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Report

Towards an Innovation-intensive Circular Economy. Integrating research, industry, and policies

Roberto Zoboli, Catholic University, Milan, and SEEDS

with contributions from
Nicolò Barbieri, University of Ferrara and SEEDS
Claudia Ghisetti, Catholic University and SEEDS
Giovanni Marin, University of Urbino and SEEDS
Susanna Paleari, IRCrES-CNR

Edited by Stefano Pareglio, Catholic University, Milan, and FEEM

FEEM
FONDAZIONE ENI ENRICO MATTEI

UNIVERSITÀ CATTOLICA del Sacro Cuore

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01 Introduction

The present picture for the Circular Economy (CE) is so lively and fragmented to suggest highlighting the evolving interconnections in which the CE is embedded - thus escaping an idea of the CE as a self-sufficient all-encompassing paradigm. The main objective of this work is to propose 'integrative approaches' to the CE that can favour a better interplay between research, industry and policy.

Two ideas are at the core of the work.
The first idea is that there is a shift currently taking place between an 'Old' and a 'New' Circular Economy. By 'Old CE' we mean the material circularity achievements we are observing since at least three decades in waste management and resource efficiency, especially as a consequence of European waste policies. By 'New CE' we mean the extension of the circularity approach to possibly all the sectors of the economy and the extension of the scope of CE to encompass changes that are not directly linked to closing the material loops, like extending the life of products in use and the sharing economy. This 'New CE' embodies the 'Old' one, which is alive as never before, by encompassing a continuation of the well-established trends in increasing material circularity. The 'New CE', however, marks a shift towards a more central role of technological and social innovation, even in the major sectors of the 'Old CE'. Therefore, in this work, we often refer to a 'New Innovation-intensive CE'. While one could say that the new features of the CE has been triggered by the EU 'Circular Economy Package' of 2015, a 'New Innovation-intensive CE' will be better seen in the very near future when, in parallel to the implementation of the EU waste directives and the new Action Plan on the CE, other areas of public policy, in particular innovation and industrial policies, will intensively target the CE as a priority, and a large part of the European production system will pursue explicit CE strategies.

The second idea is that, given its intrinsically systemic nature, the CE can be better understood by means of systemic and integrative approaches, which allow highlighting further elements of openness and interconnection of the CE from a research-industry-policy interaction perspective.
We propose two integrative and systemic approaches. The first one is to look at the CE through the lens of the 'System of Innovation' concepts, which has been fruitfully developed in the economics of innovation and seems particularly suited for the understanding and the governance of a 'New Innovation-intensive CE'. The second integrative approach is based on the idea of the NEXUS, which is increasingly used as an analytical tool to avoid missing the links between critical sectors in development policies (in particular water, food, and energy) and then useful to improve policy integration within governance. We propose and sketch a NEXUS approach to the (positive and negative)

connections between the CE, decarbonisation, and the bioeconomy.

The scope of the report is largely the CE in Europe, although with various references to Italy. The report is not primarily focused on the (very lively) picture for the CE in Italy because the latter has been depicted and explored by recent reports produced by some of the Italian initiatives described in Section 5. The European focus is adopted also to clarify that the CE transition is a European-scale process and, while it spreads across the reality of nations, regions, and local communities, its main drivers and directions arise at the European level.

The work is made of two parts.
In Part 1, we take stock of the present conceptual framework on the CE (Section 1), the evolving policy drivers (Section 2), the quantifications on the CE (Section 3), the innovation for the CE (Section 4), and a set of selected initiatives undertaken in Europe and Italy to favour a CE transition (Section 5). The developments reviewed in Part 1 are necessarily selective, also in terms of areas considered, and 'temporary', given the extremely lively picture of initiatives taking place on the CE at all levels.

In Part 2, we propose the arguments to look at the CE as an 'Innovation System' (Section 6) and we propose a sketch of a 'CE System of Innovation' also based on the picture emerging from Part 1. We then provide arguments to place the CE in the framework of a NEXUS approach linking the CE itself, the Decarbonisation transition, and the Bioeconomy (Section 7). Even in this case, we propose a preliminary sketch of the main (positive and negative) relationships in the NEXUS. We finally highlight some open and emerging issues in the 'economics' of the CE, in particular the role of prices, costs, taxes, and consumers, and the development of the 'finance for the CE' (Section 8).

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The report has been prepared by Roberto Zoboli (Catholic University), with contributions from Nicolò Barbieri (University of Ferrara), Claudia Ghisetti (Catholic University), Giovanni Marin (University of Urbino), Susanna Paleari (IRCrES-CNR).

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The main author and the contributors belong to SEEDS – Sustainability, Environmental Economics, and Dynamics Studies, an inter-university research centre created in 2013 that gathers the competencies in environmental economics and policy of researchers from five Italian Universities (University of Ferrara, Catholic University, University of Bologna,

University of Rome 3, University of Rome Tor Vergata)[1].

In this report, we exploit a several years research experience on waste economics and eco-innovation, and the experience gained in our several years activity within the ETCs - European Topic Centres of the EEA European Environment Agency - at present: ETC/WMGE – Waste and Materials in a Green Economy, 2019-2021, of which SEEDS and IRCrES-CNR are the Italian partners[2].

The responsibility on what presented in the report is to be attributed only to the author(s).

1 *http://www.sustainability-seeds.org/*

2 *The EEA and ETC/WMGE activities on the Circular Economy are briefly described in Section 5.*

02 Executive summary

Part 1: Taking stock of the CE knowledge base

Section 1: Concepts and ideas on the CE

- While stimulating an extremely lively attention at all levels, the Circular Economy (CE) is still the subject of different definitions and ideas that, on the common ground of the material circularity in the economic system, provide different visions, sometimes envisioning the CE as a fundamentally new paradigm of production/consumption and even a general social setting transition. Particularly open is the set of interpretations and analytical approaches provided by the academic research, which is booming.

- In this report, the preferred CE conceptual framework is the one proposed by Bocken et al. (2016) and OECD (2017), which organises the CE in three nested levels: 'Closing the resource loops' (narrower); 'Slowing down resource loops' (intermediate); 'Narrowing resource flow' (larger). This approach allows us to see the CE in the framework of a general transition of resource efficiency, which is general enough to encompass both the original core of the CE, that is the waste and recycling system - for which the idea of circularity is embodied since a long time in the EU Waste Hierarchy - and the other levels of material resource efficiency, like useful life of goods, material/energy saving innovations, organisational innovations like the sharing economy, product/process innovation at large, and social innovation in life styles.

Section 2: Policy drivers

- The EU policy framework for the CE is still largely based on waste policies, which are at the very core of the CE Package proposed by the Commission in 2015 (including the Action Plan on the CE) and the revised directives on waste adopted in 2018-2019. The latter are further pushing in the direction of 'zero landfill', maximum recycling and recovery, a specific focus on plastics (Plastic Strategy), with an emphasis on Extended Producer Responsibility (EPR). The new EU waste policy setting is bound to change the operational framework of many industrial sectors well beyond the border of the waste management industries.

- We focus on two key the waste policy principles that have been - and are now in a reinforced way - key drivers of achievements in CE: Waste Hierarchy and the Extended Producer Responsibility (EPR) principle. The Waste Hierarchy is now backed by a cumulative LCA-based knowledge (Life Cycle Assessment) but not from economic analysis (e.g. socially optimal recycling) and allows flexibility in selecting management options when using extended LCA approaches. The EPR principle is at the roots of major CE successes of the past, or the 'Old CE', in sectors like packaging waste, WEEE, ELV, batteries, and has a widespread application in other areas that are bound to be enlarged.

- Other EU policies and strategies that are, directly or indirectly, pushing towards the CE are the revised Bioeconomy Strategy and the Carbon Neutral Economy strategy of 2018. The Bioeconomy strategy has many recognised overlaps with the CE (e.g. food waste) and has been revised accordingly. The Carbon Neutral Economy strategy explicitly sees in the CE one of the processes needed to achieve carbon neutrality. The possible interactions between the CE, the Bioeconomy, and Decarbonisation are further discussed in Section 7 of the report.

Section 3: Quantifications

- A fully consistent quantification of the CE is still an open process. Waste statistics provide an important information basis but they do not cover the full cycle of materials before and after waste. Even the attempts to link waste statistics with LCA information at the macro-scale are non-systematic. Material Flow Accounts provide a useful basis but they are not fully integrated with waste statistics and their focus is still on the aggregate performance of resource efficiency. Eurostat recently developed a specific set of CE indicators to monitor progresses. This monitoring framework largely hinges on waste statistics and MFA statistics, then including data on materials in industries from other sources and data on recycling-related patents. In the Eurostat framework, an attempt is done to integrate waste data and MFA data through the Sankey Diagram. The latter, while being still open to improvements and completion, suggests that in the EU28 the cycle of materials is still very open, with 0,8/1,5 billion/tons of materials still going to landfills.

- Other tools for quantifying the CE can be found in the input-output tables, which are part of the National Accounts, in particular after the introduction of the classification NACE 2.0, which better groups the waste related industries. With IO tables, it is possible to see (for the EU27) the inter-industry relationships of the waste industries - an important macro-sector in terms of value added - with the rest of the EU economy, thus highlighting also the degree of dependence of various industrial sectors on the inputs from the waste industry. However, IO data are often not timely.

- Other IO-based tools developed within European research programmes, like EXIOBASE and WIOD, also allow measuring how a number of industrial sectors are highly dependent on waste inputs (e.g. metal and paper industries), then representing the core of a macro-scale CE. These tools are also augmented with 'environmental extensions' (Environmentally Extended IO; MRIO models) that allow measuring, in some cases, the 'vertically integrated' content of materials in final consumption, also in terms of international spillover of resource pressures through 'trade embodied' pollution and materials. In general, these models highlight that gains in resource efficiency in Europe are accompanied by the international transfer of resource pressures to other countries. Even in this case, data are not timely.

- The set of economic macro-models (e.g.

Computable General Equilibrium, macro-econometric models), often shows a non-specific consideration of the CE component, and presents a number of simplifying assumptions on the material side of the economy. The results on the dynamics of the CE depend, inter alia, on the way models do incorporate technological change and policy shocks.

Section 4: Innovation for the CE

- Innovation can be a fundamental lever for the CE, especially for a 'New Innovation-intensive CE'. We firstly analyse the data and information on conventional indicators of innovation for the CE (arguments on the CE as an 'Innovation System' are proposed in Section 6). In Europe, the trend of patents on CE-related areas was not booming before the CE Package of 2015, differently from the patents in energy/climate that had a fast growing trends from the 1990s. However, for CE-related technologies there has been an increasing patenting activity from the mid of the 2000s.

- The CIS – Community Innovation Survey (2014) shows interesting information on the adoption of CE –related technologies by European companies (technological diffusion). Adoption rates (share of companies introducing CE innovations) are not higher than 40% and largely differ across countries. In the majority of countries (with the notable exception of Italy) innovations adoption rates to reduce energy/climate footprint have been higher than those for material/water intensity reduction. However, with the notable (opposite) exceptions of Germany and Italy, there is a significant degree of 'complementarity' in the adoption of the two types of eco-innovations (energy/climate footprint and material/water intensity) with rates that do not substantially differ.

- While technological innovation has not been, so far, at the core of observed 'Old CE' developments in Europe, much more important has been 'organisational innovation', in particular in those 'value chains' targeted by EPR-based policies. To comply with policy targets and provisions, the sectors linked to packaging and packaging materials, the automotive sectors and the related materials, the electric and electronic products sectors and the related materials, and the batteries sectors, had to organise innovative inter-industrial networks for post-consumer collection and processing of products and materials. These systems, which are in some cases very complex and have different effectiveness and economic effects on industry, provide good examples of CE developments based on inter-industry organisational innovation. Part of the activities and the effects of these schemes can be product design and product making innovation, which can provide extended CE resource-efficiency effects.

Section 5: Selected initiatives

- At present, the picture of institutional and stakeholder initiatives for the CE is extraordinarily lively. Many of these initiatives are from the bottom up. We selected just few important examples.

- At the European level, the Ellen MacArthur Foundation has been the first and still most active actor to address the CE. Since 2012 it produced dozens of reports and operates as a reference for policy making on different sub-areas the CE. Since 1994, the EEA – European Environment Agency, carried out analysis and reporting on waste and materials in support to policies and the EIONET network. The EEA also managed the Commission's European Reference Model for Waste. The Agency, also with the support of the European Topic Centres (at present the ETC/WMGE 2019-2021), produces reporting and information tools on CE-related topics. The European Circular Economy Stakeholder Platform is a joint initiative by the European Commission and the European Economic and Social Committee aimed at providing a platform for networking and cooperation among industries, research, and other actors. The Platform is the entry point to a great number of other platforms (national, local, sectoral). BusinessEurope has created a platform in which CE practices by European companies are collected.

- In Italy, the main institutional initiative has been taken by the Italian Ministry of the Environment, which produced policy positions and measurement reports on the CE. ENEA provides the support to MATTM for the activities on the CE. In 2018, MATTM and MISE (Italian Ministry of Economic Development) become members of the Italian Circular Economy Stakeholder Platform – ICESP, promoted by ENEA in line with the European Platform. A 'Circular Economy Network' has been created by the Istituto per lo Sviluppo Sostenibile and includes a number of promoters and associations (companies and industrial associations). In cooperation with ENEA, it produced a report on Circular Economy in Italy in 2019. Confindustria, the Italian industrial association, launched a project on CE aimed at stimulating knowledge creation, sharing and transfer among Italian industrial actors in different sectors. Confindustria organised several workshops in different locations and published a report on the CE. ASviS is the main promoter and reference network for the implementation of the UN Agenda 2030 and SDGs in Italy and is carrying out several actions and partnerships with a CE focus. The Government of the Lombardy Region created the 'Regional Observatory on circular economy and the energy transition' which includes more than 100 participants from industrial associations, university and research, representatives of the civil society, and represents a participatory process in support to regional policies.

Part 2: Towards a New Innovation-intensive Circular Economy: Integrative approaches

Section 6: Integrative approach 1: The CE as a 'System of innovation'

- A first suggested integrative approach is to look at the CE as a 'System of Innovation'. The CE is about change and can be framed at the intersection of different types and levels of innovation.

- At a first level, the waste system can be seen through the innovation lens starting from prevention innovations, micro-level technological inventions/innovations inside different management options (reuse, recycling, recovery), shifting across different management options (e.g. diversion from landfills), and organisational innovations (e.g. EPR compliance schemes). At a broader level, with reference to the preferred 'nested' conceptual framework of Section 1, a broader field of process/product innovations and drivers, including non-waste policies (e.g. industrial policies) and market drivers, can be relevant for the CE.

- The conceptual framework of 'Sectoral Systems of Innovation' and 'National Systems of Innovation', as developed in innovation economics and policy, is suggested to address the CE, which could be located at crossroad between the two frameworks given the possible pervasiveness of the CE-related changes across the industrial and consumption systems. An organising framework that integrates the 'Sectoral system of innovation' elements and the 'National System of Innovation' elements of the CE can be developed to map the real CE Sectoral/National CE Innovation System. The major blocks/actors to map are the industrial/economic actors according to innovativeness or other criteria, the relevant policy system (all levels), the university/research system, the financial system. In addition to the actors, mapping must address the flows inside and outside the system, e.g. the inter-industry relationships and the flows of public and private investments and funding. Policy processes involving the CE can similarly be mapper and monitored. The sketch of a 'CE Innovation System' is presented.

- The present activism in allocating EU research and innovation funds to the CE can be a push to CE innovation for the future, up to supporting a 'New Innovation-intensive CE'. Existing lines of funding to the CE are examined. Within Horizon 2020, in the last few years (from 2015), the projects strictly related to the circular economy (i.e. explicitly referring to 'circular economy') that received funding under different calls have been 61, for a total cost of 345 million/€. Many other Horizon 2020 projects can have a relationship with the CE through parts/links within their program of work. In the H2020 Work Programme 2018-2020, the Circular Economy is a 'Focus areas' receiving a total budget of 964 million/€. In the programme for the new FP9 'Horizon Europe' (2021-2027), there is not a specific cluster on the CE (as is the case with the revision of Italian National Research Programme), but several other clusters can involve CE research to a significant extent. Overall, the European funding to the CE, through different programmes including Structural Fuds, has been 10 billion/€ from 2016.

Section 7: Integrative approach 2: A NEXUS linking CE, decarbonisation, and the bioeconomy

- A second suggestion is to adopt a NEXUS approach to the CE through its relationships with Decarbonisation and the Bioeconomy. While often recognised, these interlinkages have a limited analytical basis and have limited policy integration consequences, as the CE and the other two strategic transitions are still seen as separate domains. A NEXUS approach is used when policy separation can create the risk of missing synergies and raise conflicts, and then can be adopted for the CE. Arguments in favour of a NEXUS on Circular Economy – Decarbonisation – Bioeconomy (CE-DEC-BIO NEXUS) approach are developed on the basis of a set of technical and policy reciprocal effects (positive and negative) of the three transitions. A preliminary scheme of the CE-DEC-BIO NEXUS is provided.

- The development of a CE-DEC-BIO NEXUS requires, first of all, steps forward from the analytical point of view, in particular by invenced identifying and measuring connections for materials and energy flows, natural resources involved, industrial sectors involved, social and policy processes involved. The second major step of a NEXUS approach is policy synergy and integration. While in the case of the EU CE strategy and the EU Bioeconomy strategy there is dialogue and a set of recognised interlinkages, these linkages are still weak in the case of climate-energy policies and the EU carbon-neutrality strategy.

- The NEXUS approach to the CE, decarbonisation, and the bioeconomy can support: (i) the achievement of better analytical and modelling tools focused on the essential linkages; (ii) provide the arguments and the tools to better integrate policies in the three areas, thus better exploiting synergies and preventing conflicts and trade-offs.

- Four horizontal elements of the CE-DEC-BIO NEXUS are suggested: (i) the CE-DEC-BIO NEXUS has a global scope by involving the materials and energy external dependence of Europe: (ii) CE oriented innovations can influence the link between the CE and DEC and innovations in the CE can change the links with the Bioeconomy: (iii) policy integration, for which there are not robust tools to check ex ante the implication of, for example, DEC policies for the CE and the Bioeconomy, and vice versa: (iv) advancement of analytical tools able to represent the inter-sectoral linkages; while a NEXUS approach, by focusing on major linkages, can 'economize' with respect to full and detailed inter-sectoral modelling tools, nonetheless more advanced integrative knowledge tools are needed.

Section 8: Open and emerging issues

- There are various open issues in the development of the CE in Europe that can be referred to the 'economics' of the circular economy.

- There are poor incentives to the CE coming from the depressed prices of commodities and raw materials, which do not stimulate material savings and gives to policies the burden of triggering and driving the CE process. At the same time, the limited, and asymmetric, information/knowledge of the micro-economic dimension of recycling and secondary materials markets can prevent from adopting the rights policy instruments, in particular 'economic instruments'. Therefore, the issue of prices, costs, taxation, as well as the role of consumers in the new Circular Business Models, are still largely open issues. Proposals for 'material resource taxes' are considered and their limitations are highlighted.

- The CE requires the creation of industrial production capacity and innovative businesses, and then requires investments from both the public side and the private business sector. Investments require finance. The present picture for CE-related finance is lively, as is the case with Green Finance in general. In particular, there are interesting - and possibly game-changing - trends towards considering circularity features, and complementarily ‘linear risks’, among the selection criteria adopted by lenders to finance projects and businesses. These developments seem to assume a complete knowledge of circularity criteria but probably still need a deeper work on taxonomies, classifications, procedures, and metrics.

03

Part 1: Taking stock of the CE knowledge base

1. Concepts and ideas on the CE

During the last few years, in particular after the proposal for an EU policy package on the 'Circular Economy' in 2015[3], the concepts and definitions of Circular Economy bloomed in different policy, institutional, industrial, and research environments, up to creating a sense of fragmentation and, sometimes, indeterminacy. To set a clear scene for the CE, it is therefore useful to look at the most relevant CE concepts and ideas[4].

1.1 Institutions and think thanks

The most known conceptualisation of the CE has been proposed by the Ellen McArthur Foundation (EMF), which has been a forerunner in formulating a vision on the CE that largely influenced the EU policy making and the debate across institutions, research, and consultancy at different levels. The definition by EMF states that the CE is *"[...] an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models"* (EMF 2012, page 7).

The general conceptual scheme of the EMF is presented in Figure 1.1. The scheme divides between biotic/renewable and non-biotic circular domains, and for each of them traces a number of feedback loops that starts from the post-collection of waste and passes through cascade reuse/recycling/recovery for biomaterials and recycling, remanufacturing, refurbishing, and reuse for non-biotic resources. The scheme does not immediately highlight the several opportunities for recycling/recovery already existing during industrial processing (e.g. 'new scrap' in the metal industries, self-production of energy in bio-industries). However, the several reports by the EMF highlight these opportunities as pervasive and important[5].

The proposed EMF conceptualisation is based on a combination of theories and concepts available in literature and communication, some of which arise from the work of 'original thinkers' even outside the mainstream scientific environments. The main referred concepts are those of: Cradle to Cradle; Performance Economy; Biomimicry; Industrial Ecology; Natural Capitalism; Blue economy; Regenerative design[6].

3 *The EC proposed the revision of various waste directives and launched an Action Plan for the Circular Economy in December 2015. The process was concluded in May 2018 with the adoption of the new waste directives, see details below in the report.*

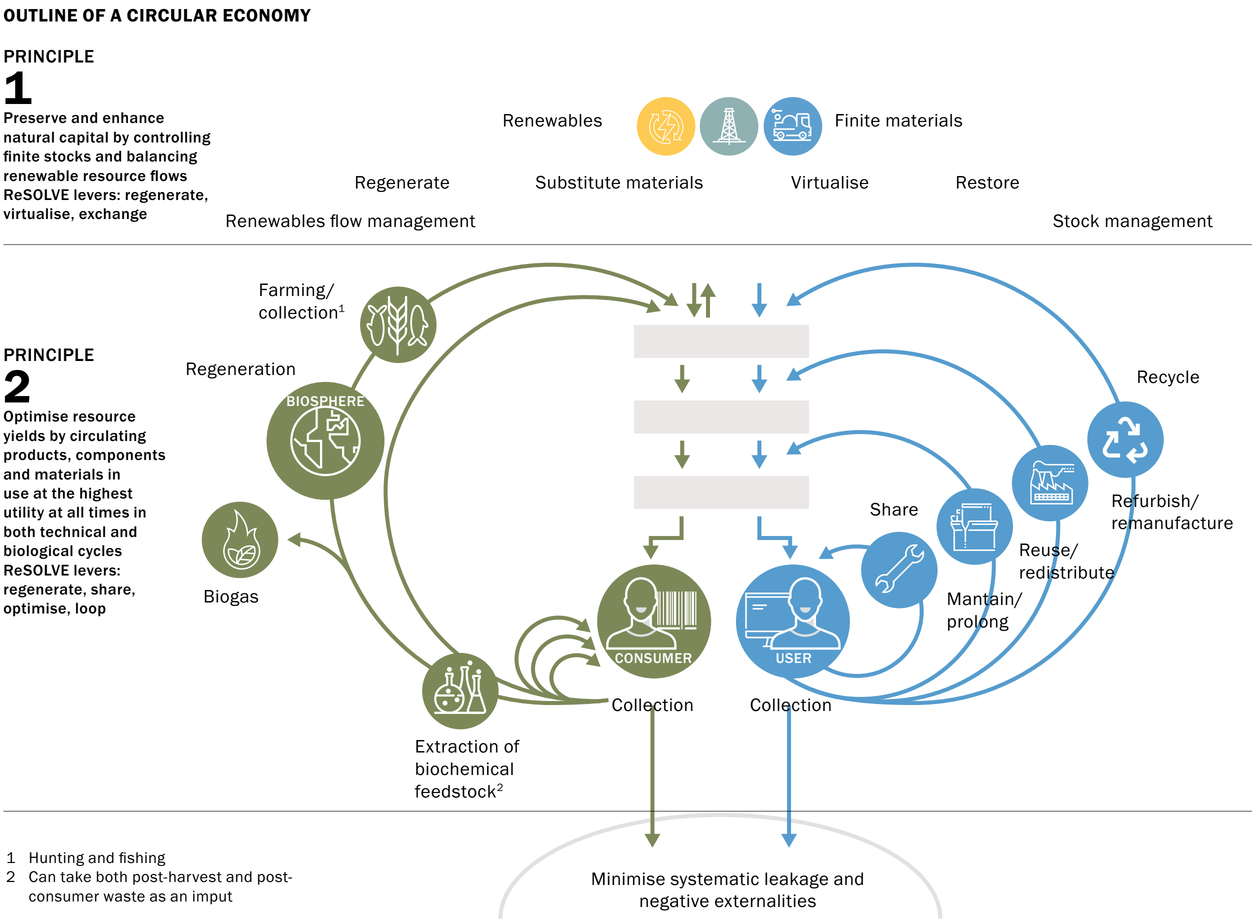
4 *An extensive discussion of the new and old ideas about the CE is presented (in Italian) in Massarutto (2019). An extension of circularity concepts to immaterial resources, that is productive knowledge, is proposed in Zoboli (2018).*

5 *All EMF reports and products are available at https://www.ellenmacarthurfoundation.org/*

6 *See https://www.ellenmacarthurfoundation.org/circular-economy/concept/schools-of-thought.*

The focuses of the EMF approach are at least two:
(i) the central role of 'circular business models' at the level of (innovative) companies and the industrial sub-systems they are part of; this micro-economic focus is certainly suited for companies that innovate by introducing CE solutions that can deliver cost savings and create leadership in CE-related emerging or lead markets; some sectors are better placed than others to create value added from CE-related innovations within their operation reach, in particular those sectors (e.g. chemical industry, bio-industries) that can create high value added products from very poor waste materials and industrial residues that, at present, are dumped in landfills or burned, or sectors that can easily integrate complex material processing technologies, like the 'bio-refinery' industrial settings (see Section 4 and 6);

Figure 1.1. The Circular Economy according to the Ellen MacArthur Foundation



Source: https://www.ellenmacarthurfoundation.org/

(ii) the net benefits of the CE at the macro-economic level (total value added and employment of the economy); this claim of EMF-inspired analyses is debated, and there is not strong evidence of this large net value added and employment outcome given the obvious substitution effects that the development of CE-based value chains can have on 'non-CE' value chains; these substitution effects cannot be seen at the level of the (innovative) CE companies and sub-sectors but can be seen at the meso-level (sectors, e.g. paper and metal industries) and at the macro-economic level (the economy as a whole); actually, macro-economic models do not indicate strong net value added and employment effects, but they have analytical limitations (see also Section 3);

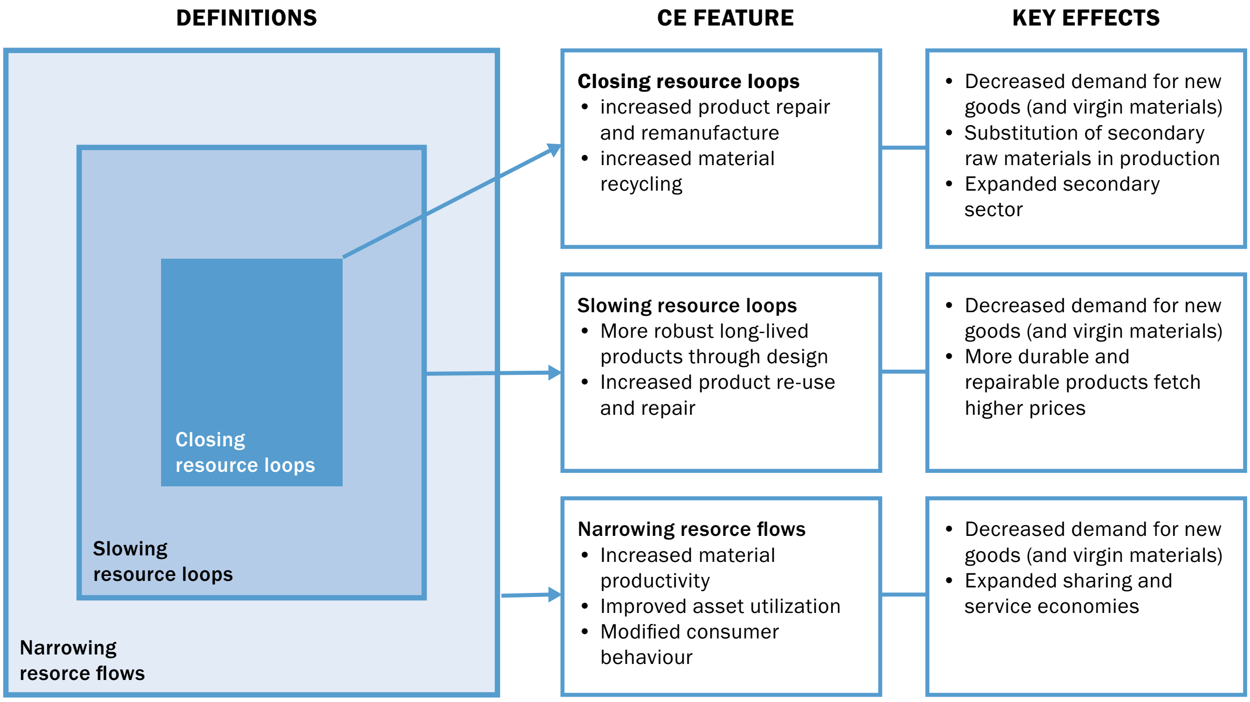
A very effective, general conceptual scheme of the CE has been elaborated by Bocken et al. (2016) and has been adopted in OECD (2017)[7]. Given that the very essence of the CE is to prevent useful/valuable resources to exit the loop of economic materiality, the most appropriate view of the CE is within the more general framework of Resource Efficiency.[8] According to OECD (2017), within the framework of resource efficiency, the CE can be seen by nested levels, each one involving different production/consumption strategies and having different economic implications (Figure 1.2).

A first level of circularity (the inner square in Figure 1.2, the narrower and the most properly 'circular'), is about the (increasing) 'closure of the use loops' of resources (waste and materials) through the (increasing) degree of material recycling and energy recovery of waste, the increase of material and products reuse, also after 're-manufacturing' of complex products or their parts (e.g. in the automotive sector). This level includes the preventive side of circularity through, in particular, 'design for recycling/recovery/reuse'. The nature of 'substitution economy' of this level is clear by observing that its expected effects are (last column in Figure 1.2) decreased demand of virgin materials and final goods through the increasing use of secondary materials and reused/remanufacturing of final goods, which leads to the relative expansion of the secondary/remanufacturing sectors.

