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

Turning waste into secondary materials on the way towards a circular economy

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Statements

'The Environment Agency in England is proud to have been associated with this project and to have had the opportunity to collaborate with other agencies in EU member states. The value of sharing our knowledge and experiences will allow us to use this learning to drive tangible improvements as we seek to deliver our ambition to be a more resource efficient economy'.
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Contents

Abstract

Europe is striving for a circular economy, where valuing waste as a resource is an important consideration. Using waste as a resource also constitutes the focus of this discussion paper. The paper provides a synthesis of nine European cases where waste has been turned into secondary material and used as a resource. The cases concentrate on recycling the waste streams prioritised in the European Commission's Circular Economy Package, namely food waste, critical raw materials, plastics, bio mass and construction and demolition waste. The original case studies are described in a working paper available from (http://epanet.pbe.eea.europa.eu/fol249409/ig-green-and-circular-economy/working-paper_from-waste-secondary-materials_case_descriptions). The experiences from individual countries were analysed and summarised in order to increase the understanding about the opportunities and pitfalls related to recycling of wastes and producing products from recycled materials.

The main drivers and barriers for promoting recycling in the selected case studies (found from the analysis), were grouped in five themes:

1) Markets for secondary materials
2) Quality assurance in the recycling chain
3) Co-operation and knowledge sharing among value circle stakeholders
4) Regulatory environment
5) Financial instruments

This discussion paper was prepared by a project team within EPA Network Interest Group on Green and Circular Economy and is addressed to all EU member states for wide dissemination, with a special focus for authorities, industrial representatives, consumers and designers, who can benefit from the findings.

1 Introduction

Using waste as a resource keeps materials circulating in the economy allowing us to extract maximum value from them and to prevent material leakage from the economy. Displacing the use of virgin raw materials with secondary materials is fundamental in addressing the overuse of resources and reducing greenhouse gas emissions. In many countries, sectors and individual businesses, they have experience on how a material, once waste, has been transformed into a valuable raw material for various products when that waste has been considered as a resource in an open-minded way. Innovative use of secondary materials works when the market conditions and regulations allow this to happen. There can also be circumstances when innovative proposals do not progress due to negative factors, such as adverse environmental impacts.

The aim of this project was to collect experiences from different European countries as case studies on how waste has been turned into secondary material and used as a resource. The experiences from individual countries were analysed and summarised in order to increase the understanding of opportunities and pitfalls, related to recycling of wastes in production of products based on recycled materials. The lessons learned on how the process has been tackled from a regulatory perspective and examples of how the European Environment Protection Agencies (EPAs), have worked with the industrial sectors (or individual businesses) and administrative bodies, is useful for all European countries when improving the circularity of wastes and promoting the circular economy.

The focus of the cases in this study is on using waste as a resource. More precisely, the cases concentrate on recycling the waste streams that are prioritised in the European Commission's Circular Economy Package (European Commission, 2017a), namely food waste, critical raw materials, plastics, biomass and construction and demolition waste (C&DW). As EPAs, we need to make sure we are facilitating the use of waste as resource and improving the resource efficiency of Europe, while continuing to protect the environment and human health in line with the European legislation, and thus ensuring transition towards sustainable circular economy. The aim of this discussion paper is to identify main drivers and barriers for promoting recycling in the selected case studies. Sharing this information and examples of the good practices enables easier application of similar activities in the future and helps in the transition towards circular economy in all European member states. Hence this discussion paper is addressed to all EU member states for everyone, and especially for authorities, industrial representatives, consumers and designers, to benefit from the findings.

This discussion paper was produced as a synthesis report on the European experiences on the use of waste as a secondary raw material. In addition, a working paper including the original case studies is published (http://epanet.pbe.eea.europa.eu/fol249409/ig-green-and-circular-economy/working-paper_from-waste-secondary-materials_case_descriptions). This discussion paper was prepared by a project team within EPA Network Interest Group on Green and Circular Economy. The work was started in January 2017 and finalised in February 2018.

2 Circular economy

The linear "take-make-dispose" model or industrial economy is placing an ever increasing strain on both our finite and renewable resources, with 'Earth Overshoot Day' happening earlier every year. Continued growth under this model is increasingly unsustainable and will ultimately come to its end, as the non-renewable resources diminish and the price volatility of natural resources increases, impacting competitiveness. A circular economy has several definitions, but the features of the various definitions can be combined into the following seven key principles (Circle Economy, 2017):

1. Prioritise regenerative resources

2. Extend product life and keep materials in use
3. Use waste as a resource
4. Rethink the business model
5. Design for the future
6. Incorporate digital technology
7. Collaborate to create joint value

A circular economy approach, strives to keep the value of materials and products as high as possible for as long as possible. This helps to minimise the need for the input of new material and energy, thereby reducing environmental pressure linked to the life cycle of products, from resource extraction, through production and use to end-of-life. (EEA, 2017).

The circular economy package, adopted by the European Commission on the 2nd December 2015, supports the transition towards a more circular economy in the EU. The package included legislative proposals on waste, with long-term targets to reduce landfilling and increase recycling and reuse. In order to close the loop of product lifecycles, it also includes an action plan to support the circular economy in each step of the value chain – from production to consumption, repair and manufacturing, waste management and secondary raw materials that are fed back into the economy. After the adoption of the Circular Economy Action Plan the Commission has prepared several legislative proposals, in the first place on waste, setting clear targets for waste recycling and establishing an ambitious long-term path leading towards waste prevention and recycling. Furthermore, proposals have been given (Council of the European Union, 2018a; 2018b; 2018c; European Commission, 2017b).

- on strengthening the consumer guarantees of online sales of goods,
- on fertilisers, recovering nutrients aiming at the creation of markets for fertilisers made from secondary raw materials, through harmonised rules for fertilisers derived from organic waste and by-products and for the recovery of nutrients into secondary raw materials, as well as
- on the restriction of the use of certain hazardous substances in electrical and electronic equipment
- on higher than current recycling targets for
    - municipal solid waste (MSW) (65% by 2035)
    - plastic packaging waste (55% by 2030)
    - overall packaging waste (70% by 2030)
- on restricting landfilling of MSW to 10% by 2025, and
- on an obligation for separate collection of bio-waste from the beginning of 2024.

One element of the circular economy is to value waste as a resource, which constitutes the focus of this discussion paper. A circular economy however, also offers economic and social benefits from products by means of services and digital solutions based on intelligent systems and integration. The full value of circularity is realised by recognising the synergies in each of the seven key principles, even though each of them provides added value in its own respect.

Transformation from a linear economic model to a circular model needs significant changes and a reorganisation of value chains as well as major changes in consumer behavior (Sitra, 2016). This opens new opportunities for existing companies (e.g., service based provision instead of ownership or application based smart services) as well as new players. At the same time this will require significant changes in companies concerning both strategic thinking and operational processes (AARRE, 2017). A circular economy thus provides opportunities to create well-being, growth and jobs, while reducing environmental pressures (EMF, 2015).

Several concepts and visualisations of a circular economy exist; Figure 1 shows a simplified model. The main idea is that waste generation and material inputs are minimised through eco-design, remanufacturing, recycling and reusing of products. This will create economic and environmental co-benefits, as the dependency on extraction and imports declines in parallel with a reduction in the emissions to the environment caused, for example, by extraction and processing of materials, incineration and landfill. (EEA, 2016).

