGM)	Recyclers have only hardly access to wastes with value in the countries where the legislation is more restricted Different interpretations of the legislation regarding the standards for the transport of wastes / wastes classification	Exclude catalytic converters from Basel Convention or classify them as 'valuable substance to be recycled' Analyse where exactly are the differences on the interpretations / classifications and harmonize them at national level

Main barrier identified

Legal differentiation between used and End-of-Life vehicles in order to avoid the illegal shipment of discarded vehicles and insufficient regulation on the export of vehicles

According to the interviewees, one of the main aspects with regard to the regulation of the End-of-Life vehicles is the definition of End-of-Life vehicles, which is not clearly stated in the European regulation. The export of EoL vehicles outside the European Union is prohibited by the European End-of-Life Vehicle Directive 2000/53/EG. Although, often used vehicles reaching their EoL (or eventually even already at End-of-Life) are declared as used, which enables their exports outside the European Union. These vehicles are mostly not further tracked and it is often not known whether they are recycled and how they are treated further. In countries with lower recycling standards losses of PGMs might occur. A clear definition of EoL vehicles and a consistent platform could help to prevent the export of vehicles reaching their End-of-Life and to keep track of the vehicles, reducing potential losses.

Solutions proposed

Even if regarded as complex and as challenging to implement by some interviewees, the clear definition of the End-of-Life stage of a vehicle is proposed as a possible solution.

Additionally, the introduction of reversed burden of proof procedures for old vehicles was suggested in order to avoid the declaration of End-of-Life vehicles as used. These procedures involve the prove that the second hand vehicles exported are functioning according to clearly defined parameters, fulfilling clearly defined criteria.

Even though it is regarded as challenging, the control of exports of used vehicles (legal or illegal) could help to reduce the material losses.

Additional barrier 2

Non transparent value chains

It was mentioned, that the treatment of the converters depends on the actors and countries where it takes place. Improper treatment and handling could therefore cause losses of materials.

Solutions proposed

It is suggested, that only certified actors with the required knowledge and technology should be involved in the material streams. This is assumed to increase recycling rates. The overall rate is the sum of the efficiencies of the individual steps during the life cycle of a product. Transparent recycling chains would simplify data collection and tracking of vehicles. The enforcement of quality standards along the value chain typically leads to higher recycling rates.

Additional barrier 3

Classification of catalytic converters in the Basel Convention as hazardous waste

Two interviewees pointed out that the Basel Convention, which aims at reducing the deposition of hazardous waste in countries where the product was not produced or used, could be regarded as a barrier as well. The transport of hazardous waste over country borders needs complex and time-consuming notification procedures. In the particular case of catalytic converters, this regulation is regarded as not the right framework by those interviewees, as the catalytic converters are, according to them, typically not deposited, but mainly recycled due to their high value. In this context, the Basel Convention can be considered as a barrier, since it makes the import of catalytic converters harder to the recyclers. Additionally, different countries classify catalytic converters differently. For example, these are regarded as hazardous waste in Germany, but not in other countries.

The different interpretations of the regulation at the national level make it difficult to the recyclers to be able to import the converters, as there is no platform or list where the different standards and needs are mentioned consistently. This makes it challenging to the recyclers to be aware of all the points that they have to comply if they want to import catalysts from other countries (e.g. transportation standards are different depending on the type of waste; the type of waste might be different from country to country).

Solutions proposed

As a solution, the catalytic converters could be excluded from the Basel Convention in order to facilitate their transport and the access to primary material for recyclers. Another possibility would be to classify this waste as 'highly valuable waste' in the Basel Convention - high valuable wastes are usually recovered and reused (not disposed).

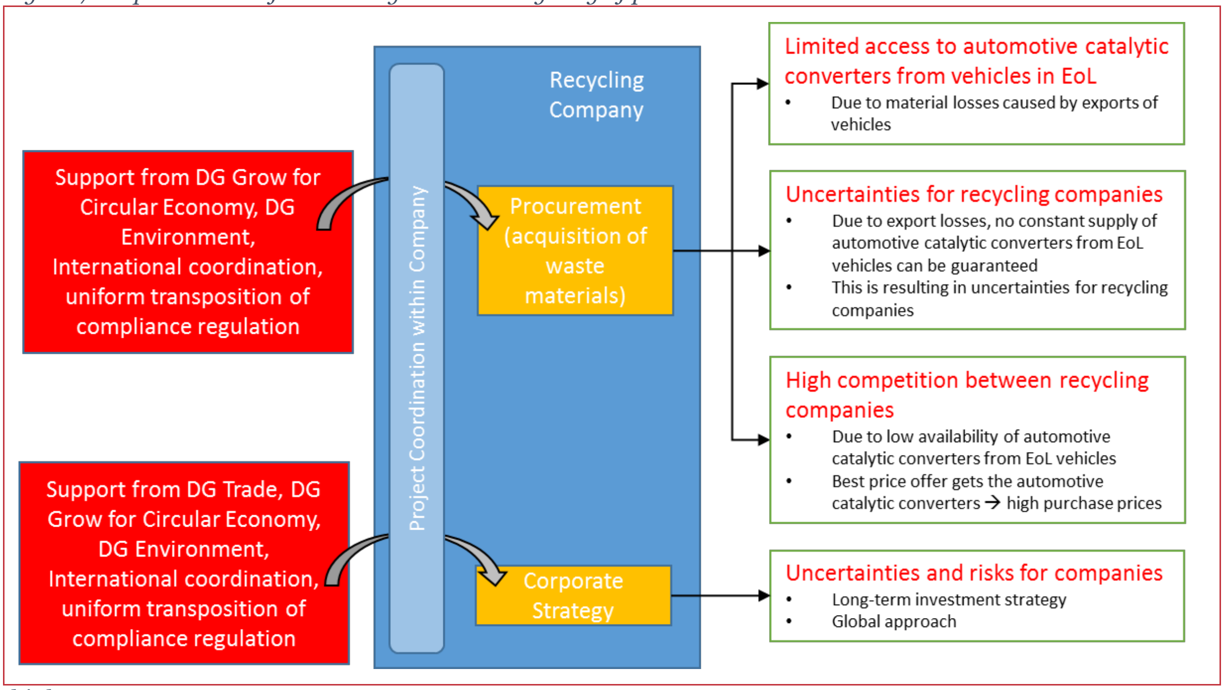
Harmonizing the national standards regarding types of wastes, as well as requirements regarding their transport, could contribute to improve the position of recyclers to import the End-of-Life converters and be able to have/provide more stable supply of catalyst wastes and PGMs.

B.1.3 Impact scheme for the actor

Figure 13 below illustrates the main impacts from the regulatory barrier for circular economy identified in this case.

It describes the organisations and their projects (blue box) with their business units (yellow box), which are involved in different activities, where there might be barriers to the circular economy (green box). These barriers can be overcome by adapting policy interventions into the circular economy (red box).

Figure 7 Impact scheme for industry actors – recycling of palladium



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In summary, the companies interviewed– three of the European industry leaders of palladium recycling -, identified the following specific impacts:

- **Recycling:** limited access to secondary palladium due to losses caused by exports of vehicles to untracked locations was mentioned to reduce the possibilities for European recycling companies of having automotive catalytic converters to recycle
- **Risk**: no constant supply of secondary palladium can be guaranteed due to the losses caused by the export of vehicles, increasing the risk for recycling companies and for the manufacturers of automotive catalytic converters
- **Market**: due to low availability of automotive catalytic converters for recycling, there is high competition between recycling companies (highest price bid will get the automotive catalytic converters). Only established recycling companies are supposed to survive in this market.

Analysis and interpretation

The main barrier identified in this case ("The legal differentiation between used and end-of-life cars in order to avoid the illegal shipment of discarded cars and insufficient legislation on the export of vehicles") was regarded to present a relevant barrier to a more circular economy of palladium within Europe.

The export of used vehicles to countries outside the EU was mentioned to result in lower availability of this waste stream to the European disassembly facilities, and consequentially to the recycling companies, which in the case of rare materials (such as precious metals) typically face challenges regarding consistency of the supply.

Regarding the palladium, the exports of vehicles was mentioned to mainly limit the access of European recycling companies to EoL automotive catalytic converters containing palladium, as these are installed in the vehicles. This is assumed to result in lower recycling rates of palladium within Europe.

The exports of vehicles are regulated by different regulatory frames, including the End-of-Life vehicles directive (doesn't clearly define when a vehicle reaches its End-of-Life) and the exports regulation (which lacks enforcement through proof procedures). A clear definition of End-of-Life vehicles, combined with an enforcement on the exports regulation through proof procedures (ensuring that the exported vehicles are in condition of 'used vehicles' and not at the End-of-Life stage when they are exported) could contribute to manage this issue. From an environmental and resource efficiency perspective, the recycling of palladium is always the preferred End-of-Life option, as it is rare, of high economic value and technically recyclable to nearly 100 % without losing its properties and quality.

A qualitative and quantitative statement and evaluation of this barrier has been reported by the interviewees as not available due to many open questions and missing information concerning the further treatment of exported vehicles, which are for example:

- In which countries do most EoL vehicles end up?
- What happens to the exported EoL vehicles in the export countries? How many are disposed, incinerated, repaired or recycled?
- If the components of exported vehicles are recycled, how are recycling standards and rates in the export countries?

The clarification of these questions is considered a priority and requires more transparency and collection of more detailed data, according to the interviewees.

It is not possible or even considered to prohibit exports of vehicles. However, the avoiding of exports of vehicles in End-of-Life has been considered important by the interviewed companies and leasing has been mentioned as a possibility to enforce Extended Producer Responsibility. More efforts in developing leasing could ensure more control over the EoL vehicles and the integrated catalytic converters.

Another aspect which should be considered when addressing the low recycling rates of palladium are the imports/exports of the autocatalysts as wastes. This aspect is related with the Basel Convention, the classification of wastes and respective consequences. The process to export hazardous waste is complex, lengthy and bureaucratic to ensure that the countries don't export their hazardous wastes to another country without a clear justification.

The classification of autocatalysts depends on the interpretation of the regulation and was mentioned to be not homogeneous: in some countries, the automotive catalytic converters are classified as hazardous waste, but in other countries, they are not. Besides, the standards to transport and treat the wastes are also mentioned to be not homogeneous among the different countries. This creates a barrier to export/import autocatalysts, as it is challenging to comply with different interpretations of the regulation or even know the differences.

Several possibilities to manage this issue have been proposed: exclude the autocatalysts from the Basel Convention; keep the autocatalysts under the Basel Convention, but declare them as 'high value waste' (high value wastes are typically not disposed, but recovered or recycled); keep the autocatalysts in the Basel Convention, but clearly homogenize their classification among the different countries, having homogeneous requirements, or at least, make available to the recyclers a consistent platform where the national requirements are clearly stated and defined.

B.1.4 Stakeholders consulted for this case study

Table 30 Overview of interviewed companies

Aspect	***Company 1***	***Company 2***	***Company 3***
Name of the company	Mairec	Umicore	Johnson Matthey
Industry sector	Recycling	Recycling	Development & Manufacturing, Refining
Summary of the role of the company in industry (general)	Recycling Company	Global materials technology and recycling group with more than 1.000 employees in 38 countries and a turnover of 8.8 billion €	Leading speciality chemicals and refining company with more than 13.000 employees in more than 30 countries and a sales of more than 11 billion € (in 2014)
Location	Germany	Distributed worldwide, headquarters in Brussels	United Kingdom

B.2 Recycling of Copper

B.2.1 The product and its value chain

Copper is an important metal, which is used in many different applications. Examples include architecture, energy production and supply, telecommunication, electronics and the usage in pipe systems[14]. While there is only little copper mining in Europe, the sector focusing on smelting and refining is large. In addition, there is a large market producing semi-fabricates. The European Copper Institute estimates the number of people employed directly in the European copper industry to be about 50,000. More people are employed in industries that use the copper as an input material.

A big actor in the mining business is Boliden, which is operating the mines in Sweden and Finland; there are also mines in Poland operated by 2 different actors. The main actors in the smelting and refining business are among other things Boliden, Aurubis and Metallo. The latter is concentrated on the recycling of copper, tin, lead and nickel. A very important actor in the production of semi-fabricates is KME which is operating several plants located in Italy, France, Germany and Spain. Putting the outputs of the European copper industry into numbers, in 2014 the European copper production was about 2.8 Mio tons, which is slightly more than 10% of the world production. About 5.6 Mio tons of semi-fabricates were produced in Europe which is slightly less than 20% of the world production (Organisation Internationale des Constructeurs d'Automobiles (OICA), 2014).

Recycled copper, when recycled in the best quality, cannot be distinguished from primary copper, therefore no problems exist to place recycled copper on the market. Researchers at Fraunhofer ISI estimated in studies for the International Copper Study group that about 50% of the copper used in the EU originates from recycling. The recycling of copper is linked to positive environmental effect: its production requires, for example, up to 80-85% less energy than primary production. Worldwide copper recycling saves per year about 100 Mio MWh of electrical energy and 40 Mio t of CO_2 (European Copper Institute, n.d.).

The recycling of copper, including the collection of scrap, is an established and working system, starting from local collectors, involving a chain of processing, trading and transport, and then being used in the copper production in or outside Europe. Copper is collected depending on the product and application it was used in. To increase the rate of recycling of WEEE, for example, retailers of electronic products have to take back old products. In addition, local waste collection sites as well as professional collectors collect end of life products from private and professional consumers. It is important to have a well-functioning collection system which ensures a proper collection and pre-treatment of the wastes and which also helps to contribute to a system with fewer illegal exports which constitutes a big problem at the moment.

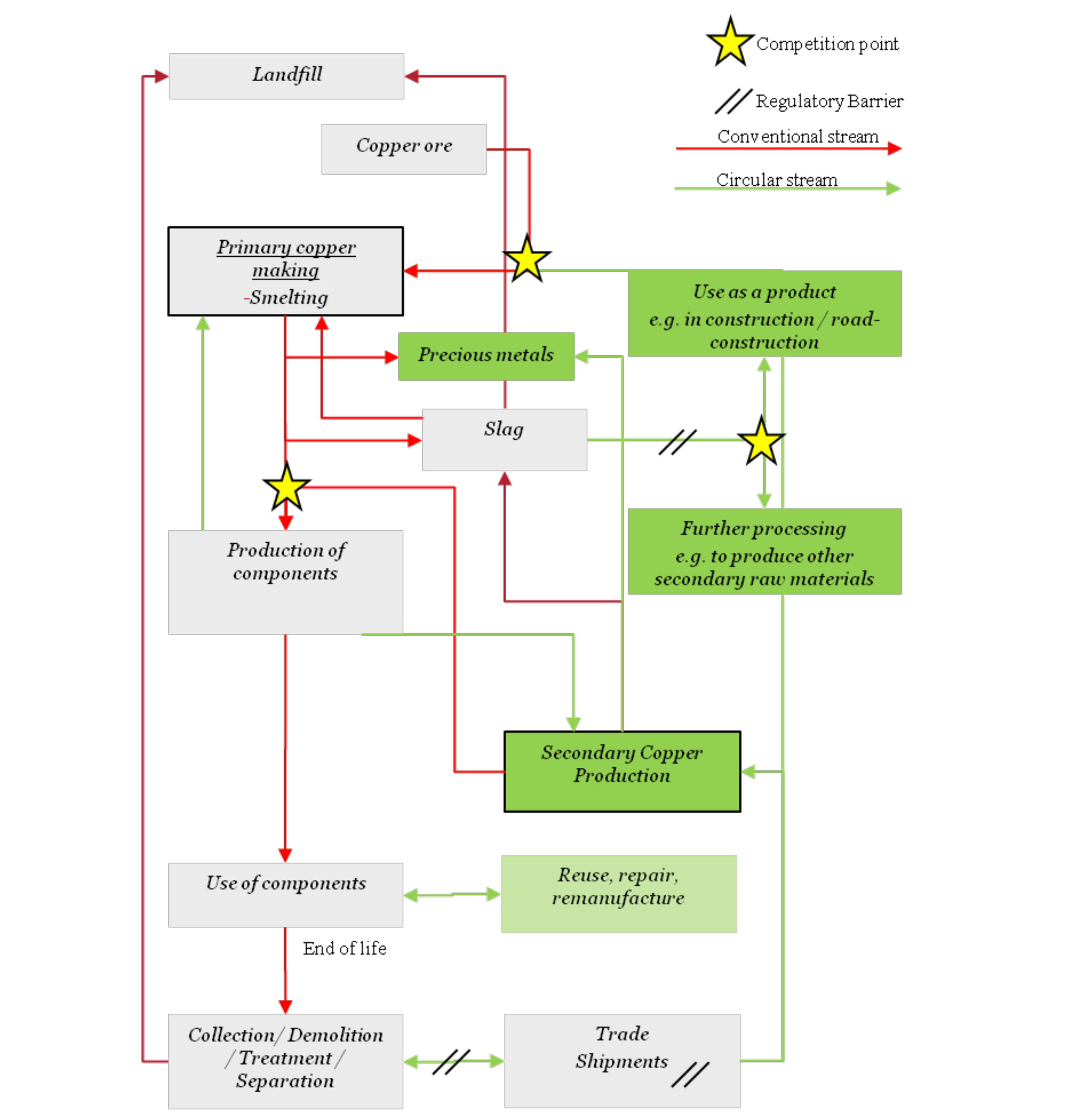
The material entering the recycling process today represents the state of the art of years ago. Depending on the application the copper was used in it takes shorter or longer until the material enters the recycling circle again. Copper that is used in buildings stays there for a long time while copper used in electronics is entering the recycling-circle much faster.

The production process of copper, both in the primary and secondary production, also results in an output of other materials. In the production of copper precious metals are additional important and valuable products. However, there are also other by-products resulting in the production process such as slag, slurry or dusts, which in theory have further circular options, which in practice can and are only partially realized.

Sometimes lead is used as a carrier material which can lead to lead content in the copper-scrap. Technically this presents no problem to the smelters. However, currently it is discussed to introduce limits for lead content in the CLP-legislation discusses. Toxicity of lead depends, however, on the form in which the metal is present.

[14] Another application is agriculture, both in plant protection and in animal nutrition. This area will not be the focus of this study.

Figure 8 The simplified value chain of copper-use and -recycling



Fraunhofer ISI

Table 31 summarizes the volumes of copper production and recycling in the European Union, the current price situation as well as the environmental impacts.

Table 31 Primary / secondary material streams and volumes

Type	*Volume*	*Comment / Source*
Total primary production	1.8 Mio t	Calculations by the Fraunhofer ISI for the International Copper Study group.
Total secondary production	0.9 Low grade copper scrap for refining and melting, 1.1 Mio t directly melted high grade copper scrap. About 50% stems from recycled copper.	Calculations by the Fraunhofer ISI for the International Copper Study group.
Recyclability (how much sec. material can be incorporated)	100 % in smelters, in the traditional press it is used to cool the process, percentage depends on economic considerations.	
Current price situation	LME settlement price of "Copper Grade A" was at less than 4100 €/t. Prices of scrap differ by scrap category. The price for "copper wire and tubing" was at around 2600€/t (Feb 2016).	The copper price is set globally. (About Money, 2016)
Environmental impact	The production of recycled copper requires up to 85% less energy than primary production: to extract copper from ores one needs about 95 Mio Btu/t, for recycling copper one needs about 10 Mio Btu/t. Emissions of CO2 emissions are about 65% lower for secondary production.	(BIR, n.d.)

B.2.2 Main regulatory barriers

The main regulatory barriers are listed below:

Table 32 Overview about regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
The discussed introduction of a maximum content of lead of at max. 0,03% into the CLP legislation	During the work for this study, the interviewees feared that if this threshold would be introduced it would (most likely) lead to a situation in which many recycling processes of copper would have to be classified as recycling of hazardous material, associated with increased process-costs for increased security measures. There was a fear of putting the metal-recycling system at the risk of losing profitability.. The barrier changed during the course of this study and is perceived less severe now. Whether the modification has detrimental effects on a circular usage of ressoureces remains to be seen. It seems that there might be effects on the usage of by-products which might exceed the defined thresholds, however it is not clear at the moment in what direction this will develop (prove of non-leakage, advanced technologies etc.).	During the study the solution was identified to define the regulation such that it differentiates according to which form the lead is present. Meanwhile, a new proposal was voted in the REACH/CLP Committee, which distinguishes between lead as a powder and lead in massive form. The interviewees welcome this distinction in general.
The geographical focus of the EU Emission Trading Scheme	Having an ETS only in the European area puts the European industry at a disadvantage in comparison to the rest of the	A possibility, but likely difficult to achieve, would be to extend the scope of the ETS also to outside of the EU.

	world. They emissions will be produced somewhere.	Probably, a "world-ETS" starts with an ETS that includes also those countries (outside the EU) that have a significant industrial sector and thereby capture the countries which are the biggest emitters. It is important that such a system has an effective design.
National implementation of waste framework directive	Different implementations between the Member States leading to a situation in which the classification (as waste or product) of material (in particular important for by-products) can vary between regions/countries and thereby leading to administrative burdens (and costs) and uncertainty for recyclers.	Better consider by-products, for example in the definition of standards and in the usage of these standards. This does not only hold for slag but also for different other materials such as organics, dust, slurry and other solids. Better align/define the product- and the waste-Directives/regulations and ease the application of law. Examples include the use of scientifically validated information, e.g. from REACH in the classification process. Improve the accessibility of REACH to local authorities in the sense that knowledge is established about the existence and content of REACH. Harmonize the different waste codes (e.g. Basel, OECD, EU) When defining/specifying the regulation it is important to keep in mind the idea to support the circular economy. It might be more useful to use realistic targets rather than overambitious targets.
Interpretation and administration of Waste Shipment Regulation	There is a link to the waste-framework directive and the classification as waste/product, thus mainly relevant for by-products. The current design of the administration of waste shipment results in high administrative efforts and costs. There are still too high levels of illegal exports. Transit countries can hinder the efficient flow of end-of-life-material-streams.	Ease and improve application and unify interpretation (e.g. by guidelines); keep in mind to support circularity. Streamline the administrative process. Possibly aim for global conventions to establish how materials are classified (comp. Basel convention). Ensuring the implementation of a high quality collection and treatment system to prevent illegal exports.
Missing design for recycling	The trend towards miniaturization and complex product design, for example in electronic devices leads to – in general - a higher number of different materials that are used – in lower concentrations - inside products. This increases the difficulty to recover the different materials and increases the technological requirements of the recovery technologies, which is associated with higher cost of recovery. While there are many innovative products on the market, the focus on a "circular design" is largely missing.	Consider ecodesign in product-design regulations. It seems to be useful to include general requirements for a design for recycling in the scope of the ecodesign directive. The specification should be made such that innovations and recycling are supported. It is important to increase the scope of the Ecodesign directive and to promote it, such that it gets more attention from product designers and industry. It might be useful to follow an approach similar to EMAS and support companies in the move towards a more circular product design by giving companies incentives to do so.
Uncertainty of regulatory application and development	Detrimental effect on investment. High costs to the economic actors.	Pursue a long-term policy-making. Ease application of law, also in terms of making law easier accessible up to

		the local level, better align different areas of law.
Implementation of the WFD obligation to separately collect scrap	Contamination" of the materials, lower values.	While the obligation for separate metal collection is specified in the WFD, it is more strictly to be pursued by the Member States.

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Max lead content in CLP regulation

Description of barrier

During the work for this study, the discussed maximum content of lead of at max. 0,03% into the CLP regulation was prominently discussed. The barrier changed during the course of this study and is perceived to be less severe now.

The fear was that without a differentiation with respect to the form of the lead, copper recycling would be classified as recycling of hazardous material (the same holds for the transport of scrap etc.). The barrier also concerns other recycling process which can contain small amounts of lead. Processing hazardous materials requires increased levels of security – if those are not already high for other reasons. Introducing such an unspecific limit was expected to be associated with high costs to the actors in the metal-recycling system and there was the fear articulated that this would put the whole metal-recycling system at the risk of losing profitability and leaving the business. SMEs are probably at highest risk.

Currently it seems that the proposal which was voted in the REACH/CLP Commitee, differentiates between lead in powder and massive form and thereby addressed the major industry concerns. The interviewees welcome this distinction in general. Whether the modification has detrimental effects on a circular usage of resources remains to be seen. It seems that there might be effects on the usage of by-products which might exceed the defined thresholds, however it is not clear at the moment in what direction this will develop (prove of non-leakage, advanced technologies etc.).

Solutions proposed

Based on the interviews we would have suggested to define the regulation such that it differentiates according to which form the lead is present and thereby target the processes that are hazardous. This seems to accounted for in the version that was now voted. The exact implications remain to be seen.

European Emission Trading Scheme

Description of the barrier

The European Emission Trading Scheme (EU ETS) is one of the most important pillars of the European climate policy. While it covers the whole European Union, it puts the producers located inside the European Union at a disadvantage compared to producers located in countries outside of the EU.

Let us discuss an extreme case in which the costs associated with compliance to the EU ETS would be prohibitively high. In that case the production of metals, both primary and secondary, would be shifted outside of Europe. This means while the emissions would not happen in Europe, there would be a carbon leakage and they would be produced somewhere else in which case no incentive to reduce emissions would be in place.

Solutions proposed

While the objective of the Emission Trading Scheme is clear and is to be pursued, in a global market as it is the case for the metal production and recycling it can only be effective when it does not lead to a shift of production. A possibility, but likely difficult to achieve, would be to extend the scope of the ETS also to outside of the EU. Probably, a "world-ETS" starts with an ETS that includes also those countries (outside the EU) that have a significant industrial sector and thereby capture the countries which are the biggest emitters. It is important that such a system has an effective design. Still, it is a very ambitious target. Alternatively, a "CO2" import tax could be discussed; however, this would be a case of trade protectionism. No easy solution was identified here.

Waste framework directive

Description of the barrier

The waste framework directive (2008/98/EC) is a directive at EU level which aims lays down priorities which should be pursued in waste and product legislation. Since it is a directive, it has to be interpreted and implemented by the Member States. Currently we observe a situation in which these implementations differ and what is important for this case-study: the classification of a material as being a "product" or a "waste" can differ from one region to the next which results in a situation that a material can have to comply with both product and waste legislation. This, furthermore, has implication what can be done with a material, e.g. whether and where it can be further processed. In the case of metal-recycling this is important in particular for the treatment and usage of by-products. The barrier is leading to administrative burdens (and costs) and uncertainty for the recyclers.

Solutions proposed

First, it is suggested supporting a harmonized approach to the implementation of the waste framework directive across the Member States. Second, it is suggested to better consider by-products, in particular also in the definition of standards. This can include the revision of existing standards, enlarging the scope of standards or setting new standards. This does not only hold for slag but also for different other materials such as organics, dust, slurry and other solids. It is important to also consider "non-mainstream" by-products in this process. In addition, it is important to ensure, that these standards are also recognized.

To prevent unnecessary bureaucratic burdens, it is suggested to better align and define the product- and the waste-directives/regulations and to ease the application of law. Examples include the .use of scientifically validated information, e.g. from REACH in the classification process. Improve the accessibility of REACH to local authorities in the sense that knowledge is established about the existence and content of REACH. This could, for example, include a communication/promotion of the ECHA website or specific trainings also to regional or local authorities.

Harmonize the different waste codes (e.g. Basel, OECD, EU). When defining/specifying the regulation it is important to keep in mind the idea to support the circular economy and to relate to practical applications. It might be more useful to use realistic targets, possibly moving targets, rather than overambitious targets.

Waste Shipment Regulation

Description of the barrier

The barrier of the waste shipment regulation is tightly linked to the implementation of the waste-framework directive and the classification of materials as waste or product. It is mainly relevant for by-products. Also, transit countries can hinder the efficient flow of end-of-life-material streams.

The current design of the administration of waste shipment (including a large number of forms on paper) results in high administrative efforts and costs. At the same time, there are still too high levels of illegal export and these seem to be even increasing.

Solutions proposed

It is proposed to ease and improve the application and unify interpretation (e.g. by guidelines) of the waste shipment regulation keeping in mind to support circularity. It is highly recommended to streamline the administrative process associated with the shipment of wastes. This is expected to free also resources at the respective authorities, which might be used to better track illegal shipments. Illegal shipments are, in addition, likely to decrease with a high quality collection and treatment system.

It might be worth wile to aim for global conventions in how materials are classified (comp. Basel convention).

It is important that a high quality collection and treatment system is implemented and enforced in all Member States.

Missing design for recycling

Description of the barrier

The trend towards miniaturization and complex product design results in scrap which contains less amounts of more materials which makes the recycling and recovery process more difficult and sets new requirements for end-of-life recovery technologies. This is in particular important in the recycling of electronic products. In addition, current product design makes it partly extremely difficult to dismantle the products prior to or in the recycling process.

Solutions proposed

As discussed in the introduction to this report, the importance of eco-design will be of increasing importance. It is suggested to consider possibilities to re-use or recycle in respective product-design regulations such as the ecodesign directive. It is suggested to create this openly enough to enable innovations and at the same time re-use and/or recycling. The specification should be such that innovations and recycling are supported. Thus, there is a need for an integrated approach. It is suggested to leave it to the participants of the value added chain.

There is a fear that by mandatory LCAs or recycling content quotas would be counterproductive by hindering innovations or being less efficient.

Uncertainty of regulatory application and development

Description of the barrier

Uncertainty of regulatory application and development was a very prevalent topic in the interviews. While uncertainty of the regulatory development is detrimental to investments – as it is difficult to make planning – the uncertainty of regulatory application is mainly associated with costs to the economic actors. While this is an issue for companies of all sizes, the effects will be most detrimental for small enterprises.

Solutions proposed

It is of importance to pursue a long-term policy making and to communicate it accordingly.

In addition, it is suggested to aim for an easier application of law. This can be achieved through aiming for a better alignment of legislation - not only between waste and product legislation but also with other parts of environmental law. It might be useful to consider the results of the studies conducted for REACH also beyond the scope of REACH.

Implementation of the WFD obligation to separately collect scrap

Description of the barrier

Depending on the material mix that is used in a product, "contaminations" through other materials, such as aluminium and bismuth, are important. For a high quality recycling process, it is important to pursue as little of these contaminations in the processes.

Solutions proposed

Ensure high-quality collection and sorting.

B.2.3 Economic effects

The exact economic effect of the above mentioned barriers are difficult to estimate. In addition to not being specific to the recycling of copper alone, the above mentioned barriers are mainly associated with cost increases for the recycling companies and therefore mainly concern the profitability of the copper recycling companies. This profitability of depends on the internal cost structure of the recycling companies which is not disclosed. The interviews suggested that the associated costs are likely to affect small recycling companies most.

If a general maximum lead content would be introduced into the CLP regulation this would concern – in the extreme case – the whole sector of copper recycling – about more than 2 Mio t copper scrap.

A topic which is of importance to the whole economy is illegal exports. On the one hand because value flows outside Europe; on the other hand, because of probable detrimental environmental effects which will be discussed in the next section. Easing and streamlining administrative procedures for waste shipment would benefit the waste shipping companies but also the respective authorities in charge. With a proper design it is likely that resources, for example in the form of personnel, could be freed to track illegal shipments. By the nature of the problem, illegal shipments are difficult to quantify. Currently they seem to be increasing (European Environment Agency, 2012). In the case of copper that means that material with a high value is risked being not properly treated and possibly partly "lost". In a coordinated inspection campaign (between 2008-2011) in the context of the project "Enforcement Actions II" it was found that almost a fifth of the inspected shipments were in violation of the European waste shipment regulation, 37% of those were illegal shipments, which is about 7% of the inspected shipments (IMPEL, 2011 cited in European Environment Agency, 2012). These numbers are not necessarily representative and by now older than 5 years.

In addition to the legal barriers it has to be noted that the financial situation of the copper recycling sector is worse than some years ago as globally prices were decreasing, like also for other metals and commodities: the LME settlement price of "Copper Grade A" was at less than 4100 €/t. Prices have been much higher, for example copper cathodes were priced at more than 6000€/t in 2011. Prices for scrap move somewhat with world market prices of copper, they have also been decreasing since 2011. Since scrap is prices in different qualities it is not easy to generalize the price. To illustrate, the prices for "copper wire and tubing" are at around 2600€/t (Feb 2016) (About Money, 2016). In addition, energy and commodity prices are low which supports primary production. Moreover, the production outside of Europe also has an effect on prices in Europe as well as on the demand of European products in- and outside of Europe.

B.2.4 Environmental effects

Recycling facilities in Europe operate with high standards of environmental and health protection, under these preconditions illegal exports may have adverse effects on the environment as well as on human health. A better enforcement of the waste shipment regulation is likely to be beneficial for the environment as well as for the European economy.

The other barriers discussed above mainly impact the profitability of the recycling sector in the EU. If this would result in a lower recycling rates of copper scrap, this is associated with more use of virgin materials, with more energy usage in the production process and with comparatively higher CO2 emissions. The use of ores always is linked with land-use. The production of recycled copper requires up to 85% less energy than primary production: to extract copper from ores one needs about 95 Mio Btu/t, for recycling copper one needs about 10 Mio Btu/t. As a consequence the production of copper from scrap, as compared to the primary production reduces CO2 emissions by about 65% (BIR, n.d.).

B.2.5 Non-regulatory barriers and other effects

Barrier	**Effect**	**Possible (legal) solution**
Low prices of commodities (oil, ores)	Lower profitability of recycling as metals from primary production can be supplied very cheaply leading to lower incentives to recycle.	