7 *OECD, 2017, The macroeconomics of the circular economy transition: A critical review of modeling approaches, ENV/ /EPOC/ WPRPW/WPIEEP(2017)1/FINAL, 27 October 2017.*

8 *The European Commission launched 'The Roadmap to a Resource Efficient Europe' already in 2011, as a part of the flagship initiative on "A Resource Efficient Europe" of the Europe 2020 strategy (2010). For a picture of the European countries' strategies on 'resource efficiency' see EEA, 2016b, More from less: material resource efficiency in Europe, EEA Report 10/2016, Copenhagen. An update of the report is being published in 2019 (personal communication).*

Figure 1.2. Definitions, features, and effects of the Circular Economy



Source: OECD, 2017.

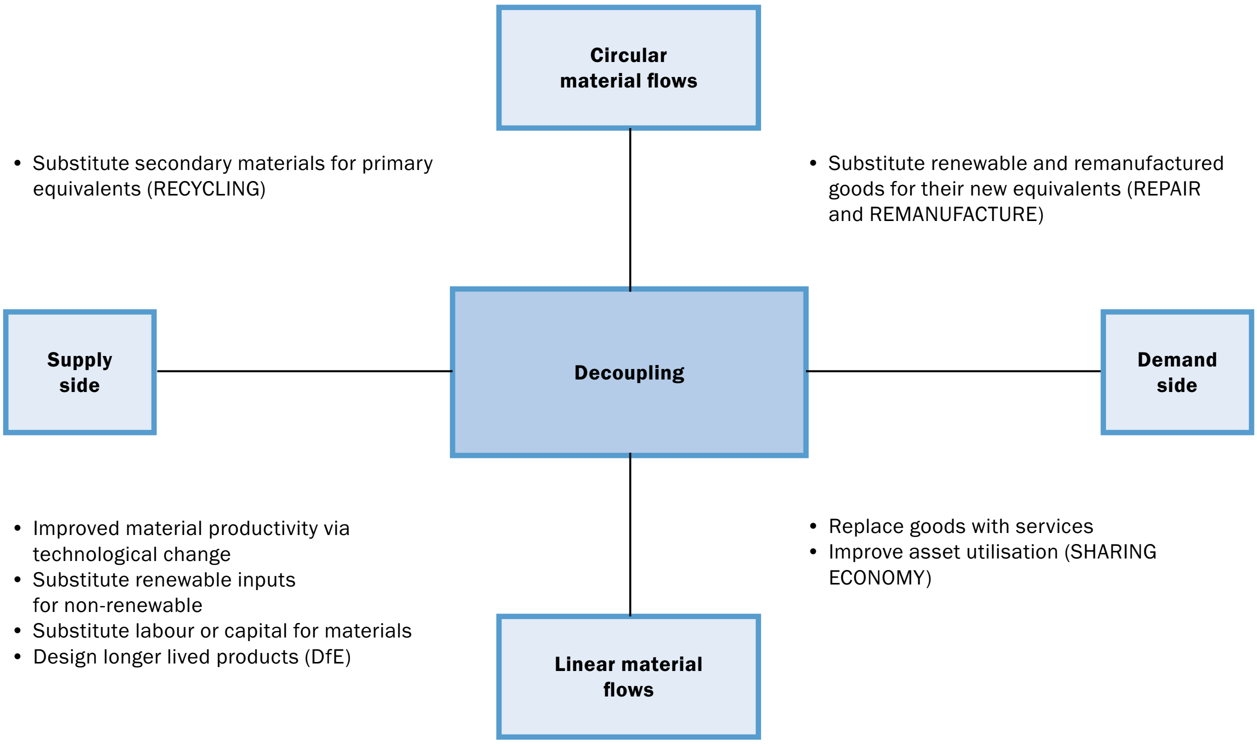
A second level of circularity (intermediate square in Figure 1.2), is about 'slowing down' the use-loops of resources (materials), which may involve again the increase of reuse/repair/remanufacturing but is mainly about the useful life of products. The latter has been generally shortened in the last few decades by industrial/company strategies of rapid product innovation, motivated by market segmentation strategies, that lead to accelerated 'social' obsolescence of still technically working devices and products. In some cases, it is claimed that there are also 'planned obsolescence' strategies that lead to accelerated scrapping. This process has led to an increasing amount of waste from, for example, electric and electronic products that represent one of the central issues of European waste strategies (see below). The extension of the useful life of goods can deliver resource saving (materials, and may be energy), of course at the cost (substitution) of a decreasing demand of new products and related sectors (but prices of more durable products can be higher). This level of CE is at the boundaries of, or even involves, the 'sharing and renting economy' and similar organisational innovations that can intensify the use of goods/capitals and give them a longer life.

The third and more general level of the CE (outer square in Figure 1.2), is the 'narrowing' of resource flows through a higher efficiency of resource use based on innovation and changing behaviours, which may imply again a more intensive use of goods and capitals (sharing, longer life) and less dissipative consumer choices on materials, energy, and final goods use. This level can also be fuelled by generalised trends of 'process innovation' (saving materials and energy) in industry and organisational innovations in services. Again in this case, there can be effects of reduced demand for new goods and services and the materials/energy they embody, but there can be price premiums for more efficient and more performing products/services. This level is the one more overlapped with Resource Efficiency strategies and also overlaps with the 'decarbonisation' strategies recently envisioned by the European Commission (November 2018, see below other sections).

As an extension of the third level, all the three levels can be seen as a process of convergence to 'decoupling', that is an innovation mechanism by which we can do the same with less resources, or we can do more with the same resources, or hopefully we can do more with less resources. The material and technological setting of decoupling associated to the CE is described in Figure 1.3. The decoupling effect from the CE can be originated from the supply side (e.g. recycling at the 'closing the loop' level, or improved material productivity at the 'narrowing resource flows' level) or from the demand side (e.g. reuse at the 'closing the loop' level, or prolonging goods life at the 'slowing down resource flows' level, or sharing at the 'narrowing the resource flows' level).

It is important to get the connections between

Figure 1.3. Decoupling and Circular Economy

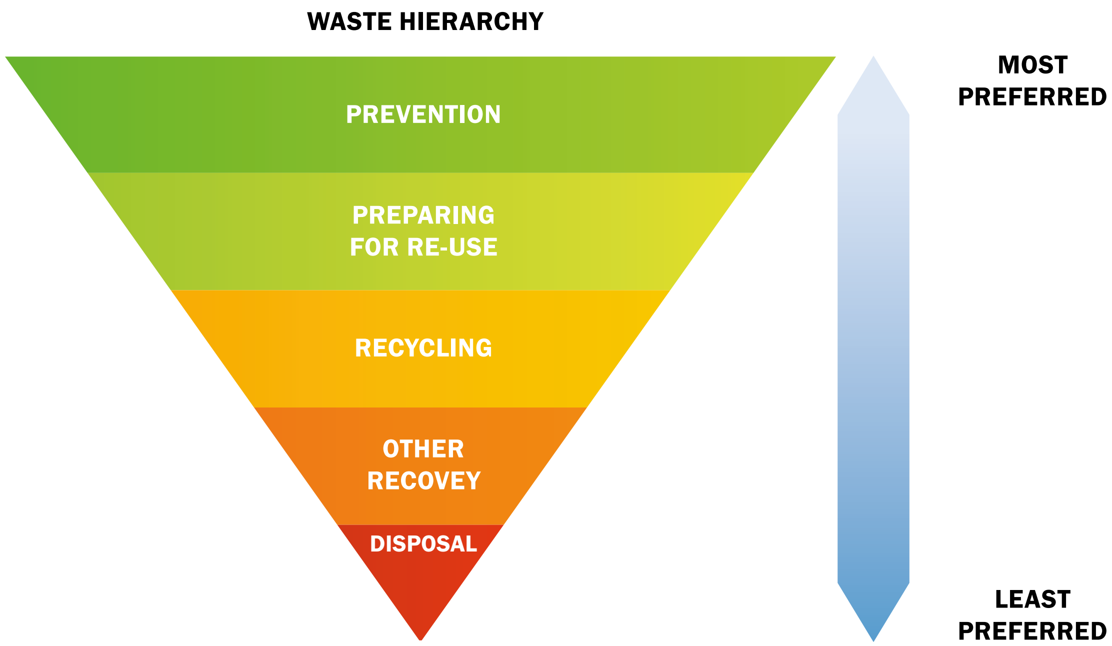


Note: Technological change can also facilitate more circular material flows when it results in improved secondary production technologies

Source: OECD, 2017.

the conceptualization of the CE, as described above in the framework of Resource Efficiency, and the so-called 'EU Waste Hierarchy', which is guiding European waste policies since the mid-1970s. The Hierarchy defines the most preferred solutions for waste in five levels, that is (from most preferred): Prevention; Preparing for re-use, Recycling (material recovery); Other recovery (mainly energy recovery); Disposal (landfill) (see Figure 1.4).

Figure 1.4. The EU waste hierarchy



Source: European Commission

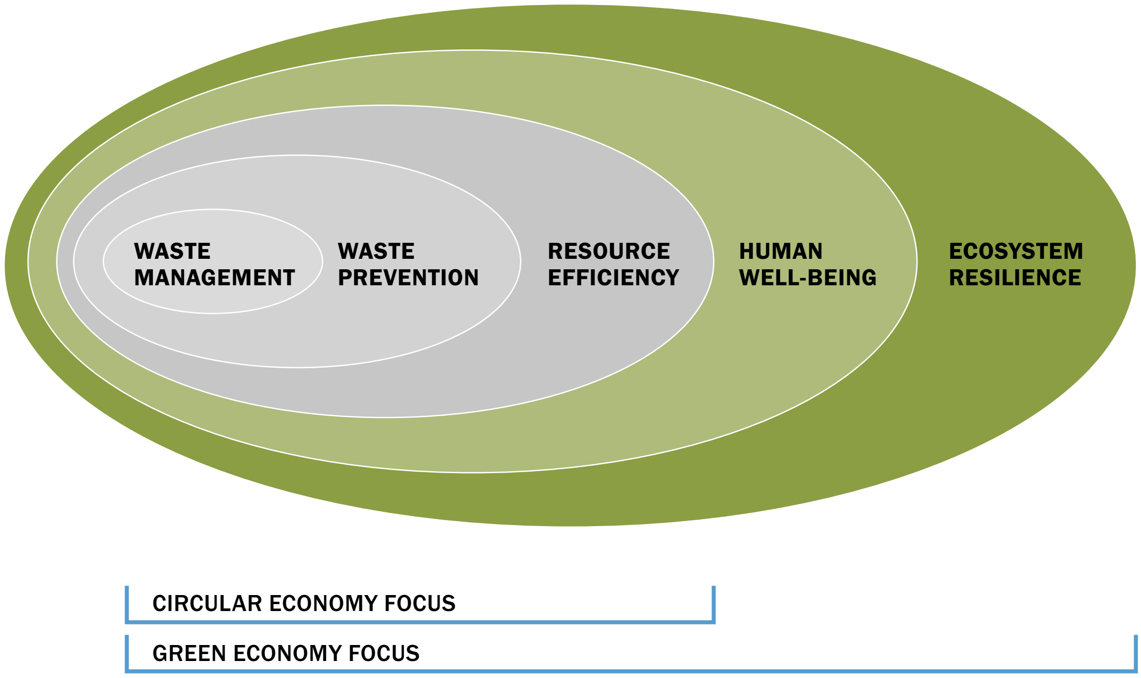
In the framework of the CE conceptualization, the first CE level in Figure 1.2 ('closing resource loops') directly corresponds to four of the five levels of the Hierarchy (preparing for reuse, recycling, recovery, and avoiding disposal) whereas it has only indirect effects on the top level option, that is 'prevention' if the latter is meant to represent the avoidance of waste production at the source (e.g. by industrial choices in product making). In this respect, it can be even suggested that a strong development of recycling and recovery industries can reduce prevention in that these industries need waste as inputs (see Section 6). A direct and net waste prevention effect can, instead, be expected by the second CE level in Figure 1.2 ('slowing down resource loops') in that, for example, longer life of goods or its more intense use ('sharing') does not involve (re)processing (and then waste) associated to new products. The same applies to the third CE level ('narrowing resource flows') in that, for example, material productivity in industrial processes is by itself waste avoidance at the source and then net waste prevention.

Arguments on the role of the 'Hierarchy' as a CE driver are proposed in Section 2.

The EEA suggests to look at the CE as a component of the more general Green Economy framework. Figure 1.5 illustrates how the CE scope can be waste management, waste prevention, and resource efficiency as nested in a broader Green Economy scope that encompasses human well-being and ecosystem resilience.

According to the EEA: *"The green economy perspective provides a framework for integrating the environment into the policies of key economic sectors. For example, European policy on material resource use can be represented as a nested set of objectives. Whereas a circular economy focuses on optimising material resource flows by minimising waste, the green economy approach extends the focus to how water, energy, land and biodiversity should be managed to secure ecosystem resilience and human well-being. The green economy also addresses wider issues, such as competitiveness and unequal exposure to environmental pressures and access to green spaces[9]."*

Figure 1.5: The Circular Economy within the Green Economy according to the EEA



Source: EEA, 2015 https://www.eea.europa.eu/soer-2015/europe/green-economy

9 *https://www.eea.europa.eu/soer-2015/europe/green-economy; see also EEA, 2014.*

1.2. Academic literature

The picture on conceptualizing the CE in academic literature (peer-reviewed journals) is still confused and yet not converging.

There are many definitions of CE. There is not a consensus on the aims of the CE, which still range from a better environment to higher national security, including stronger economic growth, lower unemployment and higher resource efficiency. In the case of the EU Action Plan for the Circular Economy, its main motivation is to address sustainability, but, according to the survey by Kirchherr et al. (2017), the relationship between CE and sustainability is almost ignored in large part of the reviewed literature, or, according to Geissdoerfer et al. (2017), this relationship is not made explicit.

The existing definitions of CE are often vague and imprecise (Haas et al., 2015). In addition, their proponents usually fail to set them in relationship with the earlier ones, or to illustrate the reasons for their new conceptualisations. Hence, the literature contains many similar definitions, which are potentially all worth consideration, although not useful for a real progress in the debate.

Although a characterizing feature of the CE is the presence of circular flows (loops) of energy and matter within the economy, there are many definitions of CE that do not mention this feature explicitly. Kirchherr et al. (2017) screen many definitions that do not include circularity of flows among the core principles. Many contributions (e.g. Geng and Doberstein, 2008; Bocken et al., 2016; Geissdoerfer et al., 2017), however, do consider flow circularity as one of the main features of the CE.

The relationship between CE and thermodynamic-based economics is largely disregarded with a few exceptions (e.g. Fischer-Kowalski et al., 2011; Allwood, 2014; Rammelt and Crisp 2014; Ghisellini et al., 2016; Winans et al. 2017).

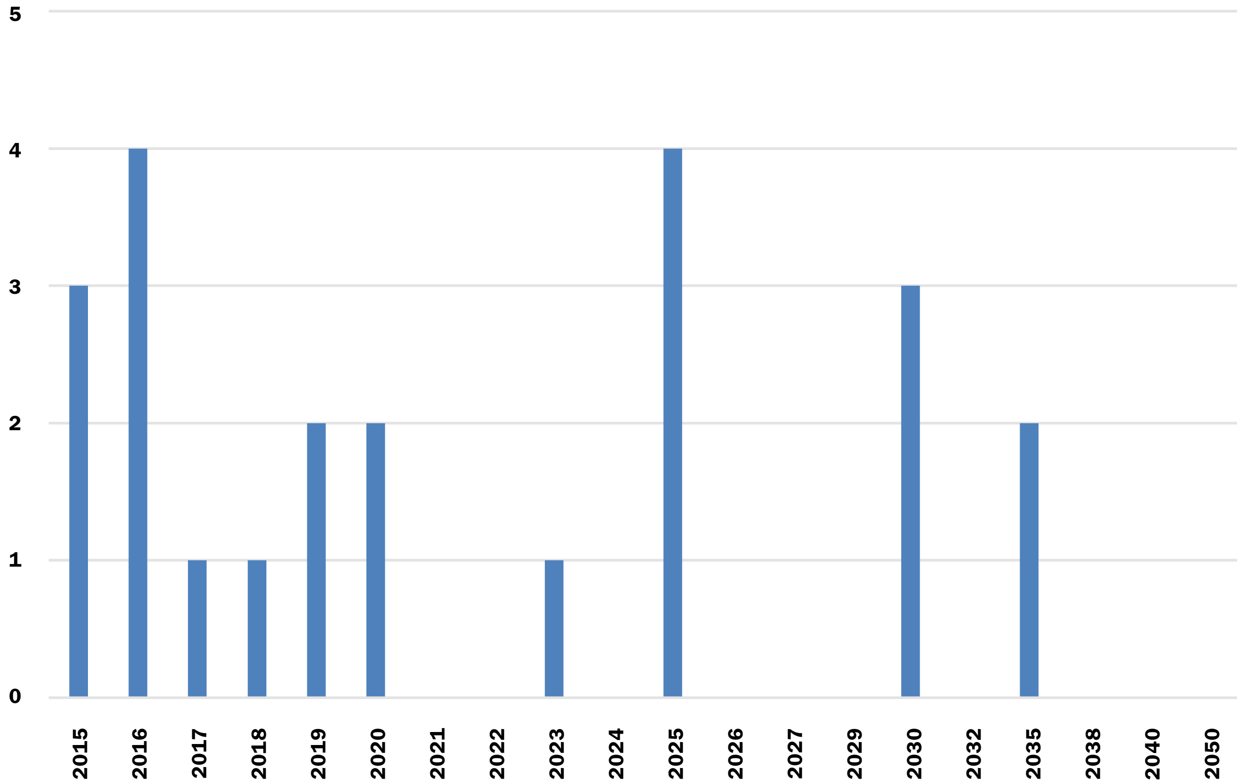
The limits of available conceptualisations and a proposal to reconcile the CE with the traditional approaches of ecological economics and basic thermodynamic principles are discussed in details in Zotti and Brignano (2019).

2. Policy drivers

EU policies, in particular waste policies, have been historically the main driver of the 'Old CE' and are still, with the 'CE Package' of 2015-2019, one of the fundamental catalysers of a 'New Innovation-intensive CE'. The policy directions of the CE package have been defined in the 2015 Action Plan which has been implemented through 54 actions around five priority areas (plastics, critical raw materials, construction and demolition waste, food waste, biomass and bio-based products). The report on implementation of the Action Plan has been published in 2019 (European Commission 2019c). A new Circular Economy Action Plan is expected to be proposed within the European Green Deal announced by the new Commission (von der Leyen 2019).

It can be stressed that the system of policy targets and objectives on 'waste and resources' in EU legislation (directives) and policy documents (communications) included, at December 2018 and with reference to the 2015-2050 period, 11 non-binding objectives (8 to 2020 and 3 to 2030) and 23 binding targets. The binding targets (Figure 2.1) from 2020 to 2035 are 12, largely related to the revised directives on waste of 2018. A summary of these policy targets and objectives is reported in Appendix 1 (see Paleari and Reichel 2019 for more details). It is also relevant to note that, according to EEA (2019), approximately 300 specific policy initiatives within EEA countries have been adopted for the CE.

Figure 2.1 EU policy targets (binding) for 'waste and resources' 2015-2050 (number by deadlines)



Source: adapted on data from Paleari and Reichel 2019.

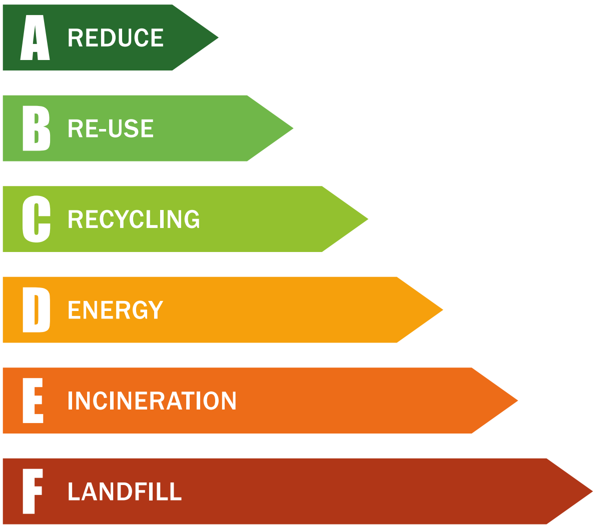
In this section, we summarise the main pillar of EU polices as drivers of the CE. We present two fundamental policy principles (the EU Waste Hierarchy and the Extended Producer Responsibility), the main recent developments of waste policies (directives of 2018, plastic strategy), and other EU policy strategies that can be relevant for the NEXUS approach to the CE we will propose in Part 2, Section 7, that is the revised Bioeconomy strategy and the strategy for a Carbon Neutral Economy at 2050.

2.1 The EU Waste Hierarchy

As mentioned in Section 1, the first level of CE in Figure 1.2 is directly linked to waste and waste policies (recycling, recovery of materials, and reuse of materials and products), and it is largely consistent with the EU Waste Hierarchy. It is useful to point out the limitations and the flexibility of the Hierarchy in dealing with the preference for different waste management options because these limitations can apply also to the CE approach and the measurement of its impacts.

The Hierarchy, also initially referred to as the 'Lansink Ladder' (Figure 2.2)[10], has been introduced already in the 1970s at the very beginning of the EU waste policies, and, while at that time the EU Hierarchy was not based on sound scientific evidence, in the subsequent developments of waste policy it has been backed by cumulative knowledge and LCA evidence.

Figure 2.2 The Lansink Ladder



Source: https://www.recycling.com/downloads/waste-hierarchy-lansinks-ladder/

The Waste Framework Directive (WFD) of 2008 provided for a strong preference for certain technological options in managing the same flow of waste. Actually, the WFD 2008 modified the waste hierarchy shaped by Directive 2006/12/EC, which recognised almost equal importance to all recovery operations (including recycling and energy recovery). However, by endorsing an LCA approach, the same Directive 2008/98/EC specifies that, when applying the waste hierarchy, Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.

In particular: *"Following the waste hierarchy should therefore lead to waste being dealt with in the most resource-efficient and environmentally sound way. Member States can only deviate from the waste hierarchy for specific waste streams and when this is justified by life-cycle thinking [...]. When Member States take decisions in line with the waste hierarchy, this does not need to be justified by life-cycle thinking on the overall impacts of the generation and management of the waste concerned"* (see EC 2012). Climbing up in the hierarchy is therefore always considered to deliver environmental benefits with respect to management options lying below in the hierarchy itself.

Historically, the LCA foundations of the hierarchy have been consolidated through an increasing amount of evidence up to the LCA-related standards that are officially suggested as references to examine the environmental pressures by waste management options. According to EC (2012) *"[...] LCT (Life Cycle Thinking) is supported in the most comprehensive manner by the use of the quantitative tool Life Cycle Assessment (LCA), as defined by the ISO 14040 and 140444. Among the existing above-mentioned LCT-based methods, Life Cycle Assessment (LCA) is the most widely used method of assessing and quantifying environmental aspects"*. JRC (2011) provides guidance for LCA/LCT application (often referred, for the LCA approach, to the

10 See, for example, https://www.recycling.com/downloads/waste-hierarchy-lansinks-ladder/

procedures provided for by CML's studies) and other approaches for waste management, together with a set of specific studies (see Ekvall et al. 2007).

However, the applicability of the waste hierarchy to all flows of waste (MSW, packaging materials, construction and demolition waste, mining waste, etc.) in all specific circumstances continues to be debated also on environmental grounds given the possibility of different LCA conclusions when different system boundaries and different sets of information/data are taken into consideration.

Furthermore, the socio-economic validity of the hierarchy, i.e. when taking into consideration the social costs-benefits associated to the different management options, has been criticised on the basis of arguments about the non-optimality of extreme solutions entailing very high recycling rates because of increasing marginal costs (increasing more than the environmental marginal benefits) of extreme rates of reuse/recycling. Arguments on the non-optimality of very high rates of recycling rates for MSW (Japan) have been produced by Kinneman et al. (2014). They estimate the average social cost of municipal waste management as a function of the recycling rate[11]. The results suggest that average social costs are minimized with recycling rates well below observed and mandated levels in Japan, and a 10% recycling rate for MSW could be optimal. The analysis includes estimates of external cost of both landfill and recycling (see also Section 3).

Within this framework, very few attempts have been made to estimate the LCA profile of waste management options on a very broad macro scale, i.e. Europe and EU Member States, in order to estimate the gains in environmental pressures of shifting from a management option to another at the large scale. One of the reasons is that, although the datasets for LCA analysis are extensive, they refer in any case to specific evidence and their generalisation can raise issues of suitability. The consequence is that the analyses at the macro scale often do not fully rely on LCA approaches (see Section 3).

The Hierarchy has been confirmed as a fundamental reference in the revision of the WFD 2008 within the CE package (Directive 2018/851 of 30 May 2018, amending Directive 2008/98/EC on waste). In the text of the Directive 2018/851, the Waste Hierarchy is mentioned 42 times. While this represents a strong regulatory push for the CE, the development of the latter should take into account the need to adopt an LCA approach in assessing the net environmental benefits from circularity and an integrated cost-benefit approach to assess a net value creation from the CE solutions.

This seems not the case as a large part of literature has, paradoxically, a limited consideration of the environmental implications of CE proposed solutions. For example, Zotti and Brignano (2019) highlights that there are a few studies in which the CE solution is compared to the non-CE equivalent to define the net environmental and economic gains of

11 Social costs include all municipal costs and revenues, costs to recycling households to prepare materials estimated with an original method, external disposal costs, and external recycling benefits.

circularity. However, there is a large evidence that the environmental pressures associated to secondary materials are lower than those associated to primary materials (see Zoboli 2018 for a discussion).

2.2. Extended producer responsibility

Extended Producer Responsibility (EPR) is indicated by the Waste Framework Directives as a general requirement for waste management. The rationale behind EPR is to make producers responsible for the environmental impacts of their products from the design to the post-consumer phase (OECD, 2016). Producers are deemed responsible for their products because they have the capacity to make changes at source, so that the environmental impacts of their products are reduced throughout their life-cycles (Lifeset et al., 2013; Lindhqvist, 1992, Lifeset and Lindhqvist 2008). While other policy instruments tend to target a single point of the chain, EPR seeks, therefore, to integrate issues related to the environmental characteristics of products and production processes throughout the product chain (Bio by Deloitte, 2014). As such, EPR provides the bridge between waste management policies and product-oriented environmental policies (Van Rossem, 2008).

EPR relies on the principle of 'getting the prices right', i.e. internalizing externalities, so that market prices reflect environmental impacts. A first relevant point is that, if markets are able to transmit price signals without frictions, EPR would not be necessary: a waste collection charge incorporating externalities (such as a landfill tax or a tax on raw materials) would generate equivalent results without distortions. EPR is, therefore, a typical second-best policy approach whose essence lies in the recognition of market imperfections and in the attempt to correct them through the deliberate introduction of some distortions to its functioning (Massarutto, 2014).

Secondly, the existence of end-of-life products with positive prices in waste streams regulated through EPR (e.g. WEEE, industrial and automotive batteries, and, more in general, business-to-business goods) raises the question of whether there is in fact market failure and whether such wastes might be excluded from EPR obligations. There are, however, practical challenges in differentiating EPR obligations according to whether market failure has occurred or even on the basis of the current price of end-of-life products.

The emergence of the concept of EPR in the EU reflects three main trends in environmental policy-making: (i) the prioritization of preventive measures over end-of-life approaches; (ii) the enhancement of life-cycle thinking and (iii) the shift from a command and control approach to a market-based, 'non-prescriptive' and 'goal-oriented' approach (Kalimo et al., 2012; Tojo, 2004; Van Rossem et al., 2006). EPR has been considered, at the EU level, as a major instrument in support of the implementation of the waste hierarchy (Bio by Deloitte, 2014; Kalimo et al, 2015).

A study by OECD (2014) reviewed the adoption of EPR policies globally in the 1970-2013 period. Out of 395 EPR-based policies, 164 have been introduced by EU Member States. In particular, EU Member States have shaped EPR systems covering four waste streams addressed by EU legislation: packaging waste, end-of-life vehicles (ELVs), waste electrical and electronic equipment (WEEE) and waste batteries.[12] The related EU directives set collection and/or recycling/recovery targets to be achieved by certain deadlines and explicitly assign to producers the responsibility for the collection and/or the management of their products, once they have been discarded. Although it was not a legal obligation under the Packaging Waste Directive before 2018 amendments, the directives have been implemented across the EU-28 through the development of EPR systems. The EPR measures in EU legislation are summarised in Table 2.1.

EPR measures may include an acceptance of returned products and of the waste that remains after those products have been used, as well as the subsequent management of the waste and financial responsibility for such activities. These measures may include the obligation to provide publicly available information as to the extent to which the product is reusable and recyclable. Member States may decide that the responsibility for arranging waste management is to be borne, partly or wholly, by the producer of the product from which the waste came and that distributors of such a product may share that responsibility. Member States may also decide that the costs of waste management are to be borne, partly or wholly, by the producer of the product from which the waste came and that the distributors of such a product may share these costs. Finally, Member States may take appropriate measures to encourage the design of products in ways that reduce their environmental impacts and the generation of waste in the course of their production and subsequent use.

We will return on EPR schemes as a form of 'organisational innovation' and a possible trigger of technological innovation in Part 2, Section 6.