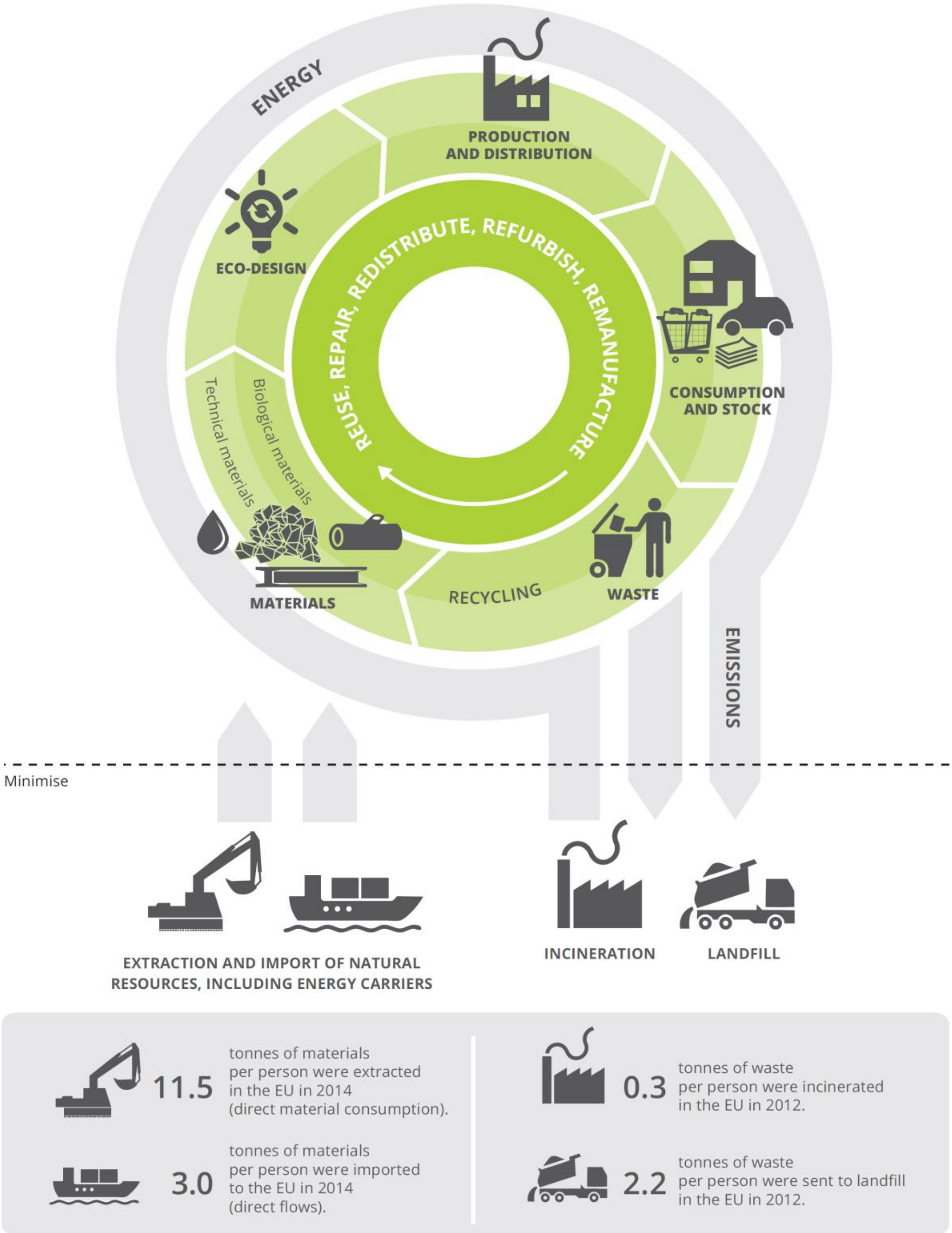

Figure 1. A simplified model of the circular economy concept. Source EEA (2016). The tonnages given in the figure show average values for Europe, but there are large differences between individual countries.

One of the first definitions for a circular economy was given by the Ellen MacArthur Foundation, who defined it as an economy that is restorative, and aims to maintain the utility of products, components and materials and retain their value (EMF, 2015). A circular economy reduces raw material and energy demand, in turn reducing environmental pressures linked to resource extraction, emissions and waste. This goes beyond just waste, requiring that natural resources are managed efficiently and sustainably throughout their life cycles. The concept can, in principle, be applied to all kinds of natural resources, including biotic and abiotic materials, water and land.

Eco-design, repair, reuse, refurbishment, remanufacture, product sharing, waste prevention and waste recycling are all important in a circular economy. At the same time, material losses through landfill and incineration will be reduced, although these may continue to play a role in safely removing hazardous substances from the biosphere and recovering energy from non-recyclable waste.

The discussion in this paper concentrates on the circular economy key principle of using waste as a resource by describing and analysing cases where waste has been recycled into raw materials. Recycling enables keeping the materials circulating and keeping the value of materials as high as possible for as long as possible. Due to recycling, the need for the input of new material and energy to the material circles can be decreased and environmental pressure linked to the life cycle of materials reduced. Recycling is effectively the last point in the waste hierarchy where materials can be maintained in circularity, thus it is important that we take every opportunity to capture material as a secondary resource.

The cases obtained from different countries indicate the potentials of turning waste into valuable raw materials. Additionally, they also help in identifying and defining barriers to circularity caused by issues connected to material quality or costs of recycling. The quality issue of waste materials has a direct link to the design and production processes, since quality of waste is more or less defined within the design phase of products that become waste at their end-of-life. By identifying quality issues which hamper recycling, the results will also facilitate options in future, for better design to enable greater recycling.

3 Cases in turning waste to secondary materials

To assess the critical factors behind the success of waste to secondary materials cases, nine examples of five waste streams from seven European countries including Austria (AT), Basque Country (E), Finland (FI), the Netherlands (NL), Scotland, Switzerland (SU) and United Kingdom (UK) were analysed (Figure 2). The focus of the case studies is on the five waste streams that are prioritised in the EU circular Economy Package, namely food waste, critical raw materials, plastics, biomass and construction and demolition waste. Choice of the following cases from each country was based on expert opinion of the national EPA representatives:

Food waste and biomass

- Soya meal: waste or (by)product
- Maximising high quality food waste recycling
- Producing compost from bio-waste
- Food waste from food industry
- Mixed MSW to produce feedstock for biocoal and ABE (acetone, butanol and ethanol) production

Plastics

- Returnable deposit system for PET-bottles

Construction and demolition waste

- Approach to recirculate mineral C&DW in the construction sector
- Roofing felt recycling

Critical raw materials

- Closing critical materials loop iron and steel industry

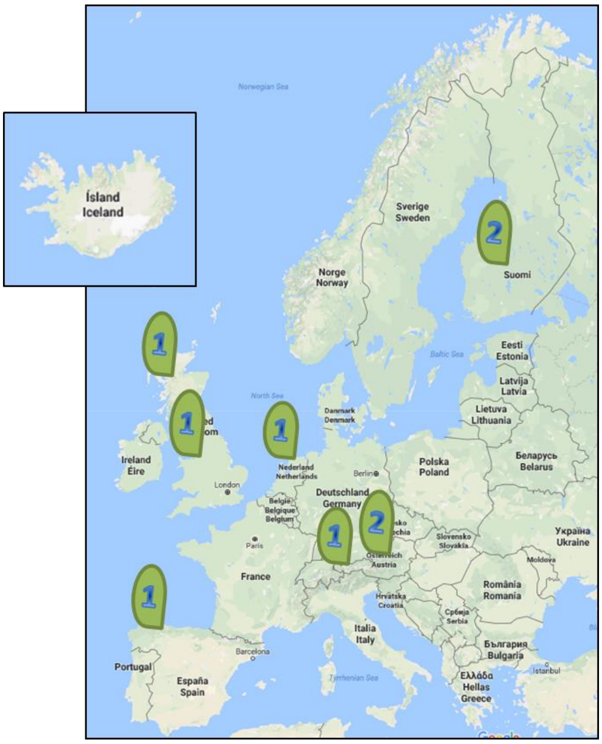

Figure 2. The number of cases from different European countries.

Case 1: Soya meal: Waste or by-product? (NL)

In many industrial plants, useful by-products originate from the production process in addition to the intended products. Examples include beet pulp from sugar production and soybean oil from the production of soya oil. In many cases by-products are treated as waste, leading to high administrative burdens. This case is about the discussion on the by-product’s status as a waste or raw material and about the role of competent authority in the consideration of that. The case outlines the dilemma between space for innovation and the utilisation of raw materials on the one hand and the monitoring of waste and risk of mixing on the other hand. Safeguarding products and production chains from contamination with waste streams and toxic or environmentally hazardous components is an ongoing concern.

The processing of soya beans produces approximately 20% of vegetable oil and 80% of protein rich soya meal. The producer sees the soya meal as a by-product, but in the Netherlands it is an important raw material for the animal feed industry. This case is about Marcor, a company that stores agribulk products (such as soya meal) and wants to have a license for a new storage location. Licensor DCMR Milieudienst Rijnmond (the joint environmental protection agency of the province of South Holland and 16 municipalities) initially believed that the soya meal should be treated as waste. Their assessment was primarily based on existing laws and regulations and the possible risks to public health and the environment. However, through feed and food regulation and the quality system used by the Dutch Food and Welfare Authority (NVWA) it was secured that there are no such risks in using the soya meal for animal feed.

After extensive consultation between the storage company (Marcor), industry organisation (providing data on the soya meal and its markets), licensor and the Ministry of Infrastructure and Environment (providing help for the licensor on the possibilities to interpret the legislation), it has been decided that soya meal should be considered as a product and therefore, not as a waste. This has advantages for the environment, as the soya meal can be used as feed instead of being treated as waste. The economic argument includes that when a product does not have waste status, it can be used as feed, the companies in the chain have a better image and they are relieved of a lot of administrative costs.

Case 2: Maximising high quality food waste recycling (SC)

Scotland has developed a package of measures to stimulate food waste recycling - making interventions across the supply chain from the point of production to the use of compost and digestate on Scottish farms. This case study centres on the effects of driving food waste recycling through regulation with particular focus on behaviour change, supply chain impacts and the quality of final compost and digestate products. It draws lessons for other jurisdictions who may be considering this approach in light of proposed separate collection requirements in the EU circular economy package.