Low prices of commodities

Description of the barrier

We explained above that prices of copper decreased, however also the prices of commodities such as oil and ores decreased. This results in a situation in which primary production gets comparatively cheap. With low prices of scrap the profitability of recycling is decreasing as well. In comparison to a high-price scenario which supports recycling, it is feared that the current low price scenario is detrimental to recycling.

B.2.6 Interviewees

Table 33 List of interviewed companies and organizations

Organisation	***Sector***	***Description***	***Location***
TSR Recycling	Recycling of steel and non-ferrous metals	TSR Recycling is one of the leading companies in Europe offering steel and non-ferrous scrap metal recycling services.	Germany
Aurubis	Copper production and recycling	Aurubis is a company active in copper production. Aurubis does both primary as well as secondary production.	Germany
Metallo-Chimique	Non-ferrous metal recycling	Metallo-Chimique operates a unique recycling and refining facility that processes secondary raw materials for the production of copper, tin, lead and nickel.	Belgium
EuRIC	European Recycling federation	Umbrella organization of European Ferrous Recovery and Recycling Federation (EFR), the European Recovered Paper Association (ERPA) and the European Metal Trade and Recycling Federation (EUROMETREC).	Belgium
European copper Institute	European Industry association	The ECI is representing actors along the copper value chain	Belgium

Eurometaux	European industry association	Eurometaux represents the NFM industry in Europe, companies active in primary and secondary metals production.	Belgium

B.3 Regulatory barriers for the circular economy: the recycling of steel and steel by-products

B.3.1 The product and its value chain

The steel sector is a large sector with high economic importance, in particular because of its importance for value-chains. Steel is a crucial input into a number of industries. Industries that have a particular high demand are the construction (35% of EU steel consumption in 2010), the automotive (18% of consumption) and the machine construction industry (14% of consumption). The value creation of the European steel sector is estimated to be about 57 billion Euros[15] (Stahl-Zentrum, n.d.).

The European production of crude steel was about 169.3 million tons in 2014; about 25% were produced in Germany, which is the largest European steel producer and the 7th largest in the world (BIR, 2015). In general steel production is associated with CO2 emissions, the exact amounts depend on whether the steel is produced from ores or from scrap and on the applied production technology. Still, the steel sector is the largest industrial emitter of CO2 (Bio Intelligence Service, 2010).

There are two different production processes of steel: the production in so-called “BOFs” (Basic Oxygen Furnaces) which represents the production of crude steel from mainly iron-ores and the production in “EAFs” (Electric Arc Furnaces) which uses mainly scrap as an input into the production system. However, in general both systems can also use the input material which is not the main input factor. The exact proportions are chosen based on economic and process technological considerations. The production of steel from secondary material consumes about 78% less energy and emits about 85% less CO2 than primary production in a blast furnace (BOF) (EuRIC, 2015). Independent of the type of production process, the resulting product (crude steel) cannot be distinguished. In 2014 about 61% of the European steel production (103.2 Mio t) were produced in BOFs, 39% (66.1 Mio t) were produced in EAFs. About 91.3 Mio t of scrap were inputted into the steel production, which is 53.9% of the total crude steel production (BIR, 2015). In 2010 this ratio was at 55.8%.

The production of steel results in a large volume of by-products. The production of 1t of steel results in – on average – between 200 and 400kg of by-products, 90% of this (by mass) being slag.

Steel is – in theory – a material which can be re-smelted over and over again without a loss of quality. However, when used in complex products such as composites, recyclability gets more difficult and more expensive (source). Also the presence of other metals in the used scrap, such as copper, can decrease the quality of the recycled steel.

It is possible to upgrade and repair steel, even re-use is often an option. Limits are set by guarantees or safety-reasons.

The recycling of steel, including the collection of scrap, is a very established process. Depending on the application the steel was used in, the material is entering the recycling process at an earlier or later point in time. Steel used in the construction sector usually is used for a long time. There are different collection systems in Germany and across Europe. Starting at local collectors, it involves a chain of processing, trading and transport, and then the scrap is being used in the European steel production or being exported. Outside the EU it can happen that no organized collection system of scrap is in place. The purchase of scrap is based on the list of scrap types (Schrottsortenliste). There is both a German as well as a European list. These lists mainly emerged from the needs of the smelters/producers and are guided by the quality that is needed for the respective process. For example, depending on the process more or less contamination in the scrap is tolerable. The value chain of steel production, use and recycling is

[15] The number is based on the estimation of the German sector as reported on www.stahl-online.de.

summarized in a very simplified ways in Figure 9.. Exports are subsumed under the heading of "Trade/ Shipments".

Figure 9 The simplified value chain of steel use and recycling

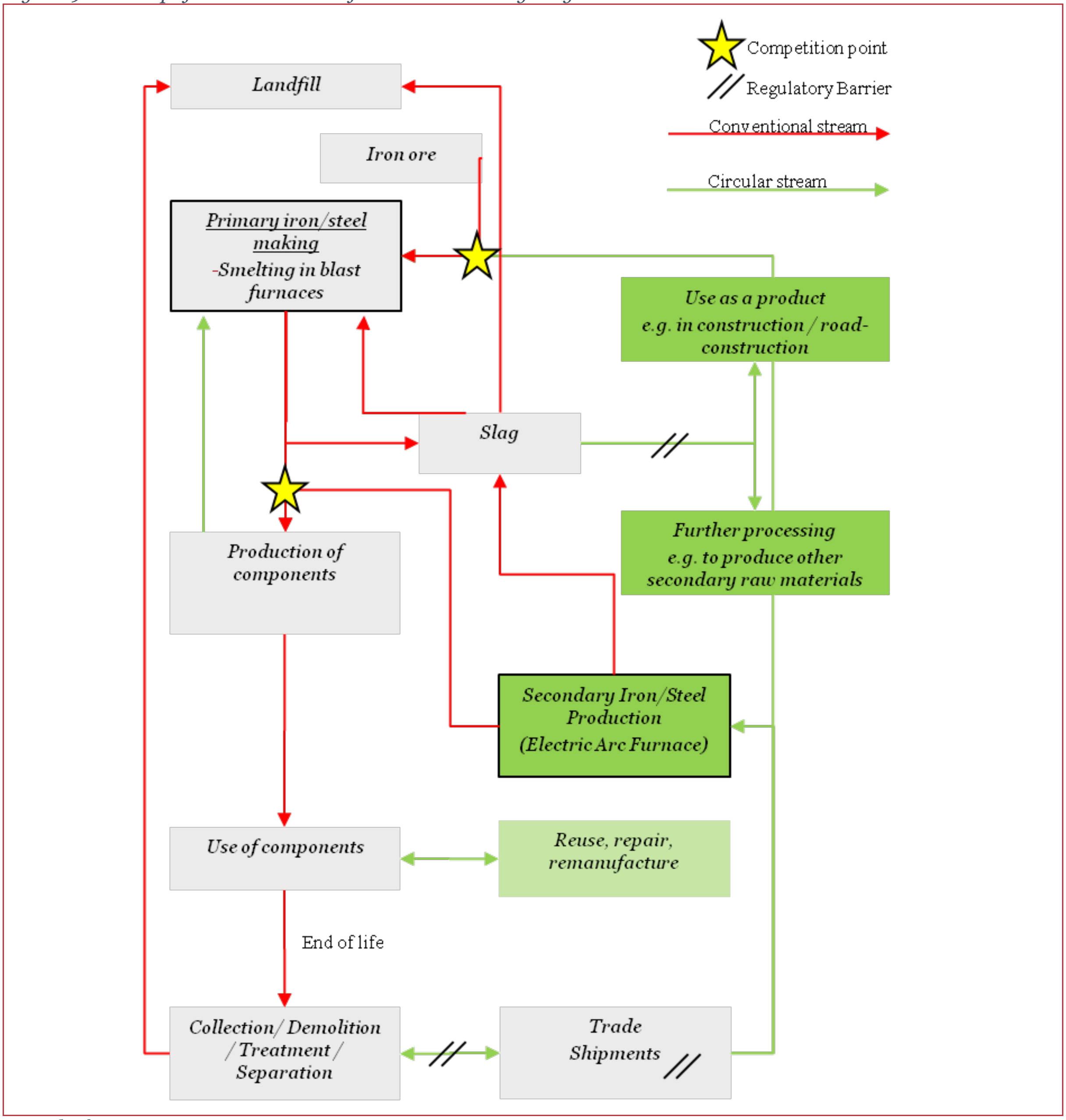

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Table 34 Primary / secondary material streams and volumes

Type	*Value + Unit*	*Comment*
Total production in BOFs	EU (2014): 103,2 Mio t (=61%) Germany (2015): ~30,7 Mio t.	(BIR, 2015) (Wirtschaftsvereinigung Stahl, 2015)
Total production in EAFs	EU (2014): 66,1 Mio t (39%) Germany (2015): ~12 Mio t	(BIR, 2015) (Wirtschaftsvereinigung Stahl, 2015)
Recyclability (how much sec. material can be incorporated)	Electric arc furnaces operate mainly on scrap, however „DRI“ (direct reduced iron) can also be used in the process. In primary production (BOF) scrap is mainly used to cool the process.	
EU share of prim. /sec. production	Share of Steel Scrap Use per total Crude Steel Production in Germany: 45% 100 Mio t. scrap recycled in 2011, about 56% of the EU production is made from scrap	(Wirtschaftsvereinigung Stahl, 2013)
Current price situation	Market price steel billet at the LME: 100US$/t (March 2016) Prices of scrap differ by scrap category. Prices of “new” steel scrap (type 2/8) were at about 150€/t at the beginning of 2016 in Germany.	(LME, kein Datum) (BDSV, 2016) The steel price is set globally.
Environmental impact	The recycling of 1t of steel saves: to 1,100 kg of iron ore, 630 kg of coal and 55 kg limestone. Co2 emissions are 58% lower through the use of ferrous scrap. Steel recycling uses 75% less energy, 90% less virgin materials and 40% less water; it also produces 76% fewer water pollutants, 86% fewer air pollutants and 97% less mining waste.	(BIR, n.d.)

B.3.2 Regulatory barriers

Table 35 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
National implementation of waste framework directive and End-of-waste criteria (council regulation No 333/2011)	Different interpretations of end-of-waste criteria by member states cause legal uncertainties w.r.t. the interpretation, this is especially important for by-products. This leads to high administrative efforts and costs for the actors. The criteria for End-of-life for Steel (Council Regulation (EU) No 333/2011) do neither correspond to the requirements in the production process.	Better consider by-products, for example in the definition of standards and in the usage of these standards. This does not only hold for slag but also for different other materials such as organics, dust, slurry and other solids. Better align/define the product- and the waste-Directives/regulations and ease the application of law. Examples include the use of scientifically validated information, e.g. from REACH in the classification process. Improve the accessibility of REACH to local authorities. Harmonize the different waste codes (e.g. Basel, OECD, EU). When defining/specifying the regulation it is important to keep in mind the idea to support the circular economy. It might be more useful to use realistic targets rather than overambitious targets
Interpretation and administration of Waste Shipment Regulation	There is a link to the waste-framework directive and the classification as waste/product, thus mainly relevant for by-products. The current design of the administration of waste shipment results in high administrative efforts and costs. There are still too high levels of illegal exports. Transit countries can hinder the efficient flow of end-of-life-material-streams.	Improve application and unify interpretation (e.g. by guidelines); keep in mind to support circularity. Streamline the administrative process. Possibly aim for global conventions to establish how materials are classified (comp. Basel convention). Ensure the implementation of a high quality collection and treatment system to prevent illegal exports.
Missing design for recycling	The trend towards miniaturization and complex product design, for example in electronic devices leads to – in general - a higher number of different materials that are used – in lower concentrations - inside products. This increases the difficulty to recover the different materials and increases the technological requirements of the recovery technologies, which is associated with higher cost of recovery. While there are many innovative products on the market, the focus on a "circular design" is largely missing. Depending on the material combination the composite cannot be (fully) recovered in the recycling process.	Consider ecodesign in product-design regulations. It seems to be useful to include general requirements for a design for recycling in the scope of the ecodesign directive. The specification should be made such that innovations and recycling are supported, without introducing mandatory LCAs or mandatory recycling content quotas etc. which can be contra productive (hinder innovations, less efficient). At the same time the directive has to be supported such that it gets more attention. It might be useful to follow an approach similar to EMAS and support companies in the move towards a more circular product design by giving companies incentives to do so.
Coherence between European regulations in different areas of law (waste, environment, etc.) as well as with national legislation	Even at national level, there are inconsistencies between legislations. For example, the planned German „Ersatzbaustoffverordnung“ is in conflict with the German Resource Efficiency Strategy ProgRess	It is important to have an integrated analysis and assessment of existing as well as with planned legislation. . Analyze the interfaces with waste legislation at Member State level.
Uncertainty of regulatory application and development	Detrimental effect on investment. High compliance costs to the economic actors, in particular for SMEs. This can have detrimental effects for the production of secondary raw materials.	Pursue a long-term policy-making. Ease the application of the legal framework, also for laypersons, also in terms of making law easier accessible up to the local level. Means to achieve this could be to issue guidelines. Better align different areas of law.

Waste framework directive / end-of-waste criteria

Description of barrier

This barrier is related on the one hand to the national implementation of the waste framework directive (2008/98/EC) and on the other hand the usefulness of the specification in the end-of-waste criteria (Commission Regulation 333/2011) for steel is discussed.

The waste framework directive is a directive at EU level which aims down priorities which should be pursued in waste and product legislation. Since it is a directive, it has to be interpreted and implemented by the Member States. Currently we observe a situation in which these implementations differ and what is important for this case-study: the classification of a material (here it is most important for the classification of by-products) as being a "product" or a "waste" can differ from one region to the next which results in a situation that a material can have to comply with both product and waste legislation. This, furthermore, has implication what can be done with a material, e.g. whether and where it can be further processed or used. In the case of metal-recycling this is important in particular for the treatment and usage of by-products. The barrier is leading to administrative burdens (and costs) and uncertainty for the economic actors.

Currently the end-of-waste criteria for steel (defined in the Commission Regulation 333/2011) are very strict. In addition to the strict criteria, there are administrative hurdles attached. Materials only get end-of-waste status after fulfilling the respective criteria and when the producer is having the respective certifications. Since the defined criteria are neither justified through the process technology nor through the environmental technologies needed in the process, they do not correspond to standards established in the industry. While the introduction of the end-of-waste regulation aimed at increasing the recycling of steel scrap, it was not successful. In all but one Member State, steel scrap is usually classified as a waste. In this context it has to be considered what should be achieved with the concept of "end-of-waste" criteria.

The material that is classified "end-of-waste" is usually substantially more expensive than material classified as wastes resulting from the administrative processes involved. This higher price is perceived as not reasonable for the companies working with them as no advantage is generated from the classification– neither from a technical nor from an environmental point of view.

In the steel production process the requirements are already quite strict, thus it means for the main process that it does not have an effect on the required technologies whether products or wastes enter the process; the process has to comply with e.g. industrial Emissions Directive (IED) (in Germany: TA-LUFT, BImSchG) which are the dominant guiding legislations for the furnaces. In contrast to that, for other areas of the business, it does make a difference, which environmental protection measures have to be taken; it is for example relevant for the operation of the scrap yard. In general, requirements but also bureaucratic hurdles seem to be higher when using wastes.

With respect to the large amounts of by-products, which result both in BOF as well as EAF production, these have largely been neglected by the EC as well as by the member-states. This is surprising considering the huge amounts of by-products that emerge during the production process. This can have serious consequences when trying to use a by-product as a product which is certainly not in the spirit of a circular economy.

Solutions proposed

First, it is suggested supporting a harmonized approach to the implementation of the waste framework directive across the Member States. Second, it is suggested to better consider by-products, in particular also in the definition of standards. This can include the revision of existing standards, enlarging the scope of standards or setting new standards. This does not only hold for slag but also for different other materials such as organics, dust, slurry and other solids. It is important to also consider "non-mainstream" by-products in this process. In addition, it is important to ensure, that these standards are also recognized.

To prevent unnecessary bureaucratic burdens, it is suggested to better align and define the product- and the waste-directives/regulations and to ease the application of law. Examples include the .use of scientifically validated information, e.g. from REACH in the classification process. Improve the accessibility of REACH to local authorities in the sense that knowledge is established about the existence and content of REACH. This could, for example, include a communication/promotion of the ECHA website or specific trainings also to regional or local authorities.

Harmonize the different waste codes (e.g. Basel, OECD, EU). When defining/specifying the regulation it is important to keep in mind the idea to support the circular economy and to relate to practical applications. It might be more useful to use realistic targets, possibly moving targets, rather than overambitious targets.

Interpretation and administration of **Waste Shipment Regulation**

Description of the barrier

The barrier of the waste shipment regulation is tightly linked to the implementation of the waste-framework directive and the classification of materials as waste or product. It is mainly relevant for by-products. Also, transit countries can hinder the efficient flow of end-of-life-material streams.

The current design of the administration of waste shipment (including a large number of forms on paper) results in high administrative efforts and costs. At the same time there are still too high levels of illegal export and these seem to be even increasing.

Currently the classification of one specific waste could change while travelling from one country to the next. In some cases, it might be cheaper to incinerate the waste or to landfill it. At the same time an integrated evaluation and assessment, also with respect to the environmentally optimal solution.

Solutions proposed

It is proposed to ease and improve the application and unify interpretation. The easiest solution might be by giving additional guidance and interpretative support to the Member States. It is essential to involve the concerned industries in this process. It is highly recommended to streamline the administrative process associated with the shipment of wastes. In this context, fast-track procedures for waste shipment and electronic handling of applications and forms are suggested. This is expected to free also resources at the respective authorities, which might be used to better track illegal shipments.

It might be worth wile to aim for global conventions in how materials are classified (comp. Basel convention).

Missing design for recycling

Description of the barrier

The products that enter the recycling process today were designed years ago (depending on the product and its lifetime). To improve recycling in the future, product design today has to also consider recyclability. Examples include composites, which sometimes are difficult to recycle. The same holds for electronics where often the number of involved materials increases while the amount of every material decreases. Thus, attempts to be resource efficient in the production process today can have rebound effects at the recycling stage.

Solutions proposed

It is suggested to include a general support for better recyclability in product-design regulations such as the ecodesign directive and motivate taking properties like recyclability, reparability, re-use etc. into consideration in the design of a product. At the same time possible effects on innovation, long time efficiency etc. should also be considered. The specification should be such that innovations and recycling are supported. Thus, there is a need for an integrated approach. It is suggested to leave it to the participants of the value added chain.

There is a fear that by mandatory LCAs or recycling content quotas would be counterproductive by hindering innovations or being less efficient.

Coherence between European regulations in different areas of law as well as with national legislation

Description of the barrier

The waste and products legislations are often not aligned. In particular, the extensive scientific work that has been performed under REACH is not reflected integrated into other directives, be it national or local.

Moreover, legal standards often insufficiently reflect by-products such as slag. As a result, some valuable by-products are "forced" to be landfilled because they are considered as waste and even more as "non-recoverable" wastes by some local authorities, ignoring the work performed under REACH, the matching of these by-products with the specifications of the users and the existence of well-functioning supply chains.

The interviewees perceive it that the EC is assuming that a general ban to landfill wastes is supporting the circular economy. Currently there is no market for certain wastes. It is suggested that rather than banning landfilling, supporting these markets would be supporting the circular economy. This is mainly related to materials from metallurgical smelting processes.

The problem with landfilling certain materials is even more urgent as some of the materials which might be used as products (e.g. in construction) cannot be used because of strict criteria. In Germany an example of such a barrier is the planned "Ersatzbaustoffverordnung" which shall regulate in the near future which types of materials can be used as alternative material for construction, e.g. in road construction. It has extremely tight requirements for soil and ground water protection. In the end the interviewees expected that this results in more material being deposited (instead of being used elsewhere).

Solutions proposed

Use the most recent and extensive knowledge, in particular REACH studies, that is available also for the purpose that it might not have been collected for initially. Also here it is important to take an interdisciplinary view and evaluation in designing and applying legislations. When defining legal standards, it is important to take into consideration also by-products.

Support the creation of markets for wastes which are currently forced to be landfilled and for which there could, however, be other applications.

Take an integrative perspective (across different areas of environmental law as well as in weighting up different environmental aims against each other) when developing/refining law and legislations.

Analyze the interfaces with waste legislation at Member State level.

Uncertainty of regulatory application and development

Description of the barrier

The complicated legal framework leads to high compliance cost, in particular for small enterprises. This can have detrimental effects for the production of secondary raw materials.

A regulatory environment that is perceived to be uncertain has detrimental effects on investment.

Solutions proposed

It is of high importance to ease the application of the legal framework. There are two ways that can be pursued and which we suggest to pursue in parallel: It will be important to on the one hand align waste/product legislation as well as try to align it with other environmental law. On the other hand, it is important to provide guidelines to the appliers of law.

In addition, a long-term policymaking is to be aimed for.

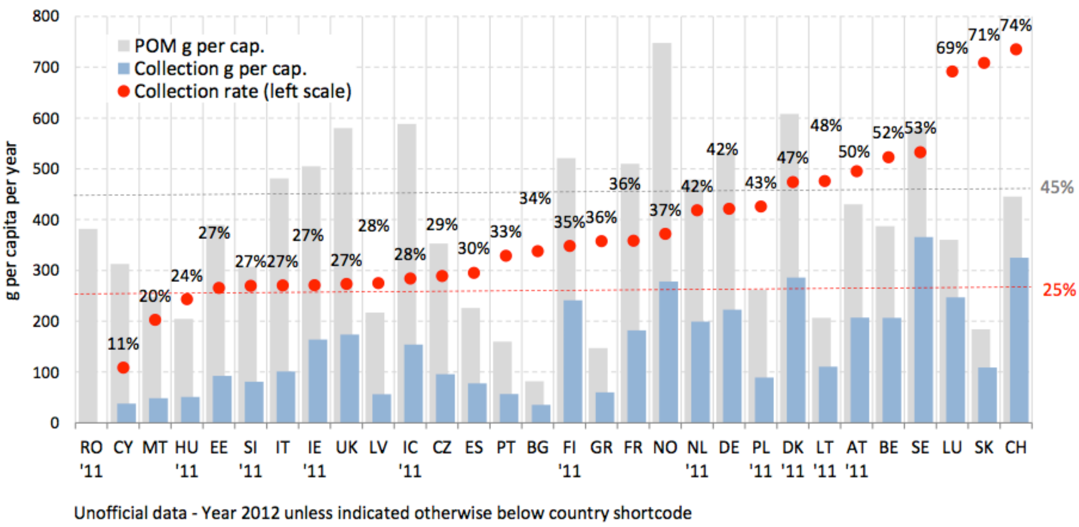
B.4 Lack of enforceable definitions for the the recyclability of electronic products as required in the WEEE directive, especially with regard to disassembling of batteries

B.4.1 The product and its value chain

Description of the product/activity

Batteries and accumulators play an essential role to ensure that many daily-used products, appliances and services work properly, constituting an indispensable energy source in our society. The two value chains analysed in this case study are virgin portable batteries and on the other hand recycled amounts of portable batteries that could then be used as input in industrial production processes, e.g. again for the production of batteries.

According to an EPBA study published in 2013[16], producers and importers reported having placed on the market in the EEA area, plus Switzerland, close to 230,000 tonnes of portable batteries in 2011, while around 72,000 tonnes of waste portable batteries were reported as collected. This corresponds to a collection rate on a current year basis of around 32%. Based on partially available data, a slightly higher collection rate of 35% was expected for 2012.



Source: Perchards-SagisEPR (2013)

All types of batteries have seen their recycled tonnage increasing. However, the growth is more noticeable for secondary batteries (industrial NiCd, NiMH and Li-Ion portable). The decrease in tonnage for portable NiCd is already visible (anticipating the future ban on NiCd in cordless power tools). Another point worth noting is the almost inexistent tonnage of Li-Ion from the E-mobility market: those batteries are still on the road and not yet at the end of their life[17].

With regard to the overall recycling rates, the first compulsory reporting deadline with respect to recycling efficiencies is in 2015 (for the year 2014). Therefore, only some, but no comprehensive data are yet available. Only two MS reported their recycling efficiency rates. The German environmental agency (Umweltbundesamt) stated that recycling efficiency rates in Germany are constantly high. From 2010 to 2012, they were in range of 95-97% for Lead-acid batteries, 83-89% for NiCd batteries and 58-72% for others. For France, Lead-acid batteries have a recycling efficiency of 90%, NiCD batteries are at 77%, and others are at 83%. A conservative estimation for the EU over all battery types could a recycling efficiency of 60%.

[16] http://www.epbaeurope.net/documents/Perchards_Sagis-EPBA_collection_target_report_-_Final.pdf

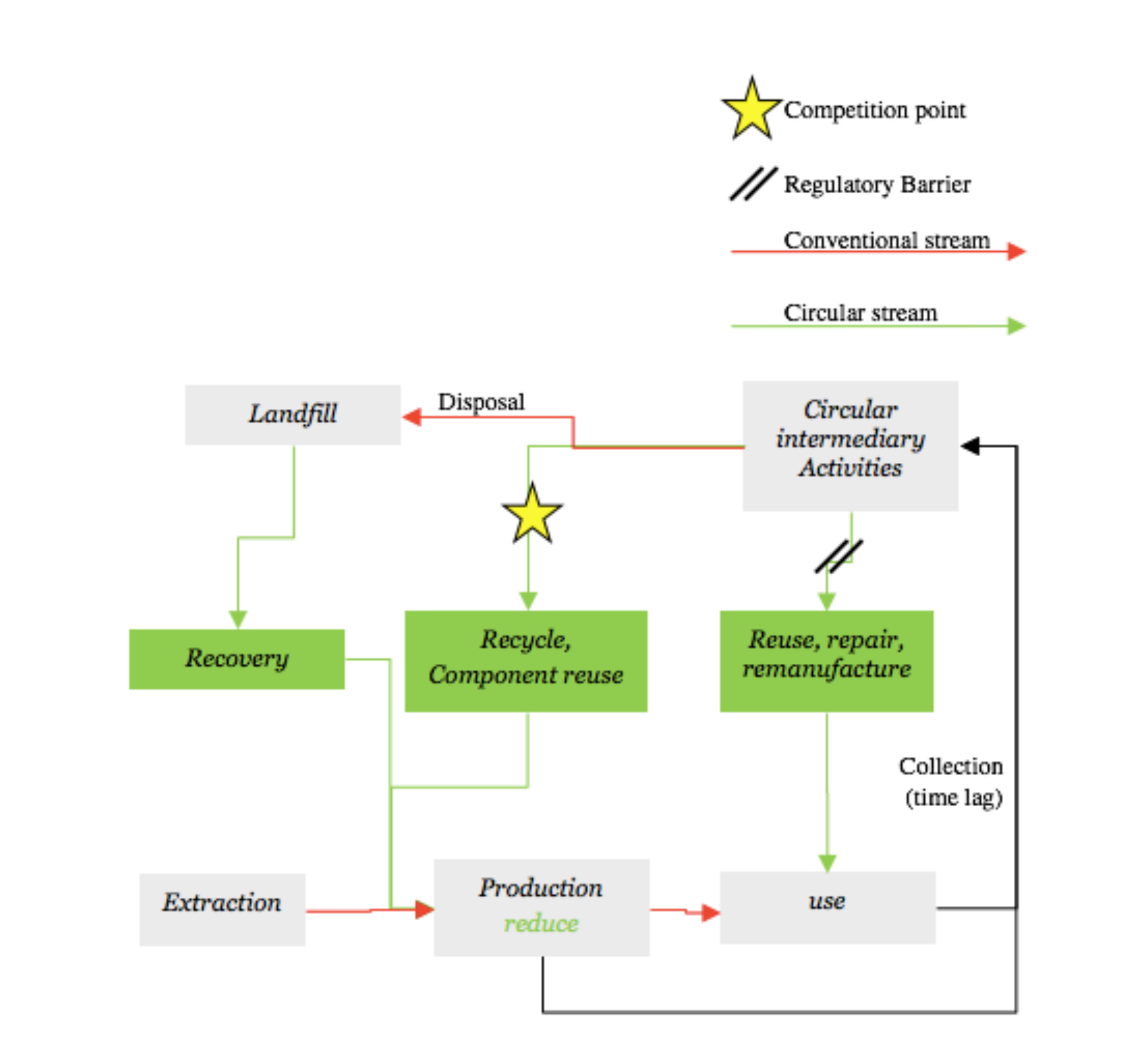
[17] http://www.ebra-recycling.org/sites/default/files/EBRA%20PR-%20BatteryStatistics_year2012_0.pdf

Value chain and life cycle of the product/activity

The specific activity which this barrier analysis focussed on is the necessary disassembling of batteries from discarded products which is seen as necessary requirement for the recycling of the products as well as of the batteries. In most cases this happens based on manual handling of products and thus is a costly step in the treatment process (depending on wage levels).

The following figure illustrates the specific value chain and the barrier analysed in this case study: Over the last years a lot of emphasis has been put on the collection of discarded batteries. Nevertheless, more and more batteries are contained in electronic products and the disassembly is often time consuming and thus costly – despite general legislations in the Battery Directive. This barrier especially affects high quality recycling and recovery of raw materials for which hazardous substances in batteries pose significant threats for the quality of potential secondary raw materials.

Figure 1 The circular value chain for recycling of discarded products



Source: Own illustration

Per step in chain: actors and their relation with connected actors

- Design and production

Producers of batteries and accumulators and producers of other products incorporating a battery or accumulator are given responsibility for the waste management of batteries and accumulators that they place on the market. This extended producer responsibility scheme is aimed to set incentives for a disassembly and repair friendly product design. Nevertheless, especially the high share of imported products lowers these incentives.

- End-of-life options of product

The amounts of recycled tonnage for all types of batteries have been increasing over the last years. However, the growth is more noticeable for secondary batteries (industrial NiCd, NiMH and Li-Ion portable). The decrease in tonnage for portable NiCd is already visible (anticipating the future ban on NiCd in cordless power tools). In Europe the member states are obligated to report on the end-of-life options and treatment ways of batteries. Recycling technologies differ significantly for different battery types: In the case of Li-Ion batteries plastics are separated from the metal components prior to the smelting process. The metals are then recycled via a High-Temperature Metal Reclamation (HTMR) process during which all of the high temperature metals contained within the battery feedstock (i.e. nickel, iron, manganese, and chromium) report to the molten-metal bath within the furnace, amalgamate, then solidify during the casting operation. The low-melt metals (i.e. zinc and cadmium) separate during the melting, the metals and plastic are then returned to be reused in new products (Battery Solutions 2016).

With regard to the overall recycling rates, the first compulsory reporting deadline with respect to recycling efficiencies is in 2015 (for the year 2014). Therefore, only some, but no comprehensive data are yet available. Only two MS reported their recycling efficiency rates. The German environmental agency (Umweltbundesamt) stated that recycling efficiency rates in Germany are constantly high. From 2010 to 2012, they were in range of 95-97% for Lead-acid batteries, 83-89% for NiCd batteries and 58-72% for others. For France, Lead-acid batteries have a recycling efficiency of 90%, NiCD batteries are at 77%, and others are at 83%. A conservative estimation for the EU over all battery types could a recycling efficiency of 60%.

- Collection system

The collection and recycling of post consumer batteries is regulated by Directive 2006/66/EC ("the Batteries Directive") on batteries and accumulators and waste batteries and accumulators that entered into force in 2006. The directive differentiates between automotive and industrial batteries as well as portable batteries which are in the focus of this case study. Portable battery or accumulator means any battery or accumulator that is sealed, can be hand-carried, and is neither an industrial battery or accumulator nor automotive battery or accumulator. One of the key objectives of the directive is to establish specific rules for the collection, treatment, recycling and disposal of waste batteries. Therefore, the Batteries Directive stipulates several producer responsibility obligations and establishes collection schemes for waste portable batteries. The European Commission´s ex-post analysis for specific waste streams concludes for batteries that especially the collection of portable batteries has improved significantly since the Directive entered into force but that many member states still struggle how to achieve the 45% collection rate in 2016.

- Market aspects

The cost efficiency of batteries collection and recycling varies significantly among the different types and chemistries of batteries. Especially for many portable batteries types (e.g. alkaline manganese, zinc carbon and non-cobalt lithium batteries), the value of recovered materials does not cover the costs of collection, sorting, transportation and recycling so it is funded by producers through collection scheme fees and these costs are transferred to consumers through increased prices. In contrast for portable NiCd batteries the recycling efficiency target as foreseen in the Batteries Directive (recycling of 75% by average weight, including recycling of the cadmium content to the highest degree that is technically feasible while avoiding excessive costs) is already met by EU recyclers (such as Accurec) because of valuable metals content. Additionally, the achieved recovery rate for cadmium content is above 99%.

There are some indications for a battery collection stream independent from collection schemes where waste batteries are returned not by the end-users, but by WEEE dismantlers. This practice has been established because recovered value from cobalt-based batteries (about EUR 3 000 per tonne) recycling covers processing costs (EUR 2500 - 3500 per tonne). However, recycling of zinc primary and lithium rechargeable batteries with low added value electrode materials such as manganese dioxide or iron phosphate is unprofitable at current prices. Costs of waste portable batteries collection also differ significantly between Member States due to several factors, inter alia the structure of the system (monopolistic or competitive), depending on the size of the market and depending on the budget that is allocated for consumer awareness or R&D. Based on the amounts of collected batteries by the member states, the total value of the current linear market for portable batteries can be estimated at ca. 1 billion Euro in total, the total value of current circular market at about 200 Mio Euro. As mentioned above the circular alternative is already a viable business model for some battery types although the current low price levels for virgin materials clearly favour the traditional linear system.