12 *Some EU Member States have also put in place EPR systems for products not directly addressed in EU legislation, such as tyres, medical waste, graphic paper, etc.*

Table 2.1. EPR in EU legislation

WFD Directive 2008/98/EC	EPR was already mentioned as a *general requirement* by the Directive before the 2018 amendments. The amended text of the Directive shapes minimum requirements applying to EPR schemes (that are set up based both on EU and national legislation). These requirements concern the scope of EPR schemes; the financial contributions to be paid by producers; transparency, the provision of information and data reporting; the monitoring and enforcement framework; etc.
Packaging Waste Directive 94/62/EC	Before the 2018 amendments, EPR was not explicitly mentioned, but the Directive has been mainly implemented by MS through EPR schemes and deposit-refund systems. According to the amended Directive, *Member States shall ensure that, by 31 December of 2024, extended producer responsibility schemes are established for all packaging.*
ELV Directive 2000/53/EC	*EPR of economic operators for ELVs' collection. (Full or partial) financial responsibility for ELVs free take-back* Economic operators set up systems for the collection of all ELVs. The delivery of the vehicle to an authorised treatment facility shall occur without any cost for the last holder and/or owner. All the costs or part of the costs incurred in transferring a vehicle to a treatment facility shall be met by the vehicle manufacturers.
WEEE Directive 2012/19/EU	*Business to consumers (B2C)* • *Distributors responsibility for taking-back very small WEEE and other WEEE on a 1:1 basis (possible derogations by MS). Producers are allowed to set up collection systems. Producers may be encouraged to finance collection.* • *Producers shall set up individual or collective systems for recovery. Producers have an individual financial responsibility for the management (after collection) of new waste and a collective financial responsibility for the management (after collection) of historical waste.* *Business to business (B2B)* • *Producers shall set up individual or collective systems for collection and recovery/disposal. Producers have a financial responsibility for collection and management after collection of new waste and historical waste replaced by new products (users other than private households are financially responsible for other 'historical waste').* *B2C:* producers may set up and operate individual and/or collective take-back systems and may, where appropriate, be encouraged to finance the related costs. When supplying a new product, distributors are responsible for ensuring that such waste can be returned to them, at least free of charge when buying a replacement, as long as the equipment is of an equivalent type and fulfilled the same function as the supplied equipment (under certain conditions MS may derogate from this provision). Distributors also provide for the collection, at retail shops with sales areas relating to EEE of at least 400 m^2, or in their immediate proximity, of very small WEEE (no external dimension more than 25 cm) free of charge to end-users. MS shall ensure that producers or third parties acting on their behalf set up individual or collective systems to provide for the recovery of WEEE using best available techniques. Producers are deemed financially responsible for WEEE management after collection: the financial responsibility is set at the individual level for products placed on the market after 13 August 2005 and at the collective level for products placed on the market on or before that date. *B2B:* MS shall ensure that producers, or third parties acting on their behalf, provide for B2B WEEE collection, as well as for its recovery, through individual or collective systems, using best available techniques. MS shall ensure that the financing of the costs of collection, treatment, recovery and environmentally sound disposal of new B2B WEEE is provided by producers. For historical waste being replaced by equivalent new products or by new products fulfilling the same function, the financing of the costs shall be provided by the producers of those products when supplying them. MS may, as an alternative, provide that users other than private households also be made partly or totally responsible for this financing. For other historical waste, the financing of the costs shall be provided by the users other than private households.

Directive 2006/66/EC on batteries and accumulators	• *Producers shall set up schemes for collection of waste automotive batteries/accumulators. MS may require producers to set up schemes for the collection of portable batteries and accumulators (other economic operators may participate).* • *Producers shall set up schemes for treatment and recycling of waste batteries and accumulators.* • *Producers shall finance any net costs from collection, treatment and recycling of (portable and industrial) waste batteries and accumulators.* • *Producers shall finance any net costs from public information campaigns related to portable waste batteries and accumulators.* Producers will be responsible for: a) taking-back waste industrial batteries and accumulators from end-users, and b) setting up schemes for the collection of waste automotive batteries and accumulators from end-users or from an accessible collection point in their vicinity, where collection is not carried out under the ELV Directive. MS may require producers to set up collection schemes for waste portable batteries and accumulators, in which other economic operators may participate. MS shall ensure that, no later than 26 September 2009 producers or third parties set up schemes using best available techniques, in terms of the protection of health and the environment, to provide for the treatment and recycling of waste batteries and accumulators. MS shall ensure that producers, or third parties acting on their behalf, finance any net costs arising from: (a) the collection, treatment and recycling of all waste portable batteries and accumulators collected; and (b) the collection, treatment and recycling of all waste industrial and automotive batteries and accumulators. MS shall oblige producers, or third parties acting on their behalf, to finance any net costs arising from public information campaigns on the collection, treatment and recycling of all waste portable batteries and accumulators.

Note: MS= Member States
Source: Paleari 2017 (and updates).

2.3. The revised directives on waste and the Plastics Strategy

In May 2018, the European Parliament approved the revised directives on waste proposed with the Circular Economy Package of 2015[14]. This is a major change in EU waste policies because of the large implications of the new directives for European industrial activities.

The amended Waste Framework Directive sets targets regarding the share of municipal waste prepared for reuse and recycling to be met by 2025, 2030, and 2035 (Table 2.2).

13 The preamble (indent 19) specifies that ‘producers should finance the costs of collecting, treating and recycling all collected batteries and accumulators minus the profit made by selling the materials recovered’.

14 Updated information is available at http://ec.europa.eu/environment/circular-economy/index_en.htm

Table 2.2. Targets from the revised directives on waste 2018

	2025	2030	2035
Share of municipal waste prepared for reuse and recycling	55%	60%	65%
Share of municipal waste landfilled			10%
Share of packaging waste recycling	65%	70%	
Share of plastic packaging waste recycling	50%	55%	
Share of wood packaging waste recycling	25%	30%	
Share of ferrous metal packaging waste recycling	70%	80%	
Share of aluminium packaging waste recycling	50%	60%	
Share of glass packaging waste recycling	70%	75%	
Share of paper and cardboard packaging waste recycling	75%	85%	

Source: Directive 1999/31/EC; Directive 94/62/EC; Directive 2008/98/EC as amended, based on the 2015 Circular Economy Package
Source: European Parliament, 2018 and updates

The amended Framework Directive explicitly includes, among the measures aimed at applying EPR, "the establishment of extended producer responsibility schemes defining specific operational and financial obligations for producers of products". It requires in particular financial contributions paid by producers to EPR schemes to be modulated based on the costs necessary to collect and treat their products at the end of their life. In addition, the directive requires Member States to use economic instruments to implement the Waste Hierarchy, to take measures to prevent waste generation and to ensure the separate collection of bio-waste by 2023 where "technically, environmentally and economically practicable".

The amended Landfill Directive introduces a landfilling ban for separately collected waste and limits the share of municipal waste landfilled to 10% by 2035. The directive requires the Commission to examine, by the end of 2024, whether a more ambitious target can be set.

The amended Packaging Directive sets targets for the share of packaging waste recycling to be met by 2025 and 2030, with specific targets for various packaging materials.

Other changes are put forward in several of the amended directives:

- aligning definitions and introducing an early warning system for monitoring progress towards the targets (Waste Framework Directive, Landfill Directive, Packaging Directive);

- clarifying methods used to calculate progress towards targets (Waste Framework Directive, Packaging Directive);

- simplifying and streamlining Member States' obligations as regards reporting;

- improving the quality and reliability of statistics; aligning provisions to Articles 90 and 291 TFEU on delegated and implementing acts (all four directives).

According to the summary by the European Parliament: *"The proposals are expected to deliver economic and environmental benefits. According to the Commission, the four legislative proposals put forward would create over 170,000 direct jobs in the EU by 2035; avoid greenhouse gases emissions (over 600 million tonnes of CO2 equivalent between 2015 and 2035); increase the competitiveness of the EU waste management, recycling and manufacturing sectors; reduce the dependency of the EU on raw material imports; and reduce the administrative burden. In addition, the proposals would reduce the impacts on environment and human health. The proposals would also generate costs, which would most likely fall on public authorities, businesses and ultimately consumers. A 2015 Ellen MacArthur Foundation report calculates, extrapolating from UK government estimates, that the cost of creating a fully efficient reuse and recycling system in the EU could be about €108 billion. The Commission indicates however that the proposals will not have an impact on the European Union budget."*

A very good analysis of the new 2018 directives on waste and the problem of implementation is presented (in Italian) in the CE report produced by Confindustria in 2018[15].

As a part of the CE strategy, in 2018 the European Commission launched the Plastics Strategy (European Commission 2018f). The essence of the Plastics strategy is summarised as follows[16]:

- *Plastics and products containing plastics are designed to allow for greater durability, reuse and high-quality recycling. By 2030, all plastics packaging placed on the EU market is either reusable or can be recycled in a cost-effective manner.*

- *Changes in production and design enable higher plastics recycling rates for all key applications. By 2030, more than half of plastics waste generated in Europe is recycled. Separate collection of plastics waste reaches very high levels. Recycling of plastics packaging waste achieves levels comparable with those of other packaging materials.*

- *EU plastics recycling capacity is significantly extended and modernised. By 2030, sorting and recycling capacity has increased fourfold since 2015, leading to the creation of 200,000 new jobs, spread all across Europe.*

- *Thanks to improved separate collection and investment in innovation, skills and capacity upscaling, export of poorly sorted plastics waste has been phased out. Recycled plastics have become an increasingly valuable feedstock for industries, both at home and abroad.*

- *The plastics value chain is far more integrated, and the chemical industry works together closely with plastics recyclers to help them find wider and higher value applications for their output. Substances hampering recycling processes have been replaced or phased out.*

15 See *http://economiacircolare.confindustria.it/*

16 See *http://ec.europa.eu/environment/circular-economy/index_en.htm*

- *The market for recycled and innovative plastics is successfully established, with clear growth perspectives as more products incorporate some recycled content. Demand for recycled plastics in Europe has grown four-fold, providing a stable flow of revenues for the recycling sector and job security for its growing workforce.*

- *More plastic recycling helps reduce Europe's dependence on imported fossil fuel and cut CO2 emissions, in line with commitments under the Paris Agreement.*

- *Innovative materials and alternative feedstocks for plastic production are developed and used where evidence clearly shows that they are more sustainable compared to the non-renewable alternatives. This supports efforts on decarbonisation and creating additional opportunities for growth.*

- *Europe confirms its leadership in sorting and recycling equipment and technologies. Exports rise in lockstep with global demand for more sustainable ways of processing end-of-life plastics. In Europe, citizens, government and industry support more sustainable and safer consumption and production patterns for plastics. This provides a fertile ground for social innovation and entrepreneurship, creating a wealth of opportunities for all Europeans.*

- *Plastic waste generation is decoupled from growth. Citizens are aware of the need to avoid waste, and make choices accordingly. Consumers, as key players, are incentivised, made aware of key benefits and thus enabled to contribute actively to the transition. Better design, new business models and innovative products emerge that offer more sustainable consumption patterns.*

- *Many entrepreneurs see the need for more resolute action on plastics waste prevention as a business opportunity. Increasingly, new companies emerge that provide circular solutions, such as reverse logistics for packaging or alternatives to disposable plastics, and they benefit from the development of digitisation.*

- *The leakage of plastics into the environment decreases drastically. Effective waste collection systems, combined with a drop in waste generation and with increased consumer awareness, avoid litter and ensure that waste is handled appropriately. Marine litter from sea-based sources such as ships, fishing and aquaculture are significantly reduced. Cleaner beaches and seas foster activities such as tourism and fisheries, and preserve fragile ecosystems. All major European cities are much cleaner.*

- *Innovative solutions are developed to prevent microplastics from reaching the seas. Their origin, routes of travel, and effects on human health are better understood, and industry and public authorities are working together to prevent them from ending up in our oceans and our air, drinking water or on our plates.*

- *The EU is taking a leading role in a global dynamic, with countries engaging and cooperating to halt the flow of plastics into the oceans and taking remedial action against plastics waste already accumulated. Best practices are disseminated widely,* *scientific knowledge improves, citizens mobilise, and innovators and scientists develop solutions that can be applied worldwide.*

The issue of over-packaging will be addressed by the European Commission as part of the future review of the essential requirements for packaging (planned for the end of 2020). The European Commission will look into the opportunities to support the development of alternative feedstocks in plastic production; EU research funding will support these efforts. The European Commission called on stakeholders to submit voluntary pledges to ensure that 10 million tonnes of recycled plastics are used into new products by 2025, and to this end promoted the Circular Plastics Alliance to which more than 100 companies participate. The ECHA (European Chemical Agency) has submitted a proposal to restrict microplastics intentionally added to mixtures used by consumers or professionals. Under the coordination of the European Commission, a new Directive has been adopted by the EU in 2019 to reduce the impact of single-use plastic products on the environment, introducing a wide range of different measures for different types of plastic products (Table 2.3).

Some of these measures, such as prohibition to place on the market and measurable reduction in consumption, are aimed at preventing plastic waste generation, while others, including separate collection targets and extended producer responsibility, mainly support waste collection and recycling. The proposal also sets a mandatory minimum recycled content for plastic bottles, with the aim of increasing EU demand for recycled plastic, which currently represents around 6 per cent of EU plastics production (European Commission, 2019b).

Table 2.3. Measures provided by the Single-Use Plastic Directive 2019 and related deadlines for implementation

	Single-use plastic products	Prohibition to place on the market	Measurable reduction in consumption	Separate collection target	Marking requirements	EPR	Product requirements (attached caps/lids)	Product requirements (minimum recycled content)	Awareness raising
Beverage packaging and products	Beverage cups and containers made of EP	2021							
	Beverage containers (up to 3 litres) - PET bottles - Beverage bottles			2025 (77%) 2029 (90%)		End 2024	2024	2025 (25%) 2030 (30%)	2021
	Composite beverage packaging					End 2024	2024		2021
	Beverage cups		2026		2021	End 2024			2021
	Beverage stirrers and straws	2021							
Food packaging and products	Containers of food for immediate consumption made of EP	2021							
	Containers of food for immediate consumption		2026			End 2024			2021
	Cutlery and plates	2021							
	Packets/wrappers made from flexible material containing food for immediate consumption					End 2024			2021
Sanitary items	Cotton bud sticks	2021							
	Sanitary towels				2021				2021
	Wet wipes				2021	End 2024			2021
Other plastic products	Balloons					End 2024			2021
	Sticks for balloons	2021							
	Oxo-degradable plastic items	2021							
	Lightweight plastic carrier bags					End 2024			2021
	Tobacco products with filters				2021	Beginning 2023			2021
	Fishing gear containing plastic			MS shall set target by 2021		End 2024			2021

Source: EU, 2019b.

2.4. The CE and the revision of the Bioeconomy strategy

The revised Bioeconomy strategy (European Commission 2018g), which re-shapes the previous strategy of 2012, is largely inspired by a Circular Economy thinking. The term 'circular' is mentioned 108 times in the Bioeconomy strategy 2018. A sketch of the bioeconomy size in the EU is presented in Figure 2.3.

It is interesting to note that the 'Biobased chemicals and pharmaceuticals' sector is the largest in terms of value added after food and agriculture.

Figure 2.3. The economic size of the bioeconomy in the EU, 2015

EMPLOYMENT (MILLION JOBS)	18
TURNOVER (TRILLION EUR)	2.3
VALUE ADDED (BILLION EUR)	621

Sector	EMPLOYMENT (MILLION JOBS)	TURNOVER (BILLION EUR)	VALUE ADDED (BILLION EUR)
AGRICULTURE	9.2	380	174
FORESTRY	0.5	50	24
FISHING AND AQUACULTURE	0.2	12	7
FOOD, BEVERAGES AND OTHER AGRO-MANUFACTURING	4.5	1153	233
BIO-BASED TEXTILES	1.0	103	28
WOOD PRODUCTS AND FURNITURE	1.4	174	47
PAPER	0.6	187	46
BIO-BASED CHEMICALS AND PHARMA-CEUTICALS, PLASTICS AND RUBBER	0.4	177	56
LIQUID BIOFUELS	0.03	12	3
BIOELECTRICITY	0.01	11	3

Source: EC, 2018g.

The bioeconomy strategy is aimed at supporting initiatives at national and regional level following a three-tiered plan:

Strengthen and scale-up the bio-based sector:

- *launching a €100 million Circular Bioeconomy Thematic Investment Platform to bring bio-based innovations closer to the market and de-risk private investments*
- *facilitating the development of new sustainable biorefineries across Europe*
- *promoting and developing standards, labels and market uptake of bio-based products, such as the EU Ecolabel or green public procurement.*

Rapidly spread bioeconomy across the whole of Europe via:

- *a strategic deployment agenda for sustainable food and farming systems, forestry and bio-based products*
- *bioeconomy innovations with pilot actions in rural, coastal and urban areas*
- *a policy support facility to help Member States and regions develop and implement their own bioeconomy strategies.*

Understand the ecological limitations of the bioeconomy by:

- *implementing an EU-wide monitoring system to track progress towards a sustainable and circular bioeconomy*

- *enhancing the knowledge base and understanding of specific – and today still young – bioeconomy sectors*

- *providing guidance on how best to operate the bioeconomy within safe ecological limits.*

The EU supports the bioeconomy mainly with research and innovation funding. It has already invested 3,85 billion/€ under Horizon 2020 (2014-2020) and proposed €10 billion for food and natural resources, including the bioeconomy, under Horizon Europe (2021-2027) (see also Section 6).

The possible synergies and trade-offs between the bio-economy and circular economy objectives and actions are examined extensively in EEA (2018).[17]

The EU's 2015 Circular Economy Action Plan and the 2018 Bioeconomy Strategy both have food waste, biomass and bio-based products as areas of intervention. They also have concepts in common, such as the chain approach, sustainability, biorefining and the cascading use of biomass. Both of these policy agendas converge with respect to economic and environmental concerns, research and innovation, and societal transition towards sustainability.

The bioeconomy is resource intensive. In 2014, biomass accounted for more than 25% of total material flows. Agriculture constitutes about 63% of the total biomass supply in the EU, forestry 36% and fisheries less than 1%. The bioeconomy is rapidly evolving, especially in the areas of bioplastics and biocomposites.

Bioplastics production as a proportion of total plastics production is still low, currently below 1%. In 2019, less than 20% of bioplastics are expected to be biodegradable, with improper collection and sorting of plastics hampering recycling. Biocomposites (wood-plastic composites and natural fibre composites) account for 15% of the total European composite market. The use of biocomposites is expected to increase further, e.g. in the automotive industry, but their recycling is also problematic.

Between 118 and 138 million tonnes of biowaste are generated annually (EC, 2010a), with a high share of food waste (100 million tonnes produced in 2012)[18]. Just about 25% of this biowaste is collected and recycled.

Further expanding the bioeconomy in response to the increasing global demand for food, feed, biomaterials and bioenergy could lead to demand/supply conflicts and shifts in the land availability for food, biomaterial or bioenergy production. Approximately 72% of the net annual increment of forests is currently harvested, pointing at a limited potential for the increased sourcing of wood biomass. As for agriculture, a shift to farming practices that either do not, or to a limited extent, rely on chemical inputs could contribute to nutrient circularity, although this may limit productivity.

Promising innovations and strategies for circular biomass use include biorefinery, three-dimensional (3D) printing with bioplastics, multipurpose crops, valorising residues and food waste, and biowaste treatment. The supporting policies are still loosely connected,

17 EEA, 2018, The circular economy and the bioeconomy. Partners in sustainability, EEA Report No 8/2018.
18 https://ec.europa.eu/food/safety/food_waste/eu_actions_en

and more synergy could be created. Aspects that appear to be underrepresented are product design, and collaboration among the actors throughout the value chain.

The connections between the CE and the Bioeconomy will be further discussed in the framework of the NEXUS in Section 7.

2.5. The CE in the 'Carbon-neutral economy 2050' strategy

The CE is considered among the options and the enablers to support the 'European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy', launched by the European Commission in November 2018[19].

The phrase 'circular economy' is mentioned 12 times in the Communication. The potential role of the CE to achieve a 'carbon neutral economy' by 2050 is detailed in the 'In-depth analysis in support to the Commission Communication COM(208)773' (European Commission, 2018b). The transition to the CE is seen as part of the processes to achieve an 80% reduction of GHGs emissions thus moving to 'well below' the +2°C degree target (Figure 2.4). The CE is often mentioned in combination with, or as part of, 'behavioural changes', and it is viewed in the framework of 'resource efficiency'.

The specific contribution attributed to the CE by the 'In-depth analysis' is largely based on what follows:

"Resource efficiency in industry means reduced raw material needs, minimisation of waste and by-products, increased recycling and material substitution. As such, it is a key part of the Circular Economy concept. Industrial and manufacturing processes can be redesigned so that material loss in the production and between the different lifecycles phases of each product or material are minimised. Improved waste management allows materials to go back into the economic cycle, thus, reducing the input of primary raw materials and the need to treat waste. The quantities of virgin material used as feedstock can reduce, part of it replaced by increased recycled and re-used material, which requires (with high quality waste streams) much less energy and carbon intensive processes for its processing. A part of virgin materials will come from the cascading use of material and reduced material loss during the processing phase. According to the International Resources Panel,[20] by 2050, resource efficiency policies could reduce global extractions by 28%. Combined with an ambitious climate action, such policies can reduce greenhouse gases emissions around 63%, and increase economic growth by 1.5%. A recent study from Material Economics[21] focused on energy-intensive sectors like steel, plastics, aluminium or cement, estimates that the circular economy model could reduce European emissions by 56% (300 MtCO2) annually until 2050. Globally, emissions savings could reach 3.6 billion of tonnes of CO2 by year. Moreover, the production and incineration of plastics produce globally every year 400 MtCO2. If it were possible to recycle all plastic waste, the equivalent to 3.5 billion of oil barrels per year would be saved. Recycling a million of tonnes of plastics is equivalent to the emissions of one million cars." (p. 144-145).

19 *European Commission, 2018a, A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018) 773 final, Brussels 28.11.2018.*

20 *http://www.resourcepanel.org/reports/resource-efficiency*

21 *http://materialeconomics.com/latest-updates/the-circular-economy*

Figure 2.4. Carbon neutral strategy: Overview of main scenario building blocks

	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficienty (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5 TECH)	1.5°C Sustalnable Lifestyle (1.5 LIFE)
Main Drivers	Electification in all sectors	Hydrogen in industry, transport and buildings	E-fuels in industry, transport and buildings	Pursuing deep energy efficiency in all sectors	Increased resources and material efficiency	Cost-efficient combination of options from 2°C scenarios	Based on COMBO with more BECCS, CCS	Based on COMBO and CIRC with lifestyle changes
GHG target in 2050	-80% GHG (excluding sinks) ("well below 2°C" ambition)	-80% GHG (excluding sinks) ("well below 2°C" ambition)	-80% GHG (excluding sinks) ("well below 2°C" ambition)	-80% GHG (excluding sinks) ("well below 2°C" ambition)	-80% GHG (excluding sinks) ("well below 2°C" ambition)	-90% GHG (including sinks)	-100% GHG (including sinks) ("1.5 C" ambition)	-100% GHG (including sinks) ("1.5 C" ambition)
Major Common Assumptions	• Higher efficienty post 2030 • Deployment of sustainable, advanced biofuels • Moderate circular economy measures • Digitilisation				• Market coordination for infrastructure deployment • BECCS present only post-2050 in 2°C scenarios • Significant learning by doing for low carbon technologies • Significant improvements in the efficiency of the transport system			
Power sector	Power is nearly decarbonised by 2050. Strong penetration of RES facilitated by system optimization (demand-side respose, storage, interconnections, role of prosumers). Nuclear still plays a role in the power sector and CCS dewploymet faces limitations.							
Industry	Electrification of processes	Use of H2 in targeted applications	Use of e-gas in targeted applications	Reducing energy demand via Energy Efficiency	Higher recycling rates, material substitution, circular measures	Combination of most Cost-efficient options from "well below 2°C" scenarios with targeted applications (escluding CIRC)	COMBO but stronger	CIRC+COMBO but stronger
Buildings	Increased deployment of heat pumps	Deployment of H2 for heating	Deployment of e-gas for heating	Increased renovation rates and depth	Sustainable buildings			CIRC+COMBO but stronger
Transport sector	Faster electrification for all transport modes	H2 deployment for HDVs and some for LDVs	E-fuels deployment for all modes	Increased modal shift	Mobility as a service			• CIRC+COMBO but stronger • Alternatives to air travel
Other Drivers		H2 in gas distribution grid	E-gas in gas distribution grid				Limited enhancement natural sink	• Dietary changes • Enhancement natural sink

Source: European Commission (2018b)

More specifically, the CIRC Scenario, includes measures of resource and material efficiency, recycling, re-use, product, process innovation, improved waste management, cascading use of materials and material substitution. According to the 'In-depth analysis':

"Two sectors demonstrate the impacts of going along this pathway:

- *Industry benefits from increased and improved recycling, less contamination and downgrading of materials and material substitution (especially via 3D printing), reduction of the need especially for virgin materials (steel, non-ferrous metals, plastics, paper, construction materials) and shift of production to the less energy demanding and lower carbon intensity secondary materials (higher recycling). Therefore, primary industrial output reduces in volumes, although at the same time industrial value chains have an increased value added focused on recycling and re-use, requiring increased services, leading to reduced energy consumption and GHG emissions. The assumed impact on primary production for the modelling in CIRC is illustrated in the below table.*

- *Transport benefits from integrating the sharing economy and connected, cooperative and automated mobility, and making full use of digitalisation, automation and mobility as a service. The vehicle fleet is smaller relative to the Baseline, but it is utilised more, it displays higher occupancy rates, and it is renewed faster. The reduced vehicle fleet also has secondary impacts on the industrial output of materials used in the car industry. Finally, improved logistics and shifts from long-distance freight to near-sourcing is assumed, together with shifts towards rail and waterborne transport. In energy terms, there is no reliance on hydrogen or e-fuels in the transport system, but biomass use increases coming in part from biomass that is not needed to reduce industrial emissions.*

- *In energy terms, there is increased waste heat recovery, and conversion of remaining waste material into useable heat, electricity or fuel. Improved management and collection of organic waste and biomass cascading, leading to the use of more sustainable biomass either as a feedstock or for the production of biogas in local bio-refineries." (p. 322).*

The expected outcomes are summarised in Table 2.4. In short, the contribution of the CE is expected to be spread over different changes in processes and products across different industrial sectors, largely relying on material innovation, 'waste-related' innovations, and sharing-economy innovations, and on reduced transport loads in a CE. However, on the quantitative side, the sources for this expectation are the two studies mentioned above, which are largely based on information review and 'partial equilibrium' analysis. As a consequence, the 'In-depth Analysis' does not make a specific analysis of the contribution of the CE (see also Section 7 on the NEXUS approach to the CE).

Table 2.4. Assumed impact of circular economy on energy intensive industries primary production in the CIRC scenario

	2050 Reduction of volume (% change from baseline projection)
Iron Steel	-6%
Non Ferrous	-3%
Chemicals	-9%
Paper & Pulp	-12%
Non Metallic Minerals	-8%

Source: European Commission (2018b)

3. Quantifications

In this section, we present different sources that can allow quantifying the CE together with examples of the evidence that can be extracted from these sources.

We include waste statistics, the European Reference Model for Waste, material flow statistics, the new Eurostat indicators for the CE, the input-output data and models, and the more general picture of macro-modelling addressing the CE and circularity in the economic system.

Although selective and possibly incomplete, the review highlights the still incomplete statistical and quantitative picture we have of the CE, a picture that is still largely based on joining, often with problems of consistency and feasibility, different data and information sets, different indicators, and different partial models.

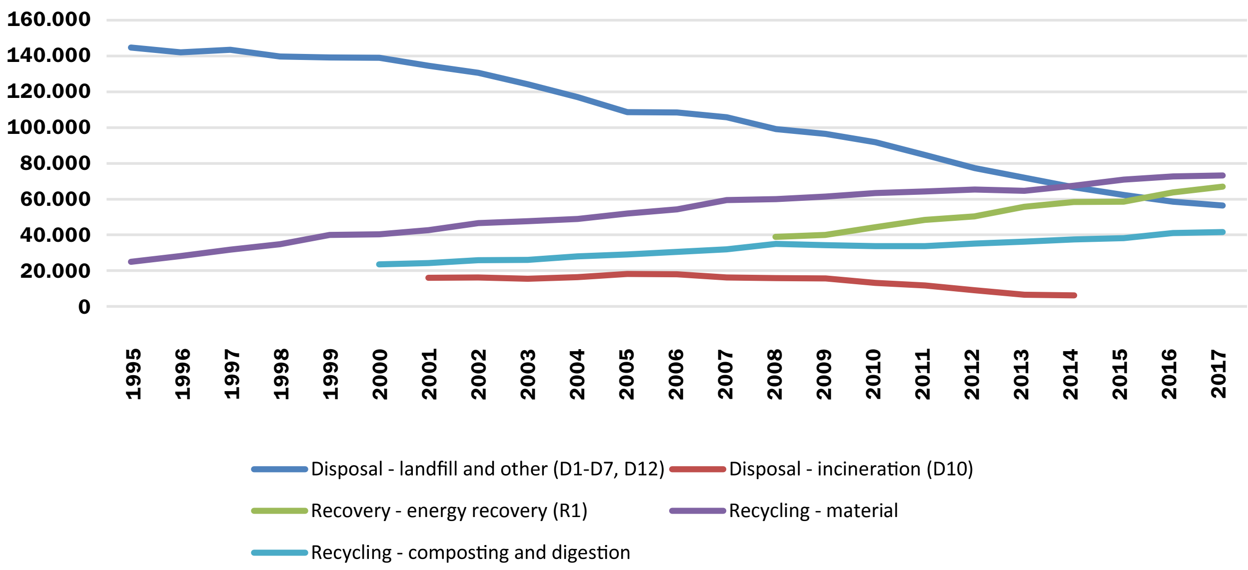
3.1. Waste statistics

After a long phase marked by incomplete and low-quality data on the waste system, at present Eurostat collects waste statistics from EU Member States, EEA/EFTA countries and enlargement countries every two years on the basis of the 'Regulation on waste statistics' (2150/2002/EC). Major Eurostat indicators on waste are[22]: Municipal waste generation & treatment, by treatment method; Generation of waste excluding major mineral wastes; Management of waste excluding major mineral wastes; Recycling rate of e-waste; Material prices for recyclates.

While the Eurostat dataset is very rich, data are incomplete (for some country/year), the aggregate figures for EU27/28 are often estimated, and most flows are well documented on a common basis for the last few years only. For many flows, however, data allow getting the general trend prevailing in the EU countries of moving waste management away from landfills to re-direct waste flows towards recycling and energy recovery. An example of data for the EU27 for municipal solid waste is provided in Figure 3.1. From 1995 to 2017, landfilling

22 See https://ec.europa.eu/eurostat/web/waste/overview and the database at https://ec.europa.eu/eurostat/data/database decreased by 61%, material recycling increased by about three times, composting/digestion doubled in the period 2000-2017, and energy recovery increased by 71% in the period 2008-2017.