Led by a desire to do better with food waste, Scotland's 2010 Zero Waste Plan placed an emphasis on the expansion of food waste recycling. The renewable energy benefits of anaerobic digestion, the reduction of biodegradable waste to landfill and compliance with Article 22 of the Waste Framework Directive (WFD) were also key considerations. Managed properly, food waste can go from being a methane generating burden in landfills to a resource for composting and digestate producers, displacing fertilisers derived from virgin resources.

A barrier to realising the benefits of food waste recycling was the limited ability of the industry to secure separated food waste from waste producers leading to caution around investment in systems, vehicles and treatment infrastructure. To address this and bring more certainty to the market, SEPA, Zero Waste Scotland and the Scottish Government consulted on regulations to introduce separate collections. The proposals had strong support from stakeholders and were passed by the Scottish Parliament in 2012, coming into effect on 1st January 2014.

Case 3: Austrian approach to produce compost from bio-waste (AT)

In Austria, a regulatory and infrastructure framework for the recycling of source separated bio-waste was established in past years. Obligations which are stipulated in the Austrian ordinance on compost, enable the status of end-of-waste for compost that has been produced from waste. The case describes the main drivers and barriers for the established system and describes the context of how the measures taken, contribute to the implementation of the European Commission´s action plan on the circular economy.

Austria decided to ban waste with high organic components from landfilling, by setting the legal framework in the Austrian ordinance on landfills beginning in 1996. In addition, an ordinance that stipulates the source separation of bio-waste from households was introduced in 1992. From that time on the treatment options for the environmentally sound management of bio-waste have been further developed and enhanced. In general, aerobic composting and anaerobic digestion, or combinations thereof have been introduced in Austria.

Environmental minimum criteria and related possibilities for the application of compost that is produced from waste, were introduced in 2001 in the Austrian ordinance on compost. Only defined input can be used to produce compost products from waste. Different categories of application (e.g. use in agriculture) for different compost types have been defined, according to the input used to produce the compost (e.g. if sewage sludge is used). In relation to its application, the different compost types have to fulfill specific requirements on physical properties and on limits for impurities.

Case 4: Study on amounts and reasons for food waste from food industry (SW)

This case study is about food waste streams analysis in the Swiss food processing industry.
The Swiss Federal Office of Environment FOEN, in cooperation with the Federation of Swiss Food Industries (FIAL), carried out an analysis on the food waste streams in the Swiss food processing industry. The aim of the study was to:
i) Analyse the amount of the food waste streams and the primary reasons for wasting food and,
ii) Highlight the factors that are important for successfully reducing food waste in the food industry.

The FOEN study was carried out between 2015 and 2017 and estimated annual food waste arising within the Swiss food processing sector to be around 508`000 t dry matter, 68% of which could have been avoided. In terms of sector-specific production quantities, the greatest losses are incurred in the tuber processing industry, followed by the oilseed/coffee/cocoa processing industry. The lowest losses are incurred in the cereals and bakeries sector. The proportion of inedible unavoidable food waste is greatest in the processing of tubers, at just under 70% of the total sector-specific losses. Also primary reasons for the occurrence of food losses across all sectors were identified.

Across all sectors, the largest part of the total waste is fed to animals, followed by energy and material recovery. Only a small proportion is incinerated.

According to the study a reduction in food losses primarily requires technical measures. In addition, for products that are not currently recovered within the food industry but which are, in principle, fit for consumption, further recovery pathways need to be defined. Food waste streams from production of; beverages, processing of tubers, fruits and vegetables, processing of oil, seeds, coffee, cacao, meat processing, processing of milk and dairy products, processing of cereals and bakery products, were considered in detail.

Preventing food waste has been a priority for FOEN for over a decade. Monitoring and reporting of food waste streams is a primary objective, which has been put in place by FOEN to deliver sustainable food waste reduction along the food value chain. The case study was initiated as part of the implementation of the Swiss biomass strategy, which has been adopted by four federal agencies in 2008 (ARE, FOEN, FOAG and SFOE).

Case 5: Autoclaving mixed MSW to produce feedstock for biocoal and ABE production; optimisation with CVORR framework (UK)

This case focuses on the use of a steam rotating autoclave, Mechanical Heat Treatment system (MHT) to process mixed municipal (or similar) waste. This methodology is being used to optimise the capture of recyclable materials from a mixed waste stream with the biogenic fraction of the waste converted into these products; sanitised fibre (to be used in a variety of technologies including approved combustion), gasification and pyrolysis, conversion into biochar, biochemicals, biofuels and anaerobic digestion. This can be considered as a global solution to the growing waste problem throughout the world. Production of Bio-Coal from Wilson Fibre® has been granted an end-of-waste status supported by legal opinion of a Queens Council and can therefore, be defined as a commodity product.

Resource Recovery from Waste (2018) (an environmental research programme funded by Natural Environment Research Council (NERC), Economic and Social Research Council (ESRC) and Department for Environment, Food & Rural Affairs (Defra)) initiated a project that aimed to develop the Complex Value Optimisation for Resource Recovery (CVORR). The framework (funded by NERC and ESRC), is designed to enable a holistic and consistent evaluation of social, environmental, technical and economic values to assess the sustainability of various supply chains, such as those that can be formed around the treatment process developed by Wilson Biochemical registered as the Wilson System®.

Whilst recycling sits in the middle of the waste hierarchy, once waste has been produced, optimisation within the hierarchy becomes the next priority for dealing with that waste. There has been much research and investment into engineered solutions for sorting mixed wastes and capturing as much recyclable material as possible. Within this tier of the hierarchy, there are now numerous technologies and systems in use, all of which claim to deliver 'good' results in terms of capture rates and efficiency of operation. It has been difficult however, to differentiate between these methodologies and to establish which has the best sustainability/resource efficiency credentials.

With the development of CVORR, this differentiation will become possible as a more sophisticated method for assessing waste management systems for the recovery of waste would be available, as it purposed to assess how different processes, technologies and interventions, could affect the capture and/or dissipation of value. The CVORR approach and framework examines both up- and downstream parts of the system within which waste production and management processes interact, and evaluates the system based on measureable environmental, economic, social and technical benefits and impacts.

The project is collaboration between Resource Recovery from Waste (RRfW) and the CVORR project at the University of Leeds, Wilson Bio-chemical, and the Bio-renewables Development Centre; it is currently being undertaken in the Yorkshire and Humber Region of the UK and was completed in autumn 2017.

Case 6: Finland's returnable deposit system for PET-bottles (FI)

The case is about a deposit return system and recycling of PET beverage packaging. Recycling of packaging is required by EU legislation. Finland has organised a deposit based return system for beverage packages of different materials. The system is based on the Finnish Waste Act, the Act on Excise Duty on Beverage Containers and a related decree on collection systems for returnable drinks packaging. Due to the joint effect of the deposit-refund system and beverage packaging tax, 93% of PET bottles placed on the market annually in Finland, are returned and directed for recycling.

A beverage packaging tax of 0.51 €/litre is collected for the packages of certain alcoholic beverages and soft drinks, but becoming a member of an approved and operational return system or organising a new return system provides for an exemption from the tax. Economical saving encourages packaging manufacturers to join the return system.

The manufacturer or importer of the beverage pays producer responsibility organisation (PALPA) the deposit for the product delivered for sales. The manufacturer or importer of the beverage delivers the product to the retailer, who pays the deposit to the manufacturer or importer of the beverage in the price of the product. The consumer pays the deposit when buying the product and receives it back when returning the empty package to the vending machine. The return point and processing plant report the returned packages to PALPA, at which point, PALPA pays the deposits to the return points. PET-bottles are baled and transported to recycling in Finland, and utilised as raw material for new products either in Finland or for export.

The deposit is a good incentive for recycling, although other considerations, such as the location of the nearest return point and the functionality of the reverse vending machines, also affect the will to recycle.

Case 7: Austrian approach to recirculate mineral construction and demolition waste in the construction sector (AT)

In Austria a regulatory and infrastructure framework for the recycling of mineral C&DW was established in the past years. High recycling rates are achieved and materials are recirculated to the construction industry enhancing the issue of circularity. The case describes the main drivers and barriers on the established system and describes the context of how the taken measures, contribute to the implementation of the European Commission´s Action Plan on the circular economy.

In Austria, since 2009 the annual generation of mineral construction and demolition waste (concrete, asphalt, tiles, bricks, stones and ceramics) increased by 46% to approximately 10 Mt in 2015 (excavated soil excluded). The high volumes of the waste stream and existing fees to landfill them, in combination with the existing demand on primary construction materials in the construction industry, resulted in the definition of national quality criteria for the recycling of this waste stream on both a technical and environmental level.