- Quality aspects

If batteries are not properly collected and recycled at the end of their life, the risk of releasing hazardous substances increases and constitutes a waste of resources. 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. Recycling of discarded batteries could also contribute to secure the European supply with raw materials like lithium, nickel or cadmium that are considered as critical for the European industry. These materials can be recovered at a very high quality level, nevertheless in most cases not high enough for a second use phase in batteries that require extremely high levels of purity.

Key figures for primary and secondary material streams are summarized in the following table.

Table 36 Indicative economic values / trends

Type	*Value + Unit*	*Comment*
Current price situation (materials, please indicate country/region of reference)		See above
Expected cost-price ratio (due to use of sec. material instead of primary)	1:1, very much depending on specific collection and disassembly costs for specific battery types (see market aspects)	
Revenue cuts or potential business losses caused by existing legislative barriers	Significant	Losses especially occur from limitations of product use phases when malfunctioning batteries can not be replaced.
Cost of non-action		
Additional indirect costs caused by legislative barriers (human resources, external consulting, research, …)	Significant	Manual disassembly of batteries is time consuming and often a key barrier for the high quality recycling of products.
Investment costs to increase circularity	Significant	Changing the current interpretation of the Directive might lead to a situation where industry may need to stop sales of already produced products, withdraw them from the distribution chain and redesign existing and viable products. Already produced, fully functional products would need to be scrapped, leading to financial and resource losses.
Any other identified costs	Significant	A strict end-user removability requirement will lead to either bulkier products with increased battery and appliance volume and weight, or to a reduced battery capacity. For various electronic devices such design changes might have a negative impact on the functionality, handling and usability as well as on the environment due increased resource requirements.
Environmental impact (e.g. higher cost due to higher emissions)	Ambivalent	Longer use phases of products might lead to significant resource savings. On the other hand the electronic products industry states that removable batteries might lead to bulkier products with increased environmental footprint.

B.4.2 Regulatory barriers

Table 37 Overview of regulatory barriers

Main Barrier	*Affected department (s)*	*Effect*	*Possible (legal) solution*	*Barrier identifier*
Lack of enforceable definitions for the the recyclability of electronic products as required in the WEEE directive, especially with regard to disassembling of batteries	Product design	Lowered incentives for high quality recycling	Specified design requirements	Company 1, 3
Implementation of bans for hazardous substances in batteries	**Recycling**	Lowered incentives for high quality recycling	**Stricter monitoring especially of imported batteries, better labelling**	Company 2

Main barrier identified

Description of barrier

According to article 11 of the European Battery Directive 2006/66/ EC, the member states shall ensure that manufacturers design appliances in such a way that waste batteries and accumulators can be readily removed. Where they cannot be readily removed by the end-user, they shall ensure that manufacturers design appliances in such a way that waste batteries and accumulators can be readily removed by qualified professionals that are independent of the manufacturer. Appliances in which batteries and accumulators are incorporated shall be accompanied by instructions on how those batteries and accumulators can be safely removed by either the end-user or by independent qualified professionals. Where appropriate, the instructions shall also inform the end-user of the types of battery or accumulator incorporated into the appliance. The provisions set out in the first paragraph shall not apply where, for safety, performance, medical or data integrity reasons, continuity of power supply is necessary and a permanent connection between the appliance and the battery or accumulator is required.

The key barrier in this case is the lacking concreteness of these requirements for the design of products. The wording in the Directive especially leaves open the question of how "readily removable" should be defined. Recyclers of electronic products report that for an increasing share of products it is not possible to change batteries without destroying the product (EUCOBAT 2014). Especially consumers are not able to take out rechargeable batteries from their electronic devices. This steady incorporation of batteries in products often leads to an unnecessary reduction of product use phases and thus to a waste of raw materials and other natural resources. According to the German EPA this is the case for more than 20 out of 120 electronic product groups, especially for ultra books, smartphones, tablet computers, navigation systems and electronic toothbrushes (Odendahl 2014).

Solutions proposed

According to the German EPA better legislations would have to specify design requirements that allow taking out batteries also in order to improve their recycling routes. The Battery Directive should be revised in a way that ensures the disassembly of batteries from products without necessary destruction of the product already during the use phase. In contrast the electronic products industry states that the global standard IEC 62075 already sufficiently promotes battery removability "either by users or skilled persons" and that proper procedures for the safe removal of the battery, information on the battery types and their location should be available to the user or skilled person.

Additional barrier 1

Description of the barrier

According to the European Battery Recycling Association there is often found that batteries placed on the European market do not live up to the substance requirements in the Batteries Directive. For example, according to a German Environmental Agency study from 2011 it was found that Cadmium contents above the limit of 20 mg/kg were found in 12 of 25 zinc/carbon mono cells and in 2 of 8 zinc chloride mono cells, as well as mercury contents contents above the limit of 5 mg/kg for mono-cells and other types were found in 4 of 25 zinc/carbon mono cells and in 1 of 11 9-V-zinc carbon batteries. The barrier has been confirmed by a study conducted by BIO et al. that identified insufficient compliance monitoring with some of the requirements (such as limits on hazardous substances and capacity labelling on imported portable batteries) of the Batteries Directive by national authorities as a major challenge for the effectiveness of the Directive.

Solutions proposed

Effective enforcement by authorities would create a level playing field among all producers placing on the market and it would allow for a more enhanced sustainability approach of the battery waste management process.

B.4.3 Impact scheme for the actor

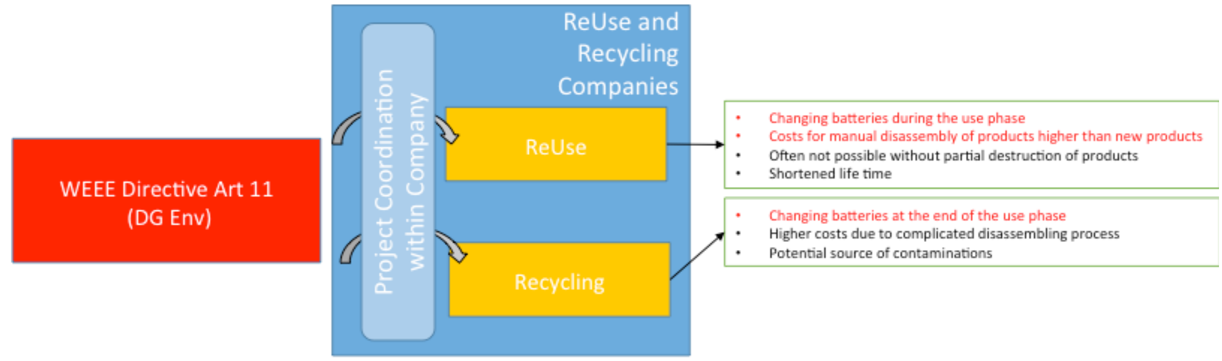
The following figure illustrates the main impacts from the regulatory barrier for circular economy identified in this case. Unclear and not enforceable legislations of recyclability have two key impacts on reuse and recycling of electronic devices:

- During the use phase difficulties to change batteries makes reuse costlier and often not economically viable compared to the purchase of new products
- At the end of the use phase, difficulties to dismantle the product and to disassemble the batteries can cause contaminations of secondary resources in the recycling process (especially taking into account lacking enforcement of hazardous substances bans)

Removing the barrier by adopting the Battery Directive will lead to significant necessary investments into new product designs and changes of production processes. As outlined above this might lead to a situation where industry may need to stop sales of already produced products, withdraw them from the distribution chain and redesign existing and viable products. In the longer run there will be economic benefits from lower disassembly costs that might be estimated in a range of 5 to 10% compared to linear alternatives (so around 50 – 100 million Euros).

Also environmental impacts of removing the barrier are ambiguous: On the one hand stricter end-user removability requirements will clearly lead to increasing product life spans; increased reuse and better recycling of several resource intensive raw materials. On the other hand, it might also cause either bulkier products with increased battery and appliance volume and weight, or to a reduced battery capacity. For various electronic devices such design changes might have a negative impact on the functionality, handling and usability as well as on the environment due increased resource requirements.

Figure 10 Impact scheme for actors in the reuse/ recycling sector



B.4.4 Interviewees

Aspect	*Company 1*	*Company 2*	*Company 3*
Name of the company	Recyclingbörse Herford	European Battery Recycling Association	AfB Group
Industry sector	Reuse	Battery Recycling	Remanufacturing
Summary of the role of the company in industry (general)	Coordinator of a German reuse network	Coordination of the inputs of European battery recyclers to the CE package	Private remanufacturing company
Location	Germany	Brussels	Germany

B.4.5 References

http://www.eucobat.eu/system/files/2014-09-24%20-%20Presentation%20Eucobat%20ICBR%2016-09.pdf, p. 7

http://www.umweltbundesamt.de/sites/default/files/medien/378/dokumente/austauschbarkeit_akkus_odendahl.pdf, p. 2

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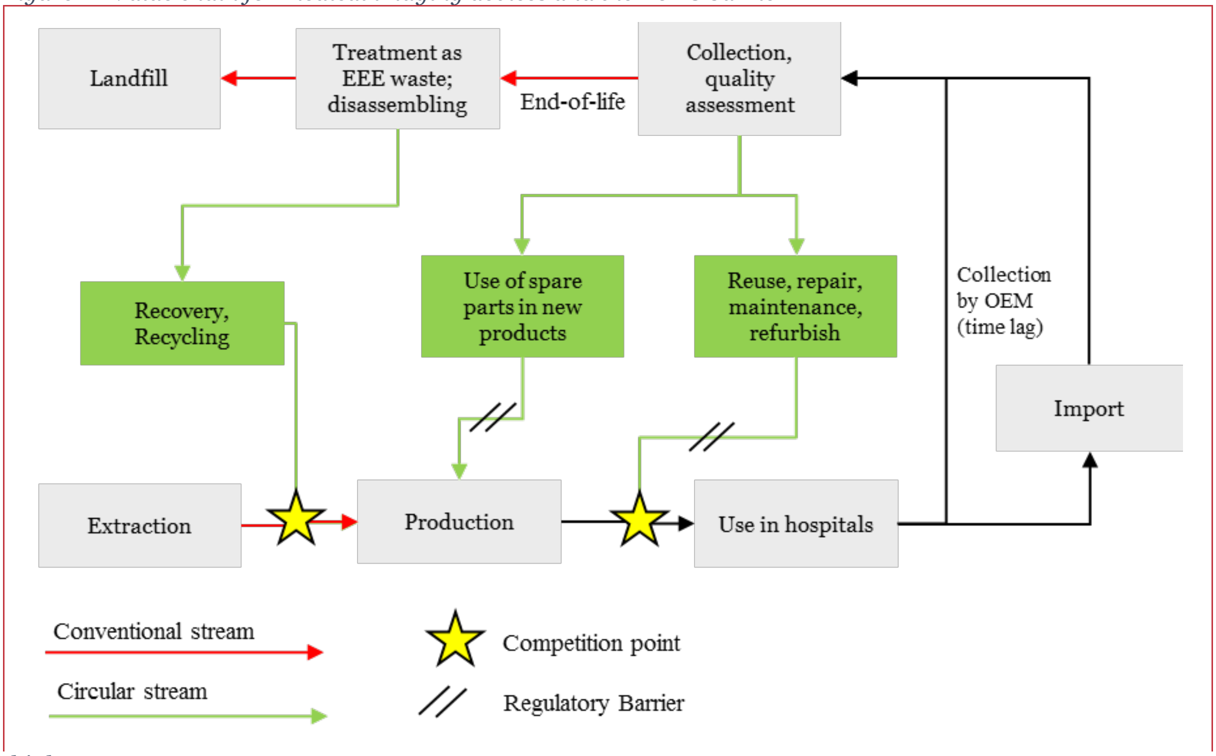
Battery Solutions (2016): End Sites Recycling Processes. URL: http://www.batteryrecycling.com/Battery+Recycling+Process (accessed April 5 2016)

B.5 Regulatory barriers for the circular economy: Remanufacturing of Medical Equipment

B.5.1 The product and its value chain

Figure 11 Value chain for medical imaging devices and the RoHS barrier



thinkstep

Description of the product/activity

Medical imaging devices such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) are widely refurbished because of their high value and their design for repair and refurbishment. Medical imaging devices are reusable (and reused), highly recyclable and contain many tons of valuable materials (steel, copper, aluminum, pure lead, etc.) Globally MRI, CT and X-Ray devices account for up to 75 % of refurbished products, so medical imaging devices make the biggest share of refurbished medical equipment products and are therefore in the scope of this study. The devices are built to last 15 to 20 years, but are often not completely utilized in their first life cycle. Refurbishment can therefore extend the overall time of the equipment. The main manufacturers are Siemens, GE Healthcare, Philips, Toshiba and Hitachi. The Original Equipment Manufacturers (OEMs) also refurbish their products in a closed-loop system.

The refurbishment business is global, however, the main markets for refurbished medical equipment are the EU and the US, approximately 90 % of shipments of used medical devices and parts for reuse go to the US and Europe. The shipment of used devices and parts for reuse add up to 14,000 tons to OECD countries and 1,500 tons non-OECD countries per year. These shipments are valued at approx. $ 3.4 billion (including equipment for repair).

Before 2014, 30 % of refurbished equipment sold in the EU was sourced from outside the EU. The refurbishment of medical equipment accounted for a global revenue of approx. 480M€ in 2012. Approximately all the refurbished systems are sold in the US (48%) and EU (26%). In 2013 refurbished medical equipment worth around 130M€ was sold in the EU. The Compound Annual Growth Rate is estimated to be 12.5 % from 2014 to 2019.

Due to their specific properties needed for medical imaging, those devices often contain hazardous materials such as lead, cadmium, and hexavalent chromium. High standards of end of life treatment of these substances reduce the risk for patients and environment. The Good Refurbishment Practice (GRP) industry standard supports this.

Value chain and life cycle of the product/activity

The value chain of medical imaging devices is mainly controlled by the OEMs. Third parties are involved in some activities such as logistics and brokerage. The OEMs produce the devices and sell them to the customers as hospitals or clinics. Once the customers need new products, they contact the OEMs and can purchase new or refurbished equipment. Public hospitals that fall under the public procurement law have to make proposals to which the companies make offers. Those offers can be new or refurbished medical equipment. Used medical equipment is taken back by the OEMs in order to be remanufactured, if the equipment was used in foreign countries it has to be imported. A quality assessment of the used parts and equipment is done to ensure the quality of refurbished equipment; a new warranty is given after refurbishment. Functioning spare parts of used equipment can be used for refurbishment or to manufacture new products. At the end of their life, the products are treated as Electrical and Electronic Equipment (EEE) waste and are recycled at quality facilities under high standards so that the material can be reused. Most materials are valuable and even plastic parts can be used for their calorific value.

Per step in chain: actors and their relation with connected actors

- Design and production

Design and production is done by the OEMs, the innovation cycle is between 3 to 4 years, meaning the average time for new generation technologies to go in the market. Customers typically exchange equipment after 7 to 10 years to buy the latest technology One problem at the design phase is the uncertainty of future legal developments and the potentially denied access to markets due to contents of materials that are then restricted. Another problem for the production is the sourcing of spare parts. The current legislation limits access to existing spare parts from other countries and the incorporation of used parts in new products is limited to parts sourced in the EU before July 2014. For medical imaging certain substances are needed to provide good healthcare.

- End-of-life options of product

Once a product or component reaches its End-of-Life, it is treated by a network of disassembly and recycling facilities under high quality standards. This network is controlled by the OEMs. Most materials can be reused.

- Repair and upgrade options

Repair and upgrade options are usually given for most components of medical imaging devices as those are designed that way. New and used spare parts can be used to repair or refurbish used equipment. As mentioned above, currently the access to spare parts is limited due to the European legislation and the barrier causes problems with placing the refurbished equipment on the European market in case it is not RoHS-compliant or components are not RoHS-compliant. In general, it is more and more difficult to get equipment back for repair etc. due to the legislation (also for example EoL legislation, WEEE legislation) and the related administrative burden.

- Collection system

The closed-loop-system works well in terms of the collection of the used products. The customers, hospitals and clinics, contact the OEMs when they need new equipment and parts or write proposals and return the old equipment to the OEMs. Due to the high value of the products and the closed-loop-system, there are no leakages on the chain. Even End-of-Life products and parts are treated properly, so that the material can be recovered. The different legislations make it increasingly difficult to get back the medical systems. procurement

- Market aspects

The uptake of refurbished medical imaging devices depends very much on the country. Main markets for pre-owned devices are the EU, the US and Canada. There is a great demand for refurbished medical equipment in Europe according to the manufacturers. Insights out of the one interview held with a procurement representative from a hospital, indicates that the acquisition of remanufactured equipment is estimated to 10% in the last 2-3 years. Other countries like China and Brazil restrict or prohibit the import of refurbished medical equipment. Countries with wealthier healthcare systems like China, India and Arabic countries prefer new products. Generally, refurbished medical equipment compete with new medical equipment even though the OEMs both produce and refurbish the products. According to the manufacturer, a refurbished product can be up to 20% cheaper than a new product. From the hospital interviewed, no data on savings from buying remanufactured is available.

- Quality aspects

The quality of refurbished products is guaranteed by the companies and new warranties are given. Otherwise the hospitals would not buy the equipment. In a quality assessment process, the companies determine whether a product or component is suitable for reuse and repair. Quality End-of-Life treatment is also guaranteed by the OEMs. Therefore, there is not risk for the patient.

Table 38 Primary / secondary material streams and volumes

Type	***Value + Unit***	***Comment***
Total primary production	MRI: 1000 CT: 1000 X-Ray: no information available	Global numbers, approx. 1/3 of that in Europe
Total secondary production	Shipments of used devices and parts for reuse: approx. 15500 t valued at around 3.4 bn.	Globally
Total demand	No information available	–
Recyclability (how much sec. material can be incorporated)	Reuse rates on average between 70-80% for one cycle	–
Potential max. secondary supply	India, China and Brazil alone could increase refurbishment by 50-100%	–
EU share of prim. /sec. production	Refurbishment market in Europe approx. 3% of total revenue for imaging devices	–

Table 39 Indicative economic values / trends

Type	***Value + Unit***	***Comment***
Current price situation (materials, please indicate country/region of reference)	No information available	–
Expected cost-price ratio (due to use of sec. material instead of primary)	Up to 20% price reduction for refurbished equipment: 100-500 mi. Euros per year	–
Revenue cuts or potential business losses caused by existing legislative barriers	30%	–
Cost of non-action	Parts worth 0.5-1 mi. Euros have to be scrapped if the new Exemption 31 does not allow the use in new products 30% less business, representing 36 million Euros	–
Additional indirect costs caused by legislative barriers (human resources, external consulting, research, …)	50 million Euros for RoHS implementation Estimated global expenditure since for RoHS compliance since 2006: 2 billion Euros	–

Investment costs to increase circularity	No information available	–
Any other identified costs	No information available	–
Environmental impact (e.g. higher cost due to higher emissions)	Refurbishment leads to lower CO_2 emissions, energy use and material use	–

B.5.2 Regulatory barriers

Within the previous work in this project, as main barrier was identified the Restriction of Hazardous Substances (RoHS), hampering the remanufacturing of medical equipment within the European Union.

Table 40 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
RoHS	Restricted access to used parts/products; Difficulties with selling refurbished equipment on EU market; Uncertainty about future restrictions	Exclude refurbished products from RoHS and allow the use of used spare parts for new products independent of the origin; Include exemptions for medical devices in legal text of RoHS; Harmonize definitions throughout all legislations; Link the term "placing on the market" with the CE-marking only; If imaging devices are considered "large-scale fixed installations" then RoHS would not apply (Article 2.4e); Add a new article to RoHS because exemptions are only temporary, have to be adapted and renewed
Additional barriers	*Effect*	*Possible (legal) solution*
Other substance regulations (REACH) in the future	Restricted access to used parts/products; Difficulties with selling refurbished equipment on EU market; Uncertainty about future restrictions	Exclude Refurbishment of medical devices
Medical Device Directive	Limited access to used parts/product	Link the term "placing on the market" with the CE-marking only
Interpretation of the Blue Guide	Limited access to used parts/product	Link the term "placing on the market" with the CE-marking only
Trade agreements/barriers	Limited access to used parts/product; Products cannot be sold to other countries	Include circular economy in Free Trade Agreement
WEEE Directive	It is more and more difficult to get equipment back	Ensure that used medical devices for refurbishment and refurbished devices are not treated as waste – eliminate the administrative burden
The definition of the terms refurbishment / remanufacturing and waste / used equipment should be reviewed harmonized	Uncertainty, lack of common understanding	Good Refurbishment Practice (GRP) as currently developed; must be applicable in EU; Define a new class of pre-owned systems

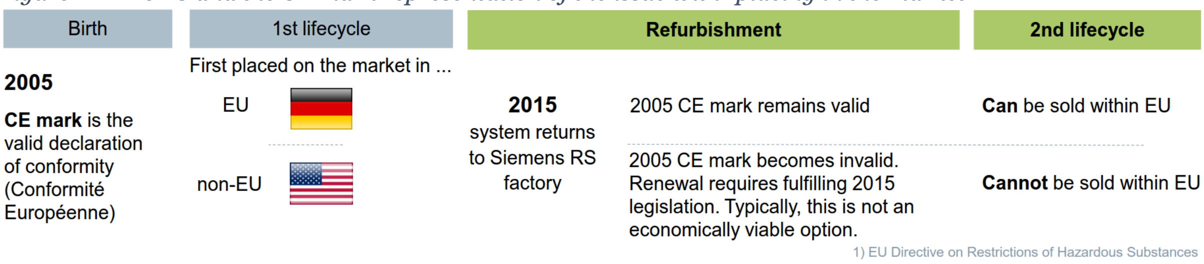
Main barrier identified

Restriction of Hazardous Substances (RoHS)

The Restriction of Hazardous Substances (RoHS) is a substance legislation and the most important barrier to circular economy for medical imaging devices. The problem is, that a lot of those substances are needed in medical devices, as mentioned above. Additionally, even if some substances could be replaced, a lot of equipment that is already on the market does contain parts with those substances and is still usable, as well as the individual parts. Lead is the largest amount of a RoHS substance used in medical devices accounting for 98.5% of all RoHS substances used. Despite a very significant effort to reduce the use of lead, a reduction of only 2.37% has been possible because most uses (shielding and counterweights) have no substitutes and so require exemptions. Most cadmium is needed in advanced detectors for imaging equipment and so the reduction in use due to RoHS has been very small. Hexavalent chromium (CrVI) some small amount was used in 2006 (pre-RoHS). CrVI is used mainly as passivation thin coatings. These are produced from soluble hexavalent chromium compounds (regulated by the REACH Regulation).

In terms of refurbishment and reuse, the problem with RoHS is, that it limits the access to used equipment and parts as approximately 30 % of the equipment is sourced outside of the EU. Equipment that was “placed on the market” before RoHS was introduced has to be RoHS-compliant when entering the EU market after refurbishment. In the context of that, the interpretation of the term “placing on the market” according to the Blue Guide causes issues. If two identical products were sold, one in the EU and one outside of the EU and both were CE-marked at that time, the product sold outside the EU cannot be taken back for refurbishment because it then has to be RoHS-compliant. **Error! Reference source not found.** illustrates with an example this issue from the first life of the product and the instances after refurbishment in the subsequent lives of the product, when the product has been placed in the European and American market in the first place.

Figure 12 – RoHS and the CE mark representation of the issue with “placing in the market”



Siemens Healthcare GmbH, 2016

Additionally, there are problems with the use of spare parts in new products if they are not RoHS-compliant. Only spare parts from medical equipment sold in the EU before July 2014 can currently be used in new products, but this might not be possible in the future as Exemption 31 of Annex IV, that allows the reuse of parts in new products in certain cases, is currently revised. The new exemption as it is expected will not allow the use of non-RoHS components in new products.

Both of these aspects limit the access to used but functional products or parts and make refurbishment difficult. Eventually this leads to less refurbished products on the market and the demand cannot be met. The hospitals have to purchase more expensive new products. It has to be noted that the hospital interviewed has not seen any unusual price increases for medical equipment in general in recent years.

There are exemptions for certain substances and products and for refurbishment. However, exemptions are only temporary, have to be adapted and renewed which takes a lot of time and resources.

Another aspect is the uncertainty about future developments in RoHS. If future market access cannot be guaranteed, there are no incentives to invest in innovation. This applies to new products as well.

Solutions proposed

Acknowledge the need for certain substances for medical imaging devices in the legal text of RoHS, because although exemptions exist, those exemptions are only temporary and have to be renewed. For example, Exemption 31 of Annex IV should be in the legal text, for example as a new article 4.7. Exclude refurbished imaging devices from RoHS because this is not the right framework. Extend article 4.5 such, that recovered parts can be used in new products. Review article 2.2 and the phrasing "[...] products newly into scope and in category 11 cannot be made available after July 2019". This could be reformulated into "[...] cannot be placed on the market after July 2019". All these aspects apply given that safety and proper handling of the hazardous substances at the product's very last end of life is guaranteed.

Additionally, to avoid issues with the term "placing on the market", this term could be linked to the CE-mark, regardless of where the product is produced and used.

Article 2.4e of RoHS says that the regulation does not apply to "large-scale fixed installations". The main imaging devices can be considered large-scale but still fall under RoHS. A better definition could help to consider the large imaging devices as large scale. This does not apply to small medical products, for example monitors.

Eventually, this would lead to more access to used equipment in the EU and make healthcare cheaper. Valuable parts that can still function do not have to be scrapped. When the EU is hindering circular economy for medical devices, other countries like China and India are not inclined to lower their restrictions on refurbished medical devices. Therefore, the global potential of the market is not used.

Additional barrier 1

Other substance regulations (e.g. REACH)

Currently, RoHS is the main substance regulation that hinders circular economy. However, if substances used in medical devices are added to other regulations like REACH, the same problems would occur.

Solutions proposed

In general, it should be thoroughly considered which substance regulations are applicable to medical devices and the benefits and risks should be balanced. The repair-as-produced-principle under RoHS (Article 4.4b) should also be mentioned in the other regulations such as REACH.

Additional barrier 2

Medical Device Directive (MDD)

The MDD also limits access to used equipment and parts sourced outside of the EU as it considers imported medical devices as new products, even if they were initially manufactured in Europe. This makes refurbishment more difficult and healthcare more expensive.

Solutions proposed

Linking the term "placing on the market" with the CE-mark as mentioned above could be a solution, as imported products would then not necessarily be considered as new products. Generally, all legislation should be consistent and aligned with the circular economy principle.

Additional barrier 3

Interpretation of the Blue Guide

The interpretation of the term "placing on the market" according to the Blue Guide causes the issues mentioned above related to RoHS and MDD with the sourcing of products from outside the EU.

Solutions proposed

Link the term placing on the market to the CE-mark.

Additional barrier 4

Trade agreements/barriers

Circular economy should be included in the Free Trade Agreement to make the sourcing from other countries easier. Some countries have restrictions or prohibit the import and use of refurbished systems. European medical imaging companies can therefore not sell refurbished systems in those countries.

Solutions proposed

Include circular economy in the Free Trade Agreement. How the EU can approach this and how individual nation legislations in other countries can be changed has not been discussed.

Additional barrier 5

Definitions throughout all legislations

The definitions in the different legislations are not coherent, e.g. the meaning of refurbishment, remanufacturing etc. in different countries. Defining used medical equipment as waste is also misleading. This causes a lack of common understanding.

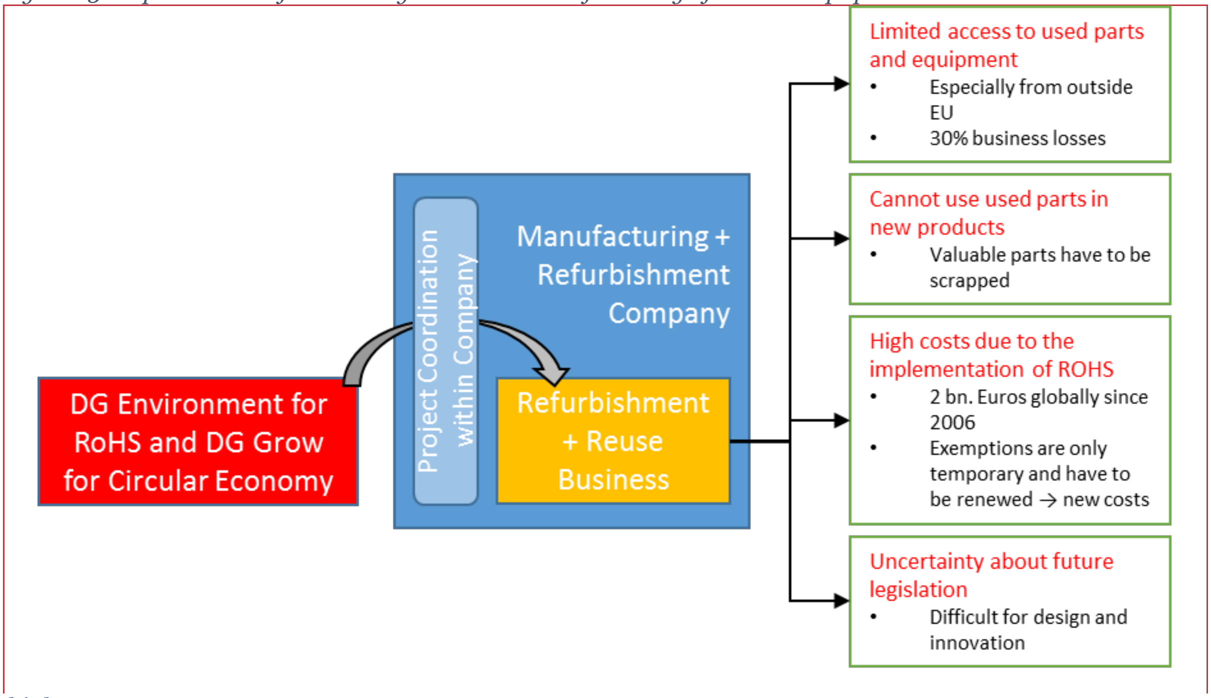
Solutions proposed

A Good Refurbishment Practice is currently developed by National Electrical Manufacturers Association (NEMA). This standard should be made applicable in the EU. A new product class for high quality pre-owned systems could help to distinguish those systems from waste.

B.5.3 Impact scheme for the actor

Figure 13 below illustrates the main impacts from the regulatory barrier for circular economy identified in this case.

Figure 13 Impact scheme for industry actor – remanufacturing of medical equipment



thinkstep

In summary, the companies interviewed - two of the European industry leaders of the manufacturing, refurbishment, and reuse of medical equipment, together with their industry association identified the following specific impacts:

- Refurbishment case: limited access to used parts and equipment
- Reuse case: inability to use used parts in new products (usable parts become obsolete)
- Cost: high costs due to the implementation of RoHS
- Risk: uncertainty about future legislation – difficulty for design and innovation
- Society: less access to used equipment in the EU and potential of higher healthcare cost
- Global: hindering the global potential of the market - other countries like China and India are not inclined to lower their restrictions on refurbished medical devices.

From the customer perspective, no significant impacts were identified and conclusions from this actor are as follows:

- Cost: Not significant perception on cost savings from refurbished equipment. In addition, no unusual price increases observed in general for medical equipment in recent years
- Environment: Environmental aspects don't seem to play a role in the procurement decision process - it depends more on the application, strategic and economic aspects

Analysis and interpretation

From a circular economy perspective for reuse and remanufacturing, the RoHS regulation in the aspects identified in this case does hinder a circular economy in this industry. Functioning usable parts (with validated extended product life) from used equipment would become obsolete. From an environmental and resource efficiency perspective, reuse and remanufacturing (if efficiency of the product is not compromised) are preferred over any other end of life option of a product (e.g., recycling, landfill).

Legislative solutions identified in the case should be taken into account to promote a circular economy in this case. However, there are some points in which more evidence should be gathered:

- Even though the companies and the industry associations interviewed claim a loss of 30% of revenue cuts or potential business losses caused by the existing legislative barriers, more arguments should be made for this claim;
- Reduce of employment in the EU for the industry was also not identified by the companies;
- It is unclear how much refurbished equipment is making or would make healthcare cheaper in the EU given that a refurbished product can be only up to 20% cheaper than a new product according to the manufacturer.

Companies interviewed have been slowly introducing alternative business models such as the medical equipment leasing (i.e., selling the service of medical imaging vs. the equipment). More efforts in developing this market will assure more control over the hazardous substances at stake in such equipment. On the other hand, a desire from the companies is to link the term “placing on the market” with the CE-marking. This would reflect the relevance of the CE-mark as the “passport for the product”, guaranteeing free circulation for the entire lifetime. A way to control such circulation to ensure proper end of life treatment of the hazardous substances is through the enforcement of inclusion of information tracking technology in the CE-mark. Enforcing the mark to have tracking technology that electronically retrieve the relevant information of the product (e.g., RFID). This way, the end of life of the product is under control even if it happens decades after its manufacturing. The same applies to further end of lives (second or third is the product is reused or remanufactured more than once in its lifetime).