Figure 3.1. Management of municipal solid waste in the EU27, 1995-2017 (by codes, thousands tons)



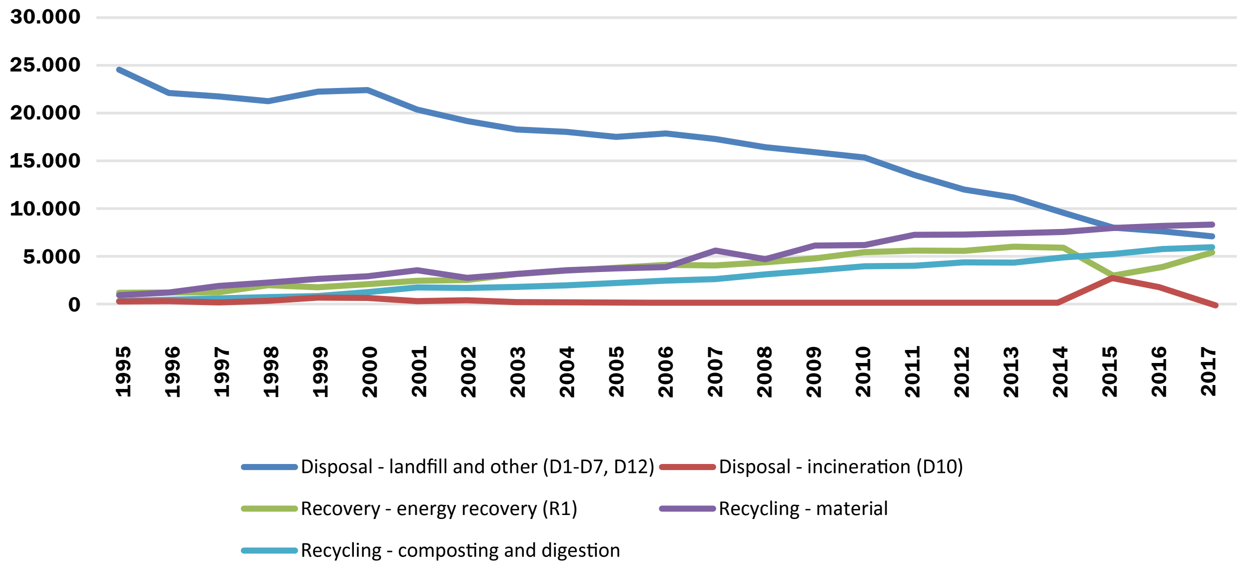
Source: own elaboration on Eurostat data

At the EU level, there is a differentiated evolution of the national (and regional) waste management systems. However, according to Marin, Nicolli and Zoboli (2017)[23], in the case of municipal solid waste there is convergence during time in the composition of management options and the variety is decreasing with a systematic reduction of landfill in all EU27 countries.

The same data for Italy are reported in Figure 3.2. Changes have been even more dramatic than in the average EU27: in the period 1995-2017, landfilling decreased by 72%, energy recovery increased by 4.6 times, recycling increased about 9 times, and composting/digestion increased about 19 times.

23 *Giovanni Marin, Francesco Nicolli & Roberto Zoboli (2017): Catching-up in waste management. Evidence from the EU, Journal of Environmental Planning and Management, DOI: 10.1080/09640568.2017.1333952*

Figure 3.2. Management of municipal solid waste in Italy, 1995-2017 (by operation codes, thousands tons)



Source: own elaboration on Eurostat data

In addition to providing data to Eurostat according to waste statistics regulations, Italy is one of the countries in the EU28 having the most detailed system of waste statistics. Since 2001, ISPRA, the institute acting as national environmental agency, produced every year detailed reports on waste, and from 2012 it produces two reports per year, one on urban waste and the other on 'special' waste (i.e. industrial waste), including also special sections of specific flows of waste (e.g. packaging)[24]. Data from ISPRA also present detailed information on plants for waste management, which is a type of information not readily available for other EU countries. A large part of the data, which are detailed up to the municipal level, are publicly available[25].

3.2. Joining waste statistics and LCA data

In spite of the many very specific research and studies addressing the environmental pressures from waste and the different waste management technologies, there are few attempts to associate environmental pressures to waste management at the broad macro-scale of full economic systems. This approach can be very relevant to understand the environmental implications of increasing circularity at the macro-scale, but the limitations to its implementation can arise from the need of LCA data that are, in general, site specific in spite of the increasing extension and standardisation of LCA datasets.

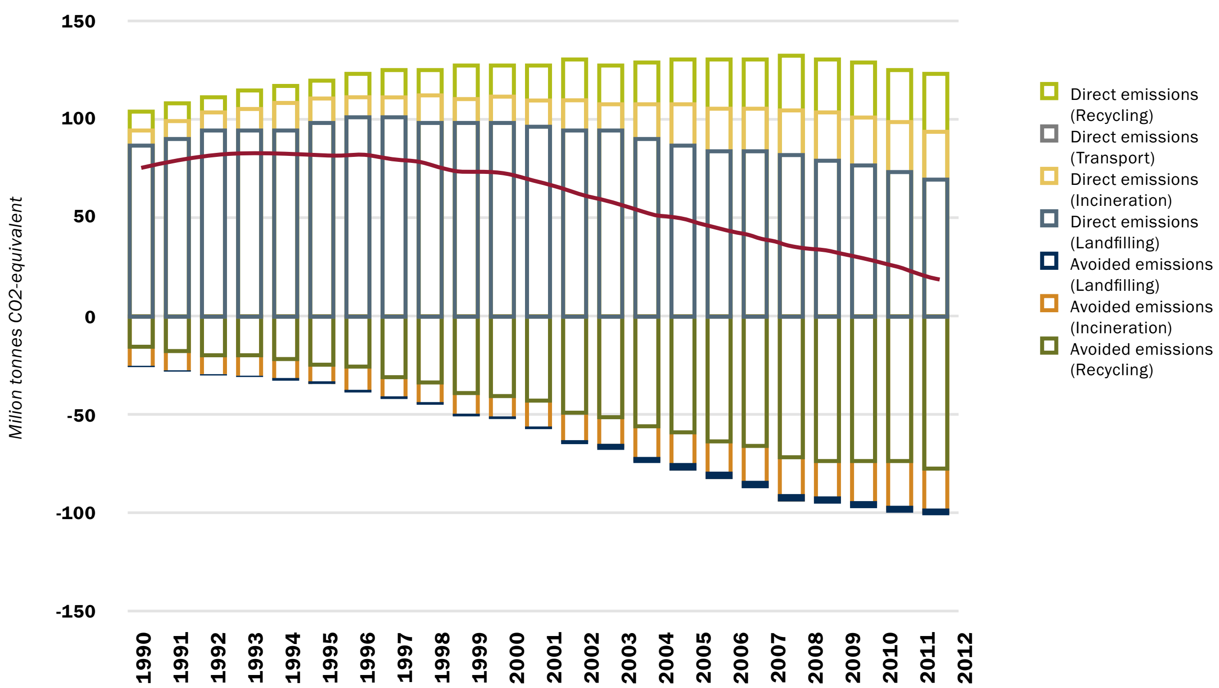
An extensive EU scale analysis, partly based on an LCA approach, has been produced and updated by the EEA[26]. The aim was to

24 See https://www.catasto-rifiuti.isprambiente.it/index.php?pg=pubblicazioni
25 See, for example, https://www.catasto-rifiuti.isprambiente.it/index.php?pg=downloadComune
26 See https://www.eea.europa.eu/soer-2015/europe/waste#note19

characterise the GHG saving associated (ex post and ex ante) to MSW management shift in European countries, including scenarios on policy compliance. The model therefore only focuses on waste management and not on the material chains. To estimate the overall effect of waste management options, avoided emissions (counted as negative) are added to the direct emissions, giving the net greenhouse gas emissions from MSW management[27].

The ex ante analysis is based on a baseline scenario that exploits projections on MSW production in European countries, a projected trend of management away from landfill, and other assumptions. The results of the baseline scenario are reported in Figure 3.3 by component of the net overall effect of changing pressures.

Figure 3.3. Net greenhouse gas emissions from municipal waste in EU-27 + Norway and Switzerland, baseline scenario (million tonnes CO2-equivalents)



Norway and Switzerland, differentiated according to the contribution of specific waste treatment paths. The GHG emissions are calculated using a life-cycle approach. In order to see the overall effect of waste management, the avoided emissions (counted as negative values) are plotted with the direct emissions, giving the total annual net GHG emissions from municipal waste management in European countries (the red line).

Data sources:

a. Eurostat. Municipal waste statistics
b. CRI. Projections of Municipal Waste Management and Greenhouse Gases' by Ioannis Bakas et al. ETC/SCP working paper 4/2011
c. ETC/SCP. Eionet review of ETC/SCP and EEA MSW model. Consultation paper of 29 April 2012.

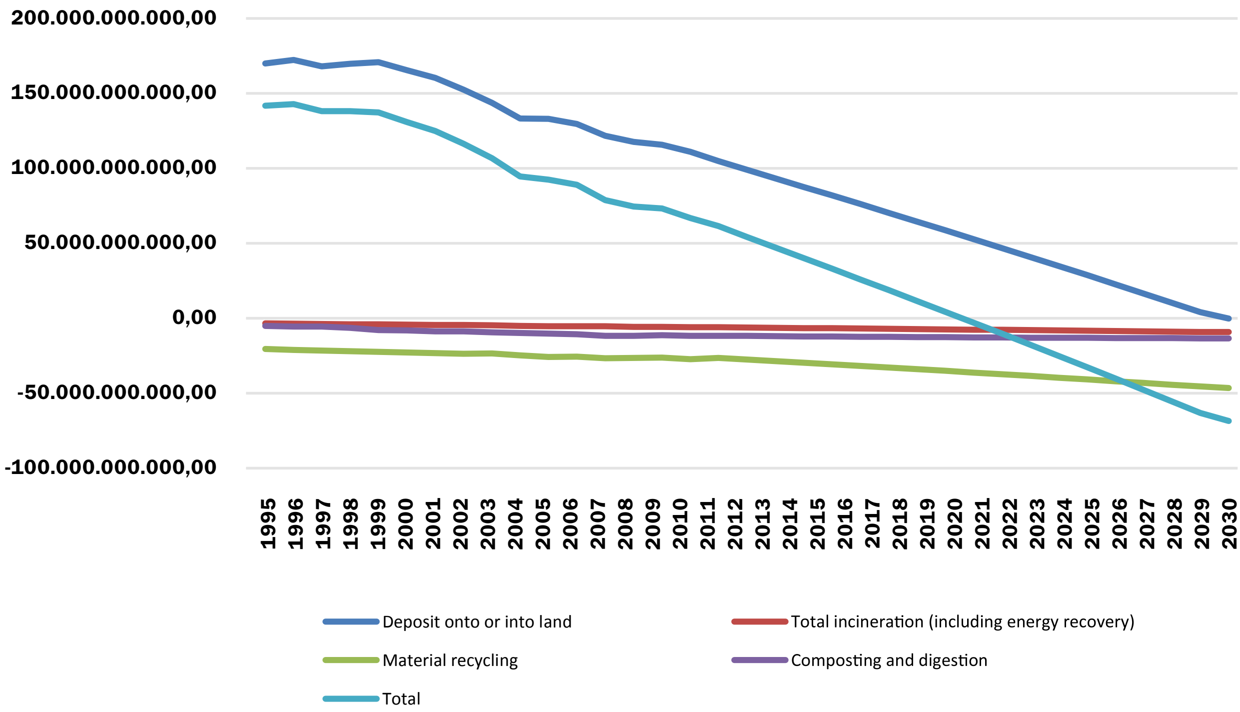
Source: EEA https://www.eea.europa.eu/soer-2015/europe/waste#note19

27 'Direct emissions' are those caused by all activities directly involved in the waste management system itself (methane emissions from landfills, energy-related GHG emissions from collection, and transport and emissions from waste incineration and recycling plants). 'Avoided emissions' are the GHG emissions from activities such as energy production from fossil fuels and production of primary materials that would be generated if there was zero energy recovery from waste and from landfill methane recovery, and zero material recovery from waste recycling.

The net emission level at 2020 is negative in all the scenarios: from the year 2017, the avoided emissions from waste management activities are higher than the burden caused by direct emissions from landfill sites, incineration plants, recycling activities, and the collection and transport of MSW (not including consumption and other operations outside the system boundaries). The level of emissions ranges from -8 Mt CO2eq in the baseline scenario to -41,8 Mt Co2eq in the 'landfill ban' scenario in 2020. The overall result is that the net greenhouse gas emissions estimated decline is around 85 million tonnes of CO2-equivalents between 1990 and 2020 in the EU-27 + Norway and Switzerland together[28].

A similar approach has been developed within the FP7 European project EminInn, by exploiting Eurostat waste data and LCA data (see Dalghren et al., 2014). The results of the projections for GHGs emissions, based on projections to the diversion of MSW from landfills in EU27, are reported in Figure 3.4. Total net emissions of CO2 eq are projected to achieve a zero level in 2021, up to become negative in 2030 (- 68 Mt CO2 eq) as a result of emissions from landfill becoming zero (with a zero share in total treatment) and increasingly negative emissions from recycling, composting, and incineration.

Figure 3.4. Scenario for GWP from MSW management in the EU27, actual data 1996-2011, projections for 2012-2030 (kg of CO2 eq)



Source: Dahlgren et al. 2014

28 See also EEA (2016).

The estimated external costs of the emissions of CO_2 (GWP) and SO_2 (acidification potential) available from recent literature have been applied to the quantity of emissions resulting from the LCA-related analysis developed above for the EU27. The resulting estimates, while suffering from limitations and the very wide range of estimates of the unit external costs from SO_2 emissions, suggest that the EU have already saved a great amount of external costs (from 12 to 82 billion/$ in 1996-2011) from shifting MSW management away from landfill and by developing incineration and especially recycling.

Furthermore, given the projection on future emissions from MSW management, an even greater monetary amount of external costs can be expected to be saved by the convergence to ‘near zero landfill’ and further development of recycling and incineration until 2030 (from 63,4 to 383,3 billion/$ in 2011-2030). Although this is not a full cost benefit analysis, and it does not encompass, for example, the industrial costs needed to develop a ‘recycling society’ or a ‘circular economy’, it seems to produce arguments in favour of the full implementation of the EU waste hierarchy in the EU countries. Alternative monetary estimates based on the quantity of waste (and not on LCA emissions) shifting from one technological option to another seem to confirm the economic value of the waste hierarchy in terms of external costs savings.

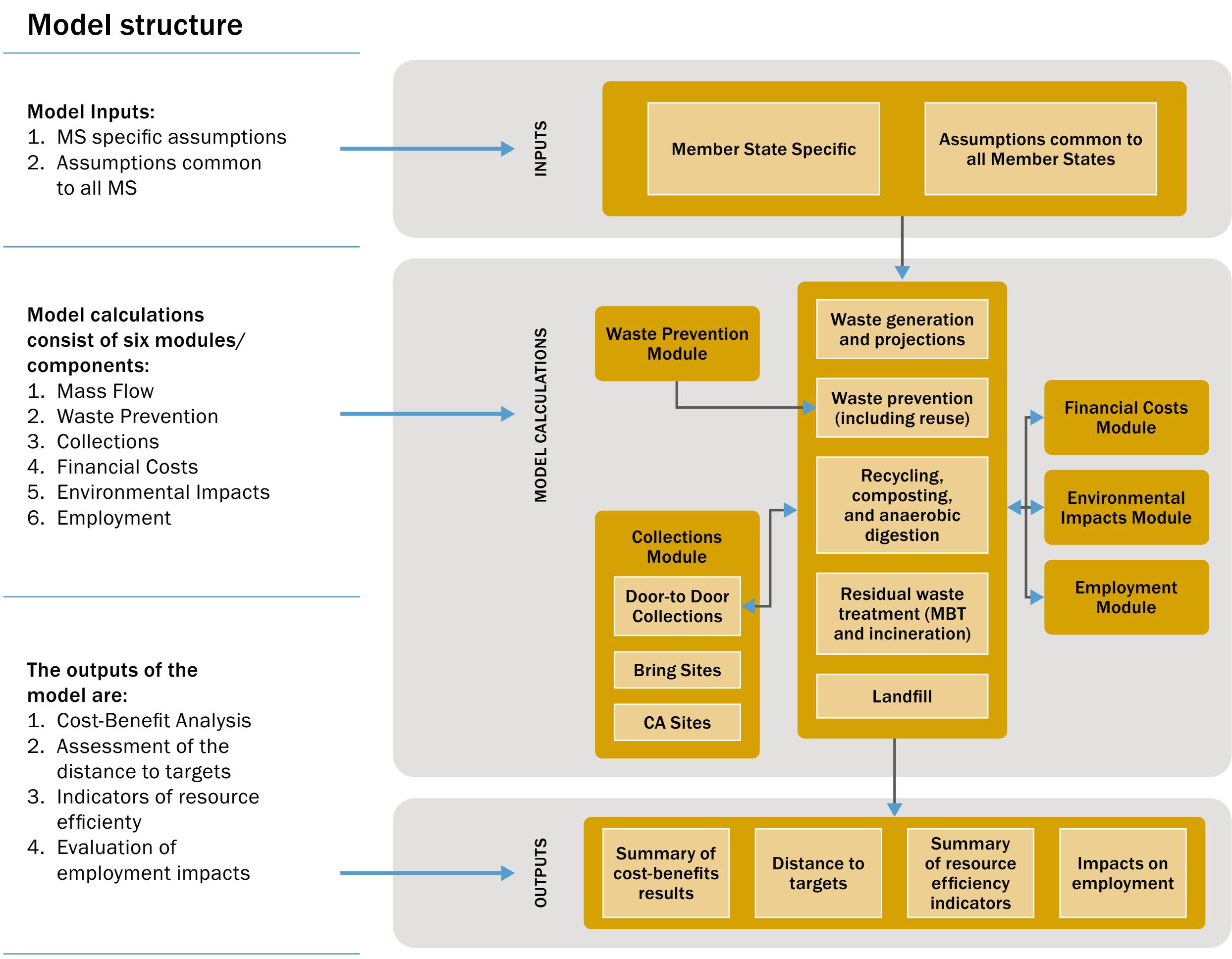
3.3 The European Reference Models for Waste

A more extensive information of the waste system in the EU has been developed through the ‘European Reference Model for Waste’. The model, which addresses municipal solid waste (then extended to packaging), has been firstly developed for the DG Environment and it has been used to support the proposal for the CE Package of 2015 by demonstrating its net benefits. The model has been then managed by the EEA with support of the ETC/WMGE (see Section 5) to provide advice to the DG Environment and single countries in their waste/CE policies.

The basic model structure is presented in Figure 3.5. The model, which has been recently augmented by a packaging waste module, is based on a mass-flow balance linking the different parts of the waste/recycling/recovery system in the different EU Member States and, from this basis, it can calculate environmental and economic costs/benefits (including employment effects) of different waste management strategies.

In spite of a set of recognised limitations, the model is still the only one covering the waste management system of each Member State and the EU as a whole for economic and environmental scenarios. The model has been made publicly available by the EEA in 2019.

Figure 3.5. Basic structure of the European Reference Model for Waste



Source: adapted from model documents

3.4. Material Flow Accounts

Material Flow Accounts (MFA) have a long tradition starting from the works of different researchers (see Fischer-Kowalski 1998 and Fischer-Kowalski et al. 2011), and provide a set of specific accounts and indicators on material flows linking natural resources and the economy.

Eurostat publishes ‘Economy-wide material flow accounts’ (EW-MFA) for European countries based on annual data collections guided by Regulation (EU) 691/2011 (consolidated version Annex III) and consistent with the UN System of Economic and Environmental Accounts - SEEA 2012 CF[29].

29 *At present, only six modules of the SEAA 2012 CF are implemented; 1) Air emissions accounts (AEA); 2) Economy-wide material flow accounts (EW-MFA); 3) Physical energy flow accounts (PEFA); 4) Environmental taxes; 5) Environmental goods and services sector (EGSS) accounts; 6) Environmental protection expenditure accounts (EPEA).*

The MFA data sets available from Eurostat are:

- *"Material flow accounts (env_ac_mfa): includes detailed material flows into (domestic extraction and physical imports) and out (physical exports) of an economy according to Regulation (EU) 691/2011.*

- *Material flow accounts - domestic processed output (env_ac_mfadpo): provides detailed material flows from an economy to the environment, termed 'domestic processed output'*

- *Material flow accounts - balancing items (env_ac_mfabi): provides balancing items required to articulate a consistent material input-output balance of an economy.*

- *Material flow accounts - main indicators (env_ac_mfain): this dataset provides highly aggregated EW-MFA and derived indicators.*

- *Material flow accounts in raw material equivalents (MFA-RME) - modelling estimates (env_ac_rme): extension to the standard EW-MFA to include the 'material footprint' indicator raw material consumption - RMC. It is based on environmental-economic modelling.*

- *Material flow accounts in raw material equivalents by final uses of products - modelling estimates (env_ac_rmefd): this data set provides estimates of material use in raw material equivalents ('material footprints') linked to final uses of products. This more detailed data set is fully consistent with the dataset material flow accounts in raw material equivalents (env_ac_rme) and is derived with the same environmental-economic model.*

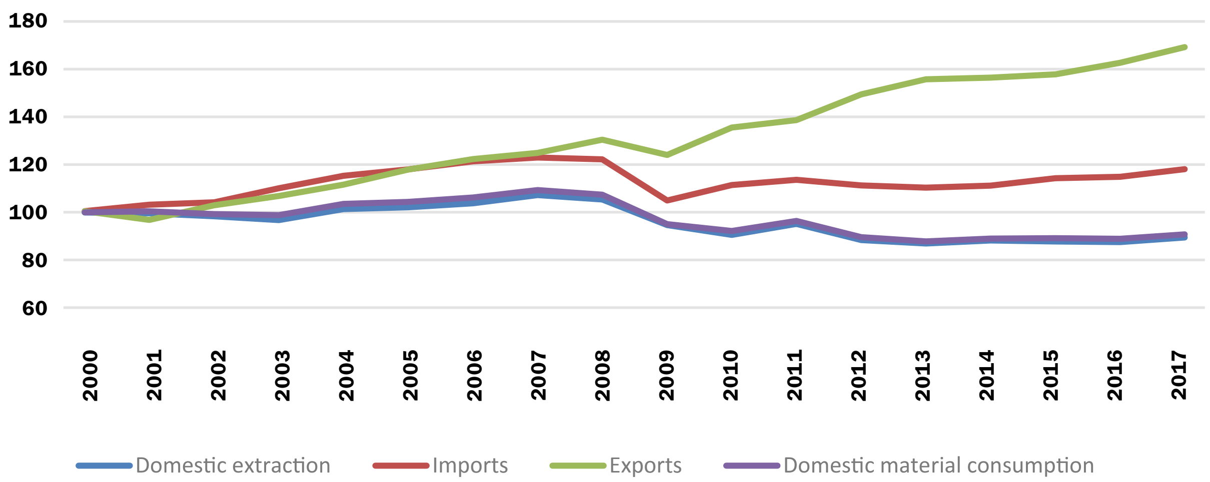
- *Resource productivity (env_ac_rp): resource productivity is the policy indicator relating gross domestic product (GDP) – measured in various units – to the main material flow indicator domestic material consumption (DMC).*

- *Circular material use rate (env_ac_cur): this small data set provides the indicator 'circular material use rate' by country and year.*

- *Circular material use rate by material type (env_ac_curm): this data set presents the 'circular material use rate' for the aggregated EU* by material type."

It can be noted that the last two datasets (Circular material use rate, and Circular material use rate by material type) are part of the newly-produced set of 'CE indicators' on which we will comment below. European data coverage and detail improved during the last few years and offer a rich set of information on raw materials and natural resources use. An example of the main indicators of MFA for EU28 is presented in Figure 3.6.

Figure 3.6. Selected MFA indicators for EU28, 2000-2017 (2000 = 100)



Source: own elaboration on Eurostat data.

MFA for Italy are regularly produced by ISTAT and are available in the website 'i.Stat' (http://dati.istat.it/) in the 'National accounts/Environmental accounts' section.

In principle, according to Eurostat: *"EW-MFA is a statistical framework conceptually embedded in environmental-economic accounts and fully compatible with concepts, principles, and classifications of national accounts – thus enabling a wide range of integrated analyses of environmental, energy and economic issues e.g. through environmental-economic modelling."* However, MFA remains a specific approach not fully linked to other statistical domains, in particular waste statistics, and economy-environment modelling tools. In particular, MFA are not framed in a conventional input output framework and, as stated by Eurostat: *"Material flows within the economy are not represented in EW-MFA."*[30] However, MFA remains a tool mainly oriented at resource efficiency analysis and the full integration between MFA accounting and nationals economic accounts is still not fully achieved, and the same applies to the integration with waste statistics.

30 See *https://ec.europa.eu/eurostat/web/environment/material-flows-and-resource-productivity*

3.5 The Eurostat indicators on the CE

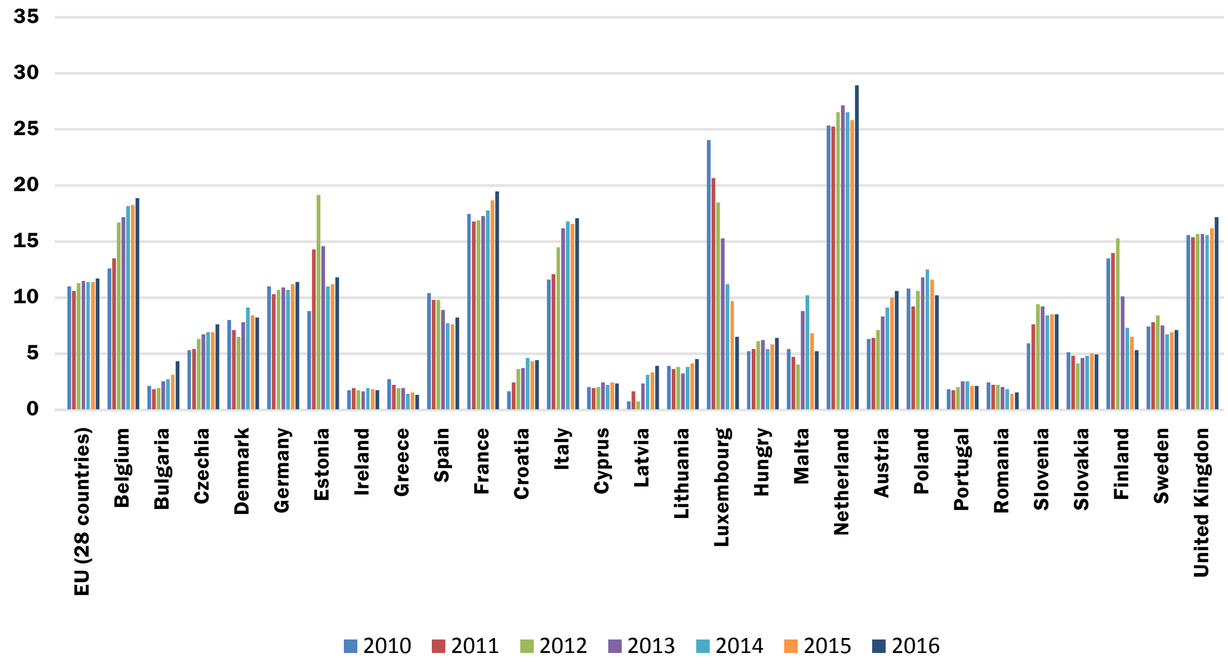
Recently, Eurostat developed a specific data framework to monitor progresses of the CE.[31] The set of indicators combines four groups: Production and consumption; Waste management; Secondary raw materials; Competitiveness and innovation. Out of 16 indictors, 9 belong to waste statistics. The other indicators (e.g. Self-sufficiency for raw materials, Contribution of recycled materials, Private investments) are derived from other data sets and have a limited data coverage in terms of product/country/years. The indicator on patents covers a limited number of CPC codes, largely in the area of waste management technologies.

The indicator on 'Circularity in material use rate', which belongs to the set of MFA (see above), is an attempt to combine waste data with MFA data, and it is built as follows: *"The indicator measures the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The circular material use (CMU) rate is defined as the ratio of the circular use of materials to the overall material use. The overall material use is measured by summing up the aggregate domestic material consumption (DMC) and the circular use of materials. DMC is defined in economy-wide material flow accounts. The circular use of materials is approximated by the amount of waste recycled in domestic recovery plants minus imported waste destined for recovery plus exported waste destined for recovery abroad. Waste recycled in domestic recovery plants comprises the recovery operations R2 to R11 - as defined in the Waste Framework Directive 75/442/EEC. The imports and exports of waste destined for recycling - i.e. the amount of imported and exported waste bound for recovery – are approximated from the European statistics on international trade in goods. A higher CMU rate value means that more secondary materials substitute for primary raw materials thus reducing the environmental impacts of extracting primary material."*

The indicator on 'Circularity in material use rate' for 2010-2016 is presented in Figure 3.7. The indicator greatly varies across countries/years and is rather stable for the EU28. Italy is one of the countries with improving performances and its level in 2016 is higher than the EU28 average and lower than those of the Netherland, the UK, Belgium, and France.

31 *https://ec.europa.eu/eurostat/web/circular-economy/overview*

Figure 3.7. The ‘Circularity in material use rate’ indicator for the EU28



Source: own elaborations on Eurostat data

The other tool in the Eurostat monitoring framework is the so-called ‘Sankey diagram’ that combines material flows and waste flows. Figure 3.8 presents the data for 2016 and highlights that out of about 5 billion/tons of material use, about 3 billion/tons are accumulated in stocks (goods), and about 2 billion go to waste. Of the latter, about 1,2 billion is recycled and backfilled, 150 million/tons are incinerated, and about 800 million/tons still go to landfill. Data on waste recycled and landfilled are possibly underestimated given that the flow, at least in this version, does not encompass the flow discarded from stock.

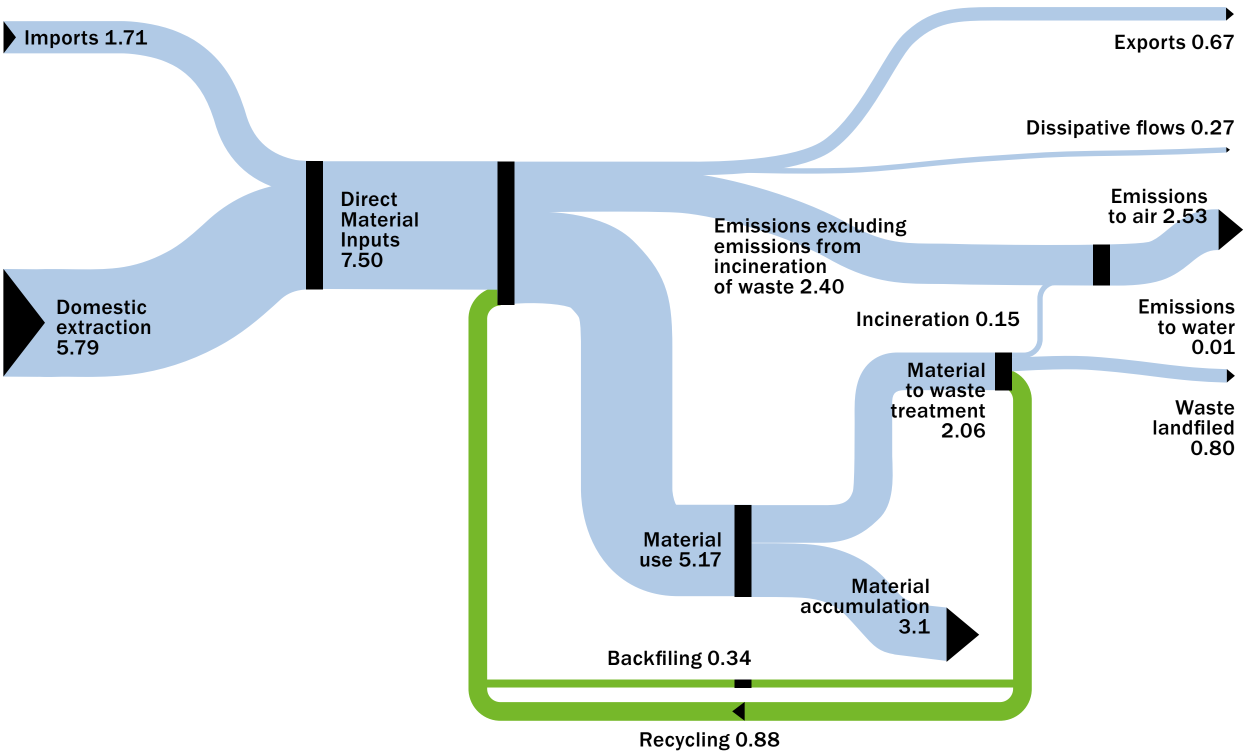
The other diagram in Figure 3.9 illustrates that dismantling and discard from the stock in use can be about 900 million/tons, and waste to landfill can be 1,5 billion/tons[32].