Environmental minimum criteria and related possibilities for the application of the recycled materials were introduced into the Austrian Waste Management Plan in 2006. Different categories of application of recycled materials have been defined, according to their use in bounded or unbounded form (with or without layer) and according to their use in hydrogeological high or low sensitivity areas. In relation to its application, the recycled materials have to fulfil specific requirements on physical properties and on limits for impurities.

The Austrian Ministry on Environment together with the Environmental Agency Austria developed and introduced the environmental minimum requirements into the Austrian Waste Management Plan. Therefore several studies were conducted to analyse and assess the quality of C&DW. In addition, the development of technical minimum requirements has been done by the Austrian Construction Materials Recycling Association, which were first issued 1996.

Case 8: Roofing felt recycling (FI)

The case is about recycling of roofing felt in Finland. The activity started from a demonstration project KIHU, funded from European regional development funds (ERDF), where the collection, treatment and recovery of roofing felt and gypsum waste were studied and piloted.

Roofing felt is used as roofing material especially in small houses. Roofing felt contains high amounts of bitumen and mineral fillers. Discarded roofing felt has previously been landfilled, but since landfilling of organic waste was banned in Finland from the beginning of 2016, roofing felt should have been combusted if no recycling options were available. Due to the high content of bitumen and mineral fillers, roofing felt has a high recycling potential as a raw material for asphalt. Recycling of roofing felt provides a solution for one of the several waste flows included in C&DW and promotes reaching the 70% recycling target for C&DW by 2020. In Finland the recycling rate was 58% in 2014. An estimated 13 000 – 15 000 t of roofing felt waste is produced annually in Finland (estimation based on the amount of roofing felt produced per inhabitant in Denmark).

Tarpaper Finland takes in bituminous demolition waste and roofing felt left overs and processes them into quality assured roofing felt crush, which is directed to the asphalt industry to be used in asphalt, displacing a share of virgin bitumen. In addition, Tarpaper Finland uses numerous local subcontractors for maintenance work, and contractors in waste sorting and lifting operations.

Tarpaper Recycling Finland started operating in Finland in 2013, but has been operating in Denmark from 2006. The method for recycling roofing felt has been developed by Tarpaper Recycling together with development partners, with grants from EU Life+ program for 2009-2010. Currently, the roofing felt collection network covers the whole Finland.

Case 9: Closing Critical Materials Loop in Basque Iron and Steel Industry (Basque country)

Driven initially by economic and environmental criteria, Sidenor, one of the leading special steel factories, launched a “Refractory Close Loop Project”, to reduce a significant part of its 5 000 t/y refractory waste and save money by maintaining or even increasing steel quality. Although most steel producers considered that it was not possible to perform better, this internal team, followed by public authorities, presented following results:

- Increase of high quality magnesite recycling rates from 8% to 75%
- Still low quality non-recyclable magnesite refractories account for 40% of the initially generated wastes
- Reduction of magnesite refractories consumption by 10% through in-factory reuse and smart management, taking into account a high material cost over 1 000 €/t
- Increasing refractory lifetime by 38%
- Saving 0.8 M€/y of materials due to reuse of magnesite refractories (savings accounted without including high additional productivity savings).
- Finalist Company in European Environmental Awards 2015-2016 based on the refractory reuse and recycling success story of Sidenor.

The identified keys for success have been:
1) A new business model for refractories, going to a pay for use model where suppliers need to commit for improvement, getting 50% of the reached results,
2) Optimisation of furnace ovens control parameters make it possible to monitor in depth process parameters,
3) Availability of highly skilled and experienced refractory experts among the manufacturers and users,
4) Commitment of interdisciplinary team members, led by research and development (R&D) department and awarded as “Best Project” by Gerdau Steel Multinational, and
5) A follow up of Industrial Emissions Directive (IED) implementing regional authority and BAT reference document (BREF) sectorial team member.

This project was also supported by the “Circular Economy Demonstration Projects Programme” of Ihobe (Basque Government). The economic support of 25 000 € facilitated a continuous public-private dialogue with the Steel Factory. Although Steel Furnaces have just adopted to new BREF and the previewed guidance of circular economy criteria into the new European Commissions BREF documents, as established in the Circular economy action plan COM(2017) 33 final, this will accelerate critical material cycle closure.

The basic information concerning each case is summarised in Table 1. More thorough descriptions can be found in the working paper on cases (Salmenperä, 2018) on the web (link).

Table 1. Basic information on the cases included in the study.

Case	**Type and volume (kt/y) of waste concerned**	**Regulatory links to existing regulation**	**Application for the secondary material**	**Contribution to CE (priority waste stream with bold)**
1. Soya meal: waste or (by)product "SOYA MEAL" The Netherlands	• Soya meal (by-product from processing soya beans • The total trade volume on soya meal in Rotterdam 10 Mt	WFD (2008/98/EC); Definition of waste and by-product; Tax on incineration	As animal feed	Reducing **food waste**
2. Maximising high quality food waste recycling "FOOD WASTE" Scotland	• Food waste – including edible and non-edible, excluding garden waste • 1.35 Mt in 2013 (44% households, 55% commerce and industry (C&I))	Reduction of biodegradable waste to landfill (WFD 2008/98/EC); Scotland's Zero Waste plan	Compost and digestate used by Scottish farms. Biogas used for electricity generation, additionally some heat recovery	Increasing recycling of **biomass**
3. Austrian approach to produce compost from bio-waste "BIO-WASTE" Austria	• Bio-waste • Waste input in treatment facilities: >0.58 Mt digestion, 1.14 Mt composting (home composting not included) in 2015. • Additionally, 1.5 Mt home composting in 2017.	Green Paper on the management of bio-waste, WFD (2008/98/EC), EU Landfill Dir (99/31/EC), National ban on landfilling waste with high organic content	As fertilizer, In re-cultivation	Increasing recycling of **biomass**
4. Study on amounts and reasons for food waste from food industry "FOOD WASTE" Switzerland	• Food waste (industrial) • 0.510 Mt annually (22% of the total 2.3 Mt of food waste).	New ordinance on the avoidance and recycling of waste (2015), Sustainable development goals (adopted in 2015)	Fed to animals (75%), digested or composted (20%), incinerated (3%)	Reducing **food waste**
5. Autoclaving mixed MSW to produce feedstock for biocoal and ABE production; optimisation with CVORR framework "MIXED WASTE" United Kingdom (England)	• MSW • This is a batch process handling 20 t at a time. • With a 2 vessel system you can process up to 0.15 Mt per annum.	Waste hierarchy (WFD 2008/98/EC); CE Package (upcycling options for MSW)	The product, Wilson Fibre® can be turned into a bio-char material to be used: to compensate coal in power stations, or as feedstock to ABE (Acetone, Butanol and Ethanol) for transport fuel or chemicals. Recovered glass, plastics, ferrous and non-ferrous metals are sold for recycling.	CVORR framework optimises the application of waste hierarchy, delivering improved recovery of recyclable materials, reducing the burden on use of virgin raw materials, and reducing energy demand in conversion. Priority waste stream **biomass**.
6. Finland's returnable deposit system for PET-bottles "PET-BOTTLES" Finland	• PET beverage packaging, • 12 kt/y collected and recycled (93% of the sold bottles); • PET bottles make up 10-14% of the overall amount of post-consumer plastic packaging waste (86-117 kt/y)	Directive on packaging and packaging waste (94/62/EC) Waste Act (646/2011) Decree on collection systems for returnable drinks packaging (526/2013). Decree on beverage packaging tax (1037/2004)	Clear recycled PET for clear plastic bottles and other products, coloured recycled PET for fleece, backbags, shoes, umbrellas etc.	Developing **plastic** recycling and enhancing recycling of packages.

		Decree on packaging and packaging waste [518/2014]		
7. Austrian approach to recirculate mineral C&DW in the construction sector "MINERAL C&DW" Austria	• Mineral C&DW (asphalt, bricks, concrete from broken infrastructure) • 10 Mt (2015) • 90% directed to recycling activities	WFD (2008/98/EC), EU C&DW protocol (2016), National fee on landfilling mineral waste	Asphalt granulates, concrete granulates and mineral granulates for road construction and concrete production. Can be used as filling material (if specific conditions are met)	**C&DW** recycling is improved and virgin raw materials are saved
8. Roofing felt recycling "ROOFING FELT" Finland	• Roofing felt waste produced • appr. 15 kt/y (1% of the overall Finnish C&DW)	WFD (2008/98/EC), National ban on landfilling organic wastes (2016); Landfill tax	In asphalt production to compensate a share of virgin bitumen.	**C&DW** recycling is improved and virgin raw materials are saved
9. Closing Critical Materials Loop in Basque Iron and Steel Industry "CRITICAL MATERIALS" Basque Country	• Magnesite (critical raw material) refractory waste from steel industry • 21 kt/y	The Raw Materials Initiative, EU (2008), Review of the list of critical raw materials for the EU (2014)	Reuse of high quality magnesite in production of new refractories.; low-quality magnesite refractories currently landfilled, but recycling oprtions are being developed	Reducing the consumption of **critical raw materials** by an integral action package of servitisation of refractory supply (pay for use), better process control, reuse of refractories, internal recycling and external recycling.