B.5.4 Description of the companies interviewed in WP3

Table 41 Overview of interviewed companies

Aspect	Company 1	Company 2	Company 3
Name of the company	Siemens Healthcare	Philips Healthcare	Charité Berlin
Industry sector	Medical Equipment	Medical Equipment	Hospital
Summary of the role of the company in industry (general)	Manufacturing and refurbishment	Manufacturing and refurbishment	University Hospital
Location	Germany	Netherlands	Germany

B.5.5 Bibliography

(DITTA, 2013)

(COCIR, 2015)

(COCIR, 2016)

(Siemens, 2016)

(Siemens, 2016)

(COCIR, Freimut Schröder)

(Siemens Healthcare, Freimut Schröder., 2014)

(Siemens Healthcare, Plumayer, Martin, 2015)

B.6 Recovery of nutrients from manure

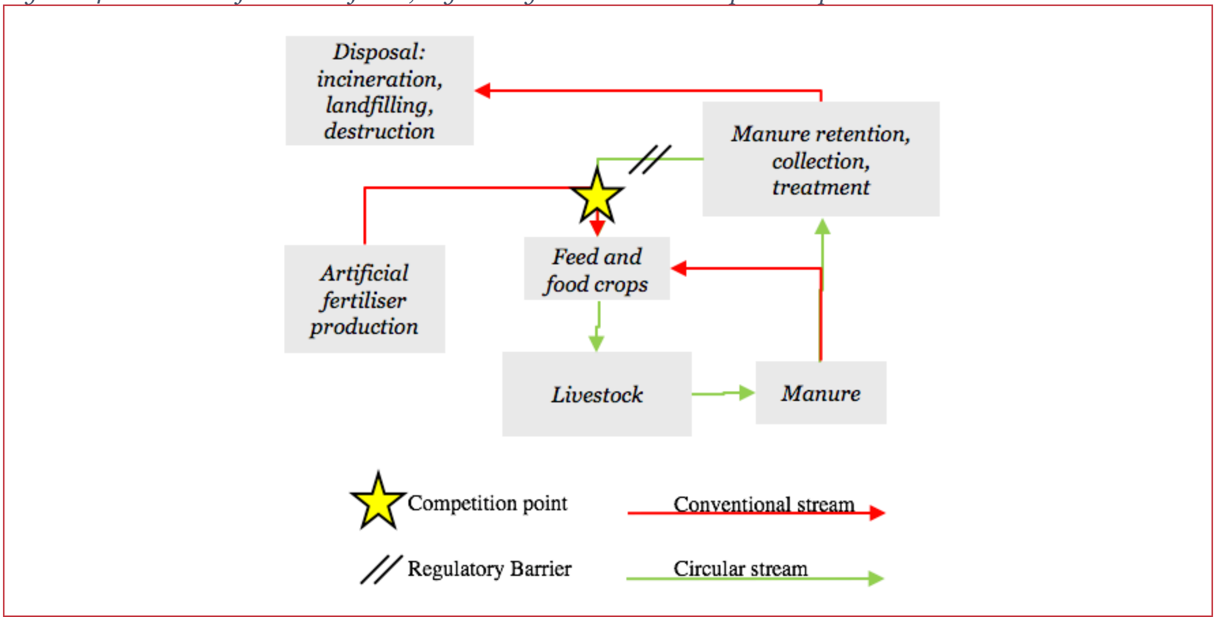
B.6.1 Summary

This case study reports on the circular options for manure disposal and nutrient recovery. Manure is a by-product of animal husbandry that arises in large volumes and thus needs effective disposal. The common practice of spreading manure on land or disposing of it is incineration, supplementing eventual nutrient deficiencies with inorganic fertilisers, comes at the price of nutrient destruction or nitrification, greenhouse gas emissions and import dependency. Options exist to separate the nutrients contained in manure and use them more efficiently. From manure and other bio wastes, energy and nutrients can be recovered to reduce greenhouse gas emissions and reduce import dependency on most notably phosphate rock. However, processing manure is a waste management activity to which a cascade of European legislations apply. These legislations do not always reflect the actual issues and qualities of especially recovered materials from manure; they can therefore be excessively prohibitive. This hampers the development of a circular mechanism and internal market for materials recovered from manure. The economic loss incurred by these issues is difficult to assess. Many figures on manure, its contents, value and processing methods are derived from surveys and estimates. It is safe to say that manure processing and nutrient extraction are costlier to farmers than direct spreading on land because of the additional labour and processing equipment involved. The Commission is aware of most issues surrounding manure and fertilisers. Currently, a revision of the Fertilisers Regulation is under way. The Commission is advised to continue these efforts and to make a more frequent inventory of the technical and environmental issues surrounding nutrients and fertilisers. This can increase employment and alleviate the import dependency for nutrients.

B.6.2 Manure as a fertiliser and inorganic fertilisers

The figure below shows a simplified material stream. Livestock (kept in stables) generates manure that is either directly spread on lead or treated first. Many technological options exist for treating manure, usually the derived products are spread on the land or incinerated, in some cases landfilled. Manure functions as a fertiliser for food and feed crops, but competes with inorganic fertiliser for this function. The crops produced serve as feed for livestock and the cycle starts again. The challenges in this cycle are in manure-derived product quality, legal classification as waste or animal by-product, and treatment costs. In this chapter an overview of manure contents, processing methods and inorganic fertilisers will be given to set the scene for understanding the regulatory barriers.

Figure 14 Overview of material flows, regulatory barriers and competition points



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Manure is an effective and cheap fertiliser

Manure plays a significant role in food production in Europe. It arises as excrement from livestock (most notably cattle, pigs and poultry) for the production of meat, dairy, eggs and other animal products. The total volume of manure produced in Europe is estimated at 1.38 billion ton per year (Foged H. L., 2011). Since the beginning of farming, manure has served as an effective fertiliser material, that can be defined as follows (Wijnands & Linders, 2013):

> *"Fertilising materials include fertilisers providing the major and secondary nutrients, as well as micronutrients, soil improvers, and more generally any product that has one or more of the following characteristics:*
>
> - *Provides plant nutrition, affects growth, reproduction, strength, performance and prevents nutritional deficiencies in plants;*
> - *Improves plant nutrition by facilitating absorption and regulates vegetative functions;*
> - *Improves the physiology of plant by enhancing nonspecific structural plant defences and the plant's resistance to stress;*
> - *Improves the technological quality and the conservation of crop production and the nutritional profile; and*
> - *Improves and maintains the soil's physical, chemical, and biological properties."*

Manure contains most notably the primary plant nutrients Nitrogen (N), Phosphorus (P) and Potassium (K) (the mixture of these often denoted as NPK) and organic solids that consist of carbon compounds. The composition of manure and subsequently the NPK and organic content balance varies with the kind of livestock, feed, season and many other variables. This governs the supply side of nutrients from manure. The demand for nutrients on the field depends among others on the crop grown on the field, the crop rotation, and the field condition and geology.

Manure is a by-product with environmental impacts

Besides manure's qualities as a fertiliser mix, it is also a by-product that arises in large volumes and thus needs effective disposal. This drives the application of manure on land, be it not as a fertiliser, then as the most (cost)-effective means of disposal (Foged H. L., 2011).

Studies and interviewees report that manure from livestock is disposed of in cascade of lowest-cost options. Current practice for cattle farmers is to apply as much manure on the field as the legal framework allows (Wijnands & Linders, 2013). Excesses are placed on the market at the inorganic fertiliser replacement value (Wijnands & Linders, 2013). In regions with manure excesses, this is a buyer's market, which means that the the buyer determines the price. Sometimes, buyers adhere a negative value to the product which means that they get compensated for taking the manure. This seems reasonable since the transfer of ownership also implies the transfer of manure management obligations (Foged H. L., 2011).

Europe exhibits strong regional differences in manure production and nutrient demand. For example, some regions show strong specialisation in animal husbandry while others are specialised in crop production. The location of supply and demand do not overlap. This means that excess manure must be transported to other regions or even member states, or stored locally until demand for nutrients rises again or when legislation permits application of manure[18]. This permission may depend for example on seasonal crop growth patterns and the related optimal uptake of nutrients by plants to reduce leaching[19].

Both storage and spreading on land of manure introduce problems because of emissions caused by evaporation of volatile compounds, leaching, and because of natural decay. These can be summarised as follows:

1. Emissions of nutrients to soil and water.
   i) Nutrients from manure applied to land are released from the organic matter in manure and slowly leach into the soil and water. This can cause an excessive supply of most notably phosphorous and nitrogen based compounds. In addition there is the toxicity and acidifying effect of ammonia (NH_3) in aquatic environments
2. Exposure of manure to the open air causes emissions of gases that degrade the environment.
   i) Decomposing manure generates the greenhouse gas CO2 and more potent greenhouse gases such as CH4 (methane) and N20 (nitrous oxide or laughing gas)
   ii) Volatile compounds in manure such as ammonia evaporate into the atmosphere and have negative environemntal effects

Some of the problems, most notably emissions to the atmosphere, can be mitigated by effective storage (sealed from the atmosphere) and application (injection into the field). Emissions to soil and water still remain. To summarise, manure introduces the following problems:

- Its production is hard to manage because it is a by-product of animal husbandry
- Application of manure on land, either as a means of disposal or as a means of fertilisation, causes environmental problems
- The nutrient composition is not tuneable or predictable

Inorganic fertilisers introduce environmental and economic issues

To mitigate the latter challenge and to allow for effective crop farming, the use of manure as a fertiliser is often supplemented by chemical or mineral fertilisers, referred to as inorganic fertilisers. These are defined as follows (Wijnands & Linders, 2013):

> *Inorganic fertiliser means a fertiliser without organic material. Calcium Cyanamid, urea and its condensation and association products are recognised as inorganic fertiliser.*

Inorganic fertilisers can be preferred over organic fertilisers among which manure, because

- The nutrient content is more concentrated than manure
- The material is easier to apply, store, produce and trade
- Inorganic fertilisers have a more predictable, consistent and adjustable nutrient content than manure
- The release of nutrients from inorganic fertilisers to the field is more predictable and tunable

The competition between and combined use of manure and inorganic fertilisers can lead to an excess accumulation of nutrients: livestock continues to generate manure while nutrients are also imported in mineral form.

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[18] In the main part of northern Europe, the animal farms must store the produced slurry specially designed storage tanks, with a total capacity corresponding to 6–9 months of slurry production (J.B. Holm-Nielsen, 2009)

[19] Leaching is the term for slow release of nutrients from fertilisers into the soil or water due to inability of plants to absorb nutrients

There is a circular mechanism in the fact that livestock consumes feed that comes from European acres fertilised with both manure and mineral fertilisers. However, a significant fraction of livestock feed is also imported from outside the EU (European Commission, 1999), adding nutrients to the balance.

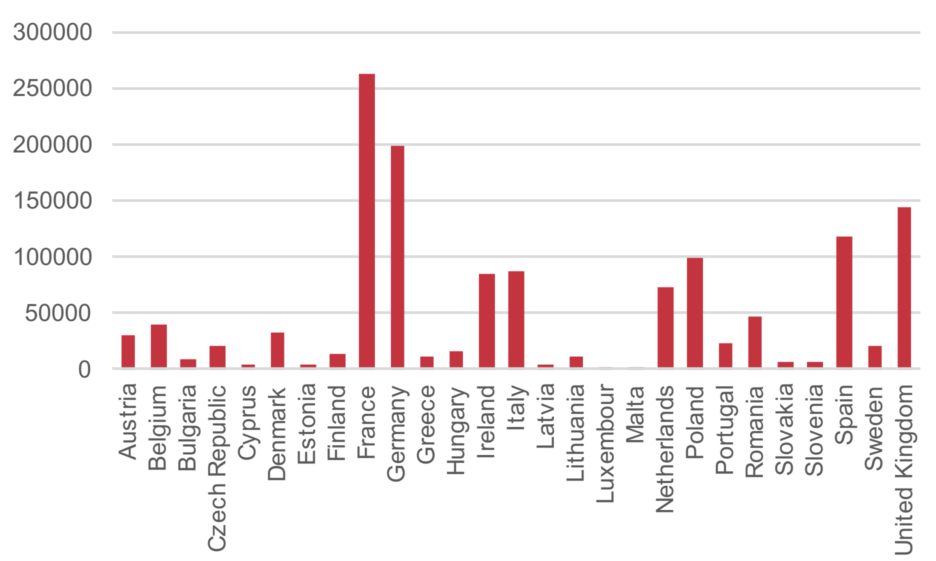
Artificial fertilisers introduce their own problems. Most notably, the supply of phosphate rock used for the production of phosphate based fertilisers is finite and is expected to last for 50-100 years, with peak production occurring in 2030 (Dana Cordella, 2009). In addition, phosphate rock is sourced from a restricted set of exporters/producers (most notably China, Morocco and Western Sahara, United States and Jordan) (Rosemarin, 2010) who therefore have very significant market power and a strategic position in the global food supply chain.

Nitrogen based fertilisers are usually made from ammonia based compounds, while the synthesis of ammonia is in general based on methane as a feedstock. This implies that the price of nitrogen-based fertilisers varies proportional to natural gas prices. Related to this is the fact that synthesis of ammonia is a very energy intensive process with an accompanying high CO2 intensity, while Europe is increasingly dependent on imports for the supply of natural gas.

Currently, most manure that is generated is spread again on the field, first on the farm of origin, then on farms nearby that require manure or the income generated by taking over the responsibilities of processing manure. Although this is an effective method of manure disposal, it is not the most efficient pathway for nutrient recycling because manure is applied to the legally maximum allowed value, instead of what crops actually need.

Figure 15 shows the manure production of 28 EU member states from pigs, cattle and poultry. These figures are based on livestock inventories, assumptions on population composition and manure output per livestock item. These assumptions indicate that it is hard to come to precise figures on manure production and, subsequently, manure composition as this depends on the kind of livestock and within that the purpose of the animal; breeding, dairy production, meat production etc.

Figure 15 Manure production from pigs, cattle and poultry, figures in ktons



Data from (Foged H. L., 2011)

Some common manure processing methods

Processing methods in use in Europe

The inventory by (Foged H. L., 2011) concludes, based on surveys and estimates, that some 8% (108Mton) of all European manure is processed in some way. The most used methods vary per member state, but the most prominent technologies are anaerobic digestion (AD, 6.4%[20]), and separation (3.1%). Note that AD can be preceded by separation, so the percentages cannot be added to yield a total figure. The total amount of nutrients contained in animal manure is estimated at 556.000 ton nitrogen and 139.000 ton Phosphorus. Since manure processing methods often also accept other biowastes, the category “livestock manure and other” is mentioned at a volume of 168 million ton. Subtracting the 108Mton yields “other” ingredients at some 60Mton, which is a very significant fraction. Many manure treatment operations take place on farms, and only in some cases in larger industrial sized installations. The inventory mentioned above counts almost 18.000 farm size installations versus 1300 medium and large size installations.

Manure consists of a wet and a dry fraction. The wet fraction consists of water, urine and liquid pats of faeces, while the dry fraction consists of organic (structural) matter largely made up of hydrocarbons and attached minerals. The composition of manure with respect to solids and liquids is expressed as dry matter (DM) content. The DM content is measured in percentage of weight and varies between an average of 6-9% for slurries from pigs, cattle and chicken, to some 25% for various kinds of (stable) litter (Agropark).

The wet and dry fractions can be separated through various methods, such as sieves, presses, flotation, coagulation and many other methods (Foged H. L., 2011). Separation has multiple benefits. Firstly, the wet part contains some 80% of the nitrogen part, whereas the solid part contains 80% of the phosphorus content. Wet-dry separation is a thus a crude first step of nutrient separation.

Liquid fraction processing

The liquid part contains many volatile compounds such as ammonia. Ammonia can be stabilised through acidification and gas scrubbing techniques. Subsequently the nitrogen content can be converted to the inert gas molecular nitrogen which is safely discarded into the atmosphere – 80% of atmospheric air consists of molecular nitrogen. This method destroys the nitrogen content of the liquid part. Since nitrogen fertiliser production is very energy intensive – each kg of nitrogen excess is associated with 30 – 70kg of CO_2 equivalent greenhouse gas (GHG emissions) (J.B. Holm-Nielsen, 2009)– this is a very wasteful method.

A better option is to concentrate the liquid fraction using, for example, reverse osmosis techniques (P. Hoeksma, 2012). The liquid fraction then becomes a product with nutrient contents in the range of 7-8 g/kg for both N and K. The material can function as a liquid fertiliser, although the low concentration prohibits the official classification as such in European regulations (P.A.I. Ehlert, 2011). After the stabilisation and/or removal of volatile contents, the liquid fraction can be processed with conventional wastewater treatment techniques and subsequently discharged in either the sewage system or surface waters.

Solid fraction processing

The solid fraction typically consists of 26% dry matter (Foged H. L., 2011). A very effective option to reduce greenhouse gas emissions from the solid fraction due to aerobe decomposition, is to process the matter using anaerobe digestion (AD) techniques. This process retains the material in an oxygen-depleted regime that is suitable for micro-organisms to decompose the material into biogas and digestate. This has several benefits:

Instead of CO_2 production through aerobic decomposition, biogas is generated that can serve as a fuel for vehicles or the generation of electricity or heat.

[20] Note that the percentages mentioned don’t add up to 8%. This is because AD is often used as a combined streams process. As such, AD processes more weight that adds to the fraction, but not all weight is manure so not the total fraction of 6.4% adds up to the 8%.

AD limits the emission of other greenhouse gases such as CH4 and N20

By converting up to between 20-95% of the carbon content present (UNITO, 2014), the minerals present in the dry fraction (mostly phosphorus) are concentrated into the remaining organic content. This increases the fertiliser concentration of the end product, which is called digestate. Anaerobic digestion often requires more energetic materials to be present in the input stream besides manure dry-fraction, such as crop residues, horticulture residues, energy crops, food waste or slaughter house waste. Today, still more than 95% of the produced digestate in Europe is used directly in the agricultural sector as a liquid fertilizer (Saveyn & Eder, 2014).

Phosphorus recovery through struvite precipitation

A technology that can be very well combined with AD is struvite precipitation[21]. Through the addition of certain reaction chemicals, the struvite is generated in a reactor coupled to the AD installation. This enables recovery of some 90% of the P content and 30-60% of the N content of the input to the AD (Md. Mukhlesur Rahman, 2013). The crystalline struvite gained through this reaction is chemically very pure such that is allows processing in inorganic fertiliser production (Langeveld, 2015) while direct application as a slow release fertiliser is also possible (Foged H. L., 2011).

Another option to process the dry matter is incineration. This destroys most nutrient content and is not very energy efficient considering the 70% water content of the material. Incineration is also an option for the digestate that remains after anaerobic digestion.

Actors and their relations

As Figure 14 shows, manure is generated on a farm and in the simplest case spread directly on the land of the farmer. In case of an excess, the manure is sent to another farmer's land and spread on that land accordingly. A distinction has to be made between farmers that own livestock *and* land, and those who own either. Crop producers that require manure pay the inorganic fertiliser replacement value, between €7.5 and €14,- per ton (Wijnands & Linders, 2013). Farmers with only livestock are forced to sell their manure on the market. These operations involve manure producers, manure accepting farmers, and manure transporters.

When legislations, meant to prevent over fertilisation and other environmental stress, temporarily prohibit manure application on land, the manure needs to be stored. Actors make efforts to minimise the volume of material to be stored. This drives the demand for manure treatment that separates solid and liquid fractions; the liquid fractions can be treated with denitrification and subsequently more conventional wastewater processing technology, after which the effluent is discarded to (surface) waters. These operations described above involve manure transporters and off-farm manure processors, and more distantly water authorities and possibly (public) wastewater treatment services.

Products from manure processors can be sold to individuals, farmers and (inorganic) fertiliser producers. In this way, fertiliser producers are at the accepting end of the chain. More often, inorganic fertiliser producers compete with manure as a fertilising material.

Finally, landfilling and incineration also takes place in unknown volumes. Operators of such processes are thus also stakeholders.

B.6.3 Regulatory barriers

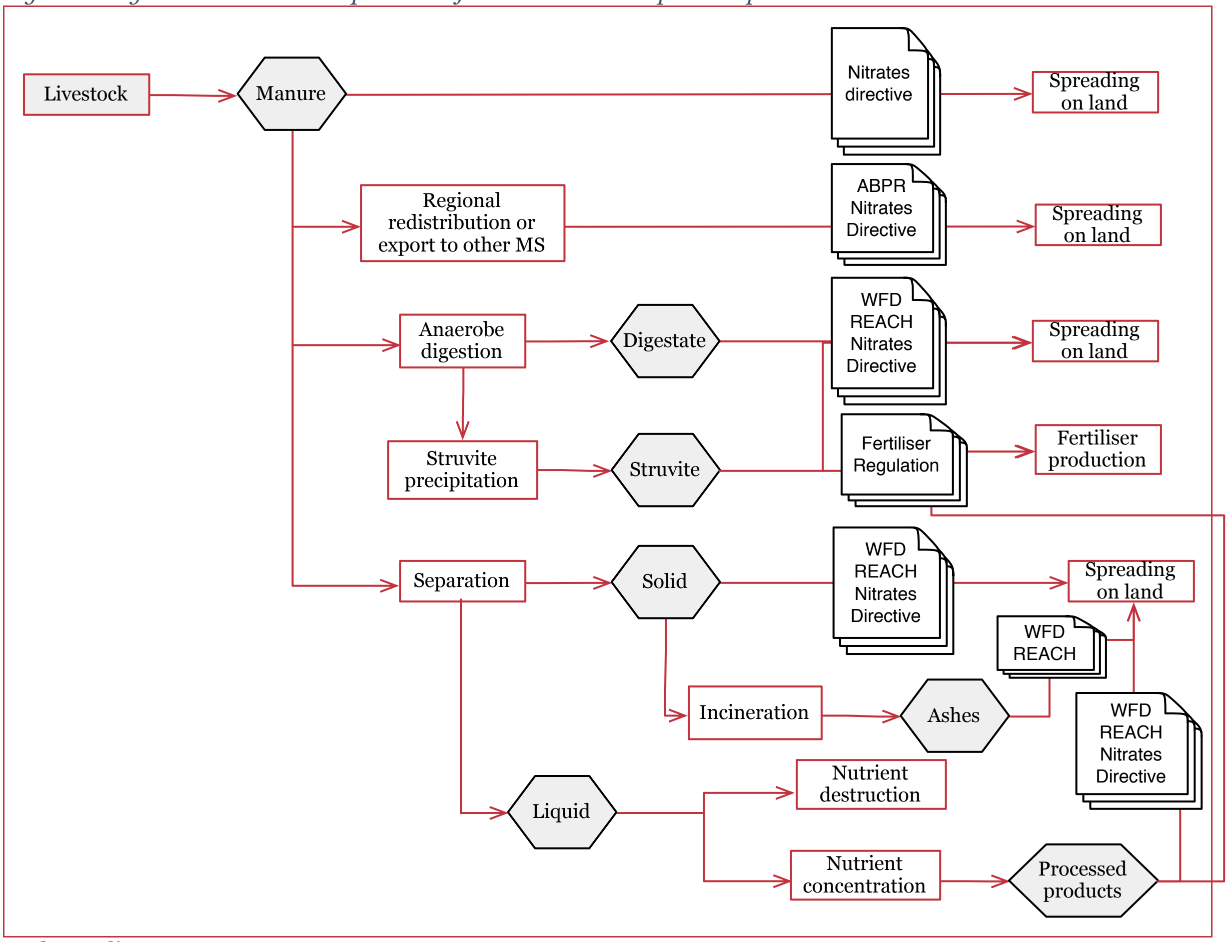
The regulatory issues governing the case of manure are many fold and depend on the place in the value chain. In principle, manure is an animal by-product that falls under the animal by-product regulation

[21] Struvite is a mineral that can be extracted from phosphate rich aqueous solutions through the addition of reaction salts. The mineral can function as a fertiliser in itself or be mixed with other fertilisers.

(ABPR). When applied to land, the nitrates directive applies with mandatory measures only if waters are polluted, and when processed in some way, the waste-framework directive applies. Manure itself is not recognised as a fertiliser in the fertiliser directive, such that a European wide market for manure and manure derived products has not developed.

The diagram below describes the nutrient processing options and the legislations encountered.

Figure 16 System overview and position of barriers and competition points



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The barriers encountered, their effects and possible solutions are described below.

Table 42 Overview of regulatory barriers

Main Barrier	Effect	Possible (legal) solution
The fertiliser regulation does not cover organic fertilisers	There is no European market for manure-derived fertilisers, while diverging national interpretations emerge.	Extend the fertiliser regulation to organic fertiliser so a European market develops for manure derived products
The Animal By-Product regulation does not take into account sanitising effects of various manure processing methods	The derived products remain labelled as C2 material for which stringent labelling and sanitation regulations apply	Research sanitation effects of various manure processing activities and certify them accordingly
The Waste Framework Directive labels AD as a recovery operation instead of recycling operation	Incineration stands on equal footing with AD.	Define AD as a recycling operation
There are no End-of-Waste criteria for manure derived products	Manure and derived products retain waste classification and face subsequent barriers in material acceptance.	Develop EoW criteria for manure derived products
REACH applies for manure derivates but not for manure, because manure processing is a waste processing activity.	Increased costs for manure derived products compared to raw manure	Assess suitability of REACH framework for manure derived products

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The Fertiliser Regulation covers only organic fertilisers

The fertiliser regulation (European Commission, 2003) was intended to harmonise the market for European Fertilisers. Although this has been successful, the narrow definitions of fertilisers in this directive combined with the variable content of organic fertilisers act to hamper the development of an internal market for organic fertilisers or fertiliser compounds with an organic origin, or organic traces. Some organic compounds are allowed listed in annex E.3.1, but this does not recognise the complexity and diversity of the constituents of fertilisers from manure origin. There is no place for soil improvers, bio-stimulants and other products of organic or livestock origin. (Dutch National Government, 2015). The Commission is aware of this issue as displayed by their roadmap to revise the fertiliser regulation (European Commission, 2015), that aims to support the improvement of an internal market to facilitate the free movement of innovative fertilisers.

Because there is no community-wide definition or acknowledgement of organic fertilisers, a cascade of other legislation comes into play.

Animal By-products regulation hinders distribution of manure and manure derivatives

As discussed above, regional differences in fertiliser excess and demand necessitate redistribution of manure. Manure is a C2 material as classified in the animal by-product regulation (European Commission, 2009). Redistribution of manure requires preceding sanitation such as pressure sterilisation. In addition, to ensure traceability of animal by-products, the Traces system should be used (European Commission, 2004) to provide information on the dispatch of C2 materials.

Since manure derivates are classified as manure, these regulations also hold for manure derivates. This regulation is reasonable to prevent spreading of animal diseases, but some manure derivates have a considerably lower pathogen spreading risk, such has digestate that has been processed at high temperatures and long retention time, mineral concentrates, or struvite.

The ABPR is especially challenging when manure is co-processed with ingredients from plant origins. All the outputs bear the C2 status, which increases the volume of C2 material. Basically, all output from processes in which manure is involved are classified as manure.

Waste framework directive hinders recovery of nutrients from manure

The WFD (European Commission, 2008) impacts the manure stream in two different pathways:

Firstly, there are no end of waste criteria for manure. As soon as manure is treated in some process to modify or enhance its properties, explicitly biogas generation, composting, landfilling, incineration or anaerobe digestion, the material classifies as waste through article 2.b. The Commission's JRC has researched possible pathways to establish end-of-waste criteria (Saveyn & Eder, 2014). These criteria lay requirements on:

- Product quality
- Input materials
- Treatment processes and techniques
- The provision of information
- Quality assurance procedures

Their work contains detailed elaborations on each of these requirements. The current status of the implementation of these recommendations is as of now unclear, although the recently release revised Circular Economy Package (European Commission, 2015) mentions the need for action on the WFD and other legislations influencing nutrient recovery and recycling.

Secondly, the WFD does not recognise AD as recycling activity but as a recovery activity through article 4. This causes a lower preference equal to that of incineration, though incineration is clearly less efficient for what concerns material recovery. Member states have the freedom to prefer certain operations that are more environmentally friendly through article 4.2 incentivises AD possible, but since incineration is cheaper than AD this freedom is not often exercised.

REACH imposes costs for products recovered from manure

Digestate is not exempt in REACH whereas compost and biogas are. (European Commission, 2006). In addition, recovered materials such as struvite need to registered under REACH, which incurs additional costs on manure processors.

Possible solutions

The barriers posed by the different legislations discussed above are not easy to solve. Each of the legislations has a clear right of existence, either to protect the environment, human or animal health, or both. The solution lies in balanced considerations of the nature of each of the possible manure derived substances. Such considerations should take into account the actual environmental and human and health risks of the manure derived products instead of their classification as waste, an animal by-product, etc. This requires detailed knowledge of the properties and behaviour of the material.

European legislation that finds this balance is difficult to realise, as per member state the products, processing technologies and market situation varies. The Commissions acknowledges these problems in various communications and research efforts (European Commission, 2015) (Saveyn & Eder, 2014) (European Commission, 2015).

Estimation of value lost

Attribution of damages incurred due to specific regulatory barriers is not possible. However, the barriers do incentivise inefficient application of manure as fertiliser. Using calculations on the value contained in manure and estimates of value lost due to inefficient manure application can be made. The values below are based on (Foged H. L., 2011) and sources referred to in the footnotes.

	Nitrogen	*Phosphorus*	*Total*
Fertiliser value	€543/ton[22]	€333/ton[23][24][25]	-
Nutrient content in manure[26]	7.5 Mton	4.7 Mton	12.2 Mton
Total value in manure	€4.1 billion Nitrogen	€1.6 billion Phosphorus	€5.7 billion Total

Assuming that 20% of fertiliser value is lost by disposing of manure as waste instead of extracting nutrients for targeted fertilisation, the damage would amount to €1.14 billion euros or €57 m per percent annually.

B.6.4 Technological, economical, financial and value chain barriers

The most prominent barriers for manure processing and nutrient recovery are listed below. Organic fertilisers or nutrients extracted from manure have a higher price than inorganic fertilisers. This high price is not regarded as justified by all crop farmers because the may not be aware of additional benefits from organic fertilisers. Also, some risks are perceived in the material: because of its natural origin, a flawless consistency cannot be guaranteed. This relates also to the technology that is still in development. This technical and legal uncertainty around manure derived products in turn scares off investors.

Table 43 Overview of technological, economical and value barriers

Barrier	**Nature of the barrier**	**Effect**	**Possible (legal) solution**
Additional beneficial effects of organic fertiliser not acknowledged or known	awareness	Higher price of manure derived products is not seen as justified	Research and communicate effects of manure derived products
Quality inconsistencies and impurities of manure derived products through immature technology and the nature of the product	Technological	No market or reduced price for manure derived products	Improve technology, review appropriateness of quality and purity demands for organic fertilisers
Manure processing towards higher quality fertilising materials is more expensive than manure spreading or inorganic fertiliser production	Economical	There is a limited demand for manure derived products	Increase cost efficiency by technological learning
Legal uncertainty around manure derived products scares off investors	financial	Reduced investments in manure treatment technology development and operations	Create rigid regulatory framework for the European market

[22] http://www.indexmundi.com/commodities/?commodity=urea&months=60&currency=eur, price point taken at €250.ton, nitrogen content based on urea fertiliser (46%N content)

[23] http://www.infomine.com/investment/metal-prices/phosphate-rock/all/

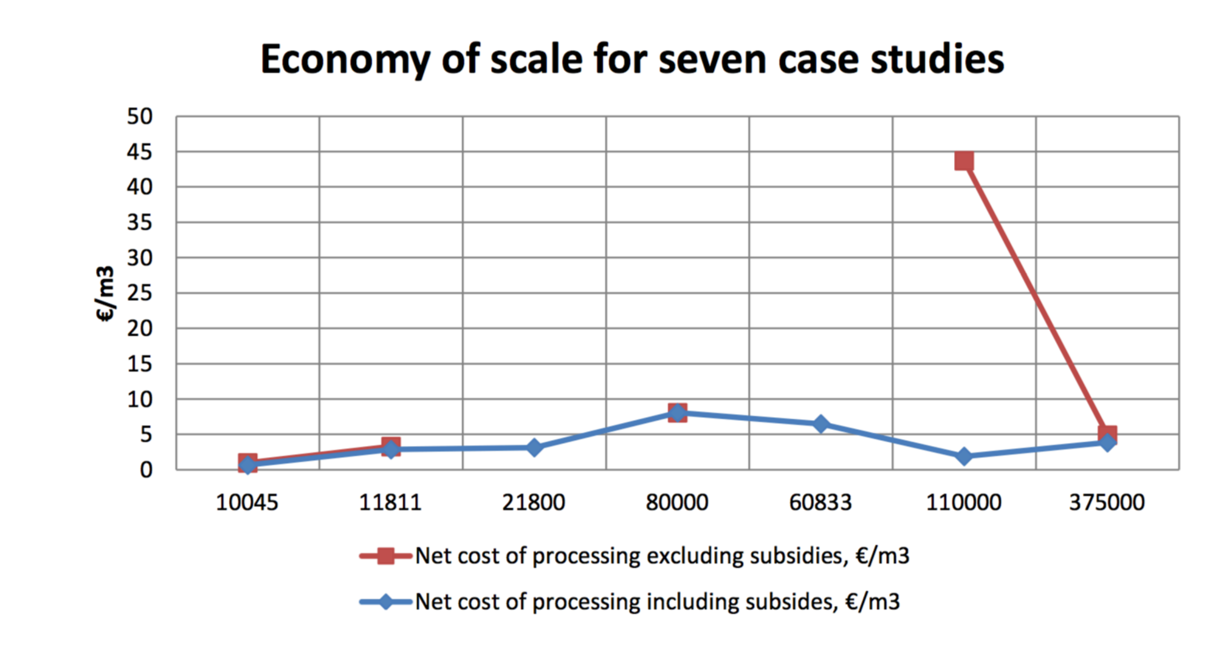
[24] http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/phospmyb04.pdf

[25] http://www.indexmundi.com/commodities/?commodity=rock-phosphate

[26] (Pleso, 2002)

Economic barriers exist in the fact that spreading manure on (own) land is cheapest, and that all additional steps in the processing chain add costs. Cost for various processing methods in Europe vary greatly. Investment costs can range from 6.6 tot 163.6 €/m3, depending on the methods used and the location of the installation (Foged H. L., 2011). Processing costs and associated economies of scale are given below:

Figure 17 Processing costs per m3



(Foged H. L., 2011)

These data show that there is no developed market with a preferred or standard technology yet. There is no economy of scale to be seen in this graph; although it does not depict a single technology that is scaled while other options are kept constant. A single, one-size fits all method has not been developed yet and may not even arise because of regional differences in material streams and fertiliser demand. Another reason for a lacking large infrastructure may be due to the (regulatory) uncertainty around manure derived products and the absence of a functioning European market. This in turn reduces investment preparedness which hampers technology development as well as capacity development.