In spite of the uncertainty in figures, it can be noted that an amount between 0,8 and 1,5 billion/tons of waste are still going to landfill in the EU28, and achieving a target of ‘zero landfill’ or fully closed circularity of materials would imply to have this large amount of materials back to production system with huge economic consequences.

Starting from Eurostat data, a reconstruction of circular flows for selected materials groups at the EU level - which integrates material flows data, waste data, and data from research - has been recently produced by EEA (2019) (Figure 3.10).

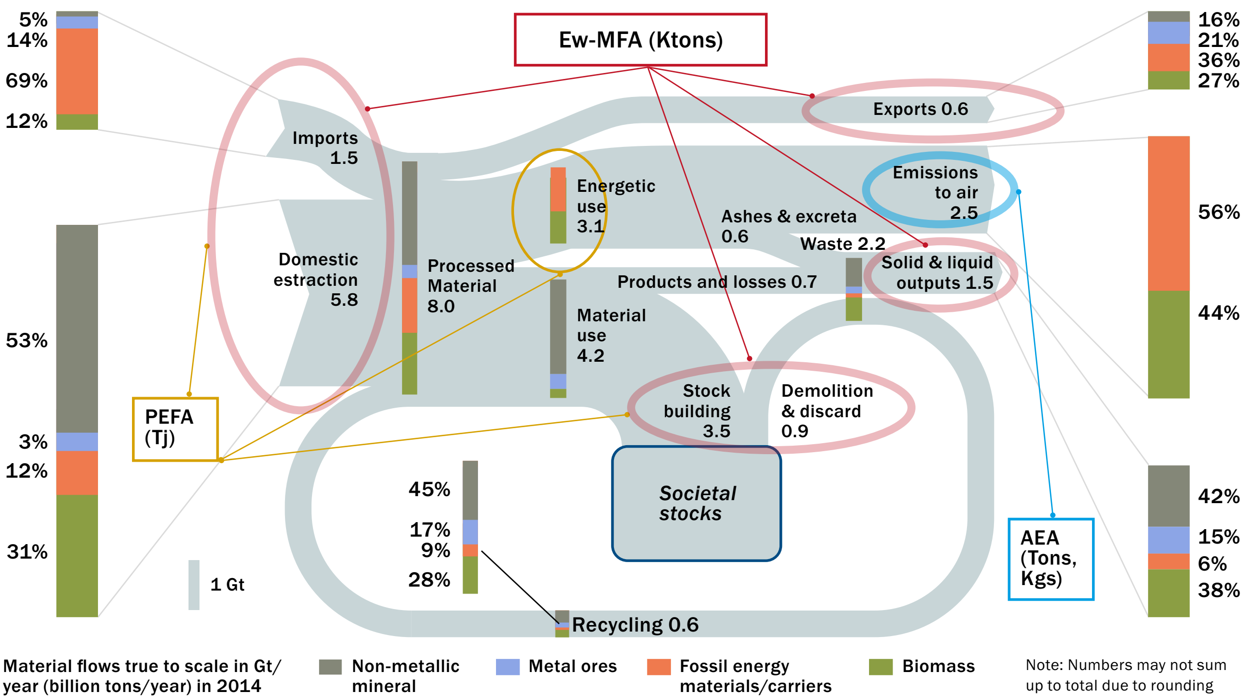
32 *In Italy, there is process to develop the integrated materials flow indicators managed by ISTAT, see Femia A., 2018, I conti ambientali a supporto delle politiche vper l’uso efficiente delle risorse e l’economia circolare, https://www.minambiente.it/sites/default/files/archivio/allegati/CReIAMO_PA/L3/FEMIA_CreiamoPA_11042018.pdf*

Figure 3.8. The Sankey diagram of materials and waste flows in the EU28, 2016, billion tonnes per year



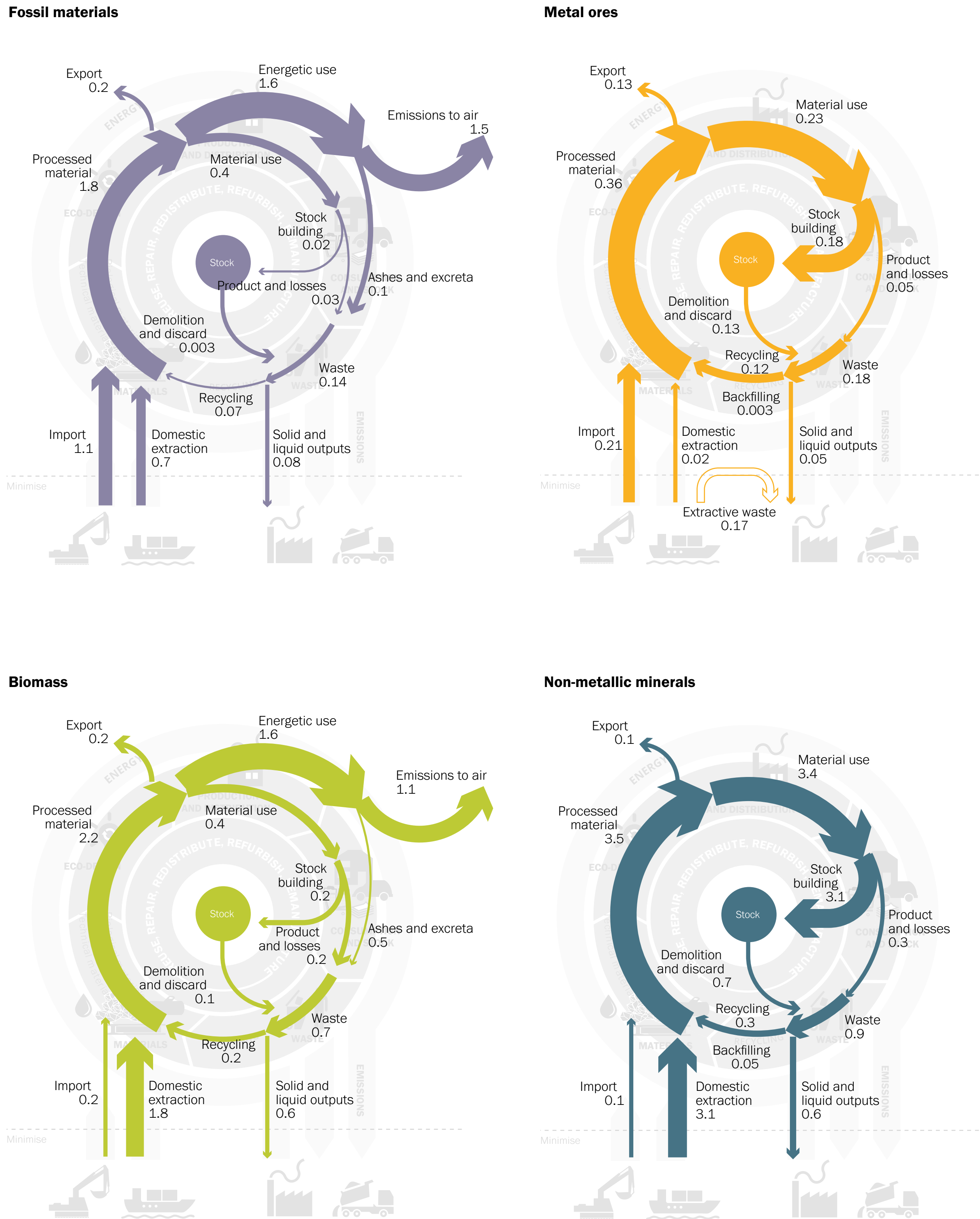
Source: Eurostat (online data codes: env_wassd; env_ac_sd; env_ac_mfa)

Figure 3.9. Estimated material and waste flows in the EU28 from combining different sources, billion tonnes



Source: Andreas Mayer, Willi Haas, Dominik Wiedenhofer, Fridolin Krausmann, Philip Nuss, Gian Andrea Blengini (in progress): Monitoring the circular economy in the EU28 - A mass balanced assessment of economy wide material flows, waste and emissions from official statistics. In: Journal of Industrial Ecology (as reported in Femia 2018)

Figure 3.10. Selected material flows through the EU economy (gigatonnes per year, 2014)



Source: EEA 2019, on data from Mayer et al., 2019, and Eurostat data.

3.6. Closing the circle: Input output data and EEIO models

As shown above, the available official data to measure and make strategies/policies on the CE are limitedly 'circular' as they do not encompass a consistent fully integrated representation of circularity in the economic and the environmental systems. Official waste statistics generally stop at the boundaries of the waste system and do not extend, in a systematic way, to the industries using waste as inputs and to processes of re-use and re-manufacturing. MFA does not include systematic and detailed accounts on the waste-related component. In any case, MFA and waste statistics are not fully integrated.

A standard statistical information that lacks a fully detailed and consistent picture of circularity and its progress favours fragmentation and inconsistency, thus representing a weak basis for circularity-oriented policies able to integrate the waste and material system into overall industrial, energy, and environmental policies.

In what follows, we present examples of integrated system-level information tools and models that are based on fully integrated economic accounts based an Input Output multi-sectoral structures: (i) the EU Input Output tables based on NACE 2.0 classification of economic activities; (ii) the EEIO Environmentally extended input-output approach, with the examples of EXIOBASE 2.0 and the WIOD database; (iii) the macro-economic models extended to the environment and circularity.

Although data provided from these tools are not updated (in particular in our examples), they can illustrate how it is possible to provide information and indicators of circularity at the level of inter-industry relationships for the economic systems as a whole.

(i) Input-output tables: the inter-industry linkages of the 'waste management' industry in the EU

Through the creation of Division 38 (Waste collection, treatment and disposal activities, materials recovery) (Table 3.1), the changes introduced with NACE 2 classification of economic activities (Eurostat 2008) allow a better identification of the inter-industry relationships of the waste management industry. Readily usable symmetric IO for EU27, Euro Area and the Member States at the needed sectors detail (65 sectors CPA, current prices) are available for 2008-2011 (released in 2014). The available IO data for the aggregate sector CPA 37-39 ('Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services') merge the three divisions: 'Sewerage' CPA 37, and 'Remediation activities' CPA 39, together with 'Waste collection, treatment and disposal activities, materials recovery' CPA 38.

Table 3.1. Section E in NACE 2

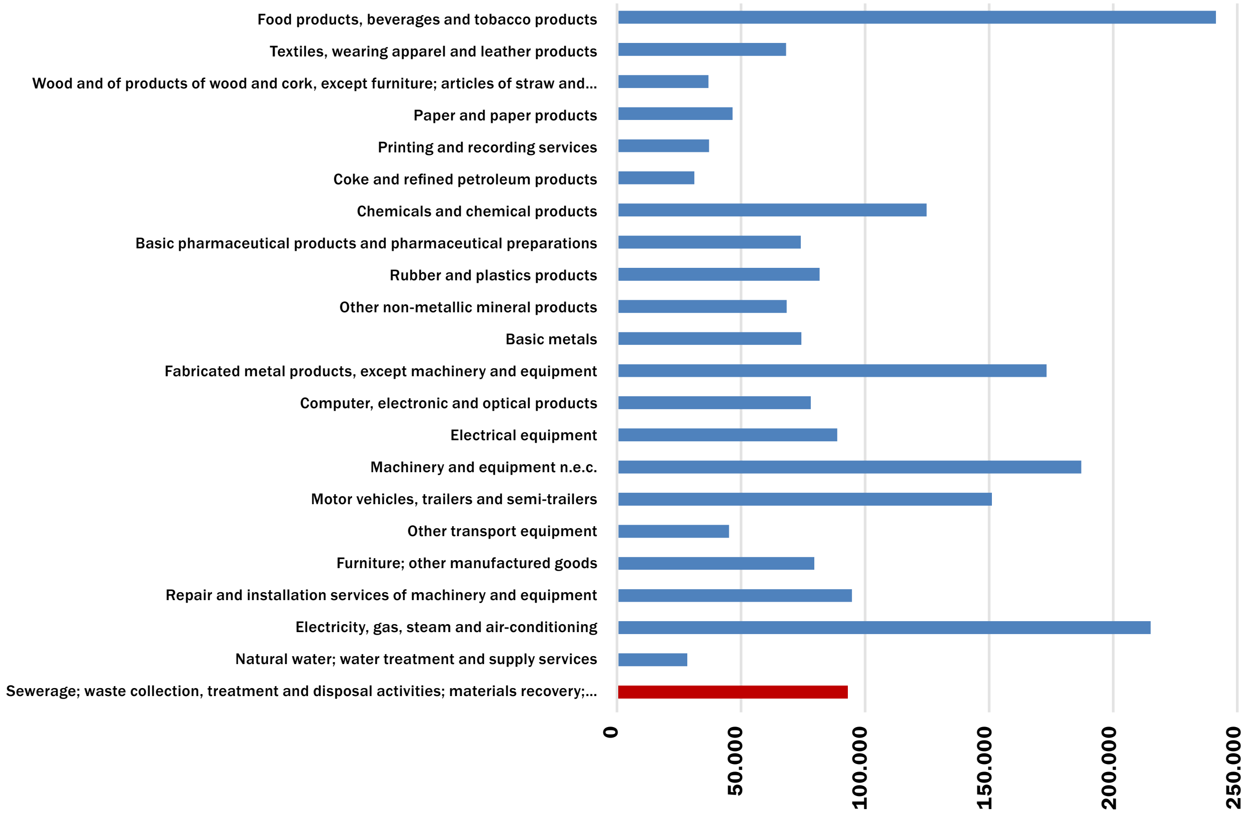
n.e.c.: not elsewhere classified				*part of
Division	**Group**	**Class**		**ISIC Rev. 4**
SECTION E - WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES				
36			Water collection, treatament and supply	
	36.0		Water collection, treatament and supply	
		36.00	Water collection, treatament and supply	3600
37			Sewerage	
	37.0		Sewerage	
		37.00	Sewerage	3700
38			Waste collection treatment and disposal activites; materials recovery	
	38.1		Waste collection	
		38.11	Collection of non-hazardous waste	3811
		38.12	Collection of hazardous waste	3812
	38.2		Waste treatment and disposal	
		38.21	Treatment and disposal of non-hazardous waste	3821
		38.22	Treatment and disposal of hazardous waste	3822
	38.3		Materials recovery	
		38.31	Dismantling of wrecks	3830*
		38.32	Recovery of sorted materials	3830*
39			Remediation activities and other waste management servicies	
	39.0		Remediation activities and other waste management servicies	
		39.00	Remediation activities and other waste management servicies	3900

In spite of these data limitations, it is possible to exploit the IO table for the EU27 (in our example for the year 2011) to have a picture of the waste management industry (as approximated by the sector CPA 37-39) in its interrelationships with the rest of the economy (see ETC/WMGE 2017). This picture can highlight this sector as both recipient and provider of inputs from/to the economy in its pivotal role for the circular economy at the macro level. We will exploit both the A matrix of the IO table and the IO data in value[33].

In 2011, the waste management industry (CPA E37-E39) in the EU27 produced a total output value of 209,4 billion/€ with a value added (VA) of 89,7 billion/€ (current prices). Within VA, the amount of compensation of employees was 46 billion/€. Compared to the total VA of manufacturing (about 2.042 billion/€) the VA of the CPA E37-E39 sector represents just a share of 4,4%. However, compared to other manufacturing sectors, the VA of this industry ranked as the 7th highest one, with a level higher than repair and maintenance, furniture, electronic equipment, computers, basic metals, rubber and plastics, pharmaceutical products, paper and paper products, textile products (see Figure 3.11).

33 The A matrix calculated from the IO table provides, for each sector (column), the technical coefficient of production of the sector expressed as the ratio of the value of inputs from other sectors on the total output value of the sector itself. The Eurostat IO tables provide a calculated A matrix in terms of decimal percentage coefficients.

Figure 3.11. Value added of manufacturing sectors in the EU27 in 2011 (billion €)



Source: own elaboration on Eurostat data (see also ETC/WMGE 2017b).

Given that a large part of the output of the waste management industry is made of inputs of intermediate products to other sectors of the economy, it is possible to exploit the A matrix and the symmetric IO table for 2011 to give a measure of the importance of the sector-related inter-industry flows at the level of the EU27 economy. This measure can give a first quantified approximation of the importance of 'circularity' of the EU economy as revealed by the pivotal role of the waste management industry (CPA E37-E39) in the closed loop circulation of materials and the valorisation of waste as industrial inputs, up to making some industries vitally depending on waste inputs.

A relatively large share of total inputs received by the CPA E37-E39 sector is coming from the sector itself (12,3% of output value): this is largely due to the level of aggregation of the data that include large circulation of inputs and outputs (positively valued) into/from different processes that, however, are classified within the same CPA E37-E39 sector. However, the waste management industry receives inputs from a large number of industrial and service sectors. Major provider sectors (above 2% of output value of CPA E37-E39) are (short names): Business support services, Architectural and engineering services; Wholesale and retail trade excluding motor vehicles, Constructions and construction works, Basic metals. Other relevant input providers from the manufacturing sectors are: Electricity, Fabricated metal products, Chemicals.

The issue of negative prices sometime prevailing in the waste management sector (which, in some cases, receives both materials and money from waste and wastewater 'owners') can be relevant in understanding the meaning of these input flows. Given that these inputs are positively valued in the IO table (the CPA E37-E39 sector being the buyer) it seems reasonable that the flows from certain sectors (e.g. basic metals) are materials and/or waste at an early stage of transformation with positive prices that are bought as inputs by the production processes of CPA E37-E39. In other cases, especially for inputs from the service sectors, it is more difficult to understand their high value (as share of output value) because their positive value suggests they are procured by CPA E37-E39 industries and are not made of positively priced waste.

Looking at the imported inputs used by the sector CPA E37-E39, they represent a very small share of total output value of the sector itself (3,4%). The relevant feature is that, differently from the domestically sourced inputs, the imported inputs are coming to a significant extent from the manufacturing sectors, in particular sectors linked to the metal production and metal use chain as well as chemicals and petroleum. Even in this case, the positive value of these inputs suggests they can be positively priced materials and wastes used by the CPA E37-E39 sector.

Looking at the role of the CPA E37-E39 sector *as provider of inputs* to other sectors, which can give a picture of its role in re-circulating waste and wasted materials back to industrial production process, we can look at the coefficients of domestic inputs from sector CPA E37-E39 to other sectors of the EU27 economy as percentage of the total output of the receiving sector (CPA E37-E39 row of the A matrix). Provided that, of course, the CPA E37-E39 sector is the major provider of inputs to itself (the share of inputs on output value, 12,3%, being the same as the one of the sector seen as producer, see above), the sectors for which inputs from CPA E37-E39 are more important (as share of their output value) are: Basic metals (5,8%), Water services (3,4%), Paper and paper products (1,7%), Public administration and social services (1,1%), Chemicals and chemical products (0,9%). All the other sectors in the economy buy inputs from the CPA E37-E39 sector for a small share of their output value. The economic interpretation of these input flows from the CPA E37-E39 sector to other sectors can be complex given the nature of the waste management industry itself and the possibility of negative prices prevailing in the 'markets for waste'.

The picture for imported inputs of the CPA E37-E39 sector into other sectors of the economy shows very small flows as a share of output value of receiving sectors. It can be noted that (leaving aside those going to the CPA E37-E39 sector itself) the relatively most important are those going to the Basic metal sector (0,6% of total output value) and to the Paper and paper product sector (0,2%).

(ii) The EEIO 'Environmentally-Extended Input-Output' approaches

Waste-based production in specific industrial sectors: evidence from EXIOBASE 2.0
Accounting for the relative importance of waste-based industries in the economy as a whole provides a synthetic measure of circularity, but could be misleading when countries with substantially different economic structures are

compared. To dig deeper in the evaluation of the role of waste-based industries it is important to see the relative importance of these sectors in their corresponding non-'waste-based' industrial sector. For example, even if the industry that deals with recycling iron could seem small compared to the size of the economy as a whole, the share of iron that is produced from recycled iron could be large, depending on the overall size of the iron industry.

We provide evidence on the size of waste-based industries within their corresponding traditional industry. We exploit detailed information on industry disaggregation from EXIOBASE 2.0 (year 2007) for the EU27 as a whole[34]. Table 3.2 reports the industries groupings that are considered: non-'waste-based' industries are reported in normal text, while 'waste-based' industries are reported in Italics.

Table 3.2. Group of sectors that include relevant waste-based production in EXIOBASE 2.0

Sector	Group
Aluminium production *Re-processing of secondary aluminium into new aluminium*	Aluminium
Manufacture of bricks, tiles and construction products, in baked clay Manufacture of cement, lime and plaster *Re-processing of ash into clinker*	Bricks and cement
Copper production *Re-processing of secondary copper into new copper*	Copper
Manufacture of glass and glass products *Re-processing of secondary glass into new glass*	Glass
Manufacture of basic iron and steel and of ferro-alloys and first products thereof *Re-processing of secondary steel into new steel*	Iron
Lead, zinc and tin production *Re-processing of secondary lead into new lead*	Lead, zinc, tin
Other non-ferrous metal production *Re-processing of secondary other non-ferrous metals into new other non-ferrous metals*	Other non-ferrous metals
Plastics, basic *Re-processing of secondary plastic into new plastic*	Plastics
Precious metals production *Re-processing of secondary precious metals into new precious metals*	Precious metals
Pulp *Re-processing of secondary paper into new pulp*	Pulp
Recycling of waste and scrap *Recycling of bottles by direct reuse*	Recycling
Biogasification of food waste, incl. land application *Biogasification of paper, incl. land application* *Biogasification of sewage slugde, incl. land application* *Composting of food waste, incl. land application* *Composting of paper and wood, incl. land application* *Incineration of waste: Food* *Incineration of waste: Metals and Inert materials* *Incineration of waste: Oil/Hazardous waste* *Incineration of waste: Paper* *Incineration of waste: Plastic* *Incineration of waste: Textiles* *Incineration of waste: Wood* *Landfill of waste: Food* *Landfill of waste: Inert/metal/hazardous* *Landfill of waste: Paper* *Landfill of waste: Plastic* *Landfill of waste: Textiles* *Landfill of waste: Wood* *Waste water treatment, food* *Waste water treatment, other*	Waste industry
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials *Re-processing of secondary wood material into new wood material*	Wood

Source: G. Marin elaboration in ETC/WME 2017b

34 EXIOBASE is the database of EXIOMOD, a Computable General Equilibrium Model (see below) using a very detailed input-output structure integrated with environmental and resource extensions.

Results for gross output, employment and value added of the sub-sectors based on waste are reported in Table 3.3. Overall, the share of waste-based industries in their larger reference industry is about 37 percent in terms of total output, about 55 percent in terms of total employment, and about 46 percent in terms of value added. For two industries, the 'Recycling' and 'Waste' ones, all production, employment and value added refer, by definition, to waste-based industries. These industries account for 2/3 of output, 1/2 of employment and almost 60 percent of value added of our selection of industries. If we exclude these industries from the calculation, the role of the waste-based industry as a share of the larger reference industry shrinks to 6 percent for total output, almost 9 percent for employment and 6.64 percent for value added.

When looking at specific industries, the sector for which the relative share of waste-based activities is the largest is the Pulp industry, followed by the Iron industry and the Glass industry. For these industries, between 1/3 and 1/4 of production, employment and value added refers to the waste-based sub-industry. The industries for which the waste-based component is the lowest, in relative terms (less than 5 percent), are the Bricks and cement industry, the Copper industry, the Other non-ferrous metals industry, the Plastics industry and the Precious metals industry.

It is interesting to note that the intrinsic value of the material at stake (e.g. precious metals vs pulp) does not seem to explain the heterogeneity in the role of the waste-based component. Heterogeneity may be due to different technological features and different regulatory frameworks, in particular when the latter pushed for increasing recycling/recovery. For example, precious metals are often embedded (in small quantities) in complex equipment (e.g. electronic devices) that are difficult to dismantle, while paper is more easily collected.

Table 3.3. Output, employment and value added in 'waste-based industries' within their larger industry group (own elaboration on EXIOBASE 2.0 data for EU27, year 2007)

Macro-sector	Total output (million euro)	Of which 'waste based'	Total employment (thousand employees)	Of which 'waste based'	Total value added (million euro)	Of which 'waste based'
Aluminium	1893	7.02%	4.76	7.70%	340	6.54%
Bricks and cement	6470	2.88%	50.57	3.30%	2196	3.04%
Copper	1950	4.98%	3.28	3.28%	316	4.24%
Glass	2383	21.08%	14.90	24.82%	852	26.99%
Iron	3792	29.32%	17.68	30.40%	967	30.73%
Lead, zinc, tin	1680	14.12%	7.27	10.45%	356	13.97%
Other non-ferrous metals	503	0.20%	0.44	0.00%	57	0.01%
Plastics	79798	1.88%	227.24	2.73%	23663	1.92%
Precious metals	729	0.23%	0.95	0.00%	71	0.00%
Pulp	1904	37.05%	10.41	43.09%	669	43.46%
Recycling	2101	100.00%	25.57	100.00%	578	100.00%
Waste industry	57636	100.00%	525.18	100.00%	25734	100.00%
Wood	20467	13.73%	205.83	12.43%	6203	15.22%
Total	181305	36.97%	1094.07	54.75%	62003	46.26%
Total (excl. 'Recycling' and 'Waste industry')	121569	5.99%	543.33	8.88%	35690	6.64%

Source: G. Marin elaborations on EXIOBASE 2.0 data

A similar estimate for Italy, not based on a modelling framework, has been developed in 'Green Italy 2017'[35]. Italy was in 2014 the second country in the EU, after Germany, in terms of quantity of waste recycled as inputs in industrial value chains, about 40 million/tons in sectors like paper, metals, glass, textiles, and the European country with the highest figure per capita. According to the Green Italy estimates, which are based on the allocation of values in proportion to waste based inputs, the turnover of 'manufacturing from recycling' was, in 2015, 34 billion/€ and the number of employees in these industries was 80.000 units.

'Trade-embodied' resource efficiency using WIOD

Marin and Zoboli (2017) present a detailed review of the many EEIO models, in particular MRIO (Multi-regional Input-Output Models) extended to the environment, that have been developed to assess resource efficiency and 'trade-embodied' pollution and resource use. The authors develop an analysis of the pressures exerted by the EU27 on resources of non-EU countries exploiting WIOD data.[36]

Figure 3.12 reports the trends in the share of environmental pressures, employment and value added that were generated out of the EU27 over the total required to satisfy the final

35 *Fondazione Symbola, Unioncamere, GreenItaly, Green Italy Rapporto 2017, Roma, 2017, http://www.symbola.net/assets/files/GreenItaly%2017_1509970511.pdf*

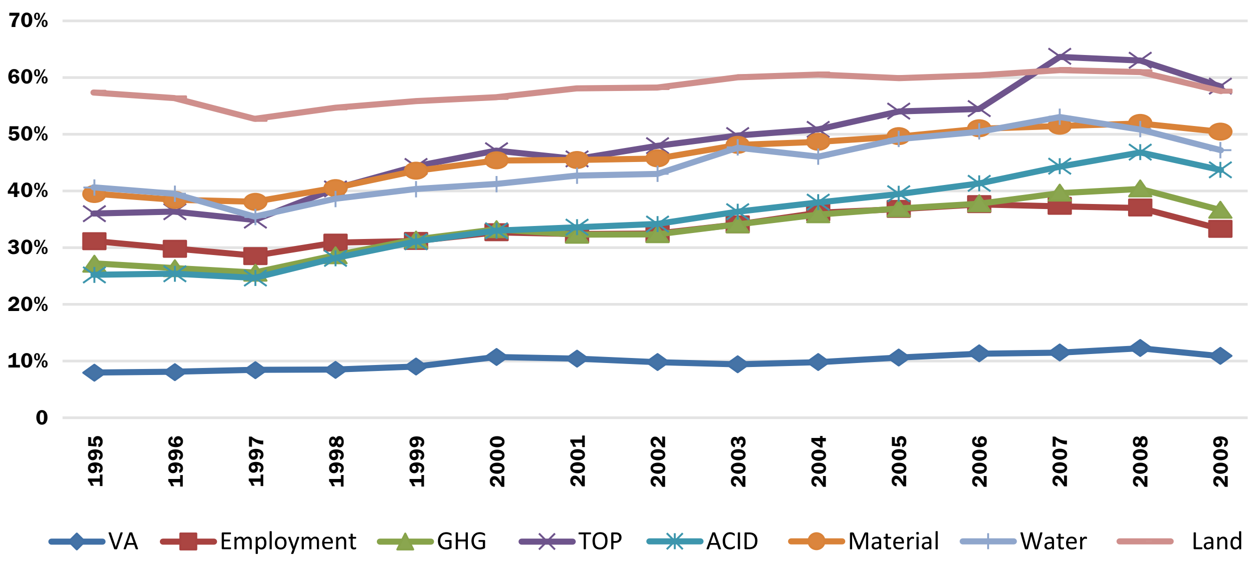
36 *The World Input-Output Database (WIOD) consists of a series of databases and covers 28 EU countries and 15 other major countries in the world. The release 2013 included environmental extensions that, unfortunately, have not been updated in the release 2016. http://www.wiod.org/home*

demand of the EU27. This is a relative indicator of how much the EU27 is relying on its trading partners to satisfy its final demand. Changes in this set of indicators reflect a combination of changes in the relative importance of domestic production (either of final products or intermediate products) to satisfy domestic final demand and of differences between the EU27 and the rest of the world in the evolution of intensity coefficients of output (related to environmental pressures, labour and value added). For example, even in presence of a completely unchanged composition of international trade, a faster improvement (e.g. reduction in CO2 emissions per monetary unit of production) in environmental efficiency in the EU27 vis-à-vis the rest of the world would result in an increase in the relative amount of environmental pressures occurring abroad to satisfy domestic demand.