4 Critical factors for the success of the cases

The analysis of the case studies comprises an identification of important key factors to describe the success of the cases. These were categorised into the following five groups (in brackets some examples of the category):
1. Institutional (for example established interests and the existing division of responsibilities in the policy chain);
2. Laws and regulations (for example waste legislation, strategy on resources, product policy, competition policy);
3. Economic (for example, the full cost of environmental impacts is not being accounted for and hence investment decisions are based on incorrect assumptions);
4. Knowledge and innovation (for example, cross-sectoral cooperation, information exchange between administrative levels and industrial sectors).
5. Public perception (in all cases where secondary materials are produced: consumer acceptance of the recycled product/material).

A summary of recommendations derived from analysis of the nine cases is presented in Chapter 5.

Table 2. Critical factors for the success of the studied cases. + = has supported case success, - = has been a hindrance for the case.

Critical factor	Learning points from the cases
Institutional	+ Co-operation, knowledge and experience and best practice sharing, open dialogue between (All Cases) • government, authorities on various levels and supervisors and enforcers • authorities, business and other relevant stakeholders • industry and knowledge institutions + Collaboration and integration across different technologies and innovations. (Case 5) + Established infrastructure on waste separation, collection and handling (Case 7) - Lack of resources and stimulus for authorities to tackle complex cases (Case 1) - Lack of discussion between different permitting sectors such as environment and food and feed (Case 1) - Lack of platforms for sharing best practices for e.g. reducing food waste (Case 4)
Laws and regulations - modified regulations for case success	*National regulations on collection, sorting, separation, recovery and treatment of waste:* + A duty on 1) municipalities to provide a separate food waste collection to households and 2) food businesses to separate food waste for recycling if producing more than 5 kg of food waste/week (Case 2) + Technical guidance for composting processes by the Austrian Ministry of Environment (Case 3) + Austrian ordinance on obligations on the source-separation of bio-waste (1996) (Case 3) + Full regulatory permits and local planning permissions for steam autoclaving of waste in the UK (Case 5) + Several cases show that national strategies and regulations have supported or enabled recycling and transition towards circular economy, such as Swiss biomass strategy and green economy action plan, Finnish Waste Act (646/2011) and Decree on collection systems for returnable drinks packaging (526/2013), Austrian national strategies and legislation on recycling C&DW and Austrian waste management plan 2006 (Cases 4, 6, 7) - Existing national requirements do not always reach high environmental improvements. For example the Basque regulation requiring 1) three recycling companies to confirm that a specific industrial waste cannot be recycled, before it can be landfilled and 2) that landfilling of a specific waste stream can be legally banned if technical-economical recycling alternatives are available, have not decreased landfilling significantly (Case 9) *National regulations on the quality of waste accepted for processing and/or the quality of secondary material produced from waste:* + Tightened end-of-waste criteria (to control the remains of plastic packaging) for compost and digestate (Case 2) + Inclusion of new waste acceptance criteria in anaerobic digestion and composting permits (Case 2) + Austrian ordinance on compost (2001) setting the environmental minimum criteria and related possibilities for the application of compost (Case 3) + Austrian ordinance on building materials (2015) (Case 7) + End-of-waste status received for the roofing felt crush to be used in asphalt or new roofing felt production (Case 8) - Non-binding Federal Waste Management Plan has not been an effective tool for setting requirements and conditions for recycling (Case 7) *Other:* + EUs circular economy action plan requires waste prevention and recycling to be included in new sectorial BREFs to establish IED Directive permit limits (Case 9) - Alloyed Scrap and Refractory Waste Prevention and Recycling Criteria for the new Steel Furnace BREF revision is to be initiated, but procedure not established (Case 9) -Waste legislation is interpreted differently by local authorities (Case 1)
Economic	*Value of the waste/by-product material* + Economic benefits from defining soya meal as a by-product, value of the by-product and demand from the feed industry (Case 1) + Renewable energy benefits of anaerobic digestion (Case 2) + Economics of decentralised composting and the use of it (Case 3) + Bio-fuels and high value chemicals produced from mixed MSW valued on the open market as non-waste products (Case 5) and recovered ferrous metals, aluminium and other materials can be sold on the market (Case 5)

	+ Deposit has been a good incentive for increasing recycling of beverage packaging (Case 6) and a well-established deposit system for one material has provided a good basis for enlarging the system to other materials (Case 6) + Supply risks of critical materials based magnesite refractories (happened in 2011) boosted development for recycling (Case 9) - Low prices for primary raw materials (Case 7) *Existing demand for the secondary product/material* + Demand for the by-product (soya-meal) from feed industry (Case 1) + Demand from the farmers for the food waste compost and digestate (Case 2) + Ongoing demand for primary mineral construction materials (Case 7) + Demand for roofing felt originating recycled bitumen from asphalt producers due to lower price than for virgin bitumen (Case 8) - Lack of pathways to the market for products that fit for consumption but currently end up in the food waste bin (Case 4) *Financial instruments (taxation, funding, incentives)* + Fixed monetary penalty of £300 as a preventive instrument (Case 2) + Landfill tax (Cases 3, 8) + Incentives for biogas treatment plants for produced biogas if fed into the public power supply system (Case 3) + Public R&D funding for the private company enabled the process development for waste treatment (Case 5) + Finnish legislation on the taxation of certain types of beverage packaging (1037/2001) caused industry to develop the deposit system to avoid the tax (Case 6) + The Austrian law for remediation of contaminated sites sets a fine for non-proper management of C&DW (Case 7) + Public funding (EU and national) received for the development of the recycling process and implementation of the recycling chain for roofing felt (Case 8) - R&D funding needed to develop new technical alternatives for low quality refractory wastes (Case 9) - Lack of EU validated Green fiscal instruments for products with low Environmental Footprint that boost innovation and secondary markets (Case 9) - Lack of harmonised landfill tax in Spain has not incentivised recycling of wastes (Case 9) *Economics of the recycling chain* + Investments in effective screening and depackaging equipment by industry to remove contaminants such as plastics from food waste flow (Case 2) + Composting enables treatment in decentralised and low capacity way and the compost product can be used where it is produced (Case 3) + Gate fees charged by the facilities receiving waste (Case 5) - Logistics play an important role in a large country and generate challenges for optimising waste collection (Case 8) *Economics/costs/savings from reducing/recycling wastes* + Giving a price tag (waste treatment costs) on food waste made hotels, restaurants etc. realise the problem and act to minimise the amounts produced and their own costs (Case 4) + Disposal fees for landfilling C&DW(9.20 €/t of non-recovered C&DW) have increased recycling (Case 7) + Cost savings for waste producers from not disposing roofing felt in landfill but instead recycling it (Case 8) + Savings of over 0.8 M€/y, which could rise to 3 M€/y if transfer of the developed concept for in factory reuse of materials to other factories can be sped up (Case 9) + A new business model for refractories (pay for use model where suppliers commit for improvements, and get 50% of the reached results, benefits or losses) (Case 9) + New external recycling business opportunity to avoid export of high quality waste (Case 9)
Knowledge and innovation	+ Communication and consultation between disciplines (e.g. environment and food) (Case 1) + Quality of secondary materials (e.g. compost, mineral materials) (Cases 3, 5, 7) + Quality assurance system to both the recycling process and recycled materials (Case 7) + Stakeholder co-operation to establish minimum environmental and technical requirements (Case 3) + A reduction in food losses primarily requires technical measures (Case 4) + Easy to use and easily accessible machines for beverage packaging with deposit (Case 6)