Employment

Nutrient recovery and manure processing are labour intensive. Interviews report that 70,000 people are employed at 17,000 bio-gas installations, amounting to some 4 people per installation on average. A similar number has been found in a technology and economics survey on manure treatment options. The interviewee mentioned above said that employment in the sector could triple in the next decade to 210,000 people employed, although not has to be taken that the biogas installations process more than manure alone.

The survey mentioned above reports that some 19,000 installations treat 8% of manure. To treat 100%, some 240,000 installations would be needed. A lower limit of 1 FTE per installation may be feasible if construction and maintenance is included. **This means that a figure of some 200,000 people employed is not unreasonable**. Considering the desire and potential for mixed approach for manure and other bio-wastes, the figure cannot be solely attributed to manure treatment alone.

Since manure is a voluminous product, local (possibly clustered) treatment is preferred to reduce transport movements. This increases the chances for SMEs to be involved.

Innovation

Room for innovation lies in:

Increasing energy yield of the process by combining more waste streams while safeguarding output consistency, managing contaminants. This improves the business case by generating more income from energy generation

Configuring a treatment installation that includes the right mix of technologies. Currently, many different installations exist each with their own process steps and product outputs. This spread in approaches shows that the technology is not yet mature.

Business case innovation: organic fertilisers and soil improvers are in demand by some farmers (grapes, bio-farmers) who recognise the additional qualities such as organic carbon content, reduced leaching, improved soil biology. These benefits can be marketed better if value chain organisation is done right. Farmers demand traceability of constituents, guarantees of performance or at least nutrient mix, stability of supply, effective storage, etc.

Winners/Losers

Considering the net costs of treating manure vs. spreading it on land, livestock farmers would pay a higher price for manure treatment. Recovered nutrients are more expensive than inorganic fertilisers; crop farmers that use the products will also pay a higher price.

Fertiliser producers can use the recovered nutrients as ingredients provided they are clear of contaminants. The input materials would be more expensive for them, too. An exception may exist for nitrogen fertilisers since the production process is very energy intensive, and nitrogen can be recovered from manure somewhat easier than phosphates.

Winners will be in the long term the European agricultural sector; they need a sustainable source of nutrients, most notably phosphorus. Europe will gain more independence and reduce price risk exposure by recovering more nutrients.

B.6.5 Conclusions

Manure treatment is technically feasible and beneficial for the environment but the optimal configuration of technologies and value chain organisations has not been developed yet. The practice encounters barriers caused by legislations, awareness, technology immaturity, uncertainty and through a higher price. For what concerns the pricing difference, GHG intensive manure processing practices may be placed under a GHG allowance scheme such as the EU ETS to level price differences. For what concerns the regulatory barriers, the lacking recognition of organic fertilisers in the Fertiliser Directive and missing EoW criteria for manure cause a cascade of other legislations to apply which incurs costs and causes uncertainties. When livestock manure is applied to land to meet crop needs, it is regarded as a fertiliser. Why are end of waste criteria needed? The Commission is aware of these issues and addressing them at the right point; the Fertiliser Directive is up for revision, and the JRC research EoW criteria for manure derived products such as digestate. It is unknown when these revisions will come into effect, and during this time value is lost. Future revisions are not foreseen for as far as the author could assess. Considering the lengthy path of regulatory revisions, a continuous monitor on nutrient economics and technology would be effective to make us of the newest technological developments. Such a practice should include continuous dialogue with farmers, processors and chemical fertiliser producers; technology development and demonstration; the designation of zones for medium scale experimentation.

B.6.6 Interviewees

For this case study, a range of stakeholders throughout the value chain (except farmers) have been interviewed. They are listed and described below.

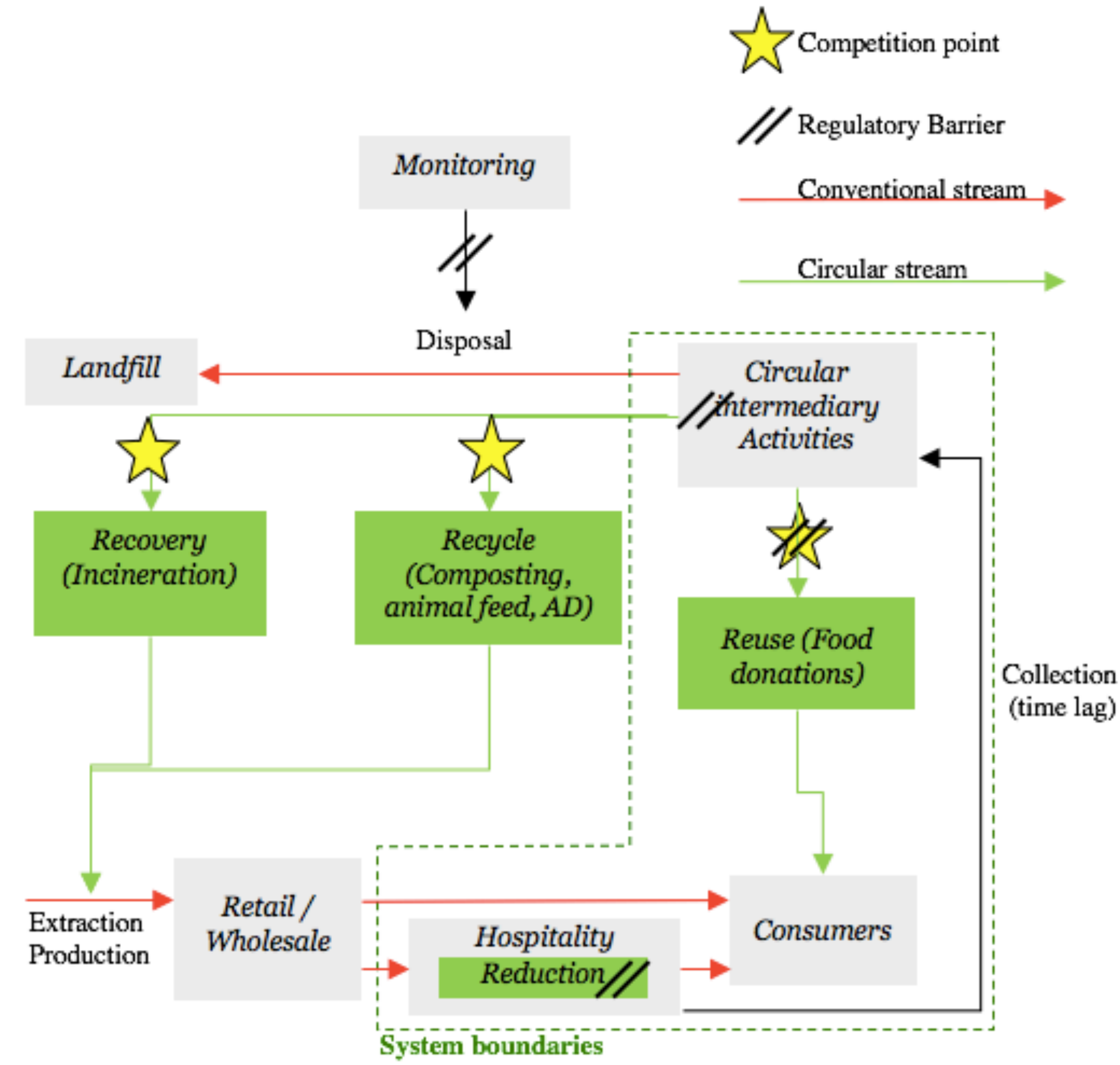
Table 44 List of interviewees

Organisation	Sector	Description	Location
Baltic Manure	European project	Research and business development for manure from waste to resource	Estonia
European Sustainable Phosphorus Platform	Advocacy organisation	Knowledge, information sharing and advocacy for sustainable phosphorus processing and sourcing	Belgium
VCM Mestverwerking	Manure processing	Manure processing agglomerate	Belgium
Fertilisers Europe	Branch organisation	European branche orgnaisation of inorganic fertiliser producers	Belgium
European Biogas Association	Branch organisation	Association promoting the use and production of biogase in Europe	Belgium
Dutch Ministry of Infrastructure and the Environment	Government	Dutch ministry responsible for environment and manure / fertiliser issues	Netherlands
European Commission, DG Environment	Government	DG responsible for European policy on manure issues	Europe

B.7 Food waste in the hospitality sector

B.7.1 The product and its value chain

Figure 18 The value chain of food waste in the hospitality sector



Technopolis, 2015

Description of the products and activities

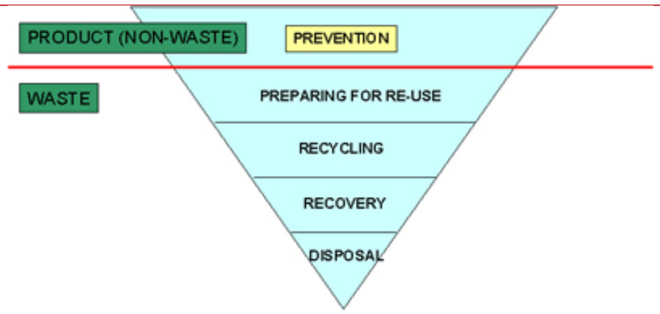
This case study focuses on food that is wasted in the hospitality sector and the ways in which this amount can be reduced. The hospitality sector consists of multiple types of food providers, including businesses like restaurants and cafeterias but also public institutions like schools and hospitals that provide food to their "customers".

In general, there is a lot of food "loss" or "waste" in the food supply chain that amounts to 89 million ton per year in the EU (BIS, 2010). National studies report some figures as well, ranging between a contribution of 5% and 17% of the total waste in the hospitality sector. It must be noted that due to its "small" part of the total waste production a very minimal amount of figures is available for the hospitality sector, when compared to for instance the waste generated by households.

There is a clear difference in definition of "loss" and "waste". Food "loss" is defined as food mass that gets extracted out of the food chain all the way up to, but excluding, retailers and consumers. Therefore, food losses take place at the production, post-harvest and processing stages of the food supply chain (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011). Food "waste" specifically covers food mass that gets lost in the end of the food chain, mainly related to behaviour of retailers, food providers and consumers, which amounts to 40% (European Commission, Food, 2016). In this case study the focus will be on part of the food that is wasted.

When talking about waste and how to handle it resource efficiently, the Waste Framework Directive (2008/98/EC) should be kept in mind. The directive includes the hierarchy of waste management. In this hierarchy "prevention" is the highest rated option, see Figure 19. This case focuses on the prevention of waste after preparation, hence options to prevent waste of food before preparation are summarily discussed. It could be argued that direct reuse of food by other people can be considered a way of prevention as well. As people in some cases can directly "reuse" food that was not used by others, it basically makes the preparation step for reuse obsolete. Reuse in this sense has more to do with ownership, responsibility and liability (think of food safety) instead of reusing a product that has been really used before. Therefore, the reuse step of the framework, with regards to human reuse without the need of preparation, will be included in the case.

Figure 19 Waste framework directive



European commission: Directive 2008/98/EC

In this sense two different areas in the prevention of food waste in the hospitality sector will be covered, namely how to reduce the amount of food that is gone to waste in the hospitality sector, and how to best handle discarded but edible food. Figure 18 shows that in these two areas, legislation plays a role. In the next chapter these legislations will be discussed in more detail.

After the description of the value chain, end-of-life options, collection system, the regulatory barriers and their solutions are presented.

Value chain and life cycle

The available amount of data on food waste in Europe is low in quality and volume. Data on food waste is for instance not collected (yet) by Eurostat in a central methodological way. This is becoming a policy priority. Eurostat has recently released information on their goals covering food waste statistics (Schrör, 2015). The lack of data is also the reason that no specific amount of food waste can be attributed to one specific regulatory barrier. National studies provide some useful insights but are often hard to compare to studies in other member states due to different methodologies. It must also be noted that the numbers that are reported are usually quite far apart.

There are two main studies that show findings of food waste on a European level:

- *Preparatory study on food waste across EU 27,* by Bio Intelligence Service (BIS) in assignment of the European Commission (DG ENV).

- The date in this section is mostly covering 2006 Eurostat and looks at various national data sources in combination with the source mentioned above. If other sources are used, this is indicated.

The BIS source presents a total of 89 million ton food waste per year in the EU, which would result in 180 kg of waste per capita per year in the EU. They estimate that around 13.8% is attributable to the hospitality sector, which would amount to 12.3 million tons per year in EU27 (or about 25 kg per capita).

The total amount waste estimated by the BIS study (12.3 million ton per year) will be used to allow for further analyses in this case study. This is the amount that was measured around 2006 / 2007. Currently the European Commission presents an estimate of the total food waste within the EU of around 100 million ton in 2012, which is expected to increase to 120 million ton in 2020 (European Commission, 2015C).

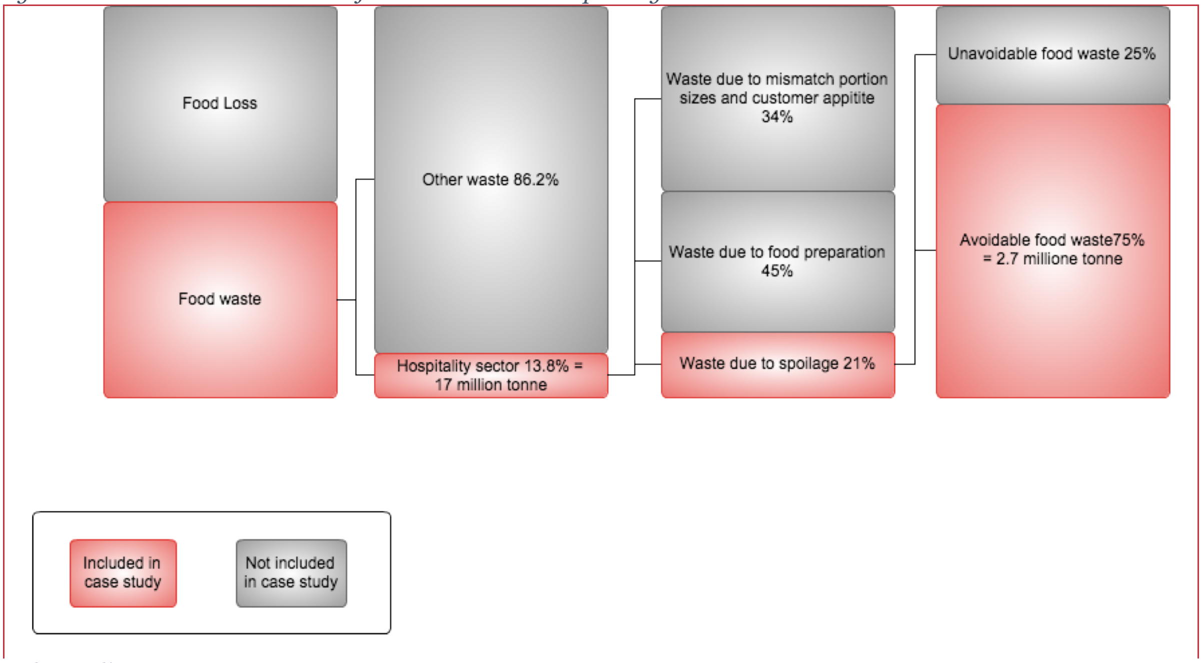
Interpolating these figures, the approximation of the total food waste in the hospitality sector in the EU would be around 14.8 million ton in 2015. The calculated amount for 2015 was 140 million ton total waste in the EU, and would respectively result in 19.3 million ton of waste in the hospitality sector. Therefore, the average of these values will be used for further calculations, namely: 17 million ton in the hospitality sector.

Discarding food is energy and resource inefficient as well as economically wasteful. In terms of costs there are very few figures available for the hospitality sector. However, based on the figures that are available for households at least an indication can be given of the economic value of the food wasted.

In terms of costs there are even less figures available for the hospitality sector. However, based on the figures that are available for households at least an indication can be given of the economic value of the food wasted.

WRAP (2015) provides a useful distribution of the waste in the hospitality sector, providing an indication to where waste takes place. Their findings are that around 21% of the waste generation is due to spoilage, 45% due to food preparation and 34% is due to a mismatch in portion size and appetite of the customer. Clearly the largest part cannot be avoided through regulatory adjustments, as the regulatory framework does not influence the issues in preparation and portion size. Therefore, only the 21% waste that is caused by spoilage, food that goes bad (based on the rules set in food legislation), can be improved. Following the work of WRAP we have already seen that about 75% of the entire amount of waste is avoidable. Relating these percentages to the earlier estimated amount of 17 million ton waste in the EU in the hospitality sector provides a figure of about 2.7 million ton waste (Figure 20)

Figure 20 Calculations avoidable food waste in the hospitality sector



Technopolis 2016

In a similar case about household food waste the amount of money wasted by households was estimated on around €1.96 per kg (Science and Technology Options Assessment (STOA), 2013) (Priestly, 2016) (WRAP, 2009) (European Commission, n.d.)[27]. This is a crude number as "a kg food" does not exist; however, it is an indication of the economic value of an average kg of food. This is important, as we need to discount this figure for the difference in cost when shopping at wholesale markets, so not at retail prices. For this an estimation of around 20% discount will be applied, providing a price per kg of around: €1.57[28].

The total potential cost savings of food waste in the hospitality sector in economic value can therefore be estimated on €4,239 million.

Zooming in on the illustrated value chain in Figure 18, both the circular and conventional paths are shown. Starting with the *conventional stream*, the raw materials are first extracted and processed into food(ingredients) before sending it to the retail/whole sale market. Sometimes this is just harvesting and transportation, in other cases more intensive processing takes place. The hospitality sector buys the food(ingredients) from the retailers and the wholesale markets and, processes the food(ingredients) into meals, portions for the consumer or buffets. After being presented to the consumer, the remaining food becomes waste and is collected and disposed as municipal waste in landfills or is incinerated.

The circular stream is more resource and energy efficient. Again the hospitality sector buys food at the retail/whole sale sector. Once in the hospitality sector, food waste can be reduced immediately by prevention. There are three prevention options:

1. A reduction in portion sizes as currently there are many left overs due to large portion sizes.

2. Tailored hygiene rules and best before dates for products. Consequently, less food will be discarded.

3. Better estimations of the amount of day to-day customers.

[27] The actual figure was produced by dividing the average of per capita assessments of money wasted, by the average assessments of per capita food wasted.

[28] *It must be noted that caution of using this figure is advised as this figure is based on multiple assumptions building on each other, but it is also the only available information.*

Unfortunately, legislations on portion sizes are non-existent, hygiene rules are rather strict, and estimation of the number of customers proves to be difficult for caterers. Hence, (regulatory) barriers preventing the reduction of food waste are in place.

Before the "waste" can be further processed and reused, it must be collected. However, an efficient collection infrastructure is lacking. Consequently, collection is expensive. Once collected, there are several circular options possible.

One option is the reuse of food through food donations. Unfortunately, this option is limited by the VAT and liability rules, which place a negative economic incentive on food donations and give a competitive advantage to anaerobic digestion (AD), incineration, composting and animal feed, which are the competing alternatives.

Recycling options are converting food into animal feed and composting. These two options are competing with each other and with donation and incineration. An additional barrier is that for these purposes, the food waste needs to be separated by caterers as only biotic materials can be processed: contaminations as plastics cannot be used as feed and are not suitable for composting. For feed, this needs to be done stricter to avoid cannibalism and safeguard animal health.

The last option would be incineration, which is incentivised in some countries as it considered a method to generate renewable energy from biofuels. However, this is not the most energy efficient option as it is one step higher than disposal (Figure 19). A final barrier is the lack of adequate measurements of food waste, which makes it hard to monitor the size of the problem. However, legislations do exist for standardized measurements; Regulation (EU) No 849/2010, Regulation No 2150/2002, and Commission Regulation (EC) No 1639/2001, yet there is a lack of enforcement.

Actors and their relation with connected actors

End-of-life products in this case refer to leftover food of consumers, buffets or food preparation in the hospitality sector, which are disposed of. Upcycling is not possible with food waste, no "purer" type of food can be created out of the food waste. However, parts of the food can be reused for other meals. E.g. leftover tomatoes from buffets can be made into soup. The governance structure for the end-of-life options can be defined as private based; most participating organisations stem from the private sector as NGO's and waste managers. Based on the interviews conducted for this case and a literature review, different end-of-life options are discussed.

Food donation

One possibility to reduce food waste is donating food to charities, such as so called *food banks* according to the interviewees. Within the EU, 33,000 charities deliver over 2 million meals per day to their clients (generally poorer people who can't afford a decent meal at commercial prices). Food banks rely for their food supply solely on donations. 50% of the food that the charities receive comes from food producers and retailers, 25 % comes the national public market (national clients from hypermarkets), and the rest comes from the EU food programme as The Fund for European Aid to the Most Deprived (FEAD). In the FEAD charitable organisations are selected by the commission, to which member states are allowed to decide what kind of contribution they want to make; food, supplies, money (European Commission, Fund for European Aid to the Most Deprived, NN). In total 3.8 million Euro is available for this fund of which 15% comes member states co-financing their national charitable organisations (Ibid.).

The percentage of donations that charities receive from the hospitality sector is rather small. The hospitality sector would mainly donate already prepared food, which means that the food has to be catered the same day, while food from retailers allows two days for distribution.

The main actors with regards to food donations would be organisations within the hospitality sector, food banks, and when possible food collectors, yet the last actor seems to be missing as there is no well working collection infrastructure.

The main problems concerning food donations in the hospitality sector, according to the respondents are the lacking infrastructure and dependence on volunteers to collect the food. Additionally, the competition of animal feed and AD, hinders donation as these options are more profitable. Moreover, the VAT places a negative economic incentive on food donations and the the donor liability ward off donations even more.

Animal feed

The second use of foodat its end-of-life state, according to the respondents, is to convert it to *animal feed*. Without converting food to animal feed, many animal-based proteins are lost. Converting animal by-products into animal feed is limited according to Regulation 1069/2009 *laying down health rules as regards animal by-products and derived products not intended for human consumption* to avoid cannibalism for safety reasons (e.g. TSE). If the hospitality sector wants to dispose of its waste as animal feed, it needs to be registered as an animal feed producer. In addition, all the animal products, non-animal based waste, and non-digestive waste needs to be separated at the caterer's premises. The extra work and costs this imposes on the caterers serves as a barrier towards the conversion of food into feed.

Anaerobic digestion

A third option is *Anaerobic Digestion* or AD according to the respondents. Food unfit for consumption can be sold to energy producers and thereby be converted into *bio-energy*. The actors for this option consist of the members of the hospitality sector, waste collectors and AD operators. For AD, a similar though less stringent problem in storage exists as with food destined for animal feed. However, as animal feed seems to be more profitable for donors, AD is in competition with animal feed production.

Composting

Composting food reduces waste because the end products can be used to enhance the soil. This also helps closing the nutrient cycle. (Goldstein, 2014; Eriksson, Strid, & Hansson, 2015) For this option again the members of the hospitality sector and waste collectors are needed. In addition, the waste needs to be composted by composters. As this option was not mentioned in the interviews, no barriers were identified. The main action that needs to be taken by the hospitality sector is separating waste in biodegradable and non-biodegradable fractions.

Collection system

The collection system of food waste in the hospitality sector is far from optimal according to the interviewees. Compared to the retail and production sector, the amount of waste generated in the hospitality sector is rather small. Collecting small quantities of waste from different places is quite expensive, so currently there is no good collection infrastructure available. The biggest barrier for a well-working infrastructure is therefore an economic barrier.

To solve this, HOTREC, the European branch organisation for the hospitality sector, points to local governance assistance. For instance, by investing in a well-working collection system, which would cancel out the economic barrier by achieving economy of scale. A best practice is found in Flanders, which also uses a pay-as-you-throw system, where one pays depending on residual waste generation. 75% of the waste in Flanders is currently separated. (ZerowasteEurope, 2014).

Table 45 Values of food waste in the hospitality sector

Type	*Amount*	*Comment*
Food waste in the EU.	89 Million ton per capita per year.	(BIS, 2010)
Food waste in the hospitality sector in ton.	17 Million ton per year.	See section on value chain (above) for justification of figures
Avoidable food waste in the hospitality sector.	2.7 Million ton per year.	

Price of food.	€1.57 per kg.	
Avoidable food waste in the hospitality sector in Euro's.	€ 4.239 million per year	
Composting	€ 40-60 per ton on scale of the order 20 000 ton tpa	For municipal waste using the common bio filters technologies (Eunomia, 2002)
AD	Ranging from 35-109 €/t between member states	For on municipal waste (Eunomia, 2002)

B.7.2 Relevant barriers

Table 46 Overview of regulatory barriers for prevention

Barriers for prevention	*Effect*	*Possible (legal) solution*
Hygiene rules and best before dates. Regulation (EU) No 1169/2011, Regulation (EC) No 589/2008, Regulation (EC) No 1881/2006,	Unnecessary food is thrown away, placing a unnecessary economic burden on the hospitality sector.	Taylor best-before dates and Hygiene rules per product.
Lacking legislations portion sizes.	Over preparation of food and unnecessary waste.	Set standards for portion sizes, yet this is problematic.

Table 47 Overview of the regulatory barriers for reuse

Barriers for reuse	effect	Possible (legal) solution
VAT on food donations: Council directive 2006/112/EC	A negative economic incentive is placed on food donations, leading food being discarded.	Adopt the Good Samaritan law throughout Europe.
Liability of food donors. Regulation(EC) no 178/2002. Council Directive 85/374/EEC .	Negative economic incentive on food donations; food is discarded instead of donated.	Define the hospitality sector as a producer.

Barriers for the prevention of waste

Hygiene rules and best before dates.

Description: This obstacle was voiced by many respondents concerning the trade-off between food safety and the reduction of food waste. Different rules fall under this category, food safety is generally prioritized.

The hygiene rules stem from the HACCP (hazard analysis and critical control points in the European regulation (EG) 852/2004 on food stuff hygiene). This HACCP is translated into a national hygiene code. The regulation states that member states can design hygiene rules as long as they are based on HACCP. As a result, in some member states the presentation rules are stricter than in other member states. Hence it is more a barrier in national legislations than a European one.

Concrete examples of "too strict" hygiene rules are the 2-hour rule of presenting food in the Netherlands. This two-hour presentation rule is a national policy from the Dutch food and drug organisation (Alliantie verduurzaming voedsel, 2015). After the food is presented on buffets, it cannot be used for the second time and has to be discarded out of food safety concerns. Such considerations are appropriate for fish and meats, but overprotective for vegetables. For example, tomatoes are still edible after being presented on a buffet for two hours and can subsequently be used in soups and sauces. Moreover, opened packages can only be stored for a maximum of 3 days, which is viewed by some respondents as too short. Table

48 shows the uncooled presentation rules of buffets in the different member states. The difference in rules is not so much a barrier, but it illustrates the possibility of longer presentation times.

Table 48 Uncooled presentation rules buffets

Country	*Presentation time in hours*	*Comment*
Belgium	0	Unless microbiologically research shows no health issue is caused
The Netherlands	2	Unless microbiologically research shows no health issue is caused
Germany	There are no strict limits	Yet scientific research must show no health issue is caused.
UK	4	Unless microbiologically research shows no health issue is caused.
Denmark	3	
Hungary	3	If it is not possible to keep the temperature of warm food stable over +63°C, the food cannot be reheated or cooled.
Luxemburg	2	Temperature should prevent the proliferation of microbes.
Spain	No time limit	
Sweden	No explicit time	Restaurants are responsible for serving safe food.
Austria	Presentation is allowed for a “short period”	Depends on the type of food. For instance, salads have to be cooled if they are to be presented for more than 2 hours.

(Bex, Van den Berg, & Marinković, 2012; Hotrec, NN)

The best-before dates cause similar problems. Food and drinks can often still be consumed after their expiration date, but are discarded out of health concerns or consumer unawareness about fitness for consumption. Regulation (EU) No 1169/2011 entails the requirement of information on food packaging such as best before dates (Vittuari, Politano, Gaiani, Canali, & Elander, 2015). Consumers are confused about the meaning and therefore throw still edible food away to avoid the risk of getting sick. The same can apply for employees in restaurants. Regulation (EC) No 589/2008 sets the best before dates for eggs. Yet it does not take into consideration that refrigerated eggs can be kept fresh longer. Hence the best before date is too strict in some cases.

These rules are problematic at they cause unnecessary waste. Additional environmental damaging as more production is needed for new products, e.g. the production of eggs requires a lot of water. Moreover, it is costly for the hospitality sector to unnecessary replace products.

Solutions proposed

As different barriers are mentioned, different solutions are needed. Starting with the maximum presentation and opening times of food packages. While this is a national problem, it does stem from too loosely defined EU Legislations. This problem can be addressed in two ways. (1) this could be regarded a national problem and national governments should find a fitting solution. (2) This could be changed throughout the EU by formulating stricter criteria which the national governments should meet. A European legislation allowing for a longer time span could reduce unnecessary food waste according to the interviewees.

A possible European solution for the "too strict" best-before dates could be to tailor these dates to the products and storage situation. The egg example shows that better storing information could allow for a later best-before date. The Dutch Alliance Verduurzaming Voedsel (2015) for instance argues that Annex X of Regulation (EU) No 1169/2011, containing a list with products exempt from the best before dates as they can be consumed for a relatively long period of time, should be expanded. Consequently, the consumer can decide whether the product is still edible, it can be longer stored, and waste is prevented.

A last option to prolong the allowed storage time after opening the food packaging would be efficient packaging. For instance, more portion packaging, freezer ready packaging, and resealable packaging. This could also extend the best-before date. Yet it could be argued that this last solution is a task of the packaging sector.

The proposed solutions can influence the situation to a certain extent, and consumer behaviour should be considered. End product users fear negative health consequences from consuming expired food.

Market potential

While it is not possible to give an exact number on how much money the hospitality sector currently wastes, it is safe to conclude that value is lost by disposing still edible food. If the best-before dates and food safety legislations would be adjusted in such a manner that they would still ensure food safety, but also generate less food waste, the hospitality sector would be a save costs as they need less products. Hence they would be the winning actors in this scenario.

Figure 18 illustrates that the hospitality sector purchases its ingredients from the retail/wholesale markets. The money the hospitality sector gains by reducing its waste, is the money the wholesale/ retail market loses. Hence, they would be the losing party in this scenario.

Lacking legislations on portion sizes

One additional barrier could be the lacking legislations on portion sizes. Currently portions tend to be too large and not all the food is eaten. Unfortunately, no data on the amount of this waste exist. Logically it follows that food that has been served cannot be used twice. This is a big source of food waste with associated costs, although the consumer pays for the waste. It is more of a behavioural barrier as clients need to realise their contribution to the source of waste. Awareness of the problems caused by large portions seems lacking. While this problem could be solved by legislations requiring portions from different sizes, this remains politically difficult as people are reluctant to behavioural change when it comes to food as mentioned by the interviewees.

Proposed solutions

A solution could be educating the consumer to accept smaller portions and order less, and also educate restaurants to address their food waste and options to reduce it. The local government could play a role in assisting the education of both guests and restaurants according to the respondents. The current practice is to take so called "doggy bags" as a solution for too large portion sizes. However, there is no guarantee that the food taken away will be eaten outside of the restaurant and so it may just shift the problem, by ending up as waste at the consumer side as one of the interviewees mentioned. Regulating portion sizes might be possible by setting mandatory smaller portion sizes, but undesirable from both the caterer, consumer, and governmental perspective. It affects client satisfaction at restaurants and it is also questionable whether governments should regulate to this level of detail. Moreover, governments are reluctant to influence the consumer as freedom of choice is a strong principle in democracies.

Market potential: Smaller portions are more expensive than bigger ones; the same amount of labour is required for a smaller portion, which could lead to consumers opting for the bigger portions, not finishing them, and the problem thus remains (Vermeer, Steenhuis, & Seidell, 2009). Yet consumers viewed a variety of different portion sizes as a positive intervention, while solely a reduction of size would come across as patronizing. Caterers have reservations themselves. They fear losing customers to competitors by reducing the portion sizes. Caterers do not view a wide variety of portion sizes as necessarily positive as it would result in more costs, extra handling of the food, and weighting of the portions (Vermeer et al., 2009). Empirical examples from New York's Soda Big Gulp soda ban showed that these kinds of legislations are not welcomed by both the public as well as food and beverages producers (Grynbaum, 2014). If a governmental obligatory portion size was introduced, the food and beverage producers would be losing turnover. The consumers on the other hand, often expect large portions when going out for dinner and as a poll held in New York showed, the majority of New Yorkers was against the Big Gulp soda ban (Grynbaum, 2014). While in this example policies were initiated to combat obesity instead of food waste, it still shows the public opposing to regulated portion sizes.