Evidence shows that a large share of total environmental pressures generated to satisfy EU final demand occurs outside the EU borders. Moreover, this share has increased. A large component of the growth in the share of environmental pressures occurring abroad is the systematic difference in environmental performance between the EU and its trading partners, with the former improving its environmental performance (environmental pressure per unit of produced output) much faster than the latter. At the same time, however, the share of value added and employment generated abroad to satisfy EU domestic demand were substantially lower than the corresponding environmental pressures, and have been stable in the period we consider. Therefore, the structural change of the EU economy is distributing worldwide more 'bads' than 'goods' as a share of those generated to satisfy final domestic demand.

In short, resource efficiency gains in the EU are accompanied by increasing pressures abroad, and the circular economy, by looking primarily in domestic resources, may report these pressures, as well as the associated value added and employment, inside Europe.

Figure 3.12. Share of environmental pressures and economic activity occurred out of the EU27 to satisfy the final demand of EU27



Source: Marin and Zoboli (2017)

(iii) Meso/macro-models addressing circularity

A general assessment of how meso/macro-models of different types address circularity is presented in OECD (2017). Two main approaches are distinguished:

(i) accounting modelling that develop scenarios regarding material circularity in one or several sectors (as referred to e.g., Bastein et al., 2013; Ellen McArthur Foundation, 2013; Stegeman, 2015, and SITRA, 2015); scenarios can be based on expert opinion on higher future recycling, remanufacturing, repair, or re-use and, in some cases, the changes in the directly affected sectors are used to calculate indirect effects using input-output tables;

(ii) economy-wide quantitative models: computable general equilibrium (CGE) and macro-econometric (ME) models represent the role that prices play in determining supply and demand for products, commodities, and natural resources; some multi-sectoral models, including all CGE and some ME models, are based on an underlying social accounting matrix (SAM). The OECD review concentrate on the second type of models (Figure 3.13).

Figure 3.13. The models reviewed in OECD (2017)

Modelling Group	Key Paper	Model Name	Regions	Sectors	Materials	Circulary
GWS-SERI	Bockemann et al. (2005)	PANTA RHEI	1	59	4 (p)	**N**
Hitotsubashi	Okushima and Yamashita (2005)	ODIN-WR	1	25	10 (s)	**Y**
NIES	Masui (2005)	AIM	1	41	18 (s)	**Y**
KEI Korea	Kang et al. (2006)	AIM-INCGE	1	32	19 (s)	**Y**
IAMC China	Unpublished	AIM-IPAC	?		?	**N**
Wppertal Institute	Distelkamp et al.. (2010)	PANTA RHEI	1	59	4 (p)	**N**
TNO	TNO (2012)	EXIOMOD	27	15	?	**N**
UCL	Ekins et al. (2012)	E3ME	30	42	19 (p)	**N**
Cambrige Econometrics	Cambrige Econometrics (2014)	E3ME	34	43	19 (p)	**N**
French Ministry of Enviroment	Godzinski (2015)	Vulcain	1	5	2 (s)	**Y**
NERA	Tuladhar et al. (2015)	NewERA	5	17	0 (p)	**N**
Ellen McArthur	Bohringer and Rutherford (2015)	?	5	16	0 (p)	**N**
World Bank	Bouzaher et al. (2015)	?	1	12	1 (s)	**N**
NIER Sweeden	Sodeman et al. (2016)	EMEC	1	26	34 (s)	**N**
EX Tax	Groothuirs et al. (2016)	E3ME	28	43	19 (p)	**N**
CSIRO	Schandl et al. (2016)	GIAM	13	21	?	**N**
ERC	Hartley et al. (2016)	SAGE	1	49	13 (s)	**Y**
DYNAMIX	Bosello et al. (2016)	ICES	19	20	?	**N**
		MEMO	1	10	?	**N**
		MEWA	1	18	?	**N**
SIMRESS	Unpublished	GINFORS	39	27	7 (p)	**N**
POLFREE	Meyer et al. (2016)	GINFORS	39	27	7 (p)	**N**
	Hut et al. (2016)	EXIOMOD	26	36	5 (p)	**N**
UCL	Winning et al. (2017)	ENGAGE Materia	17	35	1,1 (p) (s)	**Y**
UNEP IRP	UNEP (2017)	GTEM	28	21	10 (p)	**N**
WIFO	Sommer and Kratena (2017)	WIFO DYNK	1	62	4 (s)	**Y**

Note: (p) = linkages with primary materials, (s) = linkages with secondary materials.

Source: OECD (2017)

The overall conclusions of the assessment are that macro-models can provide insights into the transition to a CE and its macro-economic and sectoral implications, but still with limitations also due to the fact that most modelling exercises including CE components have been developed just from 2015.

In particular: *"Four key conclusions emerge from the existing literature. First, most economic models find these shifts will have an insignificant or even positive impact on aggregate macroeconomic outcomes. In other words, the current literature indicates that a transition to a (broadly defined) circular economy – with the associated reductions in resource extraction and waste generation – could take place with potentially significant positive (or at least without negative) consequences for economic growth or overall employment. Second, all models highlight the potential re-allocation effects that the introduction of circular economy enabling policies could have. The competitiveness of material intensive sectors – natural resource extraction and certain types of manufacturing – will probably decline; workers, regions, and countries specialising in these activities may be made worse off in any circular economy transition. Other sectors – waste management and recycling, remanufacturing and repair, and services more generally – will probably expand as their output becomes relatively affordable. Third, dynamic multi-region models are well suited to capturing the transition in the economy, as well as the socioeconomic trends and trade impacts that will accompany any transition. In contrast, (static) single region models may be better suited to representing material circularity in more detail. Fourth, three key sets of assumptions that drive modelling outcomes, and the quality of the policy advice that emerges from them, are identified: (i) assumptions on future efficiency improvements (e.g. future rates of material productivity growth, cost of the underlying drivers, and role of policies), (ii) assumptions on the degree of substitutability between primary and secondary materials, both for different materials, and in different applications, and (iii) assumptions on the changes in the future structure of the economy and consumption patterns, and to what extent will these take place in the absence of policy drivers."* (p. 4-5)

Key open issues in modelling are the level of sectoral disaggregation, the inter-material and material/energy substitution effects, the way innovation is incorporated into the model structure, and how policies are dealt with in scenario building.

4. Innovation for the CE

Innovation is a fundamental lever for the GE. While in Part 2, Section 6 below we will present a view on the CE entirely based on the innovation angle and the 'innovation system' approaches, in this section we present an overview of the CE-related innovation in Europe through 'conventional' indicators of innovation (patents, innovation adoption) and the specific 'organisational innovations' taking place in the CE through the EPR-based compliance schemes[37].

37 *Instead, we will not report on R&D data because the aggregation of R&D statistics, which goes just to the level of expenses and scientists for 'environment' and 'energy', does not allow to extract a specific CE focus.*

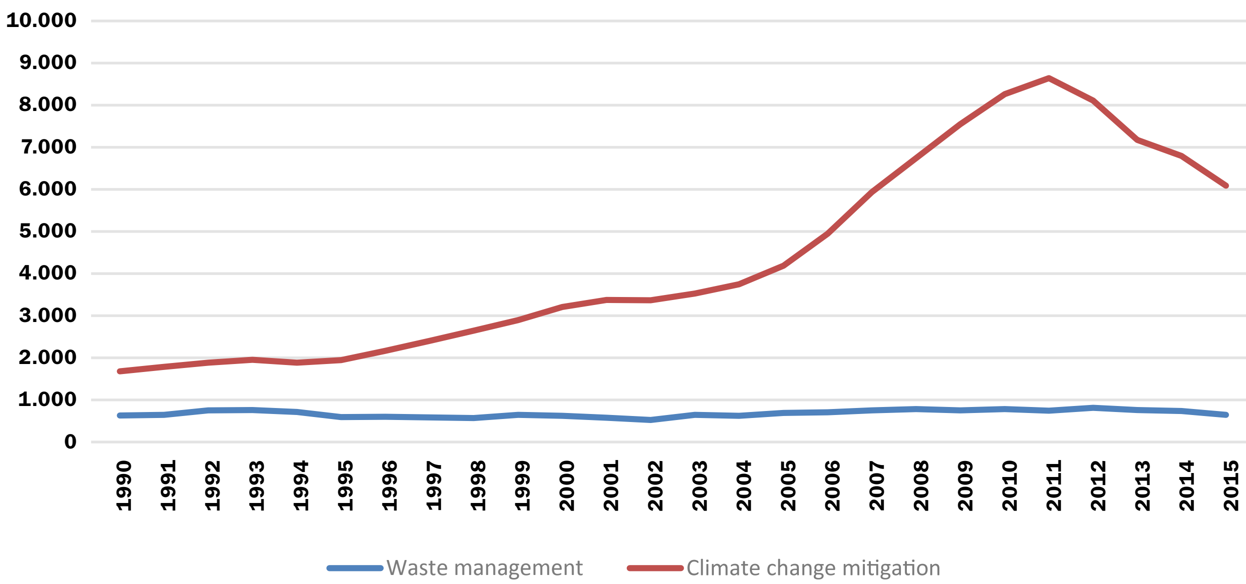
For data availability reasons, the trends in patents, innovation adoption, and value-chain organisational innovations can be documented for the years before the CE Package of 2015 and the entry into force of revised waste directives in 2018/2019. The possible effects of this policy push for CE innovation will be discussed in Part 2, Section 6.

4.1. Evidence on patents for the CE

Patent data suggest that, at least until the beginning of the present decade, the areas of invention related to the CE - that is waste and product making - were not major areas of formal invention[38]. The ENV-TECH classification (OECD, 2016) can be employed to capture the trends over time in the development of patents by 'patent families'.

As a major trend, Figure 4.1 highlights the very different dynamics of patents in two major groups of technologies: 'Waste management' and 'Climate change mitigation' over the period 1990-2015. Leaving aside the collapse in 'Climate change mitigation' patents in 2011-2015, which can be partly due to data problems and, possibly, to the (expected) decrease of incentive to renewable energy sources (RES) in many European countries, the trends are completely diverging in favour of the buoyant energy/climate sector with respect to the flat 'waste management' sector.

Figure 4.1. Trends in the number of patents (filing) in 'Waste management' and 'Climate change mitigation', OECD Europe, 1990-2015



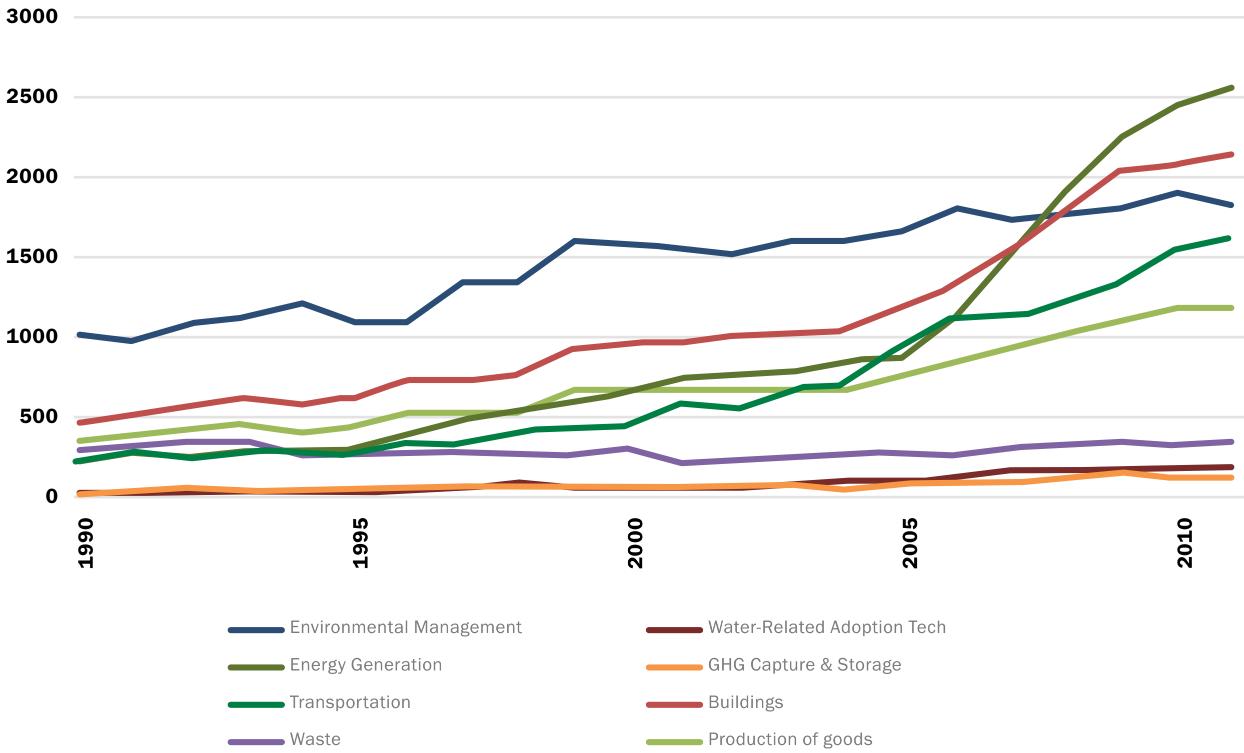
Source: own elaboration on OECD data.

38 Data on patents suffer from significant delays and reliable data are those until 2011.

Figure 4.2 shows the patterns of green patent families over time for selected European countries, those with a major patenting activity. The group of technologies that are increasing from 1990 to 2011 are in the field of environmental management, energy efficiency in buildings, transportation, production of green goods and energy generation. Instead, another group that includes greenhouse gas capture and storage, waste management and water-related technologies has stable trends over time in terms of patenting activities.[39]

From Figure 4.3 we see the relative expansion of each green technology. Energy generation technologies experience an increase in their relative size over time. Instead, environmental management technologies, waste management and production of goods, i.e. those more directly related to the CE, are shrinking their relative weight in invention activity.

Figure 4.2. Green patent families by ENV-TECH (OECD, 2016) technological domain

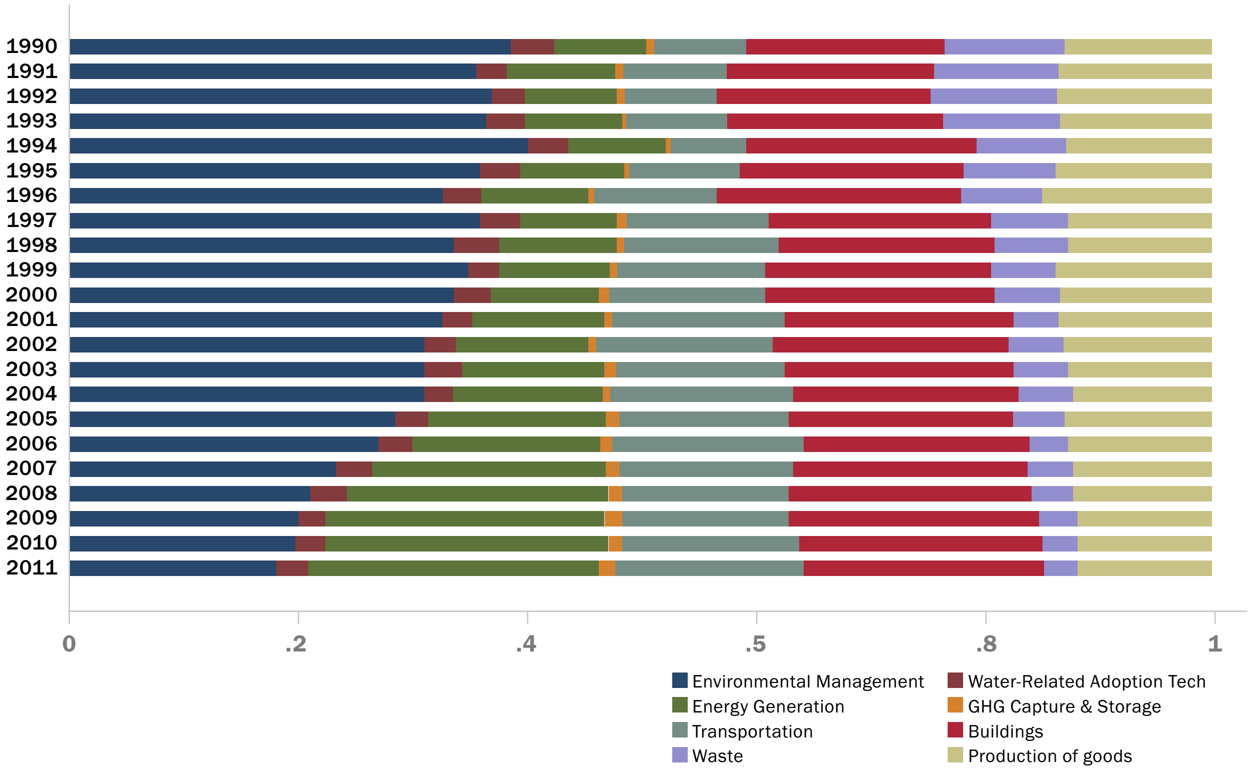


Note: Technological domains are provided by the ENV-TECH report (OECD, 2016).

Source: N. Barbieri elaboration using REGPAT, PATSTAT

39 It can be noted that, in the first part of the 1990s, waste-related patents were at a level similar to patents in energy generation.

Figure 4.3. Green patent family share by ENV-TECH technological domain

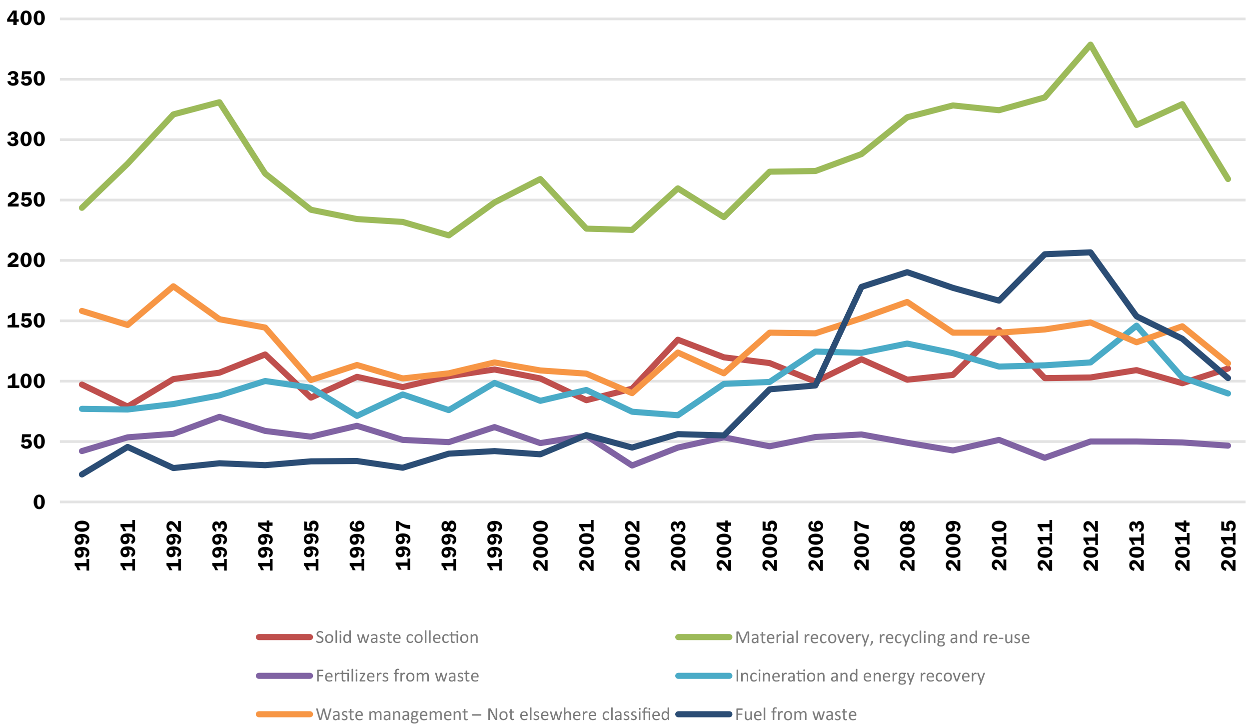


Note: Technological domains are provided by the ENV-TECH report (OECD, 2016).

Source: Nicolò Barbieri elaboration using REGPAT, PATSTAT

More detailed data (Figure 4.4) highlight that, for the main waste/CE-related technologies, the trend in patenting activity has been oscillating over the period 1990-2015. Even though most recent data can be not fully reliable, the largest and most dynamic area of invention is ‘Material recovery, recycling and reuse’, that peaked in the early 1990s in connection with the first wave of national and EU packaging policies (e.g. the Toepfer Ordinance on packaging in Germany), and then grew again from 2002, after the directives restricting incineration and landfill of the late-1990s and the ELV, WEEE, and packaging waste policies of the early 2000s. However, it can be noted that, in the most recent period, technologies for ‘Incineration and energy recovery’ and, even more, ‘Fuel from waste’ (less favoured by waste policies but favoured by RES policies) have been more dynamic than ‘Material recovery, recycling and reuse’. This trend seems to go in the opposite direction of waste policy priority to material reuse/recovery/recycling (Waste Hierarchy). At the same time, a bit surprisingly, patents in technologies on ‘Waste collection’ have been very flat over the entire period, which seems in contrast with the widespread diffusion of separate collection systems, the latter representing a process of diffusion of existing technologies and, even more, a form of ‘Organisational innovation’.

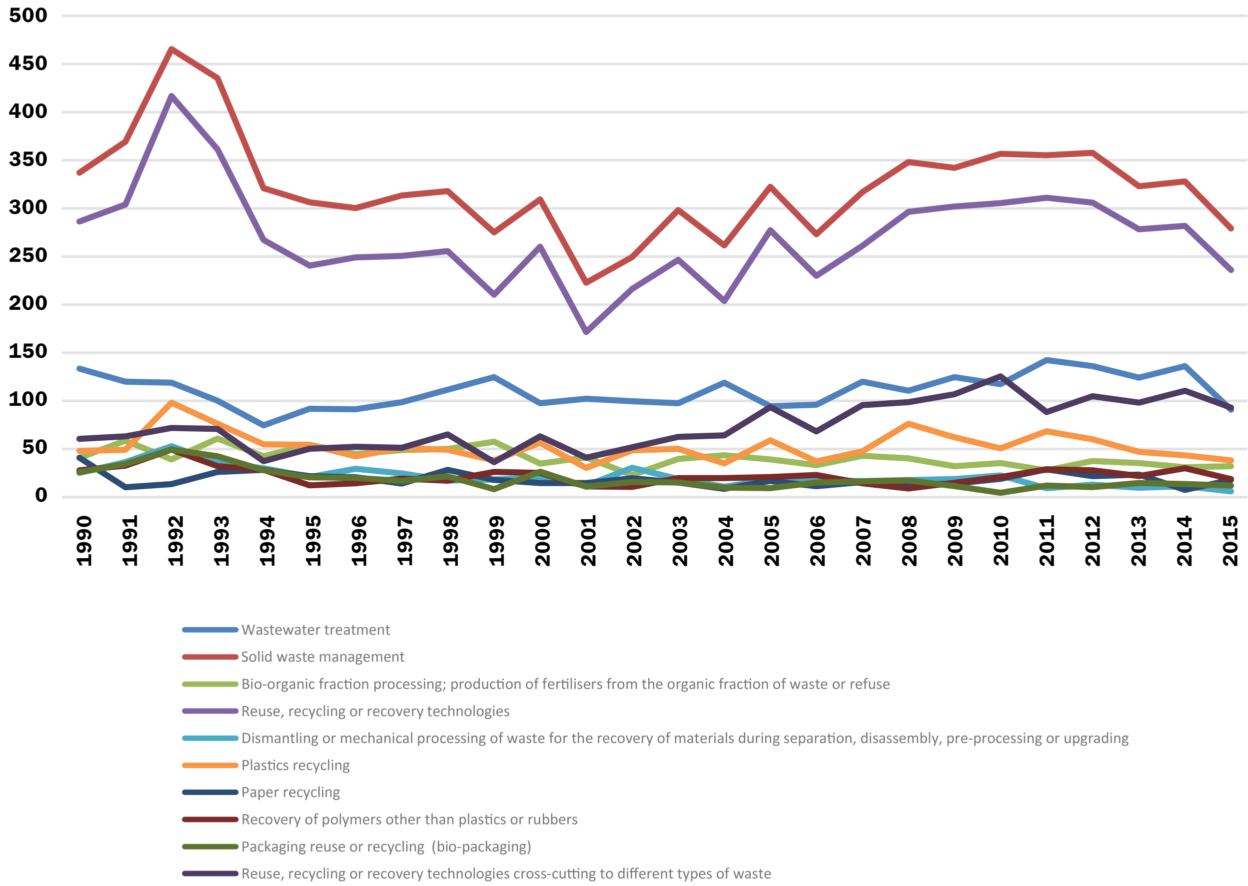
Figure 4.4. Trend of the number of patents (filing) in different waste/CE technologies, OECD Europe, 1990-2015



Source: own elaboration on OECD data.

The picture is slightly different when looking at the patents on wastewater and waste/CE technologies having implications for climate change, according to the OECD classification (Figure 4.5). In the period 1990 to 2015, the trend is almost flat for the major technology groups (‘Solid waste management’, ‘Reuse’, ‘Recycling or recovery technologies’) that peaked in the early-1990s and only partially recovered from 2002, as well as the other groups, like ‘Packaging reuse or recycling and bio-packaging’, ‘Paper recycling’, and ‘Plastics recycling’. It seems that, in this framework, the invention efforts are concentrated on most ‘conventional’ technological areas, with little activity in those more policy-targeted sectors/issues (e.g. ‘Plastics recycling’).

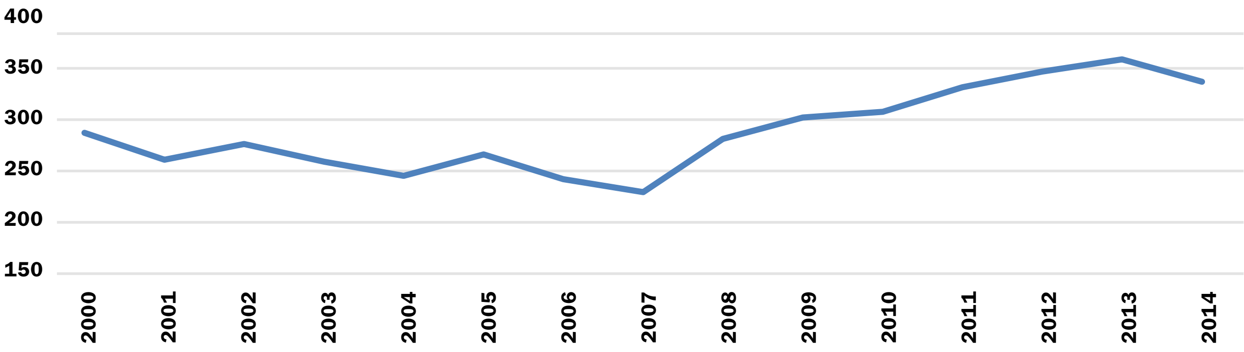
Figure 4.5. Patents (filing) in climate change mitigation technologies related to wastewater treatment or waste management, OECD Europe, 1990-2015



Source: own elaboration on OECD data

According to the indicator on patents included in the Eurostat 'monitoring framework' of the CE (see above), the patent count related to recycling and waste management technologies (Eurostat selection on CPC codes) is the one presented in Figure 4.6 for 2000-2014. The trend is similar to those emerging from previous data and figures, but a signficant increase after 2007 can be noted (+48%).

Figure 4.6. Patents on recycling and waste management technologies according to Eurostat CE indicators framework, 2000-2014, number of patents



Source: own elaboration on Eurostat data.

4.2 Evidence on CE innovation adoption by enterprises

The main source of information on innovation adoption in European countries is the CIS – Community Innovation Survey - the last CIS wave including questions on environmental innovation being the one of 2014. The coverage and the questions of CIS section on environmental innovation are described in the Box.

Box: Environmental innovation in the CIS 2014

The results of the 2014 wave of the CIS Community Innovation Survey cover the following countries: Bulgaria, Czechia, Denmark, Germany, Estonia, Greece, Spain, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, Iceland, North Macedonia, Serbia, Turkey, The coverage is incomplete with respect to EU28 but includes some non-EU countries, and data on various question are incomplete for a number of countries.

The sector disaggregation is based on the NACE revision 2.0 classification.

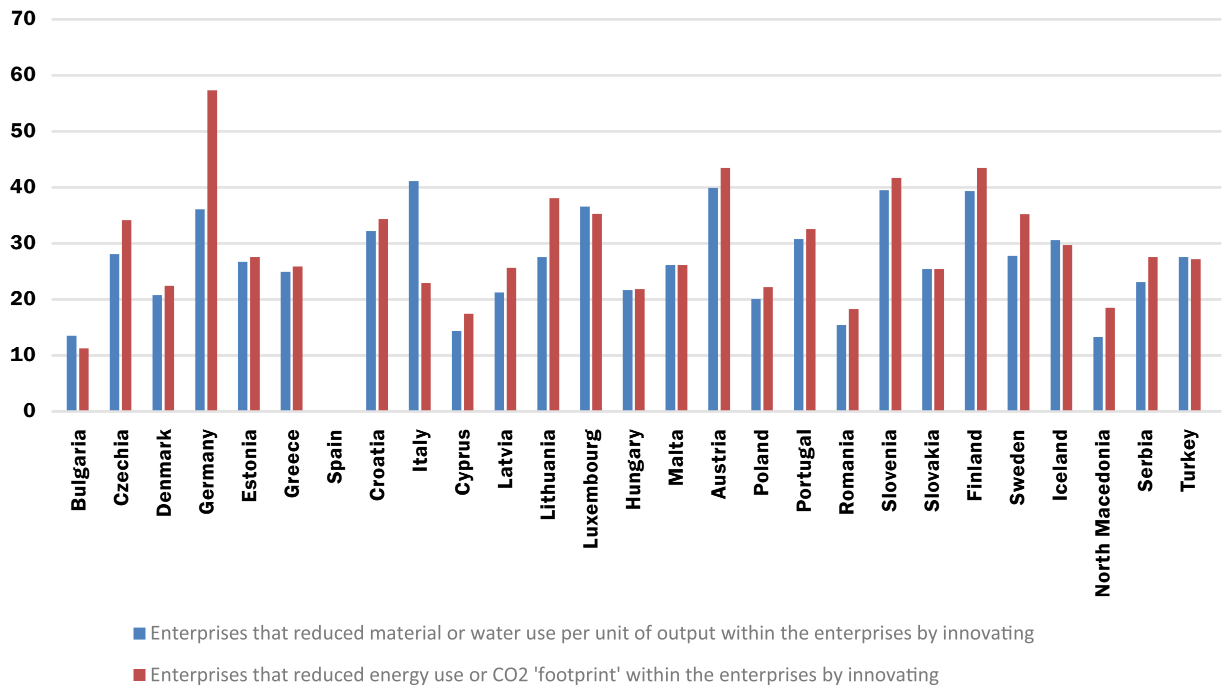
The questions on environmental innovation are the following:

- Enterprises that reduced energy use or CO2 'footprint' during the consumption or use of a good or service by the end user, by innovating
- Enterprises that reduced material or water use per unit of output within the enterprises by innovating
- Enterprises that reduced air, water, noise or soil pollution within the enterprises by innovating
- Enterprises that reduced air, water, noise or soil pollution during the consumption or use of a good or service by the end user, by innovating
- Enterprises that facilitated recycling of product after use by the end user, by innovating
- Enterprises that recycled waste, water, or materials for own use or sale within the enterprises by innovating
- Enterprises that replaced a share of materials with less polluting or hazardous substitutes within the enterprises by innovating
- Enterprises that introduced an innovation with environmental benefits (obtained within the enterprise or by the end user)
- Enterprises that introduced an innovation with environmental benefits obtained within the enterprise
- Enterprises that reduced energy use or CO2 'footprint' within the enterprises by innovating
- Enterprises that replaced a share of fossil energy with renewable energy sources within the enterprises by innovating
- Enterprises that introduced an innovation with environmental benefits obtained by the end user
- Enterprises that extended product life through more durable products, by innovating
- Enterprises with environmental benefits due to product innovation
- Enterprises with environmental benefits due to process innovation
- Enterprises with environmental benefits due to organisation innovation
- Enterprises with environmental benefits due to marketing innovation.