	+ Standards (EU and national level) on recycled aggregates and stakeholder co-operation establish the minimum environmental and technical requirements (Case 7) + Study on hazardous substances and their emissions performed to show ecological and occupational risks being unlikely or low (Case 8) + Enable CE marking for the secondary material to satisfy the customer requirements (Case 8) + Availability of skilled and experienced refractory experts among the manufacturers and users, including a long term improvement agreement between supplier and manufacturer based on "pay for use" (Case 9) - Rapid expansion of food waste recycling lead to contamination of the material (with plastic) (Case 2) -Quality issues of produced compost (Case 3) -Industrial quality standards can play a key role in minimising food waste flows (Case 4) -R&D needed to improve process control in high temperature processes and to recycle low quality magnesite refractories (Case 9)
Stakeholder and public perception	+ Communication is needed in all relevant languages (ethnic restaurants) (Case 2) + When businesses commit themselves to food waste recycling, it quickly becomes their second nature (Case 2) + Quality assurance system for secondary material (e.g. compost, mineral materials) to gain perception by consumers and industry (Cases 3, 7) + Acceptance from market obtained by pilot tests and end-of-waste status (Case 8) + Campaigns of awareness arising by national associations for consumer acceptance (Case 7) + Traditions and habits in consumer behaviour support recycling, e.g. beverage packaging take back (Case 6) and UK citizens participation in recycling schemes (Case 5) + Motivation of the public to continue recycling requires information on improved efficiency and reduced costs (Case 5) + Knowledge on high volumes of C&DW produced and volumes increasing (Case 7) + European Environmental Award (EU Finalist) has facilitated raising awareness of industry professionals (Case 9) -Change of behaviour needed to get the source separation working and material quality right (Case 2) - Small companies need more support and engagement than large ones (Case 2) - Low acceptance from the consumers despite of awareness raising campaigns etc. (Case 3) - Consumers have difficulties in understanding the concept of wasted food (Case 4) - "Optical quality standards" may cause consumer to reject edible food products (Case 4) - Consumer acceptance for recycled materials and products is still low (Case 5) - Black sheep sometimes contradict the regulatory framework (Case 7) - Criticality of materials yet not perceived by industry (Case 9)

5 Lessons learned from the cases

5.1 Markets for secondary materials

The role of markets is a key in driving demand for products that are made from or contain secondary materials. Secondary materials with a higher value are more robust to price fluctuations, so any process that focuses on maintaining the intrinsic value of a material has a better chance of finding investment and remaining viable. This is the case for some secondary materials (i.e. metals, higher grade plastics etc.), however, some materials are much more marginal and cannot compete with the cost of virgin materials on the basis of supply and demand alone. For the secondary materials included in the case studies, demand and markets existed for soya meal (Case 1), bitumen out of roofing felt waste (Case 8) and PET-bottles (Case 6). However, even of these the soya meal needed first to be defined as a by-product and for the roofing felt end-of-waste status was applied and obtained.

The markets for secondary materials can be created, stimulated or regulated by fiscal/economic policies, depending upon the view taken by governments both within the EU and individual member states. For the other secondary materials included in the case studies, i.e. compost from bio-waste (Case 2), mineral fraction from C&DW (Case 7) and low quality magnesite refractory waste (Case 9) different regulations and economic incentives have been put in place or measures need to be taken to boost their demand and market acceptance.

Because of the susceptibility of markets to volatility in commodity prices, it is important to look for a raft of policies that are capable of generating a more stable platform for secondary materials in the longer term. It is important to recognise that intervention is required, if the target is to alter a market to take account of externalities, for instance, or to stimulate growth where time frames for returns on investment may be longer than the current norm.

Supporting this process can be achieved through taking a systems approach and by applying Life Cycle Thinking to value systems. By taking this approach, developing markets for secondary materials can be underpinned by sustainability criteria that reach beyond the more immediate actors upon the market. It may be necessary to intervene to create conditions of stability and greater certainty in developing investment potential for options further up the waste hierarchy. This may require that longer return periods are considered in relation to sustainable investments and that the operational life spans of intermediate and transitional technologies (i.e. energy from waste) are also considered in relation to sustainable investment.

Environmental sustainability can be verified by (e.g. product environmental footprint (PEF) European Commission, 2017c), or Eco labels such as EU or Nordic Ecolabel (European Commission, 2017d; Nordic Ecolabelling, 2017). Some examples of possible interventions identified in the case studies are listed below:

- Regulation and policy – the circular economy package is an example of regulation creating an intervention. In this case the setting of targets for recovery of recyclable materials from the waste stream (e.g. C&DW), banning of materials going to landfill (to supplement meeting recycling targets and reduce overall reliance on landfill (e.g. organic waste) and Extended Producer Responsibility (EPR), to reinforce polluter pays principle and to create more circular material flows (e.g. for packaging).
  Policy designed to increase the uptake of secondary materials is an important aspect of creating and growing markets for secondary materials (e.g., the Green Paper on the management of bio-waste in Austria, Case 3), or the national strategies and legislation on recycling C&DW in Austria (Case 7), Zero-Waste Plan of Scotland (Case 2) and Swiss biomass strategy (Case 4)).
  Green procurement policies and those designed to ensure a prescribed secondary content will help to drive demand, encourage new capacity and greater efficiency. These policies also help to overcome short term investment strategies, by providing the prospect of growth within the medium term.
- End-of-waste criteria are important in defining the point at which a waste ceases to be defined as a waste. In addition, the definition of quality criteria for recovery of secondary materials, clarifies the move back into the supply chain as a product or raw material (e.g. Cases 3, 5, 7 and 8). This is an important factor in establishing value and promoting a circular economy. Separate collection mechanisms, bespoke treatment and the concept of EPR all support this by helping to define pathways for the effective management of waste materials, by reducing contamination and by reducing onward treatment costs.
- Fiscal/economic instruments – such as landfill and incineration taxes have played an important part in driving investment and innovation into activities further up the waste hierarchy in several of the cases. In the current context, it is not completely clear as to what

extent these taxes have contributed to any particular secondary resource activities, however, they have served to create a 'recycling culture'.

- Even other measures not identified in our cases, such as reducing VAT on refurbished products or products made of secondary materials (if proved to perform well environmentally), or introducing a carbon tax linked to the greenhouse gas savings generated by using secondary materials, could play a role in accounting for externalities and better recognising the value of secondary materials.

All attempts to recycle waste would benefit from greater support through policy, regulatory or other interventions. Left to the market, only the highest value materials would be recovered, leaving greater quantities of waste to be treated/disposed at a lower stage of the hierarchy and the true cost of externalities would not be accounted for.

Suggestions on who could act in order to promote the topic:

- EU, national governments, regional administrations
- public procurers by setting requirements on secondary material use
- operators in the recycling sector, by assuring the quality of the secondary material and the products produced from it

5.2 Quality assurance in the recycling chain

The quality of secondary raw material is a crucial factor to enable its uptake into the market and acceptance by the consumers. Only where the quality of the secondary raw material is comparable to that of primary material, will trust be established among consumers. The following instruments are discussed in the case studies as suitable ones to ensure high quality of secondary raw materials.

Introduction of acceptance criteria for waste input into the recovery/recycling process:
Essential for the quality of secondary raw materials, is the quality of the waste input material into the related recovery/recycling process. Specific requirements or limitations need to be defined for the waste input, in order to identify and exclude hazardous substances which can influence the quality of secondary raw materials. The acceptance procedure may also include wastes sample analysis. Usually, the acceptance criteria are defined on company level by contract between the involved parties. Nevertheless general rules (e. g. excluding specific fractions/waste streams) from recycling processes, are also defined on national regulatory basis. Examples identified in the analysed cases are: Inclusion of Waste Acceptance Criteria into AD and composting permits (see Case 2); List of possible waste input to produce compost (see Case 3).

Introduction of end-of-waste criteria for secondary raw materials:
At European level, the WFD (2008/98/EC) enables in Article 6 the introduction of end-of-waste criteria under which, waste could cease to be waste, and could be regarded as a material freely traded in the open market. Up to now, criteria have been laid down for the following materials: iron, steel and aluminium scrap (see Council Regulation (EU) No 333/2011), glass cullet (see Commission Regulation (EU) N° 1179/2012) and copper scrap (see Commission Regulation (EU) N° 715/2013). As stipulated in the European Commission´s Action Plan for a circular economy, plastic is one further waste stream on which end-of-waste criteria at European level should be elaborated.

At national level several end-of-waste streams have been established by Member States, stipulated by national legislation or on a single case decision on permitting authority level. Examples therefore, are reflected in some of these case studies: Order on quality requirements pertaining to composts made from waste (Austrian Federal Minister for Agriculture, Forestry, Environment and Water Management, see Case 3); Recycled Construction Materials Ordinance (Austrian Federal Minister for Agriculture, Forestry, Environment and Water Management, see Case 7); Production of Bio-Coal from Wilson Fibre® (Legal opinion of a UK Queens Council, see Case 5); Production of roofing felt crush to be used in asphalt or new roofing felt (Tarpaper Recycling Finland, included in the company permit, see Case 8).

Establishing of quality standards for secondary raw materials or adopt existing raw material standards to secondary materials:
Common standards are essential to build and support trade of secondary raw materials. In its factsheet on waste to resources the Commission aims at developing standards where needed (European Commission, 2015). This needs to issue both, the environmental and technical minimum requirements for secondary raw materials. As an example several standards have been published on the technical minimum requirements on recycled aggregate at European on Member State´s level.

Defining types of application for secondary raw materials:
Different qualities of secondary raw materials may be suitable for specific uses. Defining requirements on different types of applications implies that environmental risks associated with such uses need to be assessed, and the producer of the secondary raw material must label the material indicating its suitability for those specific uses. There are examples of definition for different types of application in national regulations (e.g. the Austrian ordinance on compost defines following types of application for different secondary raw materials: use for agriculture uses, landscape construction and conservation, construction of bio filters, re-cultivation of landfills, private garden use, soil production, see Case 3).