The outcomes for the hospitality sector in this scenario are not clear. Smaller portion sizes could reduce food waste, but respondents mentioned that consumers could order more dishes at the same time when they think the smaller portions do not suffice, and the effect is reduced. On the other hand, providing consumers with various "stop-moments" may reduce food waste as the consumer has more opportunities to consider ordering more food.

Barriers for the reuse of waste

Value added tax

Many respondents mentioned the Value added tax (VAT) on donated products stemming from Council directive 2006/112/EC as a barrier hindering reuse of food. This barrier is caused by the national interpretation of the directive. Again the problem can be approached in two ways. 1) As a national issue. 2) As a problem stemming from lacking of EU legislations. This choice determines the required solution.

The directive states that that food donations will be taxed when they are made by a person that is in fact taxable. Additionally, the VAT on the purchase of the food must be partially or fully deductible. What is further mentioned is that tax exemptions on food are not allowed. (O' Connor et al., 2014). The Value Added Tax (VAT) prohibits waste reduction through donations (Vittuari et al., 2015, 2013). The VAT thus places a negative economic incentive on donations and therefore caterers are more inclined to discard the food instead of donating. However, the market value of the VAT differs per country as in some countries when the product is unsellable, the price is zero, hence a zero tax is to be paid by the donor (Table 49). In other countries the product can still be sold and have the original market value, and the vat is calculated on the original price. This leads to producers, retailers and the hospitality sector opting for waste discard instead of donations. This is mainly due to variation of terminology in legal texts which opens the door for different interpretations (O' Connor et al., 2014).

By discarding food instead of donating it, materials are lost, which is not resource efficient. Aside from the environmental concerns, it is morally questionable to discard still edible food, while it could also be transferred to people in need.

Solutions proposed

The VAT can be reasoned to cause a lot of food waste. To reduce this waste, the negative economic incentive on donations must be lifted. If argued that the VAT on food donation exists due to a lack of EU legislations, then the solution should be made at the European level.

A mentioned problem in the directive is the lack of clarity in the terminology. This could be of the directive could be enhanced by rewriting the text or add a guidance document which would allow for a clear national interpretation.

More important is the negative economic incentive on donating caused by the VAT and especially the no exemption clause on food donations. The good Samaritan law good be a solution as it both defines charitable organizations, which allows for a free distribution of food products, and simultaneously sets standards for storage, transport, and preservations (European Comission, 2012). Moreover, the manner in which the Good Samaritan law (Law No. 155/2003) is adopted in Italy also protects donors from liability issues (European Economic and social commitee, 2014). The adoption of the law is said to have removed the incentives for food disposal as donating does not put extra economic costs on the donor. Yet in combination with (EC) No. 852/2004, regarding hygiene regulation, the Good Samaritan law ensures standards for food safety. The problem of the VAT could thus be tackled if the good Samaritan law is adopted as an EU regulation and thereby filling the legislation void surrounding the VAT.

Table 49 Value added tax per country

Country	VAT regulation	Comments
UK	Yes; Zero rated	Due to negotiations before EU membership.
France	No	Due to 14/02/84 Finance act no 87/571 and 275.8 of the general tax code. 60% reduction on donations to a philanthropic, scientific, social, humanitarian, or educational organisation.
Belgium	No	Decision N E.T. 124.417 this only applies to donation to the 9 registered food banks.
Germany	No	Since a court ruling in 2012 vat on food donation is either zero or symbolic,
Italy	No	Since the legislative degree on December 4 1997 n,.460 there is no VAT on food donations to an O.N.L.U.S. Has adopted the good Samaritan law. Additionally, the law sets criteria to meet a standard for preservation, storing, moving and using the food.
Spain	Yes	Donation is seen as placing food on the market, consequently they are subject to the VAT. The tax is either 10% or 4 %.
Greece	No	Article 46 of law 4238/2014 states that the donation of food, medicine, clothes and other products tot Greek legally non-profit organization to reduce peoples suffering, no VAT is charged
Portugal	No	Due to Article 64 of the Portuguese Tax benefit code food donations are free of the VAT if they are donated to people in need.
Hungary	No	Article 3 of the Hungarian VAT act states that the VAT is not imposed on donation to public use. Moreover, the National Act n° CLXXV/2011 - Corporate tax benefit for donations which provides a positive incentive for corporations to donate as 20% is tax deductible.
Poland	No	No VAT on donated food since 2013 with the amendment of the law for donations to charitable organizations: article 43 of act February 15 1992 on corporate income tax and amendment of some acts on tax regulation. Yes the administrative requirements and procedures are not
Sweden	Yes	
Denmark	Yes	

(O'Connor, Ghroldus, & Jan, 2014)

Market Potential: Figure 20 indicates that 79% of the food waste in the hospitality sector cannot be avoided through legislations, but as stated earlier in the economic setting, food can also be reused in order to prevent it from becoming discarded as "waste". For this 79% a significant proportion can be reused by charities in order to feed people in need, which it seems is hindered by a regulatory barrier. This 79% would result in 10 million ton of food. The European Federation of Food Banks reports that less than 1% of the food wasted by manufacturers, caterers and retailers is currently collected. How much food of this total 10 million tons can be directly passed to food banks is unknown, also considering practical issues it will probably be impossible to massively collect food outside of the urban areas.

The European Commission reports that about two thirds of the European population lives in urban regions (Commission, 2015D). So even when assuming that: 1) one third of the food can be used by charities, and 2) that also one third is collectable in urban regions, the potential is great. This would result in 1.1 million ton food that can be collected The economic value of this food is however impossible to calculate as charities in general do not pay for food, however when pursuing this option please look at the study done for the European Economic and Social Committee, called *"Comparative Study on EU*

Member States' legislation and practices on food donation – Final report". However, as argued above, due to practical problems as collection and negative economic incentives, the actual amount of donation from the hospitality sector is low. While in theory there is great potential (about 1 million ton) in practice the hospitality sector is a small contributor to the food banks.

Overall, the market for donated food in Europe is growing (O'Connor et al., 2014). Unfortunately, little information is available on the amount of food donations throughout Europe. Research on the effects of the adoption of the good Samaritan law can be found in the USA. The USA adopted the good Samaritan law in 1996, a growth in the amount of food banks was shown (Kim, 2015).

Assuming that the adoption of the good Samaritan law would have similar effects in Europe, there would be three categories of winners, and one loser. The winners would firstly be the people in need who cannot afford buying food their selves. Lifting the VAT would allow them to escape hunger and malnutrition. Food banks would also come out as winners as they now receive more donations which allows them to meet their goals and targets, combatting hunger. The last category of winners would be the hospitality sector which would not have to pay for their food donations.

The losing category would exist of the national government. Governments gain income through taxation. Placing a tax on donations renders extra income for the state. If the VAT would be cancelled for food donations, the state would thus loose a source of income. However, it can be argued that this loss of income is relatively small. The VAT currently prohibits donations; caterers rather through edible food away to avoid paying for the tax. Hence it could be argued that the states source of income stemming from the VAT is already small. Hence it would not be a big economic loss for the national state when cancelling the VAT on food donations.

Liability of food donors

Many of the respondents believe donation will incur extra costs on the hospitality sector, as a special insurance against liability is needed . Here the same argument as on the VAT on food donations can be given. A negative economic incentive and potential brand damage makes discarding food more attractive. According to article 3.8 of the general food law (Regulation EC/178/2002) food donations mean placing food on the market and food business operators have to follow the same rules as if they were selling the food (O'Connor, Ghroldus, & Jan, 2014). According to article 17 of the regulation, food and feed business operators are responsible for meeting the requirements of the general food law, including hygiene standards. However, according to article 7 of the Council Directive 85/374/EEC, the producer in the case of food donation is not liable. The definition of producer should be clarified. Regulation (EC) No 178/2002 mentions the following on producers in article 19 section 2:

"*feed business' means any undertaking whether for profit or not and whether public or private, carrying out any operation of production, manufacture, processing, storage, transport or distribution of feed including any producer producing, processing or storing feed for feeding to animals on his own holding*"

Yet according to this definition, producers are feed business operators. Food operators are responsible for their role in the chain. If an incident happens, liability is handled through national jurisdiction. Hence, liability seems to be a national problem. Yet it can also be argued, based on article 7 of Council Directive 85/374/EEC, that there is a lack of legislation, which would make it a European problem.

Table 50 Liability rules food donation per country

Country	Liability rule	Comment
UK	General food regulations of 2004	This law states that persons who fail to comply with the Regulation (EC) No. 178/2002 is liable to fine or imprisonment.
France	Code civil – article 1382	Following this law every person who is responsible for damaging other people, must resolve the damage. Food donors and food charities sign a partnership and a liability insurance to cover the potential damage.
Italy	Law June 25 2003 N. 155 (Good Samaritan law)	Defining food banks as the final consumer takes the liability from the O.N.L.U.S. away and prevent liability law suits against the donor from persons receiving food from food banks.

Country	Liability rule	Comment
Greece	yes	Boroume NGO fighting food waste, designed a note of understanding liability ensuring hygiene and food safety. Similar the the transmission slip in France.

(O'Connor, Ghroldus, & Jan, 2014)

Solutions proposed

First it must be clarified what the distinction is between a producer and a food business operator. Yet if the hospitality sector is not seen as a producer, it might be worthwhile to define them as such if the term producer and food business operator can be separated. Once these definitions are separated and caterers are defined as producer, the hospitality sector, food banks, and people in need will be the winning actors. The waste treatment companies would be the losing actors as their waste income stream is reduced. However, this is defined in a directive, and thus it can be argued that it is a national problem instead of a European one. Nonetheless, if approached as a lack of legislation, it becomes a European problem in which the definition of producer should be investigated.

B.7.3 Conclusion

This case study analyses the regulatory barriers to preventing waste from biotic materials in the hospitality sector. Two different sub-categories are identified; legislations functioning as barriers to prevention and legislation functioning as barriers for reuse. The too strict hygiene rules and best-before-dates, and lacking legislations on portion sizes fall under the first category. Both lead to unnecessary discard of food. This is energy inefficient, places extra costs on the hospitality sector as products need to be replaced, and is environmental damaging as more production places more pressure on the environment. Solutions could be tailoring best-before dates to products and storage conditions, extending the list with products exempted from best-before dates. Lastly, it could be considered to regulate portion sizes, but as shown it is not the most favourable option.

The VAT and liability rules both place a negative economic incentive on donations, causing a favourable situation for discarding instead of donation, and fall under the second category. Discarding food instead of donations is environmentally damaging as it is not resource efficient, moreover, it is morally questionable to discard food instead of giving it to the people in need. Possible solutions would be lifting the VAT on food donations by adopting the good Samaritan law and separating the term food business from producer. Next to the identification of the barriers, they are classified as European or national ones

B.7.4 Interviewees

Table 51 List of interviewees.

Organisation	*Sector*	*Description*	*Location*
Feba	Food banks	Supporting national food banks and awareness raising and information sharing among their members.	France
Food Drink Europe	Advocacy organisation	Aims to improve the environment in which all food and drink companies operate.	Belgium
Koninklijke horeca Nederland	Manure processing	Supports and shares information among their members.	The Netherlands
CBL	Branch organisation	Branch organisation for the retail and food service sector in The Netherlands. Supports its members by providing information and good conditions.	The Netherlands
HOTREC	Branch organisation	European branch organisation for the hospitality sector which protects the interest of the hospitality sector in Brussels.	Belgium

Dutch Ministry of Infrastructure and Environment.	Government	Dutch ministry responsible for environment and infrastructure.	The Netherlands
Director General for Health and Food safety Innovation and Sustainability.	Government	DG responsible for European policy on health and food safety.	Europe

B.7.5 Relevant EU legislation

The information contained in this section is based on the Fusions report written by Vittuari et al. (2015).

Regulations that could potentially generate food waste

Regulation (EC) No 543/2011 from June 2011

Description: This regulation specifies marketing standards for citrus fruits, apples, kiwis, lettuce, broad-leaved endives, pears, peaches, strawberries, nectarines, table grapes, sweet peppers and tomatoes (Vittuari et al., 2015). Food that does not meet the criteria is not seen fit for sales and is discarded. This has nothing to do with health issues, but purely based on marketing.

Regulation (EU) No 1169/2011 of the European Parliament and of the Council from

25 October 2011.

Description: This regulation determines the type and content of food information for consumers. Information needs to include nutrition information of processed foods, the type of meat, highlighted allergens in the ingredient list, this must also be made available on non packed food, and better readability (Vittuari et al., 2015). The focus is on food safety and not on environmental aspects as storage directives. Additionally, consumers tend to misinterpreted the best before dates.

Council Directive 2009/28/EC from 23 April 2009.

Description: The directive promotes the use of renewable resource by setting national targets for both energies needed for consumption and transportation. These targets for a certain percentage of renewable energy lead to the promotion of Anaerobic digestion of food waste (Vittuari et al., 2015). It is questionable whether this is the most efficient food waste treatment when looking at the waste pyramid. Donating the food or converting it into animal feed would be more energy efficient.

Regulation (EC) No 589/2008 from June 2008

Description: This regulation sets the standards for the production transportation selling and the best before dates of eggs (Vittuari et al., 2015). The best before dates could be too general for every European country. In northern countries with a colder climate, the best before date is too short which leads to edible eggs being thrown away.

Commission Regulation (EC) No 1881/2006 from 19 December 2006.

Description: This regulation was implemented to protect the public health (Vittuari et al., 2015). It has a zero tolerance policy for genotoxic carcinogens, contaminants or certain exposures that could harm the population. However, with this zero tolerance policy some edible products are completely excluded from the market, while with improvement in technology allow some parts of the products still to be eaten.

Regulation (EC) No 183/2005 of the European Parliament and of the Council from January 2005, (EC) No 852/2004 of the European Parliament and of the Council from 29 April 2004, (EC) No 853/2004 of the European Parliament and of the Council from 29 April 2004. (EC) No 882/2004 of the European Parliament and of the Council from 29 April 2004 & Council Directive 2002/99/EC from 16 December 2002.

Description: These legislations and the directive all refer to hygiene of food and act to insure food hygiene throughout the supply chain (Vittuari et al., 2015). Overall, these hygiene rules reduce food waste as it also requires food being fresh and edible. Yet when these are too strict as the shelf life limitations and presentation time during buffets, still edible food ends up being wasted. Hence there is a trade-off between food safety and food waste reduction where food safety is given priority.

Regulation (EC) No 999/2001 of the European Parliament and of the Council from 22 May 2001.

Description: This regulation was adopted to prevent, control, monitor and stop transmissible spongiform encephalopathy (TSE) in animals (Vittuari et al., 2015). These rules impact both living animals and animal originated products. According to this regulation ruminant are not allowed to consume animal protein from mammals and strict monitoring of the TSE risk and a common definition of TSE risk throughout Europe. Additionally, Annex IV prohibits the use of protein containing by-products as feed for fish and livestock. When these by-products are harmless, unnecessary food is wasted. Again, food safety is prioritized over food waste reduction.

Directive 2000/29/EC from 8 May 2000.

Description: This directive focusses on controlling the spread of invasive organisms on plants (Vittuari et al., 2015). Currently, when plants are found contaminated, the entire collection is send back or destroyed causing food waste. Yet again food safety is deemed more important than food waste reduction.

Regulation (EC) No 258/97 of the European Parliament and of the Council from 27 January 1997.

Description: According to this regulation new foods need to be approved, even though the products are already eaten outside of Europe (Vittuari et al., 2015). This regulation does not necessarily imply food waste, but more inefficient resource management.

Council Regulation (EEC) No 315/93 from 8 February 1993.

Description: This regulation determines determines the maximum limit of unintentionally substances which are added to food (Vittuari et al., 2015). When the maximum limit is exceeded, the whole batch is discarded due to the zero tolerance attitude. Yet with better detection mechanisms not everything has to be thrown always and food waste could be reduced.

Regulation (EC) No1069/2009 of the European Parliament and of the Council from 21 October 2009.

Description: this regulation contains the regulation regarding animal by-products in order to reduce public and animal health risk to a minimum (Vittuari et al., 2015). It prohibits the use of food waste in certain situation as the feeding of kitchen waste to animals as this could lead to animal diseases. This could lead to food waste generation. This was also indicated by many of the respondents. Yet, these regulations seem to exist for a reason as some animal by-products, even though they are not intended for human consumption could leas to TSE especially in cows. These animal diseases do not solely impact animal welfare, but also the socio-economic situation of the farmer as farmers lost many cows during the bovine spongiform encephalopathy.

Regulation hindering the prevention/reduction of food waste.

Commission Regulation (EU) No 849/2010 from 27 September 2010.

Description: This regulation indicated the waste reporting to Eurostat (Vittuari et al., 2015). While it does not effect food and food waste directly, it indirectly helps to monitor the effectiveness of EU policies regarding food waste. Yet, as was shown in many of the conducted interviews, there is a lack of information and this should be improved. It seems that this regulation should be made stronger and include monitoring.

Regulation No 2150/2002 of the European Parliament and of the Council from 25 November 2002 on waste statistics.

Description: This regulation was adopted in order to establish a common framework for disposal, recovery and generation of waste (Vittuari et al., 2015). Through this framework, accurate statistics on waste can be gathered. However, interviews with key actors from the supply chain argued that there is no clear definition of food waste and therefore there is no accurate data available on food waste. Estimations of the size of the problem are thus hard to make.

Commission Regulation (EC) No 1639/2001 from 25 July 2001.

Description: This regulation actually implements another regulation; Council Regulation (EC) No. 1543/2000 which is developed in order to establish a common framework on the collection and management of data regarding the implementation of common fisheries policy (Vittuari et al., 2015). However, data on discards of fish is not accurate and the reason why is not clear.

Commission Regulation (EU) No 142/2011 from 25 February 2011.

Description: This regulation sets the requirements for (1) animal by-products and animal derived products which are not meant for human consumption and (2) exemptions in samples of the veterinary checks at the border which were included in Directive 97/78/EC (Vittuari et al., 2015). The regulation regards the discards of by-products. When these rules are too strict it could lead to food waste. Many respondents indeed argued that these rules were too strict. Materials early on in the supply chain are characterized as by-products, hence can be used again. Later on in the supply chain, the exact same material is characterized as waste. Reducing the strictness of these rules could lead to food waste reduction.

Directive 2010/75/EU of the European Parliament and of the Council from 24 November 2010.

Description: This directive combines 7 different industrial emission directives into a single one. The general aim of this directive is to reduce polluting industrial emissions in order to protect the environmental health (Vittuari et al., 2015). One of the core ideas of this directive is to reduce waste, and when waste avoidance is not possible, recovery should be stimulated over disposal. However, in practice the reduction of food waste through composting is not included in the industry obligations of enhancing energy efficiency.

Council Directive 1999/31/EC from 26 April 1999.

Description: This directive includes the regulations that aim to prevent or reduce the negative environmental impacts from landfilling. A target was set to reduce the bio degradable waste, of which food waste accounts to, with 65% by 2016 compared to the 1995 levels (Vittuari et al., 2015). One drawback of this direction is that there are no specific rules set on the methods for this reduction. Many member states tend to favour incineration instead of reusing the food waste for new food, which is more energy efficient when looking at the waste pyramid. For this reason, this directive is not necessarily generating waste, but it inhibits waste reduction.

Council Directive 85/374/EEC from 25 July 1985.

Description: This directive determines that the producer is responsible bad and harmful products (Vittuari et al.,2015). This could generate food waste as producers might not want to face reputation damage of pay compensation fees. However, in article 7 of this directive an exemption is made for food producers "if the product is not distributed by in in the course of business", which is the case with food donations (Vittuari et al., 2015:32). Thus national product liability rules do not apply on food donations.

Council directive 2006/112/EC from 28 November 2006 (O' Connor, Cheoldus & Jan, 2014).

Description: This directive states that that food donations will be taxed when they are made by a person that is in fact taxable. Additionally, the VAT on the purchase of the food must be partially or fully deductible. What is further mentioned is that tax exemptions on food are not allowed. (O' Connor et al., 2014). The Value Added Tax (VAT) prohibits waste reduction through donations (Vittuari et al., 2015, 2013). The VAT places taxes on food donations which makes it more economically interesting to discard the food waste and energy will be lost. However, the market value of the VAT differs per country as in some countries when the product is unsellable, the price is zero, hence a zero tax is to be paid by the donor. In other countries the product can still be sold and have the original market value and the vat is calculated on the original price. This leads to producers, retailers and the hospitality sector opting for waste discard instead of donations. This is mainly due to variation of terminology in legal texts which opens the door for different interpretations (O' Connor et al., 2014).

B.8 Regulatory barriers for the circular economy: Lacking legislations for access to discarded electronic products that would allow preparation for reuse

B.8.1 The product and its value chain

Description of the product/activity

The role of reuse and preparation for reuse in a circular economy has been significantly strengthened by the five-step waste hierarchy; these concepts are inter alia mentioned by the Roadmap for a Resource Efficient Europe as two of the key strategies to increase resource efficiency in Europe. Reusing products or components enables to maintain the natural and financial resources that have imbedded into them during the production process. Against this background reuse, repair or remanufacturing are core elements of the "inner circles" of a circular economy. Over the past few decades, repair and reuse of used products has been stabile on a rather low level (Poppe 2014) - mainly due to the increasing complexity of products along with shorter innovation cycles leading to a rapid loss in value of products. However, just recently the interest in reuse has increased significantly – together with innovative approaches and new business models to overcome "linear product systems of produce-use-throw away".

Directive 2008/98/EC, Article 11.1 of the European Parliament and of the Council of 19 November 2008 - the Waste Framework Directive states that m*ember states "shall take measures, as appropriate, to promote the reuse of products and preparing for reuse activities, notably by encouraging the establishment and support of reuse and repair networks, the use of economic instruments, procurement criteria, quantitative objectives or other measures."*

Basic definitions for reuse and preparation for reuse are given in the Waste Framework Directive:

- 'reuse' means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived;
- '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 can be reused without any other pre-processing;

Value chain and life cycle of the product/activity

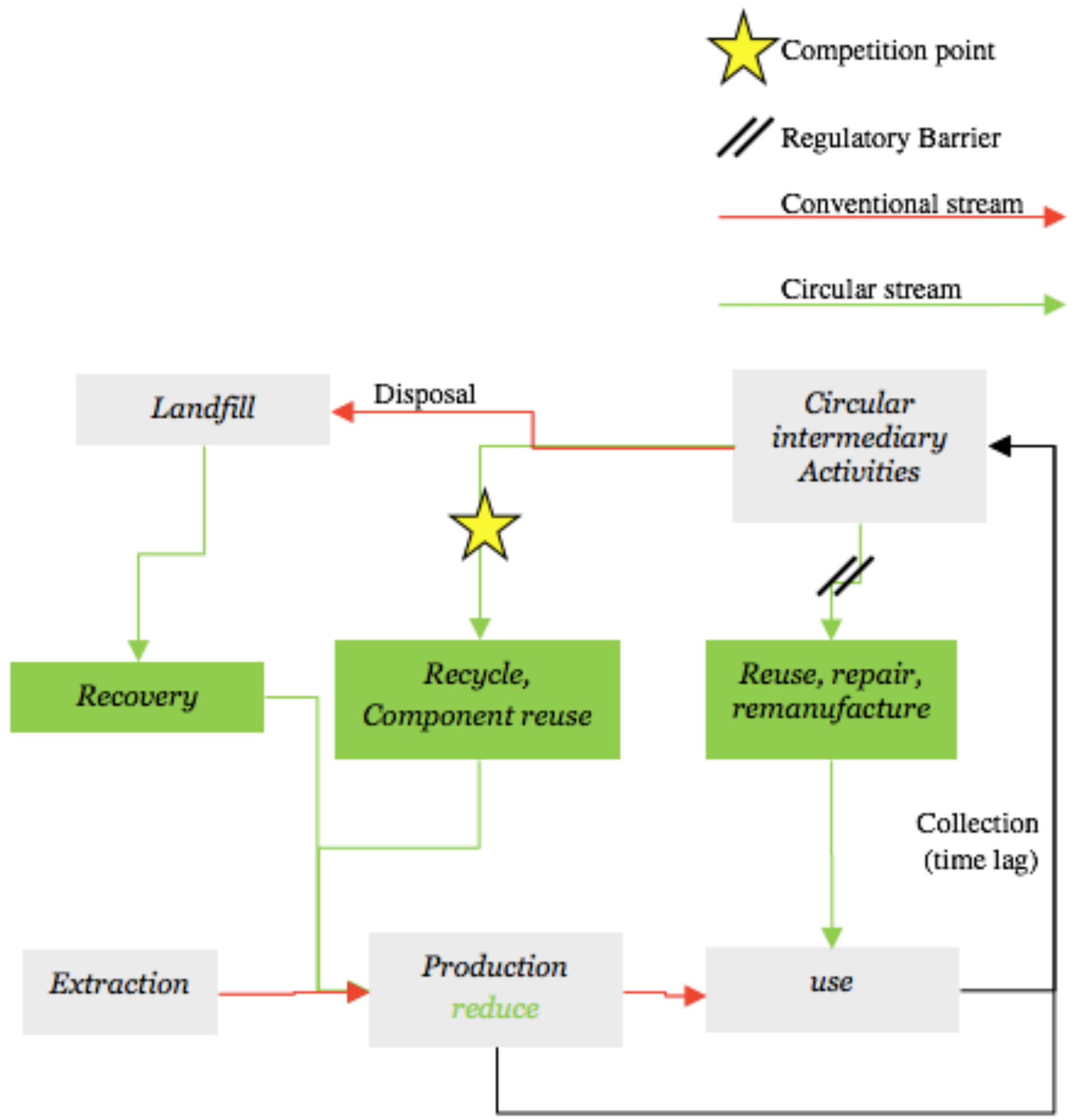
Repair of WEEE (Waste Electrical and Electronic Equipment) has the goal to return products that at their end of their life cycle to the market and create so a secondary life cycle for the product. This could in theory reduce the overall demand for products, as well as reduce the amount of products, which go to waste for treatment and disposal. Reusing products and components is seen as one of the key strategies in the transition towards a circular economy – in contrast to recycling, reuse offers opportunities to extend the use phase of products and thus to conserve the physical assets of raw materials as well as the energy embodied in these products. Inter alia the 7th Environment Action Programme calls for measures to 'further improve the environmental performance of goods and services on the EU market over their whole life cycle'. This should include 'optimising resource and material efficiency, by addressing inter alia recyclability (...) and durability'.

Although reuse and preparation for reuse seem to be high on the political agenda, the conceptualisation remains rather vague – very different activities such as individual sales via flea markets or organised waste management and third sector activities seem to be covered by these terms. Due to the lack of consensus on a conceptual framework, it is so far very difficult to describe the actual relevance of re-use and preparation for reuse in specific waste regimes or to assess progress in moving up the waste hierarchy from disposal and recycling to reuse or prevention.

Reuse is of special relevance for electric and electronic equipment (EEE), ranging from electric household appliances such as washing machines, fridges and lamps to electronic equipment such as computers, mobile phones, electronic toys and smoke detectors. The use of EEE is an integral part of modern Europe, both in the private and in the working sphere. Waste electrical and electronic products (WEEE) is one of the major potential sources for an increased recovery of critical materials and one of the fastest growing fractions of municipal solid waste. Considering the multitude of actors and products, the rapid changes of technology, product design and related material composition, as well as the rather opaque life cycle chains, WEEE is also one of the most complex waste fractions in terms of its highly heterogeneous mix of materials. Essential constituents of much EEE include precious metals (gold, silver, and palladium) and special metals (indium, selenium, tellurium, tantalum, bismuth, antimony) (cf. Chancerel 2010). Today, as many as 60 different elements are used in fabricating integrated circuits. A large number of these elements are used as compounds or alloys with other elements and exhibiting unique electrical, dielectric, or optical properties but which can pose an insurmountable challenge for recycling processes.

The two alternative flows in this case study are virgin and reused products. Obviously these two types of products have significant differences, especially when it comes to the “status value” of high quality brands. Nevertheless, they fulfil more or less the same functions so that second hand, repaired products can be seen as “circular alternative” for virgin products. Electric and electronic equipment are a quickly growing consumption area. In 2011, EU-27 consumers spent on average 5.6 % of their budget on EEE, up from 2.3 % in 1995. The total market size of electronic products in Europe is estimated at about 640 billion Euros (Produktion 2014). The alternative of second hand products is much harder to estimate. According to Eurostat the recent overall reuse rate can be estimated at a maximum of 1% of collected WEEE and differs significantly between the member states as well as product groups.

Figure 21 The circular value chain for the reuse of electronic products



Source: Own illustration

Per step in chain: actors and their relation with connected actors

Actors in this field include producers of electronic products, WEEE collectors, often including municipal waste management companies, companies in the field of sorting and pre-treatment of WEEE, e.g. Remondis, Veolia or Suez and specific companies focussed on the preparation for reuse of discarded electronic products (organized inter alia in the RREUSE association).

- Design and production

The design of electronic products plays a key role for the preparation for reuse: The reparability of a product predetermines the time and thus costs for repairing a product. Within this case study several actors in the repair sector stated that it has become more and more difficult to repair white goods, the older products were much easier to repair for the centre, but now with increasing electronic systems in place the preparation for reuse becomes much more challenging. Also it is reported that the construction of many products moved from system that use screws and bolds that could be replaced to adhesive bindings that cannot be removed quickly. Therefore, many of the centres think about stopping reuse activities with white goods and focus on smaller electric items, like smartphones, tablets, and laptops, which require less storage space.

- Repair and upgrade options (including technology available)

Against this background the actors in the field of preparation for reuse stated that hardly any complete repair of WEEE is done. The activities conducted by are more about the preparation for reuse, such as cleaning, maintenance, and check of product functionality. A complete repair process would mostly be too expensive/time consuming to consider.

- End-of-life options of product

The management of discarded products is regulated by the EU WEEE Directive and foresees a mandatory check for reusability of all products. Due to several barriers for an economically viable preparation for reuse, these checks often stay on a rather superficial level. WEEE recycling technologies exist for almost all discarded products and achieve high recovery rates for many raw materials contained in the products.

- Collection system

Collection schemes for discarded products are organized at the municipal level and run in very different ways: bring systems with recycling centres; collection bins in public spaces or private institutions etc.; but in most cases pick up systems in combination with bulky waste. Often valuable discarded electronic products are picked up by illegal scavengers and even if not they´re often managed together with the bulky waste. Especially the handling of TV sets can lead to broken screens with the consequence that for health protection reasons discarded products can´t even be tested for reusability. In only very few cases reuse organisations are granted access to discarded products in order to test them.

- Market aspects

As described above the collection discarded products together with other waste streams leads to mixed waste fraction for which a separation and testing of electronic products is under no circumstances economically viable. On the other hand, the European RREUSE association states that more than four times of second hand products could be sold on the market – taking into account cost savings of around 30-50%.

- Quality aspects

Quality aspects especially matter with regard to quality standards of repaired products. This represents a barrier at the interface between reuse organizations and private consumers and against this background several organisations already work on the establishment of credible quality standards. Such examples can be found throughout Europe including the Furniture Reuse Network in the UK which have devised the first UK Reuse Quality Management System, 'Approved Re-use Centre' (ARC) network, plus standardised WEEE reuse guidance in the FRN publication 'Fit for Reuse'. There also exist a number of quality guarantee labels including Revisie (Flanders) and ElectroREV (Brussels and Wallonia). ENVIE, who collect and treat 25% of all WEEE in France also have dedicated systems for traceability for what goes for reuse and what for recycling.

Table 52 Indicative economic values / trends

Type	*Value + Unit*		*Comment*
	Company 1	**Other sources**	
Current price situation (materials, please indicate country/region of reference)	Ca 7 Euro per product	WP 1	

Expected cost-price ratio (due to use of sec. material instead of primary)	Ca 30%	WP 1	
Revenue cuts or potential business losses caused by existing legislative barriers	Ca 300.000	WP 2	
Cost of non-action			
Additional indirect costs caused by legislative barriers (human resources, external consulting, research, …)	-	WP 2	
Investment costs to increase circularity	low		
Any other identified costs	medium		Costs would occur in the organization of the collection schemes (two separate systems) and due to lower amounts of recycled products.
Environmental impact (e.g. higher cost due to higher emissions)	significant		Compared to recycling, reuse would achieve significantly better environmental results.

B.8.2 Regulatory barriers

Table 53 Overview of regulatory barriers

Main Barrier	*Affected department (s)*	*Effect*	*Possible (legal) solution*	*Barrier identifier*
Lacking legislations for access to discarded electronic products that would allow preparation for reuse	Repair and second hand sales	Reduced amount of inputs	Priority access and enforcement of mandatory testing for reuse or reparability	Company 1-3
Additional barriers (other barriers mentioned as important): Implementable design legislations for reparability	**Product design**	**Non-repairable products**	**Concretisation of so far too vague design requirements**	Company 1-3

Source: Own compilation.