The CIS results for 2014 can provide a picture of CE innovation adoption before the CE Package 2015-2018. Unfortunately, given the differences in questions and coverage across the different waves of the CIS survey, in particular for the eco-innovation section, data on 2014 cannot be compared to those of the previous CIS waves and with the one of 2016, thus preventing us from getting an evolving picture on adoption.

Figure 4.7 compares the rate (% of total) of enterprises in the industrial sector (extraction and manufacturing, excluding constructions) that introduced (adopted) innovations to reduce energy/climate footprint and material/water intensity within the enterprise. Provided that the rates are, in general, not higher than 40% and largely differ across countries, in the majority of countries (with a notable exception for Italy) innovations adoption rates to reduce energy/climate footprint have been higher than those for material/water intensity reduction. However, with the notable (opposite) exceptions of Germany and Italy, there is a significant degree of 'complementarity' in the adoption of the two types of eco-innovations (energy/climate footprint and material/water intensity) with rates that do not substantially differ. A rather general attitude of enterprises to jointly adopt different types of eco- innovations has been highlighted in a series of studies based on direct surveys on samples of enterprises (see Cainelli, Mazzanti and Zoboli 2011). Therefore, at the enterprise level, CE innovation must be placed in the framework of the overall (eco) innovation strategy.

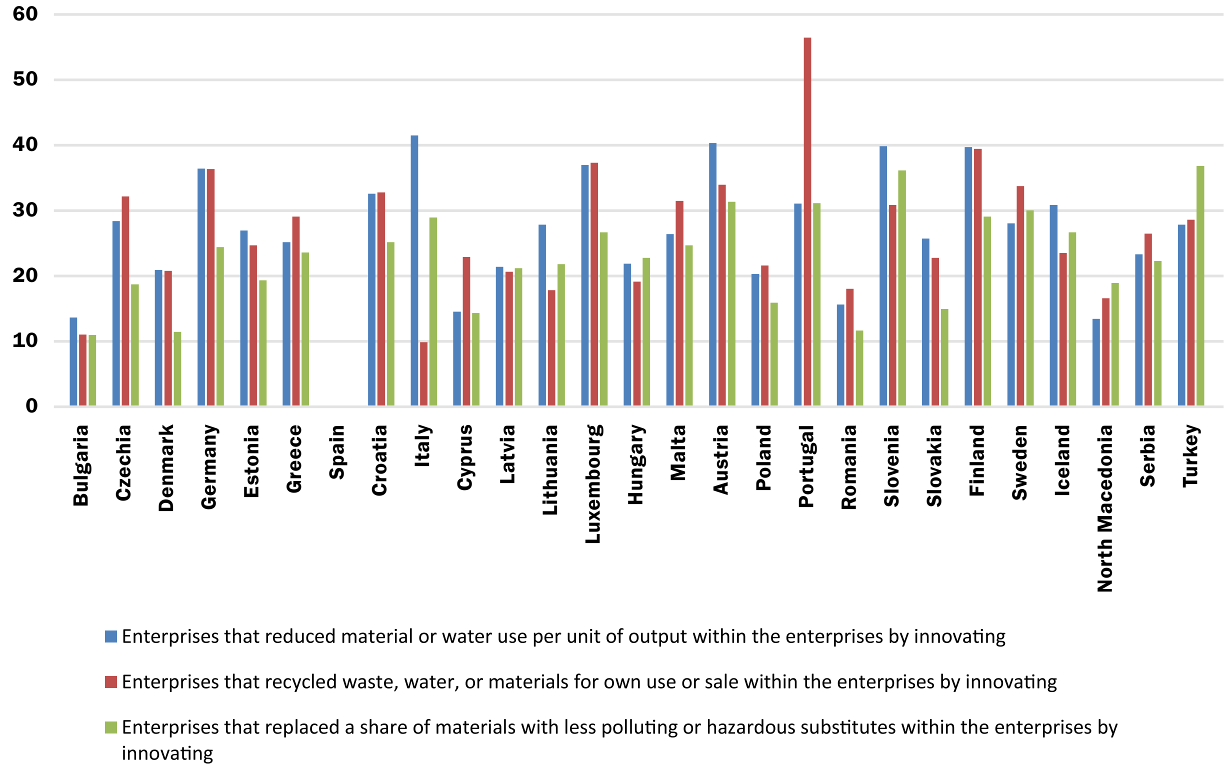
Figure 4.7. CIS: enterprises in Industry (excluding construction) introducing innovations to reduce energy/CO2 footprint and materials/water use, all size classes, % of introducing enterprises, 2014



Source: own elaboration on CIS data.

Figure 4.8 presents the rate of adoptions of CE innovations aimed at saving materials, recycling and reducing toxicity of materials by substitution within the enterprise. In general, in spite of the emerging variety of national 'models', there is a dominance of innovation to reduce materials/water intensity (dematerialisation) with respect to innovations to recycle (for internal use or for sale) and to substitute materials for environmental performance purposes, the latter being the least important area of innovation in many EU countries.

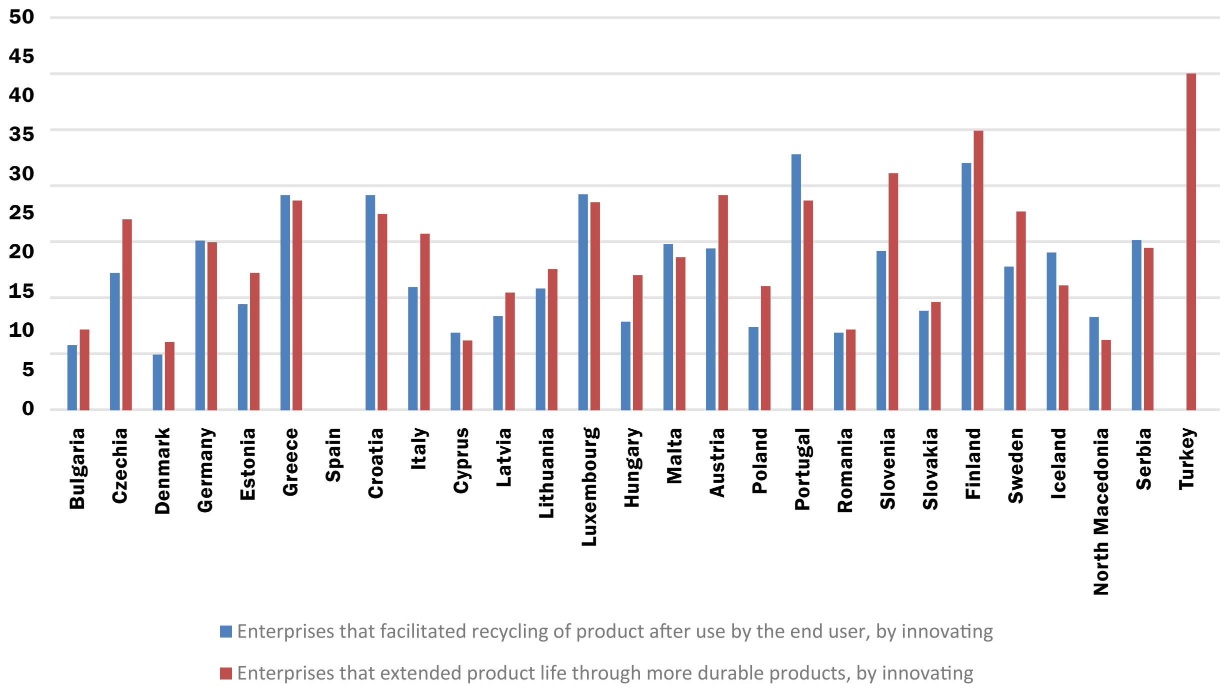
Figure 4.8. CIS: different types of 'internal' CE innovations introduced by enterprises in Industry (excluding constructions), all size classes, % of introducing enterprises, 2014



Source: own elaboration on CIS data.

Figure 4.9 presents the results for other types of CE innovations - facilitating recycling in downstream sectors and extending products life – that create benefits 'outside' the enterprise by favouring CE in subsequent phases of the chain (production in other sectors and consumption). In general, the rates are relatively low compared to innovations aimed at CE benefits 'inside' the enterprise (see above). However, it can be noted that increasing durability of goods is an important innovation aim (about 25% rate) in some EU countries, in particular Finland (35%).

Figure 4.9. CIS: CE innovations having 'external' benefits introduced by enterprises in Industry (excluding constructions), all size classes, % of introducing enterprises, 2014



Source: own elaboration on CIS data.

4.3. Evidence on CE organisational innovation: EPR-based value-chains

In Section 2, EPR - Extended Producer Responsibility has been identified as a fundamental policy principle of the CE. Its role in the 'Old CE' has been powerful in inducing the creation of a number of 'compliance schemes' in response to EU directives that changed the setting of the industrial value chains targeted by EPR-based policies. These compliance schemes have limited dimensions of technological innovation, although having also innovation aims, and are instead 'Organisational innovations' having huge economic and industrial implications (Paleari, 2019).

EPR for waste collection and/or management after collection comprises, at least, a physical and financial dimension (Linhqvist, 1992, Tojo, 2004; Van Rossem et al., 2008). In theory, both the physical and financial responsibility can be set at the individual (IPR) or collective (CPR) level, so that they can be combined in different ways, bringing to pure (IPR or CPR) models, as well as to mixed or hybrid models (Fig. 4.10). Individual producer responsibility means that each producer takes back the product he/she has put on the market, while in a collective producer responsibility model, different producers take collective responsibility.

Pure models are those which give producers an individual responsibility (or, as an alternative, a collective responsibility) for both the physical management of waste and its financing. When the physical responsibility is set at the individual level and the financial responsibility at the collective one (or vice versa, the physical responsibility at the collective level and the financial responsibility at the individual one), we have a mixed or hybrid model.

Figure 4.10. Matrix of EPR responsibilities

		Financial responsibility for collection and/or management	
		Individual	Collective
Physical responsibility for collection and/or management	Individual	Pure IPR	Hybrid
	Collective	Hybrid	Pure IPR

Source: S. Paleari in ETC/WMGE 2017b

Some provisions of the EU directives on packaging, ELVs, WEEE, and batteries specifically regulate the physical and (especially) the financial dimensions of EPR. The type of responsibility transferred to producers through EPR systems highly depends on the characteristics of the regulated waste stream (Bio by Deloitte, 2014). Waste streams that are usually collected from industrial or commercial sources (e.g. ELVs) have both hazardous potential and positive value (their treatment is often self-financed by revenues from sales of the resulting recycled materials). In this case, there is a tendency to maintain the existing direct transactions or contracts between waste holders and waste management companies, while producers tend to play a financial role only, supporting a part of the net cost necessary to reach the targets set by the regulator.

Waste streams which arise on the household level and are potentially hazardous (batteries and WEEE) demand a rather physical responsibility, since it is necessary to set up a new specific treatment path adapted to these products. The whole range of possible configurations from financial responsibility to financial and full physical responsibility can be identified with regard to waste types that arise at the household level and which are collected by the municipal services along with the household waste (e.g. packaging). These waste streams have been usually separately collected/sorted and sent to recycling, to some extent, by local authorities before the introduction of the EPR systems (e.g. glass and paper packaging). Regarding packaging, the heterogeneity of configurations can also be related to the fact that in most Member States it was the first EPR scheme ever introduced. As such, this product stream has been more experimental and has given rise to a diversity of bottom-up approaches.

Only a few provisions of the EU directives explicitly assign to producers an individual or a collective responsibility. Since producers are mainly required to 'set up systems' for collecting waste or managing waste after collection, they are generally allowed meeting their EPR obligations individually or collectively.

Individual compliance schemes have been sometimes established by Member States when the product market is highly concentrated and producers can implement a take-back system to their consumers. German car producers, for instance, have implemented individual compliance schemes, based on individual contracts with collection and dismantling facilities. However, in most cases, producers have set up collective compliance schemes, managed by producer responsibility organizations (PROs).

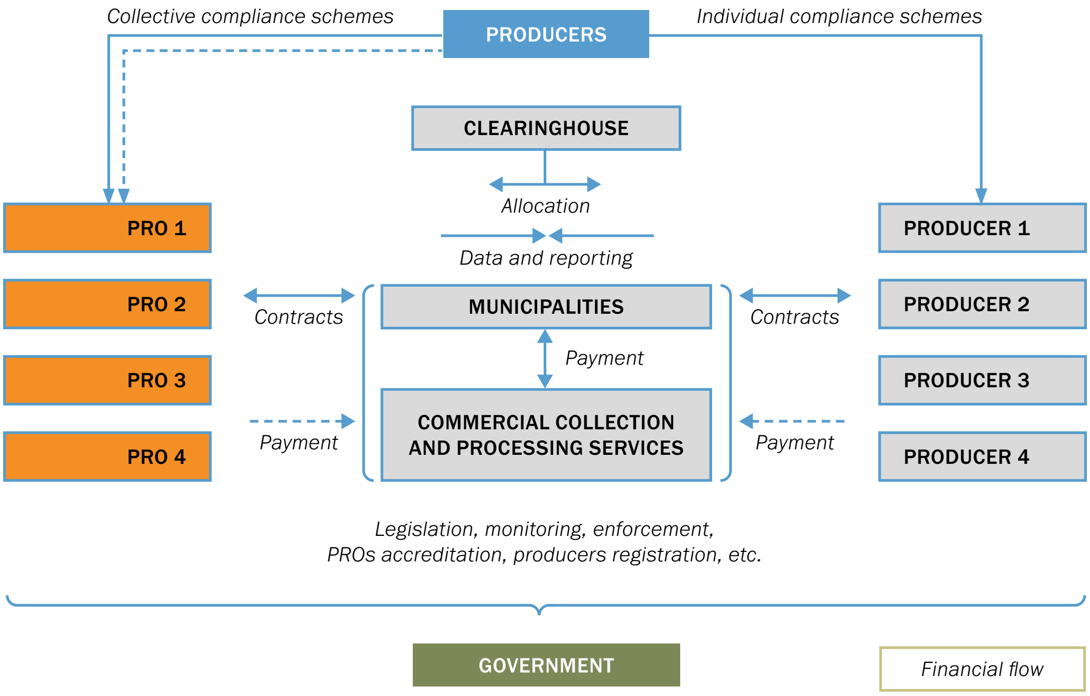
In the EU27, there were about 160 collective compliance schemes in 2015 only for the management of WEEE (B2C and B2B) (Paleari, 2015). Moreover, some compliance schemes that are formally defined as 'individual' in practice depart from a pure IPR model. For instance, in Germany, 'individual non-selective take-back schemes' are the prevailing system for managing WEEE. But within these 'individual schemes', producers do not take individually back their own brand products, but the share of e-waste falling under their responsibility within each collection group stored at municipal collection points. Then, they directly contract with end-of-life service providers to arrange WEEE management after collection (Paleari, 2015).

Collective schemes (PROs) as well as combined collective and individual schemes are predominant across EU Member States. Several reasons explain the flourishing of PROs across the EU: through shared infrastructures, PROs take advantage of the economies of scale in collection and treatment, reducing the costs for participants; they can help to decrease free riding through collective action by producers and peer pressure; they can simplify operations and reduce administrative burdens for consumers, retailers and municipalities; and they provide a mean for governments to manage waste generated by orphan products (OECD, 2016). Legal requirements imposed by Member States can also discourage individual compliance. For instance, with regard to WEEE, according to the EU legislation, producers shall provide a financial guarantee (such as a blocked bank account or recycling insurance) to prevent the occurrence of orphan products.

The development of EPR systems in Member States has been driven by EU legislation especially in the case of WEEE and waste batteries, while several schemes were already operated in Europe for packaging waste and ELVs before the adoption of the related EU directives.

In most countries, the government has traditionally been involved in waste management as a regulator and a service provider (at the national, regional or local level), but the implementation of EPR has resulted in a redefinition of its role (OECD, 2015 and 2016). In many cases municipalities still participate in collection and processing of regulated waste within EPR systems, while different government agencies are in charge of formulating, evaluating, and enforcing policies; registering producers and accrediting PROs; providing for coordination (when there are competing PROs and the clearinghouse is a government agency); monitoring the technical and financial performance of the whole EPR system (producers, PROs, waste operators and municipalities) (Figure 4.11). In general, like for several market-based instruments, EPR is evolving in the 'shadow of governance hierarchy' where public authorities have the responsibility to intervene with guidance and regulation in case of market failures (Kalimo et al., 2015).

Figure 4.11. Role of stakeholders in an EPR system



Source: Paleari, 2019

PROs mainly interact with municipalities and waste processors. With regard to municipalities, the central issue in most cases revolves around whether local governments provide EPR-related collection services and the extent to which their costs are covered by PROs. In this respect, we can distinguish between 'shared systems' and 'dual systems' (Quoden, 2014). Within 'shared systems', which are frequently in place for packaging waste (e.g. in France, Spain and Italy), municipalities have the obligation/prerogative to provide for collection and sometimes sorting of regulated wastes. They are, then, reimbursed in whole or in part for the costs of their services, if producers bear a financial responsibility for collection. In this case, PROs may not be able to ensure that the service is delivered in a cost effective manner and to control costs to their satisfaction (e.g. since a municipality may want to provide frequent collection services that the PRO judges not to be necessary to meet its obligations). Some EPR schemes have, therefore, established reference costs for municipal services based on a variety of strategies (e.g. reimbursement of the municipality tied to quantity or percentage of designated materials collected or definition of a standard level of service beyond which reimbursement is not provided; Bio by Deloitte, 2014).

Within the 'dual systems' (used e.g. in Germany, Austria, and Sweden for packaging waste) municipalities may compete to provide collection and sorting, but the PROs are not obliged to use their services (OECD, 2016). Many PROs, indeed, procure waste collection, sorting and processing services (while in some instances PROs themselves perform some of these services). There is evidence that the use of fair and competitive tenders significantly reduces collection/processing costs and that the duration of contracts (which should be affected by the time required to recover sunk costs) also matters (OECD, 2016). Treatment operators are sometimes collectively organized, as documented in several cases for ELVs. In Austria, for instance, the six shredders plants that are in operation in 2012 joined to form a collective system or in Germany the dismantling facilities are partly organized in a network (Bio by Deloitte, 2014; Cahill et al., 2011).

Other actors involved in EPR systems include consumers, who play a relevant role with regard to the collection of various products/waste streams and retailers, who can be an important conduit of information from producers to consumers and can take part in the collection of end-of-life products (voluntarily or based on legal obligations). For instance, pursuant to the WEEE recast Directive, retailers have now an obligation for collecting small appliances, regardless of whether customers buy new equipment.

Eurostat data show, in general, a positive trend in the management of waste streams covered by EPR, with increasing collection and recycling rates and reduced landfilling. The decrease in waste generation (when it is taking place) is less impressive and seems to be also driven by the economic downturn. Assessing the impacts of EPR systems is difficult for several reasons: a considerable lack of data (in particular, sharing information proves to be challenging in highly competitive markets, such as the WEEE market where multiple PROs exist), analytical difficulties in distinguishing the effect of EPR systems from other factors/instruments and the wide variety of EPR systems with different scopes which limits comparison among them (Bio by Deloitte 2014; OECD, 2016).

There is, however, mounting evidence from the empirical literature about the relationship between the advent of EPR and the remarkable increases of separate collection and recycling (Bio by Deloitte, 2014; Massarutto, 2014; OECD, 2014; OECD, 2016). Recycling markets existed well before the 1980s, but they were limited in scope and operated with many imperfections, so that the socially optimal level of recycling was not achieved and the burden of treating the residual waste fell on municipalities. Current recycling rates were generally considered unfeasible, given the limited development of downstream markets, the high costs of collection/sorting and the low market value of some waste. In the last 20 years, we have witnessed a gigantic exercise of market creation, which has been facilitated by the involvement of producers and, especially, of PROs that have taken over the task to organize and structure waste recycling. Italy is a case in point, in particular with the case of CONAI.

The creation of recycling markets involves a wide range of correlated issues, including infrastructure development, technological innovation and organisational innovation. Funding, setting up or expanding infrastructure for collection, treatment and recycling has been indicated as one of the fundamental achievements of EPR, which is also crucial to its success (Bio Intelligence Service, 2012; Lifeset et al., 2013; Santini et al., 2011). The

Packaging Directive has had a relevant impact in promoting the establishment of selective collection (Bio Intelligence Service et al., 2014). Very different separate collection systems for MSW have been set up by Member States to collect paper, plastic, glass and metals (which mainly concerns packaging waste, as well as WEEE and batteries). Apart from MSW collection, other specific collection channels have been operated in EU Member States for EPR waste streams. For instance, WEEE is also collected by retailers or can sometimes be directly returned to producer or recycler via postal/courier service. ELVs are delivered by the holders to take-back points (that are often selling points) established by economic operators or to authorized dismantlers or treatment facilities.

Economic instruments, including take-back requirements, may induce innovation. Mazzanti and Zoboli (2006), however, show that when these instruments are used inside complex and systemic industrial settings (such as ELVs), they can result in different innovation paths (also in paths not preferred by policy makers), depending on 'where' along the production chain and 'how' in terms of net cost allocation, the incentive is introduced.

Several examples of technological innovation in the post-consumption phase (which is connected to up-stream innovation in eco-design) have been documented for EPR waste streams. Until recently, the approach to increasing rates of ELVs recycling has focused on dismantling, with the remaining material directed to produce energy. The final ELV material, after post-shredding processes designed to recover the metal, has traditionally been destined to landfill as Auto Shredder Residue (ASR). New technologies of post-shredder treatment (PST) have been developed by many Member States (Austria, Belgium, France, the Netherlands, Sweden and UK), based on mechanical separation methods to recover/recycle material or thermal treatment, which processes materials as energy feedstock (Bio Intelligence et al., 2014).

At the time the WEEE Directive was adopted, manual dismantling was used in most Member States. Today, some products may be treated in automatic, even if automated disassembly still faces several technical limitations (high variety and complex design of EEE, differences in the mounting processes, etc.). Moreover, technologies have been improved, so that certain processes are capable of treating complete WEEE fractions (without removal of components) or even complete products whilst achieving high recovery rates for valuable materials and ensuring that hazardous substances are controlled, at a lower cost compared to disassembly (e.g. cellular phones are processed in modern copper smelters; Kalimo et al. 2015), however, most of the recovered WEEE currently undergoes material shredding and that the absence of product-specific treatment implies that many complex technologies are not considered profitable.

With regard to packaging waste, the technological impact of the Packaging Directive appears to be limited. Some technological innovation has been identified in a few Member States (France, Germany and the UK), but it is not clear to what extent the innovation is a direct result of the Directive or other national initiatives (Bio Intelligence Service et al., 2014). Significant areas of innovation are represented, e.g., by the engineering of sorting plants, finding higher value applications for recycled polymers, recycling of composite packages (e.g. tetrapak), etc. (Massarutto, 2014).

Moreover, several documented examples of innovation have occurred in anticipation of the implementation of EPR legislation (Tojo, 2004). It is also reasonable to suppose that the slow patenting growth, recently experienced, might have been more pronounced if no policy measures had been introduced (Nicolli 2013). When focusing on the impact of EPR systems on waste management, an interesting explanation is that, for technologically mature sectors, behavioural and organizational innovations, rather than technological inventions, are the most likely responses to environmental policy shocks (OECD, 2011).

With respect to EPR, the four most relevant dimensions of design for the environment (DfE) are the following: (1) selection of low impact materials (e.g. avoiding hazardous substances or using recycled resources), (2) reduction of material (e.g. development of lightweight products or reducing packaging), (3) optimisation of initial lifetime (e.g. increasing durability or re-use of components) and (4) optimisation of end-of-life system (e.g. design for disassembly or producing mono-material goods). It has also to be underlined that DfE has implications going beyond the 'green' aspects of a product, as it may affect product functionality and aesthetic, costs related to manufacture/purchase of materials and components, safety requirements, production and distribution processes, etc.

The effectiveness of EPR with respect to DfE is disputed and, in any case, lower than expected (Massarutto, 2014). In theory, incentives to invest in DfE are limited by a wide range of factors: the durability of products (it is difficult to pay back up-front redesign investments in reduced end-of-life costs that are incurred, e.g., 10 years later); the possibility to pass costs of waste management on to consumers; the fact that post-consumption cost does not adequately take into account the environmental cost of waste treatment (recycling is then disadvantaged); (Bio by Deloitte, 2014; Huisman, 2013).

According to OECD (2016), there is not empirical information shedding light on the relative effectiveness of EPR compliance schemes in promoting eco-design. Due to the above problems in assessing the impact of EPR on DfE, most of the studies focusing on this topic are limited in scope (i.e. they cover a single or a few case studies). Some success stories, in terms of DfE, are however reported by the empirical literature.

5. Selected initiatives

The EU policy on the CE and the associated industrial and cultural responses, stimulated un unprecedented wave of hundreds of initiatives and 'voices'.

In this section, we report information on a set of selected initiatives chosen among those undertaken by private organisations and public institutions having a certain degree of stability and robustness and aiming at contributing to research/knowledge, or to industrial CE-related developments, or to support CE-related policies.

The selection does not include single initiatives, in particular the hundreds of events and conferences, occasional studies and reports, and communications by companies on their own CE strategies. The initiatives on scientific research for the CE, in particular those linked EU funding (e.g. the EIT Communities), are referred to in Section 6.

5.1. Ellen MacArthur Foundation

https://www.ellenmacarthurfoundation.org/

The Ellen MacArthur Foundation has been a forerunner in addressing and promoting the CE as a vision and an area of industrial and societal change, thus positioning itself as a reference in the European debate and policy making process. The basic conceptual framework for the CE of the Ellen MacArthur Foundation has been presented in Section 1. Since 2012, the foundation has published dozens of reports on different aspects of the CE, all publicly available at https://www.ellenmacarthurfoundation.org/publications, and has carried out a number of initiatives also on education. As of 2018, the foundation has a staff of about 100 people running an extensive program of activities on, for example, the CE100 network, the CE in cities, the CE and food, and many other events and initiatives of a worldwide scope.

5.2. EEA – European Environment Agency

https://www.eea.europa.eu/

The EEA *"provides sound, independent information on the environment for those involved in developing, adopting, implementing and evaluating environmental policy, and also the general public. In close collaboration with the European Environmental Information and Observation Network (Eionet) and its 33 member countries, the EEA gathers data and produces assessments on a wide range of topics related to the environment."* The EEA addressed the topics of the waste and materials system since the start of its operations in 1994. These topics are covered in the five-years SOER State of the Environment Report (including the SOER 2020 under finalisation), the system of EEA indicators, and the work in support to European institutions (various DGs of the Commission, the European Parliament, and EEA Member countries), also for the assessment of the EAPs – Environmental Action Programmes of the European Union. Since the early 2000s, the EEA dedicated one of its European Topic Centres (ETCs) to waste/materials, and the ETCs on this area continued (renewed by tender every 3 or 4 years with different denominations) up the recently established EEA/WMGE – European Topic Centre on Waste and Materials in a Green Economy, 2019-2021 (existing with the same name already in 2014-2018)[40]. The EEA, also with the support of the ETCs, produced a great number of reports and studies on waste and materials and related topics (about 62 reports since 1994). On the same topics, the ETCs have produced a number of (largely unpublished) reports to support the EEA. On the Circular Economy and Resource Efficiency, the EEA recently published the following reports[41]:

40 The partners of the international consortium ETC/WMGE 2019-2021 are: VITO (Belgium, leader), CENIA (Czech Republic), CSCP (Germany), Wuppertal Institute (Germany), IRCrES-CNR (Italy), SEEDS (Italy), OVAM (Belgium), VTT (Finland), World Spotlight (Ireland). Topic centres of the past have been: ETC/WMF - European Topic Center on Waste and Material Flows; ETC/RWM - European Topic Centre on Resource and Waste Management; ETC/SCP - European Topic Centre on Sustainable Consumption and Production.

41 See https://www.eea.europa.eu/publications#c7=en&c11=50&c14=&c12=&b_start=0&c13=circular+economy

- Paving the way for a circular economy: insights on status and potentials, EEA Report No 11/2019
- Electric vehicles from life cycle and circular economy perspectives - TERM 2018, 22 Nov 2018
- The circular economy and the bioeconomy — Partners in sustainability, 27 Aug 2018
- Circular by design - Products in the circular economy, 06 Jun 2017
- More from less — material resource efficiency in Europe, 09 Jun 2016
- Circular economy in Europe — Developing the knowledge base, 18 Jan 2016

The ETC/WMGE major activity areas at present are on Waste Management, Waste prevention, Resource efficiency, Sectoral integration and the Green Economy, Plastics and the environment, and Circular Economy.

5.3. European Circular Economy Stakeholder Platform

https://circulareconomy.europa.eu/platform/

The Platform is a joint initiative by the European Commission and the European Economic and Social Committee aimed at providing a platform for catalysing the CE in Europe through networking and cooperation among industries, research, and other actors. The main activities of the Platform are aimed at the exchange of good practices, knowledge transfer, forums, and conferences. The site of the Platform is the entry point to a number of other platforms (national, local, sectoral), which at present are 31 spread over all European countries (including Italy)[42], and a great number of 'good practices' (including some in Italy)[43]. The coordination group is made of industrial associations (e.g. BusinessEurope), environmental agencies (e.g. OVAM), research centres and think thanks (e.g. Ellen MacArthur Foundation, CSCP, ENEA), and NGOs (e.g. EEB).