Ensuring process quality of the whole recycling chain (process performance and environmental impacts):
The adoption of process controls and end point criteria for treated wastes are essential to maintaining and creating enhanced value for secondary materials. This will be essential in meeting objectives in relation to end-of-waste criteria, REACH and equality with products manufactured from raw materials (i.e. ISO/BSI/CEN). The best way to achieve consistent standards and provide for regulatory oversight and reporting, would be to bring these criteria into the permitting system.

The Hazard Control and Critical Path Process (HACCP) offers a methodology that could provide the basis for both a robust and conditional process within a permit, whilst also offering opportunities for monitoring and accreditation of end products. The definition of process control parameters (e.g. temperature, residence times, pH, etc.) for the recovery/recycling process can be an important additional attribute to ensure high quality output of a process.

Applying and promoting state-of-the art technologies and minimising environmental impacts occurring from industrial recovery/recycling processes are also addressed in the Commission´s Action Plan for a circular economy (see also Reference Documents on Best Available Techniques (BREF) published for different industrial sectors, http://eippcb.jrc.ec.europa.eu/reference/).

The introduction of a Quality Management System (QMS) for the recovery/recycling process is a proper way to enable high recycling efficiency, low environmental impacts and high quality of the secondary raw material, covering aspects on monitoring, reporting and document control. Examples highlighted in the case studies are: Optimisation of furnace ovens control parameters (make it possible to monitor process parameters in depth); Circular Economy Refractory Criteria for the new Steel Furnace BREF revision (see Case 9); Quality system used by the Dutch Food and Welfare Authority (NVWA) (see Case 1); Swiss industrial quality standards (see Case 4); Quality monitoring system for waste received from renovation and demolition sites (see Case 8); Austrian Standard ÖNORM B 3151 for selective de-construction of buildings (see Case 7).

Beyond this, the concept of circularity considers that the material that might be directed to recovery/recycling at the end of the first use phase, should be designed in a proper way to enable processing for recycling. The initial design of products should be done in a way to help recyclers and/or repairers, to disassemble products in order to recover/recycle valuable materials and components and save valuable resources (European Commission, 2017a).

In future, issues such as reparability, durability, upgradability, recyclability, or the identification of certain materials or substances will be systematically targeted under the Eco-design Directive (2009/125/EC). In this context the issue on avoiding hazardous substances throughout the initial production of products seems to be one of the key aspects to enable recycling of end-of-life products in an environmentally-sound manner. The European framework on this matter is set by legislative acts such as Regulation (EC) No 850/2004 on persistent organic pollutants (POPs), Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as well as Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment. Context to the analysed cases: Licenses to ensure the quality of the feed chain (see Case 1).

High quality secondary raw materials will foster its acceptance on the market and thus, will enable higher amounts to be recovered/recycled. This will contribute significantly towards achieving the new EU targets for recycling of waste (see Chapter 2) defined in the new legislative proposals on waste under the Commission´s circular economy package.

Suggestions on who could act in order to promote the topic:

- EU, national governments, regional administrations, standardisation institutes (e.g. CEN CENELEC working on European Commissions mandate), industrial organisations
- operators of the recycling sector

5.3 Co-operation and knowledge sharing among value circle stakeholders

All cases identified co-operation and knowledge sharing between various stakeholder groups as a key factor behind the success of innovative developments. Co-operation between the actors along the recycling chain is self-evidently necessary, in order to establish practical operation of recycling practice. Likewise, co-operation and discussions between the operators and permit authorities at an early stage as possible, facilitates decision making, especially related to IED affected companies. Permit authorities have an overview of secondary material flows and of potential industrial symbiosis between different sectors that is uniquely available, based on a public-private cooperation (see Case 9).

Additionally, knowledge, experience and best practice sharing helps operators and other stakeholders learn from each other, both from failures and from successes. In this way good examples can be spread, and best practices can be put to operation more broadly. Resources and time can be saved when mistakes are not repeated and the wheel is not reinvented several times. Sectoral organisations have an important role to play in spreading knowledge with their partners and members on lessons from case studies and best practice. Equally important is the feedback that can be obtained from the sectoral organisations to the national agencies or institutes (e.g. about the ambitions and challenges for the sector companies), and the possibilities to define a shared vision of the future, to create goals, and develop action plans to achieve results.

Knowledge sharing and open dialogue is required also between authorities on various levels (national, regional, local). In many subject areas the authority for permitting and supervision, is delegated to regional level, where resources can be scarce, and areas of responsibility of individuals vast. Time to acquire knowledge and information on research, development and innovation is not always available. Nevertheless, at the same time, the competent authority should make its decisions taking into consideration up-to-date knowledge. Decisions from one region may differ from the decisions at another region, giving industry uneven basis for operating and leading to inconsistent application of regulations.

Another learning point is the importance of interdisciplinary consultation, (e.g. between environment and food sectors and regulations). Issues related to wastes, environment and circular economy, are most often complicated questions concerning several branches of science and administration. From the cases analysed the one on soya meal (Case 1) can be picked as an example. It was concluded that the discussion needs to be broadened from the environment and waste sector to institutions that have knowledge on food and feed and the safety requirements already covered by existing food regulation. In this way, all relevant knowledge would be put on the table and a broader and better informed decision could be made. Additionally, one very current example is plastics recycling, where the problem of hazardous substances that have been added to plastics in order to improve product properties and fulfil the requirements (e.g. on fire safety). On the one hand, chemicals legislation requires materials with hazardous substances to be substituted or removed from the market, but on the other hand, waste legislation requires more recycling of waste materials. Interdisciplinary consultation on both national and European level is required to find consensus on how to increase recycling safely and within the confines of the waste hierarchy.

Governments could facilitate the exchange of interdisciplinary knowledge and experience between competent authorities (i.e. permitting, compliance and enforcement), industry or sector organisations and knowledge institutions, (e.g. through a learning environment or a platform). In addition to utilisation of the digital environment, possibilities for face to face meeting should be organised on a regular basis. The European Commission launched in 2017 a joint initiative by the European Commission and the European Economic and Social Committee the European circular economy stakeholder platform, which can be seen as one step for facilitating communication and best practice sharing among circular economy stakeholders (European Union, 2018).

Suggestions on who could act in order to promote the topic:

- EU (at least on IED), governments, EPAs, regional authorities, industrial organisations
- operators of the recycling sector

5.4 Regulatory environment

The community level legislation, such as the WFD (2008/98/EC), EU Landfill Directive (99/31/EC), Directive on packaging and packaging waste (94/62/EC) and EU circular economy package have been identified as driving forces in most of the cases. The setting of recycling and recovery targets and targets for diverting organic waste from landfills have forced EU member states to work on or encourage operators to work on solutions for moving up in the waste hierarchy. However, in several cases this has not been enough. Additionally, various national regulatory approaches have been used. Some of these have already been introduced and discussed in the lessons learned on quality assurance in the recycling chain (Chapter 5.1) and markets for secondary materials (Chapter 5.2). Some additional regulatory drivers are discussed below.

National regulations have been laid down concerning the collection, sorting and separation of wastes for recovery. In Scotland both a duty on municipalities to provide a separate food waste collection to householders and a duty on food businesses producing over 5 kg of food waste per week to separate it for recycling were laid down in order to increase the separate collection of bio-waste (Case 2). For the same reason, but earlier, in Austria, an ordinance on obligations concerning the source-separation of bio-waste was introduced in 1996 (Case 3). Additionally, in Finland a decree on collection systems for returnable drinks packaging (526/2013) was laid down to increase packaging recycling (Case 6). Deposit Return Schemes (DRS) offer a good opportunity to segregate more valuable waste types at point of discard, this methodology sits well with EPR and the circular economy. There may be scope however, to use the higher value wastes to fund collection of lower value ones (either as DRS or through funding for other schemes (i.e. PET could fund food tray collection and sorting).

National regulations on the quality of waste accepted for processing and/or the quality of secondary material produced from waste were used in several of the cases and they are discussed in the other lessons learned on quality assurance in the recycling chain (Chapter 5.1).

In addition to landfill or incineration tax (discussed in financial instruments, Chapter 5.5), national regulations have been laid down on specific fees or penalties to increase recycling. Examples can be found in Scotland, Finland and Austria. In Scotland, SEPA used a Fixed Monetary Penalty (FMP) of £300 as an enforcement tool for their bio-waste enforcement campaign. SEPA also carried out inspections on food businesses that previously had been unwilling to adopt a separate food waste collection. In most cases a FMP was enough to change behaviour. In only two cases, did SEPA issue FMPs and will return to those businesses in future (Case 2). In Austria the law for remediation of contaminated sites (Altlastensanierungsgesetz, ALSAG) has set a fine for non-proper management of C&DW with a charge of 9.20 €/t that is not recovered. This has been a main driver for recycling (Case 7).