Main barrier identified

Description of barrier

Regarding the access to waste streams article 6, paragraph 2 WEEE directive states that "In order to maximize preparing for reuse, Member States shall promote that, prior to any further transfer, collection schemes or facilities provide, where appropriate, for the separation at the collection points of WEEE that is to be prepared for reuse from other separately collected WEEE, in particular by granting access for personnel from reuse centres. Nevertheless, reuse organisations are restricted from accessing collection points. To be able to access high quality goods for reuse the organisations need to close contracts with local authorities or other responsible collecting institutions. Especially for small organisations this can be already a difficult challenge, as it requires approaching and convincing the local decision makers to change their process. On the other side it is also important to only allow reliable organisations to access materials for reuse, as also a strong informal market is active in this field all over Europe. The main change required for reuse is the separate collection at waste centres; many places have already adopted this and provide specific containers where products can be placed, if they are still functioning well. In some cases, organisations involved in reuse also face barriers to access materials due to required licensing as waste management company allowed to process waste (in German "Erstbehandler"), even though the organisations do not intend to process waste, but just prepare the products for reuse.

Solutions proposed

Regarding access for reuse some solutions was mentioned in Flanders. Here collaboration between reuse centres and take-back schemes for extended producer responsibility was found. First both parties felt in this collaboration as in a "forced marriage"; nevertheless, both parties now see the already the benefits of the collaboration. In Flanders the members of the regional reuse network Komosie now have better access to high quality products, which can be resold, in their shops, while the take-back scheme reduces its cost for treatment. Though it is expected that the reused products lifetime is only extended for a little bit further, but at a later point still have to be recycled.

Additional barrier 1

Description of the barrier

Article 4 WEEE directive states that Member States shall take appropriate measures so that the Eco design requirements facilitating reuse and treatment of WEEE. Nevertheless, these regulatory requirements are not precise enough to control access to the European market so that Europe is experiencing a flood of cheaper and poorly designed products on the market. This barrier of design legislation was confirmed in the interviews with reuse centres. For them it has become more and more difficult to repair white goods, the older products were much easier to repair for the centre, but now with increasing electronic systems in place the preparation for reuse becomes much more challenging. Also it is reported that the construction of many products moved from system that use screws and bolds that could be replaced to adhesive bindings that cannot be removed quickly. Therefore, many of the centres think about stopping reuse activities with white goods and focus on smaller electric items, like smartphones, tablets, and laptops, which require less storage space.

Solutions proposed

In order to promote a better design of especially electronic products the European Commission within its Circular Economy Action Plan aims to emphasise circular economy aspects in future product design requirements under the Eco design Directive. To date, Eco design requirements have mainly targeted energy efficiency; in the future, issues such as reparability, durability and inter alia upgradability will be systematically examined. As a first step, and under the framework of the Eco design directive, the Commission has developed and will propose shortly to Member States mandatory product design and marking requirements to make it easier and safer to dismantle, reuse and recycle electronic displays (e.g. flat computer or television screens).

B.8.3 Technological, economical, financial and value chain barriers

The following table summarizes additional economic barriers that have not been in the focus of this study but nevertheless closely linked to specific legislations.

Table 54 Overview of technological, economical and value barriers

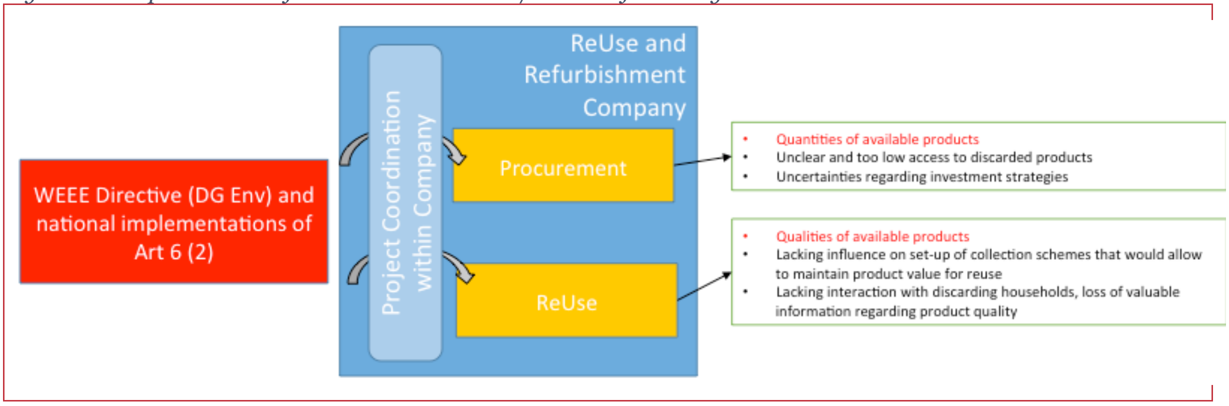
Barrier	**Nature of the barrier (e.g. technological)**	**Affected department**	**Effect**	**Possible (legal) solution**
Purchase of comparable new products often cheaper than repairing, especially taking into account on-going functionality improvements	Economical/ value chain	Reuse organisations	Focus on primary products and recycling of WEEE as preferable option.	
Legal and illegal export of used and waste electronic products	Economical/ value chain	Reuse organisations	Lacking input for reuse organisations.	Stricter monitoring of waste flows.

B.8.4 Impact scheme for the actor

The following figure illustrates the main impacts from the regulatory barrier for circular economy identified in this case. Lacking legislations for the access to discarded products has two key impacts on reuse as one of the key circular activities:

- impact on quantities: less than useful amounts of products are prepared for reuse
- impact on qualities: collection schemes are set up in a way that leads to the loss of information concerning product qualities. This leads to high transaction costs (e.g. testing of products for functionality) and threatens the economic viability of the business model

Figure 22 Impact scheme for actors in the reuse/ remanufacturing sector



Supporting reuse seems especially beneficial with regard to potential job creation: Estimations based on the reuse network in Flanders show that for 10,000 tonnes of waste products and materials, 1 job can be created if incinerated, 6 jobs if landfilled, 36 jobs if recycled, and up to 296 if refurbished and reused. A recent study by the European Environment Bureau cited by RREUSE (2015) suggests that with ambitious reuse targets, 300,000 jobs could be created in Europe just in this sector.

B.8.5 Interviewees

Sector	*Position*	*Organisation*	*Location*
Reuse	Coordinator/ consultant for Austrian reuse networks	Pulswerk	Austria

Sector	*Position*	*Organisation*	*Location*
Reuse	Coordinator of a German reuse network	Recyclingbörse Herford	Germany
Remanufacture	Public Affairs	Private remanufacturing company	Germany

B.8.6 Bibliography

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Chancerel, P (2010): Substance flow analysis of the recycling of small waste electrical and electronic equipment - An assessment of the recovery of gold and palladium. Dissertation. Technische Universität Berlin.

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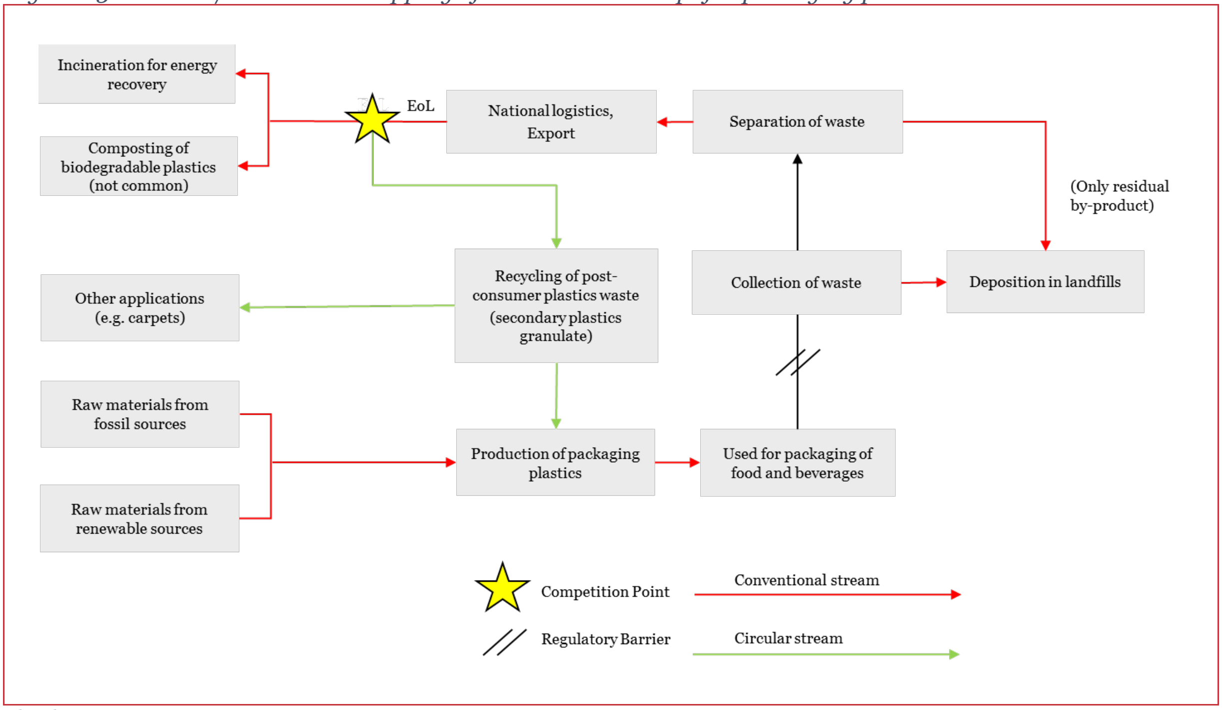
B.9 Recycling of packaging for food and beverages – plastics and polymers

B.9.1 The product and its value chain

Figure 23 Material/value chain mapping of the circular concept for packaging plastics



thinkstep

Description of the product/activity

Plastics are valuable materials used in a wide range of applications in everyday life. Since 1950, global as well as European plastic production has been continuously growing. In 2012, Europe had a share of 20 % in the global plastics production, representing 57 million tonnes of produced plastics. Today, Asia, especially China, is the biggest growing market worldwide. (Plastics Europe, 2013) The global plastic packaging market was 78.4 mega tons in 2013, corresponding to a value of about US$ 260 billion in 2013. Plastics packaging for food and beverages represent the biggest application market share of plastics packaging (65 %). (Transparency Market Research, 2015). Parallel with a steadily increasing plastics packaging production, the amount of post-consumer plastics has been growing as well. In 2012, European countries produced 25.2 million tonnes of plastics waste. With a share of 62.2 %, packaging consisting of different plastics such as Polyethylene (PE), Polypropylene (PP) and Polystyrene (PS) is the dominant fraction.

Although plastics are almost fully recyclable, (European Commission, 2013) only a small share of plastics waste is currently recycled. In 2012, only 26 % of the total post-consumer plastics waste (including plastics packaging for food and beverages) was recycled, meaning that the largest share was either incinerated for energy recovery (36 %) or sent to landfill (38 %) (Plastics Europe, 2015). Only half of the collected and recycled plastics waste is managed by European facilities; the rest is exported, mainly to China. (Velis, 2014) This leads to an actual post-consumer plastics waste recycling quote of only 13 % in Europe. This rate is far away from a resource efficient "circular economy" scenario. According to the Waste Framework Directive, the target for recycling of plastics is 50% by weight in 2020. (European Union, 2008).

Value chain and life cycle of the product/activity

Plastics are derived from organic materials which can either be fossil or renewable resources. Since organic substances, especially crude oil, consist of a complex mixture of compounds, they have to be processed in order to extract the useful components for plastics production. The two major processes used are polymerisation and polycondensation, both requiring specific catalysts. Three different types of plastics can be produced: thermoplasts, duroplasts and elastomers. Thermoplasts can be recycled and used many times; they are the most common polymers in use. The plastics are used in a huge field of applications, in this study the packaging plastics for food and beverage are considered, since they represent the biggest share in produced plastics waste in Europe.

Per step in chain: actors and their relation with connected actors

- Design and production

Product design for recycling as a strong potential to assist in recycling efforts. (Hopewell, 2009) For example, it is reported that flexible packaging for children's drinks (made by fusing together different materials) is of growing concerns since it cannot currently be recycled. (MacKerron, 2015) Multi-layer packaging, consisting of different thin material layers are complex to sort and their treatment is complex. Growing distribution of flexible packaging and the use of multi-layer packaging plastics are seen as challenges to increase recyclability of packaging material. Recycling could be possible if flexible and multi-layer plastics were made of one single type of plastics, but this is not easy to achieve from a technical perspective. Multi-layer packaging can be treated by pyrolysis procedures. Pyrolysis can be used to re-transform plastics into oil by de-polymerization, which again can be used to produce plastics or fuel, for example diesel. However, it has also been mentioned that for recycling multi-layers packaging, additional chemicals such as modifiers and stabilizers would be necessary to protect the chain of polymers during thermo stress and mechanical stress activities, which is expected to lead to a faster "down cycling" of materials when compared with other packaging types.

On the other hand, it has been mentioned that flexible, non-recyclable packaging can help to prevent waste and save primary material more effectively, even if it has to be incinerated at its End-of-Life. For the production of flexible plastics, significantly less material is needed, therefore, also the generated waste amount is lower.

There are different perspectives over this topic and in order to ensure that all the aspects are considered, it is necessary to use a holistic perspective and to consider not only the End-of-Life, but all the phases of the life cycle of the packaging, analysing case by case what is the best option.

- End-of-life options of product

Since packaging for food and beverages accounts for the highest share of the consumer packaging, in terms of wastes stream, this will also be the main origin.

Plastics which are not economically viable to be recycled or separated or those which enter the fraction of undifferentiated wastes are usually incinerated. However, it was mentioned that incineration of plastics has a benefit associated, as the plastics can substitute other fuels. Due to their high calorific value and good flammability, mixed plastics waste can partially be used to substitute coke in furnaces or natural gas in the incineration of residual waste (residual waste has to be incinerated by law but contains a lot of water. To obtain a proper combustion, additional natural gas is often used to fuel the incineration process).

- Collection system

It was mentioned that collection schemes vary within the EU. In some Member States (MS), the collection of different materials like paper, metal, plastic and glass is not very efficient, whilst in other countries the efficiency is higher

For example, in Germany, the so-called "Duales System Deutschland" (DSD - German Dual System) collects, sorts and recycles post-consumer packaging (plastics, glass, paper, etc.) from households and industry. The DSD is a commercial industry and operates in conjunction with the already existing public waste management structure in Germany, what gave the dual system its name. It was set up as a result to the packaging law passed in 1991, which requires manufacturers to take care of the recycling or disposal of any consumer packaging material they bring into the market. This system presents an effective and legislative form of Extended Producer Responsibility. DSD only collects packaging materials, which are labelled with a “green dot” (or other labels), showing that manufacturers pay a license to finance the DSD. The packaging waste with the according labels is collected in yellow bins or yellow bags and is afterwards sorted in DSD facilities. (Der Grüne Punkt - Duales System Deutschland) This system is also established in other Member States, but not always to the same extent.

In general, even though the European Waste Framework Directive favours the recycling of materials, the greatest share of the plastics waste (74 %) goes to landfills or incineration. (Plastics Europe, 2015) For example, in Germany, incineration is favoured by the so-called “Heizwertklausel” (Caloric Value Clause) – it will be no longer valid from the beginning of 2017, but has been in place. Additionally, to the low recycling rates, only half of the collected and recycled plastics waste is managed in Europe, the rest is exported, mainly to China. (Velis, 2014)

Collection and sorting are in some cases not completely structured, not standardized and lack transparency, which leads to unpredictable quantity and quality of recycled plastics creating challenges to establish economic viable recycling capacities and uncertainties to long-term investments.

- Market aspects

One of the interviewees mentioned, that landfilling and incineration receive large MS subsidies, whereas collection and recycling do not receive as much. According to this interviewee, this represents an important market barrier, hampering the recycling of plastics.

It was also reported that, due to the high costs for collection and separation of plastics waste, the recycling of plastics cannot be uphold by itself as collection costs more than the value of the collected material. Only relatively high “Grüne Punkt” (Green Dot) fees were mentioned to enable the profitability of collection and sorting of plastics. Those fees are paid by manufacturers, which are bringing their products on the market. This represents a form of the Extended Producer Responsibility (EPR), since producers pay for the recycling and collection of plastics waste, financing it through the fees (which in turn are passed over to the customers).

- Quality aspects

Usually, the quality of secondary plastics is subject to fluctuations. Used plastic material cannot simply be recycled as sourced from mixed municipal plastic waste streams of unknown origin: the sorting technology defines the purity of the material to a significant extent. After various sorting and separating processes, the material is further purified by filtration and degassing. To obtain the desired properties, it is necessary to reprocess the material with a highly optimised re-compounding system. To ensure that the final product is not a surrogate low-quality material, it is necessary to modify it and upgrade it, so that it fulfils the requirements for extended material life. Packaging made of secondary plastics was mentioned to have a quality comparable to new material and can be recycled and used for different applications many times, as long as it is sorted and recycled with appropriate techniques.

Table 55 Primary / secondary material streams and volumes

Type	***Value + Unit***	***Comment***
Total primary production	285 million tonnes worldwide in 2012 57 million tonnes in Europe in 2012 (share of 20 %)	Referring to total plastics production, not only to packaging plastics (packaging plastics has a share of 39.4 % of produced plastics)
Total secondary production	One of the interviewees reported to produce 30.000 tonnes annually 6.6 Mio. tonnes total plastics waste in 2012 in Europe (3.2 Mio. tonnes recycled in Europe)	From 25.2 million tonnes produced total plastics waste in Europe per year, only 26 % was collected for recycling and only the half is recycled in European facilities, leading to 13 % recycling quote for Europe in 2012

	5.6 Mio. tonnes packaging plastics waste in Europe.	Packaging waste has a share of 62 % of generated total plastics waste (equals 15.6 Mio. tonnes). 36 % of packaging plastics have been recycled (equals 5.6 Mio. tonnes).
Total demand	Demand for secondary material is given and exceeds the supply PET, PE, PP show the highest demand in European packaging plastics market Demand for high qualitatively secondary plastics is lower than for primary due to higher prices of recycled plastic of high quality	–
Recyclability (how much sec. material can be incorporated)	60 % (dependent on collection and sorting quality)	The remaining 40 % cannot be recovered and end up as waste
Potential max. secondary supply	60 – 80 % 62 % recycling quota total plastics (equals 15.6 Mio. tonnes) 82 % recycling quote for packaging plastics (equals 12.5 Mio. tonnes)	Current recycling performance: Total plastics: 26 % Packaging plastics: 36 %
EU share of prim. /sec. production	20 % share in worldwide primary plastics production	Worldwide secondary production unknown

Table 56 Indicative economic values / trends

Type	*Value + Unit*	*Comment*
Current price situation (materials, please indicate country/region of reference)	Recycled plastics of high quality used for high quality applications are often more expensive than primary plastics. 367 € per tonne average price for plastic waste (2013) Primary Plastic [€/kg]: PE: 0.93 PP: 0.95 PS: 1.07 Secondary plastic [€/kg]: PE: 0.80 - 0.82 PP: 0.86 PS: 0.99	The market price for secondary plastics is lower than for primary (7 – 20 % cheaper) in 2015 Crude oil price is of high importance, since it influences the market with a time shift
Expected cost-price ratio (due to use of sec. material instead of primary)	Cost savings could be in the range of 10 %	Derived from the price difference per kg above
Revenue cuts or potential business losses caused by existing legislative barriers	None Secondary plastics can be produced at significantly lower price level than primary material	–
Cost of non-action	900 Mio. € cost savings for total plastic per year 700 Mio. € cost savings for packaging plastics per year	Calculated for 62 % recycling rate for total plastics and 80 % recycling rate for packaging plastics with numbers for 2020 Here, a price difference of 0.10 € per kg was used (10 % savings, see above)
Additional indirect costs caused by legislative barriers	Landfill costs (gate fees and landfill tax) for deposition of plastics waste. Varies strongly between MS.	Examples: Bulgaria: < 5 €/ton Sweden: > 150 €/ton

(human resources, external consulting, research, …)		
Investment costs to increase circularity	In the range of billions of euros	–
Any other identified costs	Increasing recycling of post-consumer waste, consisting in parts of multi-layer, could lead to higher treatment costs (direct costs) and could impair the quality of other (cleaner) materials (indirect costs) Recycling was mentioned to create about 10 times more jobs per tonne than sending waste to landfill or incineration. Increasing of the recycling sector is an opportunity for states to reduce their social spending (jobs creation).	–
Environ-mental impact (e.g. higher cost due to higher emissions)	Less littering and plastic debris in oceans if more plastics are recycled Less exploitation of fossil resources for the production of primary plastics needed, if recycling rates are increased. Less pollution of the environment with plastics waste (reduce the littering and plastic debris)	–

B.9.2 Regulatory barriers

Within the previous work in this project, as main barrier was identified the "lacking implementation of waste hierarchy that hinders the material recycling of plastics or even favours incineration".

Table 57 Overview of regulatory barriers

Main Barrier	*Effect*	*Possible (legal) solution*
Lacking implementation of the waste hierarchy (Directive 2008/98/EC on waste - Waste Framework Directive - WFD)	A large part of post-consumer plastics waste ends up in energy recovery and landfilling instead of being recycled	Ban landfilling of plastics Identify main sources of insufficiencies / inefficiencies in collection systems in EU Establish clear requirements / standards for collection systems in EU (e.g. mechanisms to separate plastics to recycle and incinerate)
Additional barriers (other barriers mentioned as important)	*Effect*	*Possible (legal) solution*
Insufficiencies in collection systems of recyclable material	Plastic waste is collected at low rates and once collected, the separation process is complex	Insufficiencies in collection systems within the EU need to be identified and harmonized in order to increase the amount as well as the quality of material collected for recycling
Missing guidance for eco-design	Lower recycling rates because of plastics designs which are challenging to sort /treat (e.g. multi-layer plastics)	Holistic perspective throughout the whole life cycle of the plastics
Insufficient recycling targets and lacking descriptions of actions in legislation	Target setting in Waste Framework Directive 2008/98/EC does not specifically address packaging plastics (household) Collections rates for materials with low quantities on the market (e.g. bio plastics) are considered low (0.1 %)	Consider the entire life cycle of a material and use technical studies with comparisons of options to support policy decision making. Consider also the materials with low shares on the market

	Focus of legislation is too much on recycling; waste prevention is even more important and sometimes overseen	
Potential lack of technical practicability (the new Circular Economy package from the European Commission states, that in case it is not technologically feasible, the waste does not have to be collected and recycled)	This is mentioned as an aspect that leaves room for different interpretations and could lead to a lack of motivation with the argument of 'lack of technical practicality'.	As solutions, there have been mentioned incentives for MS with regard to the recycling of wastes of plastics with lower shares in the market and the development and explanation of mechanisms

Main barrier identified

Lacking implementation of the waste hierarchy (Directive 2008/98/EC on waste - Waste Framework Directive - WFD)

The waste hierarchy favours recycling of waste over incineration and deposition. The re-use is in some cases overlooked. The lacking implementation of the waste hierarchy in Europe cannot be assigned to a single source but to a broad variety of different issues, including the policy background of the different MS, missing guidance for eco-product design of packaging, insufficiencies in the collection systems, insufficient recycling targets and regulation for plastics exports. All these barriers influence the recycling of plastics.

Solutions proposed

As mentioned in the table, the main solutions proposed involve: ban the landfilling of plastic; adjust Waste Shipment Regulation; identify and improve the main sources of insufficiencies / inefficiencies in collection systems in EU; establish clear requirements / standards for collection systems in EU (e.g. mechanisms to separate plastics to recycle and incinerate).

Additional barrier 1

Insufficiencies in collection systems of recyclable material

One of the interviewees mentioned, that landfilling and incineration receive large MS subsidies, whereas collection and recycling do not receive as much. According to this interviewee, this represents an important barrier, hampering the recycling of plastics. Due to different and, in some cases insufficient/inefficient collection schemes within the EU, a large part of post-consumer plastics waste ends up in energy recovery and landfilling instead of being recycled.

Additionally, it was mentioned that diffuse and complex supply of collected plastic wastes leads to risks in the investments on building capacities and innovate from the recyclers.

There is a lack of a clear definition of 'collection system', as well as requirements of implementation.

Solutions proposed

It is important to identify, understand and improve insufficiencies in collection systems in order to increase the amount of material collected for recycling, as well as its quality, would help to guarantee a stable supply of waste materials and therefore also investments, innovation and capacity expansion.

Standards or guidelines for European collection schemes of plastics waste with consideration of different aspects such as combined material collection (e.g. together with metal or with glass), material treatment processes (e.g. manual or automatic sorting plant) and material ownership (e.g. local authority or recycling company) could help improving the existent schemes.

Additional barrier 2

Missing guidance on for eco-design

The design of products is frequently focused on other aspects than the recycling or 'eco' performance. For example, multi-layer plastics perform well in terms of conservation of food and beverages, but their end of life sorting and treatment is challenging. Another aspect is for example the colouring of the waste material. If sorted and recycled in the right way, packaging made of plastics can be recycled and used for different applications many times – however, there are restrictions: the main mentioned are the multi-layer packaging, the colouring and the contamination of food, drinks and other materials / substances. It was mentioned that the recycling of multi-layers involves the addition of chemicals such as modifiers and stabilizers in order to protect the chain of polymers during thermo stress and mechanical stress activities. Thus, although recycling in parts is possible, the variety of different multi-layer packaging types, each one requiring a different approach, is considered challenging for recycling activities.

According to another interviewee, given the material savings which the flexible packaging brings may be more advantageous than the recycling of plastics, even if the flexible packaging is not recyclable and has to be incinerated. A study from the German Institute for Energy and Environmental Research in Heidelberg (Institut für Energie- und Umweltforschung Heidelberg GmbH) found out that "[…] though even with a hypothetical recycling rate of 100% for non-flexible packaging the GWP [Global Warming Potential] and ADP [Abiotic Depletion Potential] results of non-flexible packaging would still be considerably higher than those of flexible packaging." (Institut für Energie und Umweltforschung (IFEU), 2014)

Solutions proposed

It is important to consider the whole life cycle of the packaging using methods such as Life Cycle Assessment (LCA), since these allow finding the 'hotspots' and understanding where shall the improvements be focused on. More guidance for eco design of products could contribute to improve the general situation of plastic packaging.

Additional barrier 3

Insufficient recycling targets and lacking descriptions of actions in legislation

The European Directive 2004/12/EC states the only valid and mandatory minimum recycling target of 22.5 % for plastics packaging which should have been implemented by all MS until 2008. (European Union, 2004). The target setting in Waste Framework Directive 2008/98/EC does not specifically address packaging plastics but puts it in a broader context: "by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight." (European Commission, 2008)

The formulated collection and recycling target of 0.1 % (by weight) regarding the materials with low shares on the market, such as bio-plastics is regarded as too low, vague, and incentives and implementation are unclear.

Furthermore, it has been mentioned that the focus of the legislation could be more on the prevention of wastes and not only on the recycling of wastes, as prevention has priority in the waste hierarchy. For example, the use of flexible plastics saves material and prevents waste. But flexible packaging is only hardly recyclable, being typically incinerated after the use phase, which is not seen as 'circular'. This is a controversial discussion and only holistic methodologies for calculating environmental impacts, such as Life Cycle Assessment (LCA), can assess which options are the most beneficial.

Solutions proposed

General collection- and recycling targets specified according to the material types could help to target also material types with lower market shares (e.g. compostable bio-based products). Although, some consider confusing and not practical to establish streams for too many materials – this is a topic of discussion.

The use of holistic methodologies for calculating environmental impacts, such as Life Cycle Assessment (LCA), can support the decision making in terms of targets.

Additional barrier 4

Plastics waste as an economic commodity

The plastic wastes are treated as an economic commodity, therefore, can be easily traded and exported. At the same time, the import of primary plastics into the European Union is subject to a duty in order to protect the domestic plastics production from competition. It is therefore considered by some stakeholders that the plastic recyclers are in a disadvantageous position, lacking base materials; primary plastic producers face a relatively comfortable position as their business is protected by duties. This was mentioned as a factor of distortion for competition between primary and secondary plastics producers within Europe.

Solutions proposed

In order to manage this issue were suggested modifications on the Waste Shipment Regulation.

Additional barrier 5

Potential lack of technical practicability

The new Circular Economy package from the European Commission states, that in case it is not technologically feasible, the waste does not have to be collected and recycled. This is mentioned as an aspect that leaves room for different interpretations and could lead to a lack of motivation to develop possibilities for making it possible with the argument of 'lack of technical practicality'. For example, for biodegradable bio-plastics, as their separation is challenging, they are typically not composted, but incinerated or landfilled.
*

As solutions, there have been mentioned incentives for MS with regard to the recycling of wastes of plastics with lower shares in the market and the development and explanation of mechanisms.

B.9.3 Technological, economical, financial and value chain barriers

Table 58 Overview of technological, economical and value barriers

Barrier	Nature of the barrier (e.g. technological)	Affected department	Effect	Possible (legal) solution
Challenges on eco-design of products	Technological	Design / production	Production of flexible packaging solutions using only one material it is not standard	Development of new designs which allow having flexible packaging made out of only one material

Insufficient recognition and handling of different types of plastics by the sorting technologies	Technological	Sorting	Higher levels of contamination of the streams to recycle	Technological developments (R&D)
Insufficient technology to recycle some types of plastics (e.g. flexible packaging, multi-layer plastics)	Technological	Recycling	Recycling is not possible	Technological developments (R&D)
Recycling is expensive and cannot be financially uphold by itself	Economic	Recycling	Less recycling, more incineration and deposition	Extended Producer Responsibility (e.g. Green Dot system)

Additional barrier 1

Insufficient recognition and handling by current sorting technology

One of the aspects mentioned has been the insufficient recognition and handling of different types of plastics by the sorting, which leads to higher levels of contamination of the streams to recycle.

Solutions proposed

Technological developments (R&D) for the sorting technologies.

Additional barrier 2

Insufficient recognition and handling by current recycling technology

Besides the sorting technologies, also the insufficient technology to recycle some types of plastics (e.g. flexible packaging, multi-layer plastics) exist.

Solutions proposed

Technological developments (R&D) for the recycling technologies.

Additional barrier 3

Recycling is expensive and cannot be uphold by itself

As pointed out by an interviewee, recycling of plastics is expensive and cannot be uphold by itself. Depending on the wished quality, the collection of post-consumer plastics frequently costs more than the value of the collected material, which makes recycling economically less attractive. The better the separation process, the higher is the financial spending and the more expensive gets the whole process. Only relatively high “Grüner Punkt” (Green Dot) fees, enable profitability on the collection and sorting of plastics - this represents a form of the Extended Producer Responsibility

Solution proposed

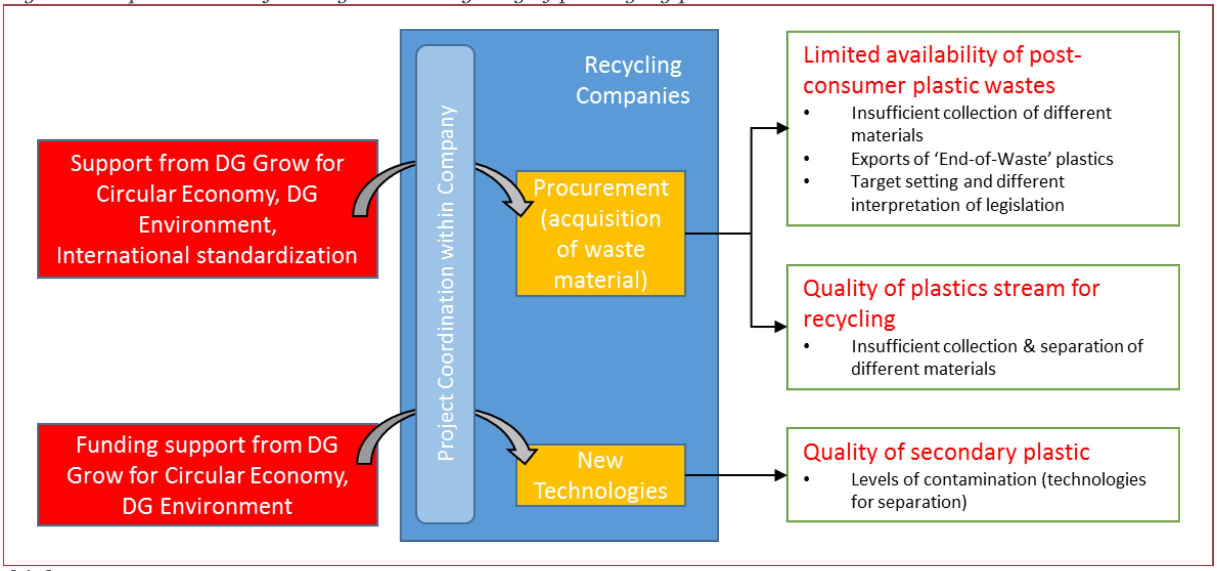
Extended Producer Responsibility (e.g. Green Dot system).

B.9.4 Impact scheme for the actor

Figure 13 and Figure below illustrate the main impacts from the regulatory barrier for circular economy identified in this case.

The schemes describe the organisations and their projects (blue box) with their business units (yellow box), which are involved in different activities, where there might be barriers to the circular economy (green box). These barriers can be overcome by adapting policy interventions into the circular economy (red box).