In addition to the legislation identified as drivers behind the cases, other community level legislation, such as the directive on industrial emissions (2010/75/EU; IED) could more efficiently be used as a driver for circular economy. Connected to the Action Plan for the EU circular economy the Commission intends to enhance better resource use, by including guidance on best waste management and resource efficiency practices in various industrial sectors, through publication of BREF documents. More focus on integrating circular economy criteria in IED permits via sectorial BREF (see Chapter 5.2) revisions should accelerate waste prevention and recycling. Open dialogue between IED companies and authorities to boost material efficiency and circular economy is highly cost-effective and should be strengthened with adequate professional profiles and skills (Case 9).

The Make it Work initiative (MiW; IEEP 2017) has been operating from 2014 to promote the launching of eco-innovations for circular economy. The initiative has the following objectives:

1) Develops recommendations for more consistent, clearer and simpler EU environmental rules and smarter implementation practices (so called 'drafting principles'),
2) provides a platform for Member States to proactively help improve the EU environmental acquis, using their practical law-making and implementation expertise, and
3) produces concrete recommendations for simpler, future-proof European environmental law and smarter implementation practices.

The approach is cross-sectoral, looking at horizontal themes, with an emphasis on strengthening consistency and coherence between directives and regulations.

The MiW organised a Workshop on enabling eco-innovations for a circular economy under EU environmental legislation in December 2017. An important finding of this workshop was that current EU environmental law already provides many tools and opportunities to enable eco-innovations for a circular economy. There are however, challenges in recognising practical benefits from these opportunities. The general provisions need to be interpreted and different interests balanced, information gaps and risks also need to be assessed and managed. To support EU member states in this complex and demanding area the workshop participants expressed the need for practical guidance for regulators and policymakers. As a next step MiW will therefore; work on the development of such guidance, focusing on the role of regulators. In developing the guidance close cooperation with the European Implementation Networks, in particular IMPEL and EPA-network, will be sought, to help align the guidance with actions taken by the European Commission.

Suggestions on who could act in order to promote the topic:
- EU, governments, EPAs generating legislation
- regional and permit authorities using the legislation in practice

5.5 Financial instruments

Financial instruments of various types were recognised as being important in almost all the cases. Landfill tax or disposal fees for landfilling wastes encourages waste producers to find and develop recovery options for waste streams if the tax is considered high. Landfill tax is in some countries connected with a ban on landfilling organic waste, which can improve the steering effect. Overall assessment on the cost-efficiency of recycling vs. landfilling can/should include all fees and costs related to landfilling (e.g. transports, tax) vs. all costs related to recycling (i.e. transports, gate fees, processing required for recycling, revenues gained from selling the secondary material). Landfill tax was identified as a key driver, at least, for cases such as bio-waste to composting (Case 3), C&DW case (Case 7) and roofing felt case (Case 8). For the refractory waste case, the landfill tax was considered currently too low (below 20 €/t) to have a steering effect (Case 9).

Legislation on the taxation of certain types of drinks packaging (1037/2001) was introduced in Finland, giving producers the possibility to avoid the tax if they organise or take part in a return and recycling system for drinks packaging (Case 6).

In addition to taxes, incentives can be used for steering waste utilisation in the desired direction. In Austria incentives for biogas treatment plants were given for produced energy from biogas if fed to the public power supply system. No incentives were given for the producers of compost (Case 3).

The research and development of innovative solutions and new concepts for waste recycling requires both economic and human resources from companies and stakeholders. In several of the cases described, external funding has been obtained from regional, national or European public funding sources to enable this R&D. Even small amounts can enable the start-up of a development process (e.g. for a company to find partners for co-operation). In the refractory waste case (Case 9), the economic support of 25 000 € facilitated a continuous public-private dialogue with the steel factory, which has contributed to the following benefits:
1) A transfer of the practical experience and innovative knowledge to the other 8 Basque steel factories.
2) To the preparation of a regional landfill ban of recyclable magnesite refractories.
3) To the preparation of specific new requirements for steel factories about refractory recycling to be integrated in the recently renewed permits.
These processes are ongoing and some additional issues are being prepared. As result of another small project on improvement of highly alloyed internal scrap, a similar process has begun also in the steel processing sector.

In the roofing felt recycling case (Case 8), public funding was obtained from the EU-level for developing the recycling method, and from the national and regional levels for implementing the recycling in practice in Finland.

The costs related to wastes can/should be made more visible than currently they are, in order to improve the realisation of the problem of wasted resources by the industry and the public. In Switzerland, food waste was given the price tag that composed of the waste treatment costs. This made hotels, restaurants etc. realise the problem and act to minimise the amounts of food waste produced and their own cost (Case 4).

Suggestions on who could act in order to promote the topic:

- financial instruments: EU, governments
- public funding: EU, national and regional financial institutions

6 Summary

Nine examples from seven European countries focusing on five waste streams were analysed in order to assess the critical factors behind the success of turning waste into secondary materials. The five waste streams studied were **food waste**, **critical raw materials**, **plastics, biomass** and **C&DW**, which are prioritised in the European Commission's Circular Economy Package as well.

For each case several crucial factors were recognised. The **role of markets** was identified as a key in driving demand for products that are made from or contain secondary materials. Secondary materials with a **higher value** are more robust to price fluctuations and can compete with **virgin materials**, however, some materials are much more marginal and **cannot compete** with the cost of virgin materials on the basis of supply and demand alone. The markets for secondary materials can be created, stimulated or regulated by fiscal/economic policies. It is important to look for a **raft of policies** that are capable of generating a more **stable platform** for secondary materials in the longer term. It is important to recognise that **intervention is required**, if the target is to alter a market to take account of **externalities,** for instance, or to stimulate growth where time frames for returns on investment may be longer than the current norm.

The **quality** of secondary raw material is a crucial factor to enable uptake within the market and for acceptance by the consumers. Only if the quality of the secondary raw material is comparable to that of primary material, can trust among consumers be established. Several instruments were discussed in the case studies as suitable ones to ensure high quality of secondary raw materials, such as **acceptance criteria** for waste input into the recovery/recycling process, **end-of-waste-criteria** for secondary raw materials, **quality standards** for secondary raw materials, defined types of application for secondary raw materials and ensured process quality of the whole recycling chain (process performance and environmental impacts). Beyond these, the concept of circularity considers that the material which might be directed to recovery/recycling at the end of the first use phase should be **designed** in a proper way to improve processing for recycling. The initial design of products should consider easy disassembling of products in order to recover/recycle valuable materials and components and avoidance of **hazardous substances** throughout the initial production of products, among others.

All the analysed cases identified **co-operation** and **knowledge sharing** between various stakeholder groups as one key factor behind successful development. Knowledge, experience and best practice sharing between the operators along the recycling chain, between the operators and permit authorities and between authorities on various levels (national, regional & local), help operators and other stakeholders learn from each other, both from failures and from successes. In this way good examples can be spread, and best practices can be put into operation on a practical basis. In addition, issues related to wastes, environment and circular economy most often are complicated questions concerning several branches of science and administration and therefore **interdisciplinary consultation**, between disciplines (i.e. environment and food) is crucially important to achieve recycling objectives.

The community level legislation was identified as an important driver for most of the cases. The setting of recycling and recovery targets and targets for diverting organic waste from landfills have forced EU member states to work on or encourage operators to work on solutions for moving materials up the **waste hierarchy**. However, in several cases this has not been enough. Additionally, various national regulatory approaches have been used. Examples of such regulations include national regulations concerning the collection, sorting and separation of wastes for recovery and on the quality of waste accepted for processing and/or the quality of secondary material produced from waste. Regulations on **landfill or incineration tax** have been used in several countries, and in addition national regulations have been laid down on specific **fees or penalties** to increase recycling.

Financial instruments of various types were recognised important in almost all the cases. Landfill tax or disposal fees can rouse waste producers find and develop recovery options for waste streams. Landfill tax is in some countries connected with a **ban on landfilling organic waste,** which can improve the steering effect. In addition to taxes, incentives can be used for steering waste utilisation in the desired direction. **External R&D funding** is often required for companies and stakeholders developing innovative solutions and new concepts for waste recycling. In several of the cases external funding was obtained from regional, national or European public funding sources to enable the R&D. Even small amounts can enable the start of a development process e.g. for a company to find partners for co-operation. On top of these, the costs related to wastes should be made **more visible** than currently in order to improve the realisation of the problem of wasted resources by the industry and the public.

For each of the topics identified above, some suggestions were made on **who could act** in order to promote the topic. Many of the topics are already being promoted by initiatives, projects, networks and platforms working on EU, national or regional levels. However, transformation from a linear economic model to a circular model needs significant changes and new organisation of **value chains** hence requiring actions from all stakeholders.

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