Figure 2 Impact scheme for recyclers – recycling of packaging plastics

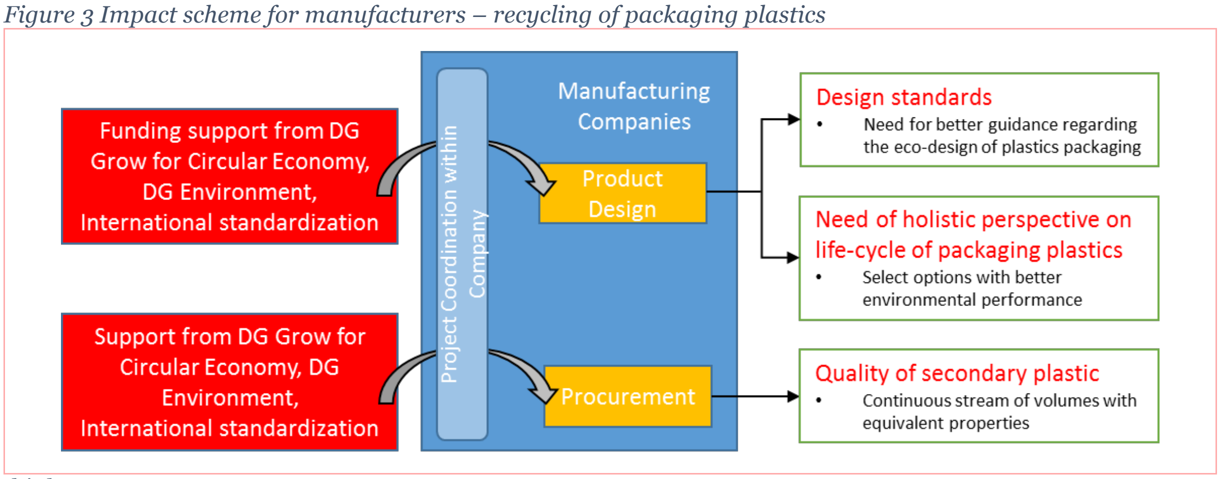


thinkstep

In summary, the following aspects concerning the recycling companies have been identified:

- **Recycling:** insufficient collection of post-consumer plastics waste as well as their exports outside the EU are considered to lead to material withdrawal for European recycling companies and therefore to limited availability for recycling companies
- **Quality**: insufficient collection and separation of different plastic streams are seen to result in material flows with high levels of contamination, leading to lower quality of secondary material
- **Technology**: in order to compensate the quality losses caused by insufficient separation, new technologies should be promoted in order to increase quality of secondary material by better sorting and the removal of hazardous substances

Figure 3 Impact scheme for manufacturers – recycling of packaging plastics



thinkstep

From the manufacturing perspective, the following aspects have been identified:

- **Product Design**: the design of products should consider the full life cycle of the product: not only the End-of-Life, but also the production phase and certainly the use (it should fit the purpose). Therefore, the product design needs better guidance from regulation regarding the eco-design of plastics packaging.
- **Quality**: the production of secondary plastics needs streams as continuous and as on a similar quality as possible. It is therefore important to improve the technologies to sorting the plastics.

Analysis and interpretation

The main barrier identified in this case is the "Lacking implementation of the waste hierarchy" and it affects the recycling companies of packaging plastics, as well as producers of materials which use secondary plastic. When considering the lack of enforcement of the waste hierarchy (from Waste Framework Directive), there are different aspects which are interlinked:

- the different policy contexts and options regarding the End-of-Life within European countries;
- target setting and different interpretations of the Waste Framework Directive (part of the reason for insufficient collection/recycling rates);
- insufficient collection/recycling rates;
- exports of plastics to outside the EU;
- need of a better guidance regarding the eco-design of products.

The policy background and options which have been decided and implemented by each country before the Waste Framework Directive have an influence on its implementation. In some European countries, the systems for collection and separation of wastes already work in relatively efficient ways, whereas in others, developments are still needed. Financial support and incentives should be considered to allow the countries where this implementation is not as developed yet.

Even though the Waste Framework Directive 2008/98/EC declares the ambitious target for common plastics waste: "[…] by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass […] shall be increased to a minimum of overall 50 % by weight.", (European Union, 2008) it does not specifically determine the recycling targets for the packaging plastics (the only valid and mandatory target for the specific plastics fraction of packaging plastics was defined by the Directive 2004/12/EC). Additionally, there are some aspects in this legislation which can be considered ambiguous: the 50 % target doesn't specify whether it concerns to re-use and recycling altogether or separately; it is not mentioned if the recycling target is related to the plastics waste produced or collected.

Insufficient recycling targets concerning innovative plastic types with smaller shares on the market (e.g. some bio plastics), have been also mentioned as an aspect to consider. Collection targets of 0.1 % (by weight) for those materials have been mentioned as too low.

The effect of insufficient supply of post-consumer plastics to recyclers has been mentioned as a key factor to be able to ensure the profitability of recycling the plastics. Typically, for a certain application and in the same degree of quality, the demand for secondary plastics is higher than for primary materials, as long as the secondary materials are cheaper than the primary. Although, the secondary materials are not sufficient to cover the total demand, therefore, the rest is covered by primary materials. If there are challenges to ensure a continuous supply of a recyclate with similar properties, this becomes also challenging to ensure the demand. Since collection schemes and separation of waste materials differ within European countries, this leads to differences in the rates and quality of the recyclate as well. So, the situation differs from country to country.

The export of plastics was also mentioned as an important aspect. Once the plastic leaves Europe, it is no longer possible to track what happens to it.

The need of better guidance regarding the eco-design of products has been mentioned as a key aspect as well, as not only the End-of Life-of the packaging solution should be considered, but the overall life cycle. Multi-layer packaging designs, as well as colouring, is recognized to make the recycling more complex, but are frequently considered important by the industry (e.g. better conservation, marketing, etc.). The Waste Framework Directive clearly favours recycling over incineration and deposition of wastes. But sometimes, its first priority is overlooked: waste prevention.

For example, in the case for plastics packaging, it is important to consider the different possibilities available, and not only focusing the End-of-Life of plastics, but the overall life cycle, including the production phase. For example, flexible packaging has been controversial and generating discussions among the different stakeholders. It is frequently regarded as a non-beneficial approach, as it is only hardly recyclable, being typically incinerated after its use phase. Supporters of flexible packaging point out, that material savings can help to prevent waste generation, leading to less resource exploitation. A study from the German Institute for Energy and Environmental Research in Heidelberg ("Institut für Energie- und Umweltforschung Heidelberg GmbH) concluded that "[...] though even with a hypothetical recycling rate of 100% for non-flexible packaging the GWP [Global Warming Potential] and ADP [Abiotic Depletion Potential] results of non-flexible packaging would still be considerably higher than those of flexible packaging." (Institut für Energie und Umweltforschung (IFEU), 2014).

This leads to the conclusion, that not only the recycling should be in the focus of a sustainable and resource efficient European Union, but that the whole life-cycle of a product should be considered in order to evaluate its environmental and economic benefit. This is also stated by the Directive 2004/12/EC of the European Union: "The operators in the packaging chain as a whole should shoulder their shared responsibility to ensure that the environmental impact of packaging and packaging waste throughout its life-cycle is reduced as far as possible." (European Union, 2004), but sometimes is not highlighted enough.

B.9.5 Description of the companies interviewed in WP3

Table 59 Overview of interviewed companies

Aspect	***Company 1***	***Company 2***	***Company 3***	***Company 4***
Name of the company	BU Recycled Resource (BU RR)	MTM Plastics (MTMP)	NatureWorks (NW)	Amcor
Industry sector	Recycling	Recycling	Production	Production
Summary of the role of the company in industry (general)	Is a subsidiary of the international environmental services and raw material provider ALBA Group. Recycling of mixed post-consumer plastics waste from households and industry collected by German Duel System and supervision of materials during their entire life chain	Recycling of mixed post-consumer plastics waste consisting of roughly 75 % of packaging waste, mainly made of Polefin. Separation of pre-sorted waste and annually production of 30.000 tonnes re-granulates.	Production of compostable and recyclable bio-based polymers, in particular polylactic acid with the brand name "Ingo" which is mainly used for packaging purposes.	Amcor is a global leader in responsible packaging solutions supplying a broad range of rigid & flexible packaging products into the food, beverage, healthcare, home and personal care and tobacco packaging industries; more than 180 sites; more than

				29.000 employees; US $ 10 Billion in sales.
Location	Germany	Germany	USA	Headquarter in Australia, Melbourne

B.9.6 Interviewees

Position	*Organisation*		
Head of Research & Development	BU Recycled Resource		
CEO	MTM Plastics		
Public Affairs	Natureworks		
Sustainability Leader	Amcor		

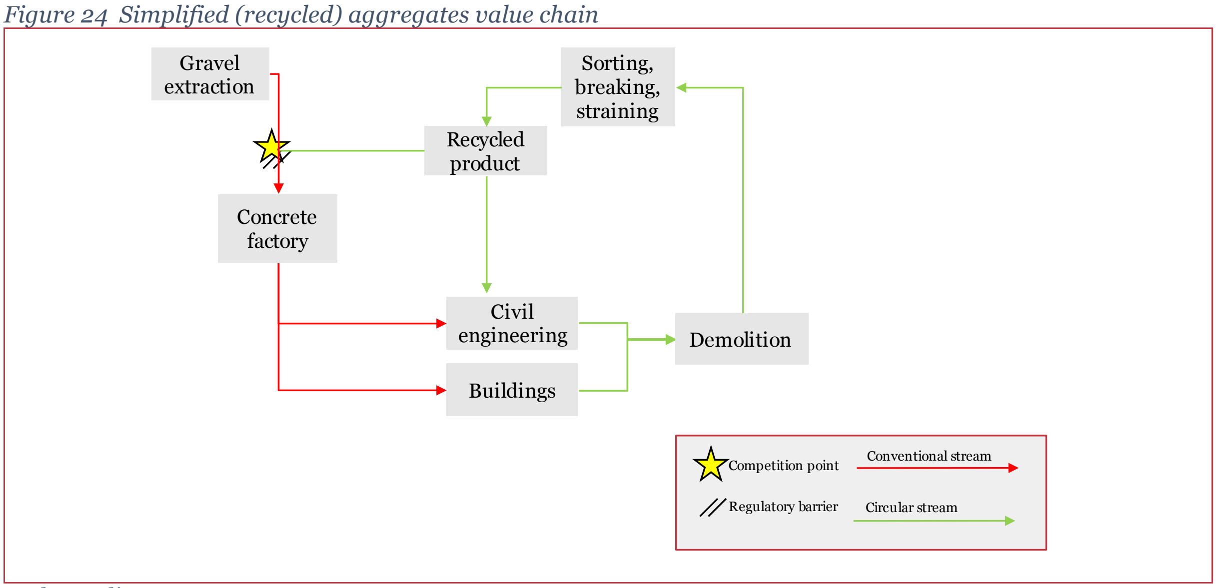
B.10 Regulatory barriers for the circular economy: Recycling of aggregates into new building materials

B.10.1 The product and its value chain

The focus of this case study lies on the recycling of construction aggregates used in buildings. In comparison to the European average of around 62 percent, the recycling rate of C&D waste in some members states as Germany and the Netherlands is quite high (depending on the source up to 96,4 percent[29]) but when considering the the destination of the flows of the recycled material, most of the secondary aggregates are used in civil engineering. In buildings the secondary aggregates are hardly used.[30] Hence, this case study addresses the (regulative) barriers determining the low recycling-rate of aggregates in buildings. The data on CDW recycling as well as the usage of recycled aggregates in the various member states show strong variety. Accordingly, the following case studies refers on European data and developments where so ever possible. However, to make the case more comprehensive the development in Germany is used as a blue print to gain larger consistency of the overall argument.

Concrete is made from different types of aggregates, cement, admixtures and water whereas the share of aggregates represents around 80% (Bio Intelligence Service, 2011). Concrete can be used for the construction of all types of buildings as well as for roadwork and civil engineering. The requirements or product specifications of the concrete, such as stability and permeability, vary depending on its field of application.

Figure 24 Simplified (recycled) aggregates value chain



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Description of the product/activity

At European level, data regarding waste management and recovery of aggregates are rare. However, it is estimated that on average concrete accounts for 60 to 70 percent of the European construction and demolition (C&D) waste.[31]

Concerning the demand and supply for mineral construction materials a certain imbalance can be identified:

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[29] The two percentages come from different sources. For the EU it is based on (Craven, 2015) and for Germany on (Institut für Bauforschung Aachen , 2015).

[30] The use of secondary materials in buildings could be referred to upcycling, as opposed to downcycling in civil engineering.

[31] The numbers in the member states differ depending on building traditions and statistical recording in the respective countries.

- On the one hand, a representative of the Central Association of German Construction Companies estimated that the demand in the building sector amounts to around 550 million tons a year in Germany.
- According to further estimations, around 150 to 200 million tons are needed for road construction for instance as foundation materials for frost and support structure layers. Thus, the overall demand for construction materials (primary and secondary) amounts to approximately 700 – 750 million tons.
- On the other hand, according to a report on the German construction industry, the mineral "supply" from waste or recycled products, in contrast, accounts for around 192,0 million tons, including 109,8 million tons of soil which are not part of the waste streams considered in this case. The remaining 84 million tons include 15,4 million tons of broken-up road highway materials, 14,6 million tons of construction waste and around 51,6 million tons mineral demolition waste. The latter is coming from buildings, streets, bridges etc. and is transformed to around 40,4 million tons recycling material. The remaining 11,2 million tons were to a large part used for the backfilling of excavations and landfills only 2,5 million tons of the material were landfilled. Hence, the supply for secondary materials is considered to be lower than the demand (Kreislaufwirtschaft Bau, 2015).

This imbalance has also implications for the use of secondary aggregates in buildings because in a nutshell, it can only be considered as a supplement to the already quite established use for civil engineering. Moreover, if the use of materials is focused too much on the application in buildings, it may even have a negative impact for the overall recycling rate.

Value chain and life cycle of the product/activity

This chapter gives an overview on the different ways conventional concrete and the one complemented with secondary materials are produced, explaining the single steps of the value chain.

For conventional streams, raw materials are extracted by blasting or excavation in the quarry. This process is often criticised as a wasting of resources as for instance in Germany, around four hectares of grit are removed each day (VDI Zentrum Ressourceneffizienz, 2014). Across, Europe around 3 billion tonnes of aggregates (crushed stone, sand & gravel) are produced a year at 24,000 quarries and pits (UEPG, 2012). Hence, generally it is expected that an increase of the recycling quota will lower the use of primary materials. Moreover, critics argue that the geographical distances between the sources and the locations where the materials are used increases environmental pressures. As quarries are located at the countryside but building material is typically used in urban agglomerations, large amounts of materials have to be transported over (long) distances. On the other hand, there are actors criticising that the secondary material is often not easy to access because it is subject to fluctuations in the supply of old buildings.

In 2006, the production of aggregates was in total 3,611 million tonnes. Of this were 253 million tonnes recycled or secondary aggregates, which accounts to a share of 7% (Siegmund Böhmer et al, 2008). The recycling process of aggregates instead already starts with the building of the house as the constructor should anticipate the demolition process in distant future to ease recyclability. The main determinants of the amount of C&D waste in the European Union are differences in building tradition, geography/geology and economic activity in the sector (Fischer & Werge, 2009). The recyclability of buildings is primary determined by two elements, the varietal purity and the absence of pollutants. When constructing a new building, experts recommend to decrease the amount of materials employed as well as to prioritize mineral building materials, facilitating an easier recyclability in case of demolition. To produce high quality secondary materials, it is crucial to guarantee that polluted or non-recyclable material are completely removed before the recycling process. Of the building rubble, only mineral materials can be recycled. Soil and stones cannot be used for recycled aggregates and are mostly used as filling for mining sites in the stone and soil-industries.

- After the actual demolition of the mineral material, the demolition waste is either delivered to a processing plant or treated by mobile sorters and crushers close to the demolition site.
- The material gets separated from non-recyclable material, crushed and strained and sometimes washed too.
- The recycled product is then delivered to a concrete producer who is mixing the pure concrete with the recycled product. Hence, certifications which declare that the aggregates are technically flawless must be provided by the recycling company. There are also companies which incorporate the whole process. Especially for roadwork made from concrete, material is directly reused for new roads.
- The share of recycled aggregates in Germany is at the moment allowed to have a share up to 45%. In Switzerland there are buildings made from concrete consisting from up to 100% recycled aggregates.
- The newly produced concrete has then to be transported to the new building or civil engineering application. The process from the demolition phase to processing the material to a proper product is often conducted by one single company.

Per step in chain: actors and their relation with connected actors

The following section describes central elements of the value chain and the key players involved in certain aspects of the processing of recycled aggregates.

- Design and production

The central actors for design and production of secondary aggregates are the constructors and architects which decide on which material will be used for the building.

Generally, in Germany according to some actors there is a rather limited need to use secondary materials in buildings as explained more elaborated in the last part. However, one interviewee suggested that maybe in future, the demand and supply of secondary materials may change so that it could be useful to initiate occasionally pilot projects. Another interviewee expects a decline of sites in civil engineering. However, some interviews revealed that actors in the construction industry very often have an insufficient knowledge of the potential use of recycled materials. The constructors are used to work with primary resources and are less open to try secondary materials due to insecurities regarding their quality which is crucial for the building, some interviewees argued. This reluctance could be lowered by the use of certificates. However, there are still doubts regarding the certificates, as reported by some interviewees. Apparently, concrete companies do not trust the certificates or have difficulties to decode them. Moreover, there seems to be a general preference for working with virgin materials in housing.

However, the normal certification procedure of the secondary material was not considered as too excessive or disproportionate by any of the interviewees as it is very important that the construction material for buildings maintains a high quality to ensure its resistance.

- End-of-life options of product

According to a report of Frost & Sullivan around 62% "of construction, demolition and excavation waste in Europe was recycled" in 2012 (Craven, 2015). This is below the EU target of 70%. However, there are strong variations across the single countries. Some countries or regions, namely the UK, Germany, France, Benelux, and the Alpine states meet this target. However, as stated above, statistic measurements of the recycling share vary as, for instance, some countries include soil etc. while others exclude it. In Germany, mineral demolition waste (building rubble, roadwork, gypsum based demolition waste, and construction waste) has a relatively high recycling rate of around 80% - 96,4%[32].

The most important argument against the reinforced use of recycled materials in new buildings – which has been mentioned by many of the interviewees – is that it would overall not be beneficial. Given that fact that a very large share of C&D waste is recycled already, a change in the purpose of the recycled materials would not reduce the use of primary resources. In other words, the recycled material would just be shifted from civil engineering to housing. While there are still considerable (unmet) demands for materials for civil engineering. However, one interviewee suggested that the processing of recycled materials to fit the requirements for the construction of new buildings might show similar (if not higher) environmental burdens compared to the extraction of virgin materials. Thus, a so called upcycling in this case might not have the desired environmental benefits. Moreover, a Finnish study found out that for certain applications such as new pavements "recycled aggregates has proved superior behaviour than virgin materials" (Bio Intelligence Service, 2011).

However, as each country has different environmental parameters for recycled aggregates which show often extreme variations, cross-border trade is considered to be hampered. Therefore, recycled aggregates which are considered as a product in one country may be labelled as waste in another country.

- Collection system

In general, houses which have an appropriate building structure to be recycled are demolished and the material is collected by the recycling company. Already at the construction site, the recycling company has to decide which materials have suitable characteristics (in terms of purity etc.) and can be used for recycling in buildings and thus, the material needs to be sorted at the site already.

- Market aspects

Regarding the price ratio between primary and secondary aggregates, interviewees have differing opinions. Some stated that secondary materials had lower prices, others claimed the opposite whereas there seem to be fluctuations in the prices as the availability of secondary material depends on the amount of houses or roads which are demolished. However, the overall picture the interviewees transmitted was that to stimulate the use of secondary materials, the prices of the latter need to be lower that those of primary materials.
However, there also seem to be regional differences. An interviewee located in Berlin said that due to the quality of the construction material of the houses being demolished (esp. in East Berlin), there is almost no "good material" available. Others state, that in Germany, the quality of the demolition scrap is good because buildings from 1950-1970 were built with pure concrete and this cohort of houses are most often demolished.

- Quality aspects

Regarding the quality of the recycled material, technical as well as environmental aspects are relevant. Technical aspects for instance refer to the grading curve, compressive strength and the humidity of the environment in which the recycled aggregate is employed. Environmental aspects may refer to the existence of polycyclic aromatic hydrocarbons or sulphates. Nevertheless, whereas the former are part of the European norm EN12620 which sets requirements regarding certain characteristics of the norm, environmental aspects are not regulated at the European level yet.

[32] The exact percentages vary by source and construction materials considered (Institut für Bauforschung Aachen , 2015) (Kreislaufwirtschaft Bau, 2015).

If treated correctly, the quality of the recycled aggregates is comparable to virgin material and can easily be used for most of the buildings. Examples in Switzerland show, that it is possible to use up to 100% of secondary materials in new buildings.

However, sometimes there seem to be misconceptions regarding the required environmental standards of aggregates used in civil engineering in comparison to those for buildings: Often, material used in civil engineering, there are higher environmental requirements because the material is more often perfused by rainwater whereas aggregates used as complement in concrete for buildings are dismantled (Susset, 2015).

Nevertheless, there is an elevated bureaucratic burden induced by introduction of the norm EN12620 which has been established in 2011 and replaced national law. Due to the missing environmental requirements, national rules apply and require a special building approval to ensure the quality of the aggregate.

In Germany, the end-of-waste status can be reached by obtaining a certificate from the German Institute for Structural Engineering (Deutsches Institute für Bautechnik) for each type of recycled aggregate.

B.10.2 Regulatory barriers

Table 60 Overview of regulatory barriers

Main Barrier	*Affected department (s)*	*Effect*	*Possible (legal) solution*	*Barrier identifier*
EN 12620 does not regulate environmentally relevant characteristics of the aggregates so that national rules apply which can lead to increased bureaucratic costs	Procurement	Use of secondary products is hampered	European committee TC 351 „Construction Products: Assessment of the release of dangerous substances" should create environmental classes for ecological characteristics of aggregates to be used in buildings. These environmental classes can be used as an indication what ingredients are allowed for what kind of usage in every member state.	(QRB, ZDB, DIBt)

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Main barrier identified

In the case of aggregates in buildings, no strong main barrier could be identified.

Due to the fact that the demand for recycled aggregates in civil engineering is higher than the supply and thus, primary resources have to be used in any case, it seems to be ecologically and economically more efficient, to use primary material rather for housing than for civil engineering. This objection has been mentioned by a number of the interviewees, stating that this would be the "main barrier" for that recycled materials in houses are used so rarely.

Generally, the recycling rate of C&D waste is already quite high in Germany. However, this recycled material is mainly used for roadworks/ civil engineering which has an overall demand of around 150 to 200 million tonnes a year vis-à-vis a supply of around 40,4 million tonnes recycled material. Hence, a shift towards use in buildings would not reduce the need for primary resources as the recycled material would just be shifted from civil engineering to buildings, and consequently, *not lead to a reduction* in the use of primary materials because they would have to be used for roadworks as a replacement.

This shift might also be coupled with some other problems as it was argued that shifting secondary material from civil engineering to buildings may even have a negative environmental impact as a higher share of the overall fraction can be recycled in civil engineering whereas for buildings a higher share of the secondary material needs to be landfilled due to the treatment process. One interviewee mentioned – in accordance with a study conducted in Finland – that for certain applications such as new pavements "recycled aggregates have proved superior behaviour than virgin materials" (Bio Intelligence Service, 2011). Due to the high recycling rate, the supply of "high quality secondary aggregates" is accordingly low because there are often no incentives for the recycling companies to process the material according to the standards needed for buildings. Hence, even if all interviewees agree that the quality of secondary materials in general is good enough to be used in buildings, they recommend the use of virgin materials because of the points explained above. Prices of recycled aggregates vary depending on their availability. If for instance a lot of buildings are tore down, there is a higher supply of recycled aggregates and consequently the prices are lower. Also, in a country with a lot of excavation sites, primary material will always be cheaper whereas in countries with scarce resources, prices for secondary aggregates will be higher. This may lead to statutory quotas such as Switzerland. An open question in this context remains whether the need for concrete for civil engineering will remain high in the future as well as from which material buildings are built in future. One interviewee is suggesting a constant demand for roads because in Europe they need to be refurbished every 30 years.

However, beyond this more general observation, the interviewees pointed towards the following barrier as most relevant barrier in the context of this case.

Description of barrier

The regulatory obstacle identified by some of the interviewees is based in norm EN12620 (Aggregates for concrete) which defines technical characteristics for aggregates such as chemical, geometrical or physical requirements. However, criteria regarding the discharge of dangerous substances have not been integrated and hence, the norm still lacking environmental test methods and parameters. As a consequence, for each country national rules apply which led to higher bureaucratic burdens. In Germany, for instance, due to the missing environmental parameters, building approvals from the German Institute for Structural Engineering must be given in individual cases which is costly, takes time and results in unnecessary damages for the reputation of recycled construction material. One interviewee working in a recycling company described that just directly after the introduction of the norm, he could not proceed with the recycling-part of his business but had to apply for a new approval of his aggregates which took around one year. Moreover, the crucial problem remains – mainly that even if environmental classes become part of the EN12620, environmental standards will remain different in each country. If a company, operating in both countries, intends to transport secondary aggregates from one country to another, for instance from the Netherlands to Germany, "building rubble" which is labelled as a product at the national level becomes "waste" according to the European connotation. Consequently, it underlies different legislations and a specific notification is required to cross the border. As a consequence, construction waste may be brought to a recycling plant which is located even further away (in the Netherlands) just to avoid the border crossing. Costs occur in terms of time (to get an EU notification, it needs around two month) as well as money (petrol, human resource costs etc.).

Solutions proposed

The European Commission already recognized the problem of the missing environmental characteristics in the norm EN12620. To solve the problem, a European committee TC 351 „Construction Products: Assessment of the release of dangerous substances" was already established. The objective of the committee is to develop test methods and norms on how to test the ecological relevance of building products.

Environmental categories need to be established at the European level too in order to obtain a European framework to determine the end-of-waste in each single country. According to the European building-product regulation, recycled aggregates are already defined as products but at the same time they are still considered as waste. With the environmental categories, each member state would have an information basis in order to decide which criteria recycled aggregates must fulfil to be used in buildings or in civil engineering, thus to receive the product status in the particular country. One interviewee stated that the European development of classes has to be so "intelligent" that after crossing the border, there is just a simple transcoding needed without measuring the material again in the country it was delivered to.

The consequences of the adaption of the norm and the establishment of environmental standards could have several consequences:

- Firstly, changes resulting from such new integrated environmental categories may be only marginal and may differ from country to country as the initial problem - different environmental standards in the countries - remains.
- Secondly, it may change national certification processes. For instance, in Germany the special rule to apply for a building approval would be obsolete and the whole procedure could be shortened.
- Thirdly, the image of the recycled products could be improved through the provision of more and better information.
- It could also be argued that material which is subject to very strict legislations in one country may be used in another country with laxer legislations instead of deposing it. This may also have positive influence on transportation costs as distances may be shorter. However, it remains very questionable whether material which is classified as environmental damaging in one country should be sold and used in another country. Therefore, it could be argued that as a result of the adaption of the norm, the EU could consider to take a vital role in the establishment of common EU standards (or at least common minimum standards) concerning environmental standards of recycled aggregates from buildings.

To date, after several years of work in the committee, an agreement on a testing method to detect environmentally damaging substances in aggregates was found. Experts expect a European testing norm in summer 2016 but one interviewee expects it to come in force just in 2018.

B.10.3 Other relevant barriers

Image and demand problems in general

Some interviewees referred to an image problem of recycled aggregates. Hence an additional barrier is the low demand for secondary aggregates by constructors which may be caused by a simple preference for virgin materials combined with insecurities towards the quality of the recycled material. The excessive bureaucratic burden, initiated by the missing environmental classes of EN12620 which lead to a special building approval would increase the negative connotation of recycled aggregates, as some interviewees argued. According to one interviewee, image problems could be overcome if it would be cheaper to use recycled aggregates. As stated above, there are different views on the prices of secondary materials which seem to be in most cases higher than the ones of regular construction material. Strong fluctuations of the availability of the material have an impact on the prices.

To tackle the problem of a lacking demand for the use of secondary material in buildings, the demand could be stimulated by quotas as is done for example in Switzerland. One reason for the elevated importance of using recycling in buildings may be that in Switzerland, excavation areas are becoming increasingly scarce. To create a demand, the use of secondary raw materials based on aggregates and limestone in buildings would have to be binding. There are two "methods" to determine the "optimal" size of the share.

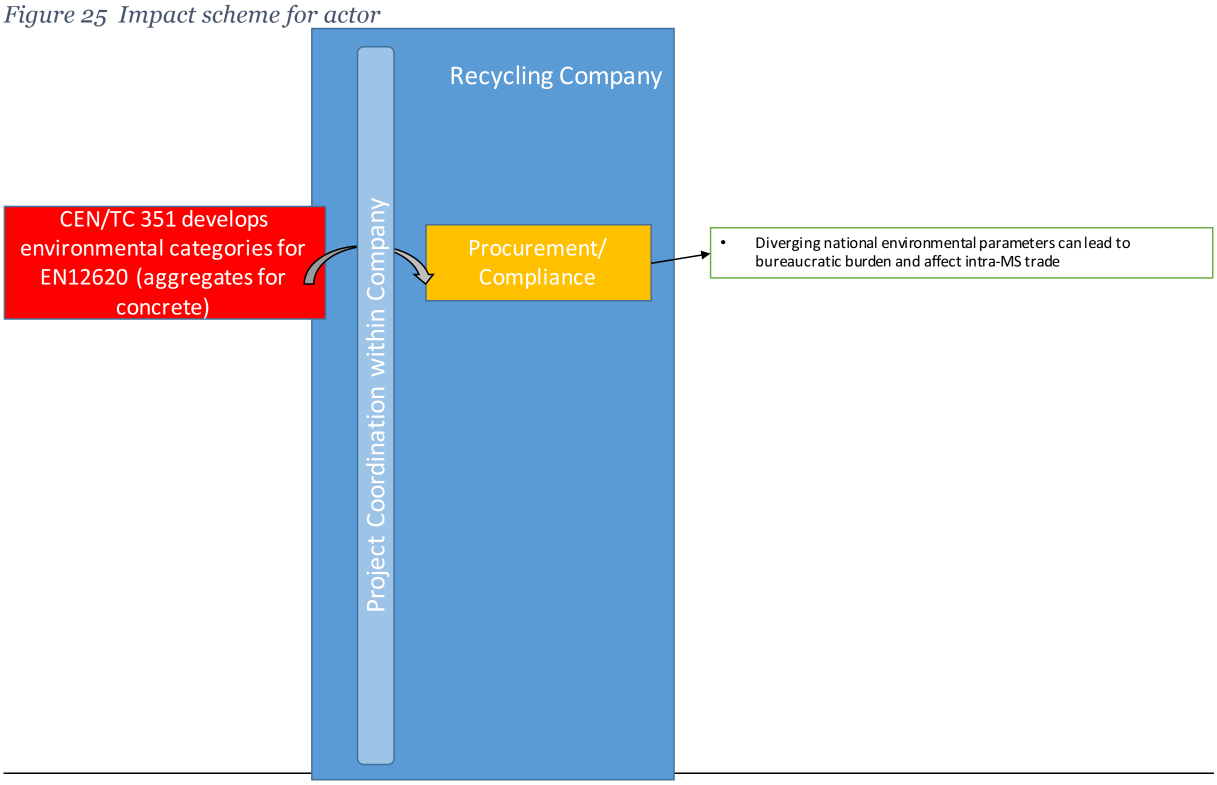
- The first approach has the aim to raise awareness amongst constructors for the material. Hence, using secondary aggregates for all kind of construction products and roads up to a share of 1% is considered as a solution to facilitate market access. “If constructors get in touch with the material, they may use it voluntary in other projects”, one interviewee suggested. In case of non-compliance, penalties could be set up (‘logical’ approach).

- However, there is also a “technical approach” which foresees a quota depending on the type of building. Especially in roadwork, up to 30% secondary materials could be used without affecting the quality of the construction material. For other areas, lower quotas are suggested (concrete building 10%; building construction 5%).

Some interviewees were also strongly in favour of giving more responsibility to the public sector and its procurement, which should operate as a role model or forerunner. Hence, civil infrastructures should use in general more secondary raw materials in their buildings. Moreover, the use of recycled material should get more attention in engineering education and training.

B.10.4 Impact scheme for the actors

Figure 25 Impact scheme for actor



B.10.5 Description of the companies interviewed in WP3

Aspect	***Company 1***	***Company 2***	***Company 3***	***Actor 1***	***Actor 2***	***Actor 3***
Name of the company/actor	AVG	Cemex	Heinrich Fees GmbH & Co KG	Central association for German construction industry (ZDB)	German Institute for Structural engineering (DIBt)	Quality assurance system for recycled construction material Baden Württemberg (QRB)
Industry sector	Buildings material company operating in Germany and the Netherlands	Concrete manufacturer	Recycling company	Association for the construction industry	Construction	Construction, quality assurance
Summary of the role of the company in industry (general)	Recycles inter alia concrete.	Concrete manufacture. Used aggregates for concrete to build a part of a university in Berlin	The recycling company located in the South of Germany produces recycled material for buildings and already delivered its aggregates for concrete to prominent pilot projects in the region.	Largest German association for the building industry. Inter alia addressing topics such as circular economy, resource efficiency and is a member of the “Initiative Kreislaufwirtschaft Bau” (Initiative circular economy for construction). Managing the Federal Quality Association for Recycling construction material as well as the European Quality Association for Recycling	The DIBt is a technical authority in the construction sector which authorizes inter alia non-regulated construction products.	Supports companies to maintain the “product status” of their recycled material.
Location	De Grens	Berlin	Kirchheim/ Teck	Berlin	Berlin	Ostfildern

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