5.4. Circulary (BusinessEurope)

http://www.circulary.eu/

Circulary is a web platform of BusinessEurope and its national members created to contribute to the EU's agenda on circular economy. It is a bottom-up hub that collects examples of innovative ways in which industry adds to the circular economy while highlighting the regulatory and non-regulatory challenges issues emerging for circular business.

5.5. MATTM, ENEA, ICEP (Italy)

https://www.minambiente.it/pagina/economia-circolare

The Italian Ministry of the Environment (Ministero dell'Ambiente e della Tutela del Territorio e del Mare) produced a position document on the CE open to public consultation in 2017, and a document of indicators to measure the progresses to CE (open to public consultation). ENEA provides the support to MATTM for the activities on the CE. In 2018, MATTM and MISE, the Italian Ministry of Economic Development, become members of the Italian Circular Economy Stakeholder Platform – ICESP, promoted by ENEA (member of ECESP). The ICEP was launched in 2018 and aims at networking the Italian stakeholders/actors for national and European level initiatives[44].

42 See *https://circulareconomy.europa.eu/platform/en/dialogue/existing-eu-platforms?page=3*

43 See *https://circulareconomy.europa.eu/platform/en/dialogue/good-practices-names-contacts*

44 *http://www.enea.it/it/seguici/events/icesp_31mag2018/presentazione-e-lancio-icesp-italian-circular-economy-stakeholder-platform*

5.6. Circular Economy Network, Istituto per lo Sviluppo Sostenibile (Italy)

https://circulareconomynetwork.it/

The Network has been created by the Istituto per lo Sviluppo Sostenibile and included (May 2019) 12 promoters (companies and industrial associations) and 25 associations and companies as additional members. The aim is to promote the CE in Italy. The Network, in cooperation with ENEA, produced a report on Circular Economy in Italy in 2019[45].

5.7 Confindustria (Italy)

http://economiacircolare.confindustria.it/

The Italian industrial association launched a project on CE aimed at stimulating knowledge creation, sharing and transfer among Italian industrial actors in different sectors. The project is in cooperation with other actors (ENEA, Fondazione Symbola, LUISS, and 4.managers). Confindustria organised several workshop in different locations to promote the CE concepts and approach among companies, and published a report on the CE focused on industrial issues raised the CE transition and the implementation of EU directives on waste of 2018[46].

5.8 ASviS (Italy)

http://asvis.it/# .

ASviS (Associazione Italiana per lo Sviluppo Sostenibile) is the main promoter and reference network for the implementation of the UN Agenda 2030 and SDGs in Italy. It includes a great number of associates and supporters and promotes initiatives (e.g. the Italian Festival on Sustainable Development, with hundreds of events), including several actions and partnerships with a CE focus.

5.9 Lombardy Region (Italy)

http://www.regione.lombardia.it/wps/portal/istituzionale/HP/lombardia-notizie/DettaglioNews/2018/10-ottobre/22-28/cattaneo-insediato-osservatorio/cattaneo-insediato-osservatorio[47]

In 2018, the Government of the Lombardy Region (DG Environment in cooperation with other DGs) created the 'Regional Observatory on circular economy and the energy transition' (Osservatorio su economia circolare e transizione energetica). The Observatory includes more than 100 participants from industrial associations, university and research, representatives of the civil society, and it is organised in Working Groups at two levels, Institutional and Thematic, that regularly meet to discuss strategies and actions. The Observatory is an interesting experience of participatory process in support to the regional Government for the implementation of regional policies on energy and climate and waste/CE, and for contributing to the national transposition of the directives on waste of 2018.

45 *See https://circulareconomynetwork.it/rapporto-economia-circolare/*

46 *https://www.confindustria.it/wcm/connect/b13312a2-c733-4eae-939b-04613f0086f2/Rapporto+Economia+Circolare+Confindustria+Ottobre+2018.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE-b13312a2-c733-4eae-939b-04613f0086f2-mvbuzpZ*

47 *See also https://www.openinnovation.regione.lombardia.it/it/b/532/osservatorioeconomiacircolareetransizioneenergeticailtavoloinregione*

04 Part 2: Towards a New Innovation-intensive Circular Economy: Integrative approaches

In this Part 2, we elaborate on conceptual frameworks that can better integrate research, industry, and policy for the New Innovation-intensive CE.

We propose two main integrative and systemic approaches: (i) the CE as an 'Innovation system' (Section 6); (ii) the CE in a NEXUS approach to the interconnections between the CE itself and other two main areas of transition: Decarbonisation and the Bioeconomy (Section 7).

Both approaches are systemic in nature and seem to respond better than sectoral approaches to the nature of the CE as a multi-sectoral, multi-material, multi-technology, multi-policy, multi-actor transition. In both the approaches, we stress the possible key role of innovation for an 'New Innovation-intensive CE'.

In Section 8, we also highlight some open and emerging issues in the 'economics of the circular economy', in particular: prices, costs, taxes, consumers and the emergence of 'finance for the CE'.

6 Integrative approach 1: The CE as a 'System of innovation'

The CE transition is a *systemic change*. As a consequence, the CE can be seen as an innovation process and the system involved in this process can be seen as an *innovation system*.

The approach to the CE as an innovation process to be possibly referred to different 'innovation systems' allows, on the one hand, to better understand how the CE is 'innovation embedded', and, on the other hand, to better understand and control its huge internal variety and complexity. In fact, while the CE may seem, at a fists sight, similar to a 'sectoral system of innovation' (Malerba 2002), the multi-sectoral, multi-material/product, multi-technology, multi-function, and multi-actor dimension of the CE system makes it to have a more general profile.

In what follows, we propose and present this approach and its implications for the connections between research, industry and policy.

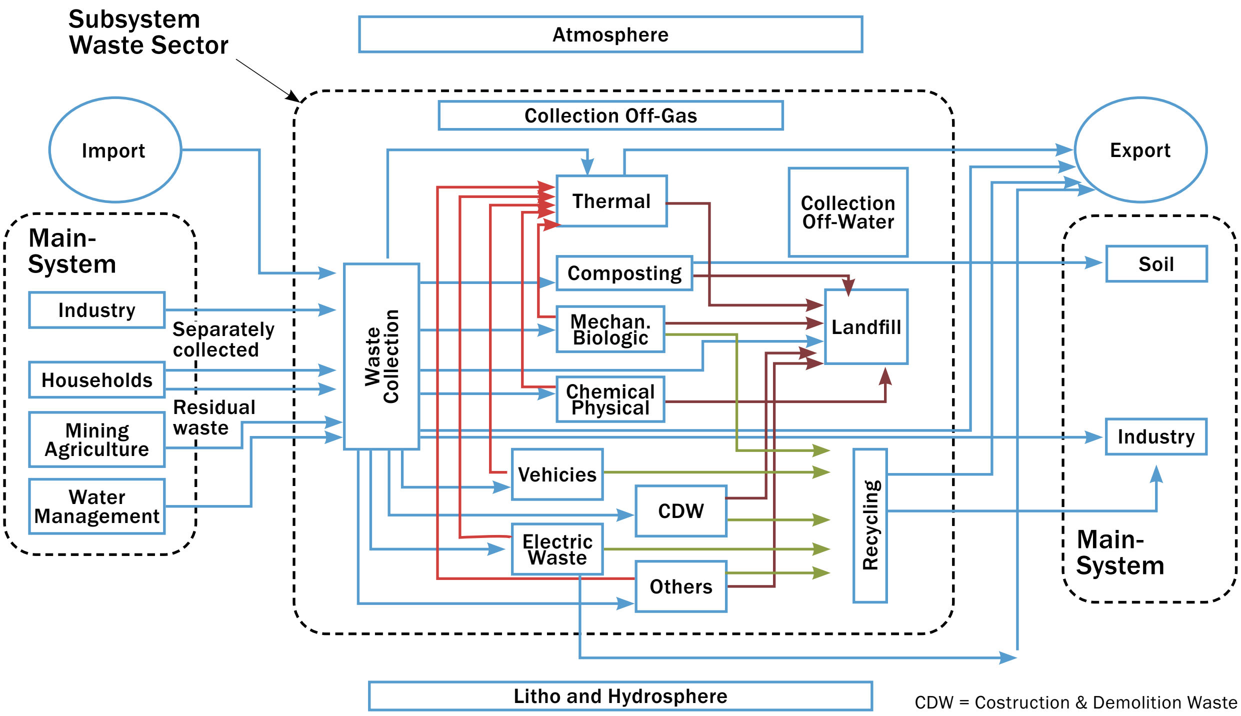
6.1 The narrower view: Innovation in the waste system[48]

Figure 6.1 presents a simplified flow diagram of the 'waste system', or 'waste sub-system',

48 *This innovation perspective to the waste system has been firstly developed within the FP7 European project EminInn – 'Environmental Macro Indicator of Innovation', 2013-2015, Work Package 8 'Waste management', and it is re-developed here.*

in a MFA framework. For a specific waste flow - as defined by the material composition (e.g. hazardous waste) or by the originating activity (e.g. municipal solid waste), which can approximately define a material composition - there can be: (i) different collection systems and management options available within the 'waste sub-system' (broadly speaking: energy recovery, composting in the case of biological waste, material recycling, disposal in landfill), and (ii) many specific technologies inside each management option (e.g. different energy recovery technologies).

Figure 6.1. The waste system in a MFA framework



Source: Hubert Reisinger et al., 2009. Material Flow Analysis (MFA) for resource policy decision support. Position Paper of the Interest Group on the Sustainable Use of Natural Resources on the needs for further development of MFA-based indicators.

Therefore, for a waste flow of a specific type there can be different types of specific innovations able to change its pressures on the environment/resources and its potential to remain in the economic system. The different types and levels of innovations within the waste system are summarised in Figure 6.2.

Prevention innovation

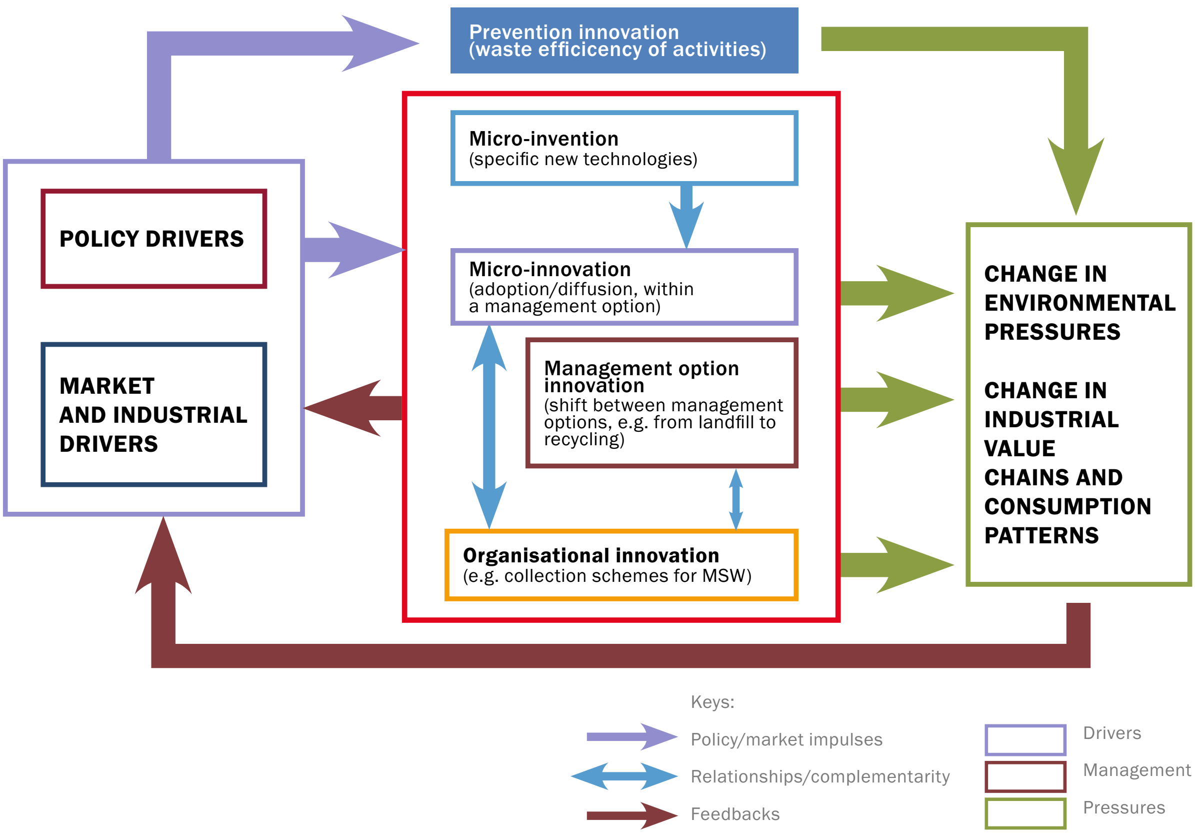
The first type of innovation is aimed at 'waste-efficiency innovations' in waste production ('Prevention innovation'). Given that waste production is a Pressure in itself, generating many specific pressures according to a specific LCA profile, waste-preventing innovations reduce all the environmental pressures associated to the waste along the life cycle of goods/services. Prevention is the main priority of EU waste policies but it is the less successful area of EU waste policy itself, e.g.

for municipals solid waste (see Mazzanti and Zoboli 2009).

Waste prevention in different sectors also depends on how the goods are made and distributed, and how they are used and discarded. Therefore, 'non-waste' innovations (e.g. ICTs diffusion) can influence the amount and the pressures of waste for a given function (consumption or production). In the case of municipal solid waste (function: final consumption), the potential waste embodied in goods depends on design and technologies at the production/distribution stages and on behaviours and life styles of households. A relevant question in an age of ICT penetration (e.g. AI, robotics) is whether non-waste innovation is important for the environmental pressure from waste production and for waste prevention at the macro-scale.

Any innovation in product making (design, material mix, and durability) can increase or decrease the potential waste embodied in goods, and any behavioural and social innovation (e.g. less products-intensive life styles) can generate prevention on the consumer side. Processes in manufacturing, extractive industries, and agriculture, and the provision of services (function: production) produce waste (e.g. hazardous waste). Any innovation in production techniques of goods/services (process innovation) or the introduction of new goods/services (product innovation) can influence waste production (prevention).

Figure 6.2. The waste system from the innovation angle



Source: adapted from EMInnIn, WP8, 2014

Micro-level invention and innovation
Given a waste flow from a certain originating activity, e.g. construction and demolition waste, its management/treatment chain encompasses one or more specific technologies that generally belong to a broad 'family' associated to a management option (landfill, energy recovery, materials recovery, and others forms of recovery).

There can be specific inventions and innovations for one technology inside a management option (or technological family). Specific technological inventions ('Micro-invention' in Figure 6.2) can be for the improvement of an existing technology or for the creation of a new technology and can change the 'potential' pressures compared with the existing technological setting. It can also change the recyclability/recoverability of the waste stream. Inventions for waste management can be relevant in creating available innovation options to be possibly adopted and can reveal the existence of a more comprehensive process of innovation that includes feed-backs from market diffusion to invention. The accumulated stock of knowledge, e.g. patents, can influence technological competition and diffusion/adoption.

Specific technological innovations, instead, are new technologies at different stages - from testing phases to commercial stages - that can be adopted for use in substitution for technologies in place - or as additional option to manage the waste flow inside the same management technology family ('Micro-innovation' in Figure 6.2). If their pressures on the environment are lower than technologies in use, then they deliver environmental benefits. Their diffusion can change the overall performance of the reference management option (e.g. landfill). The extent of the change they introduce through adoption depends on how much they are radical innovations and then can be very limited (e.g. post-shredding recycling of plastics) or can involve substantial changes in the technological and industrial setting (e.g. feedstock recycling of plastics).

Management-option innovation
The management option for a defined 'homogeneous' waste flow can change subject to techno-economic and organisational constraint ('Management option innovation' in Figure 6.2). However, there can be extensive possibilities of shifting the same waste flow from a management option to another, i.e. from a technological family to another (e.g. from landfill to recycling, recovery). In many cases, landfill, recycling and incineration (and reuse) technologies can manage the same waste flow ('material balance'), they substitute one another (under technical constraints) and each (some) can expand at the expenses of some others. Competition and complementarity between management options are very important in the waste system.

The shift in management option is a major objective of waste policies in Europe and can be looked at as 'institutional innovation' in itself. It involves technology diffusion and, at the same time, technological substitution. The implications for environmental pressures can be extensive. In passing from a technological family (e.g. landfill) to anther (e.g. recycling) the composition of environmental pressures can substantially change and the same applies to the overall level of pressures.

Management option innovation (shift in management technologies), in particular from landfill to recycling/recovery is probably the most powerful large scale change in delivering reduced environmental pressures (see also Section 3 on 'Quantifications').

Organisational innovation

The last type of innovation considered in Figure 6.2 is 'Organisational innovation', which may consist of many - and sometimes not fully measurable - changes in management (e.g. collection schemes for household waste, EPR compliance schemes for ELV and WEEE) - that can be critical also for the effectiveness of technological innovation adoption, deployment, and diffusion and their environmental/ economic outcomes.

On the one hand, some organisational innovations can deliver direct effects on waste management and their environmental pressures. On the other hand, complementarity between technological and organisational innovation can be very strong especially for 'Management option innovation' (e.g. collection system for municipal solid waste to shift flows from landfill to recycling). Therefore, it will be critical to understand both how organisational innovation can be effective in reducing pressures and how important is the interaction between organisational and technological innovation to reduce environmental pressures at the macro-scale.

Policy and market drivers for innovation direction and complementarity

As depicted in Figure 6.2, policy is a fundamental driver of innovation in the waste system (see Part 1). Most EU waste policies are directing the waste system towards 'Management-option innovation' (e.g. from landfill to recycling) according to the 'EU waste hierarchy'. The same policies are imposing, through legislation, detailed technological provisions on the environmental impacts of waste management which call for the invention, adoption, diffusion of technological and organisational innovations.

Given the 'material balance' for each waste flow, policies for separate collection and recovery/recycling of specific materials (i.e. shifting from one management option to another) can interact reciprocally. For example, the implementation of packaging waste and recycling policy (which impose specific targets) have diverted municipal solid waste away from landfill and energy recovery, which are subject to specific pieces of EU waste legislation. The same cross-policy effect can arise from the prices of recycling materials, and RES policies can have contributed to 'Management option innovation' by stimulating energy recovery from (renewable) waste (see Part 1).

While waste innovations (invention, diffusion) are expected to be mainly policy-driven, market variables (e.g. virgin material prices) and the evolution of the value chains in the different waste/recycling/recovery sectors are relevant for technology invention/diffusion. Technology diffusion is slow due to capital investment needs; treatment capacity changes by jumps at the local level, and then smoothly at the macro level. Micro-economic considerations (by public administrations and private companies) can be very relevant for investments able to shift management towards different technologies.

With the development of recycling industries and energy recovery from waste, also in connection with RES policies, the role of endogenous industrial dynamics is increasing in driving the diffusion of waste management technologies (e.g. energy recovery) different from disposal in landfill. The waste system becomes an industrial system with industrial production capacity and huge investments in place rather than an environmental management sector.

Moreover, markets for recyclable materials can be affected by imperfect information, and consequently market failure (for instance, the presence of contaminants in used waste oils, the structural strength of scrap, the mix of different plastics, etc.) can reduce the value of the material to the buyer. Technological innovation can reduce these information asymmetries by, for instance, facilitating market participants' assessment of the characteristics of different materials.

However, the development of recycling and energy recovery industries can hinder waste prevention at the macro scale because the increasing industrial capacity needs inputs (i.e. waste) whereas prevention reduces the availability of waste for treatment. Waste policy itself can become endogenous along these developments (i.e. influenced by recycling/energy stakeholders). This dynamic feed-back can be relevant for the overall balance of pressures from waste innovation.

Policy drivers produce extensive impulses for both 'Prevention innovation', although so far with limited effectiveness, and 'Management option innovations', the latter encompassing from 'Micro-invention' to 'Organisational innovation'. 'Micro-invention' can enlarge the technological options for management. 'Micro-innovation', which mainly consists of adoption of new or improved technologies for a specific management option (e.g. landfill) can both draw from new 'Micro-inventions' or can simply extend the diffusion of existing technologies in substitution for those already in use for that management option.

'Organisational innovation' can work as an autonomous source of changes in waste management but it can be better placed in the framework of complementarity with both 'Micro-innovation' and even more with 'Management option' innovation'.

Generally speaking, the key actors in the system are: (i) policy makers for 'Policy drivers' and Pressure/impact/state appraisal; (ii) industrial actors for 'Market drivers', including the waste management facilities, industrial recycling chains, materials and energy industries; (iii) consumers/households and industries producing waste in 'Prevention innovation', which however may also depend on design and product-making thus involving manufacturers and other sectors (e.g. services); (iv) waste management facilities, jointly with providers of innovative knowledge.

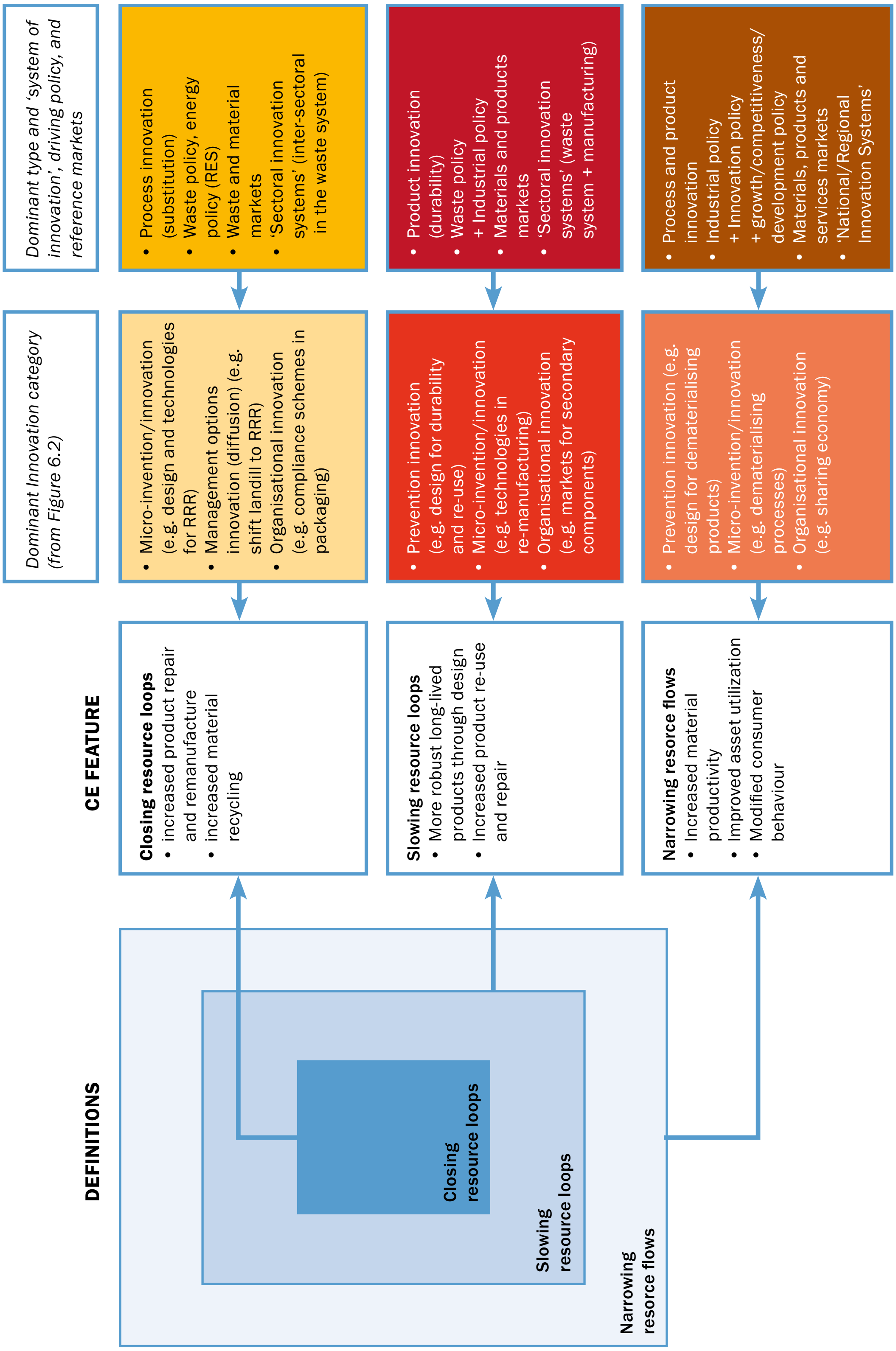
6.2. Innovation in the broader CE perspective

The innovation-based view of the 'waste sub-system' and the innovation categories, as depicted in Figure 6.2 above, can be extended to the broader conceptual framework of the CE, as described in Part 1. However, putting the CE in the broader conceptual framework implies also a broader set of innovation analysis concepts. Therefore, in Figure 6.3, the three nested circles of the CE according to Figure 1.2 in Part 1, are referred to both the categories of innovation discussed above (fist column) and other prominent features of innovation for the same nested circles (second column).

In the narrower inner circle of the CE in Figure 6.3 (‘Closing resource loops’), the relevant innovation categories are ‘Micro inventions/innovations’, for example in specific technologies for recycling or energy from waste and, possibly more relevant, the ‘Management option innovation’ leading to the diversion from landfill to preparation for reuse, recycling and energy recovery. The other most relevant innovation category is ‘Organisational innovation’, for example in separate collection and compliance schemes (under EPR) for specific flows of waste (e.g. packaging). For this same narrower CE circle, the broader features of the innovation process (as summarized in the second column) are the prominence of process innovation, the central role of waste policy and energy policy (RES) as drivers, and the dominance of waste and material markets as ‘non-policy’ innovation drivers and triggers.

In the second and larger circle of Figure 6.3 (‘Slowing the resource loop’), a prominent role can have the category of ‘Prevention innovation’, like in the case of design for durability and reuse. Other categories dominating the circle are ‘Micro-invention/innovation’ in, for example, technologies to re-manufacture products, and ‘Organisational innovations’ to develop markets for reusable and re-manufactured spare parts and components (e.g. in the automotive industry). Among the broader features of the innovation process at this level (second column), we can put a dominance of product innovation (instead of process innovation, although the latter can be important for re-manufacturing, e.g. 3D printing) because durability is at the core of ‘Slowing the resource loop’. Given the centrality of products (design, making, commercialisation, differentiation) at this level, it is clear that the driving/triggering role of waste policies is augmented by an important role of industrial policies (especially in manufacturing), with a possibly critical role of technical standards (e.g. re-manufactured products). For the same reason, at this level not only materials markets are relevant but there is an increasing role of product markets, for example for the possibility of not losing businesses and, instead, possibly enjoying price premiums from longer-life or re-manufactured innovative products.

Figure 6.3. Innovation in the broader CE perspective



Source: own elaboration starting from OECD 2017, Figure 1.2, Part 1, and Figure 6.2 above.

In the broader outer circle ('Narrowing resource flows'), the prevailing innovations can belong to the 'Prevention' category, for example product design for dematerializing products. Innovation can also be 'Micro-inventions/innovations' aimed at minimizing materials and energy use in production processes. 'Organisational innovations' can prevail when the CE is overlapped with the sharing/renting economy thus giving rise to more intensive asset use and reduced production of goods/services for a given (i.e. without rebound effects) total use demand. In this broader framework, among the other innovation features (second column), both process and product innovation are dominant for a large set of industries. At the same time, waste policy does not play a central role because the relevant policy drivers/triggers belong to the area of industrial and innovation policy (see also below) and even to the realm of growth/competitiveness and (sustainable) development policies. Similarly, the relevant market drivers/triggers are not critically related to waste markets, while materials markets keep importance (material productivity), and the dominant signals for innovation can come from a large number of markets for products and even services (e.g. sharing economy). It can be also noted that, in the broader view/circle, a number of 'non-CE aimed' innovations can have important implications for the CE by de-materialising products and processes, which can be the case, for example, with Internet of things, IT and AI-based innovations.

In the broader CE view, therefore, CE innovation tends to become 'non-specific' because it largely overlaps and becomes part of innovation at the most general level.

Even from an historical perspective, the focus and scope of CE innovation enlarged and evolved though different phases. In the first wave of waste policies, from the 1970s and the 1980s, innovation in waste and material circularity mainly addressed 'Closing resource loops' (inner/narrower circle) by 'Micro-invention/innovation' and 'Management options innovation' (diffusion of incineration and recycling instead of landfill). The policies and directives of the 1990s and 2000s enlarged the focus to collection networks of post-consumer waste for material recycling (in particular MSW separate collection; EPR schemes on packaging, ELV, WEEE, batteries) thus inducing a central role of 'Organisational innovation' in closing the industrial value chains involved.

While keeping a relevant role for 'Micro-invention/innovation' and 'Management options innovation', and possibly emphasising the role of 'conventional' 'Organisational innovation' (e.g. by promoting EPR approaches), the Circular Economy Package of 2015 and its aftermath – or the 'New Innovation-intensive Circular Economy' - paves the way to an increasing role for 'Prevention innovation', in particular in re-use, re-manufacturing and longer product life within the circle of 'Slowing resource loops'. At the same time, the 'New CE' pushes towards new forms of 'Organisational innovation' in the outer circle of 'Narrowing the resource loop', in particular in sharing/renting and asset-use intensification. This enlarged perspective to CE innovation, with a new role of prevention-oriented and organisational innovation, is also conveyed by the emerging attention to 'circular business models' in which also the 'internal CE' of the companies are put on the forefront (see Ellen MacArthur Foundation and McKinsey, 2015; EEA 2017 and

2019) (see Box). However, this same attention to new circular business models stimulate a new attention to technological innovation, that is 'Micro-invention/innovation' at all levels and 'Management options innovation' within the 'Closing resource loops' circle, in particular to give more value added to poor materials that are currently directed to energy recovery, possibly within the short-arm inter-sectoral circularity of the Industrial Metabolism type.

Innovative circular business models
A number of examples of innovative CE business models, actual or potential, are presented in the reports of Ellen MacArthur Foundation (https://www.ellenmacarthurfoundation.org/publications). A number of innovative product innovation strategies aligned with the CE are analysed in EEA (2017), which also highlights the uncertainties in terms of their net environmental, economic, and social consequences (e.g. as a results of possible rebound effects). A great number of alleged innovative business circular models are proposed within the initiatives described in Section 5 (e.g. the European Circular Economy Stakeholder Platform).

Grossi et al. (2015)* classify the innovative circular business strategies according to the following typologies:
"Circular economy business strategies aim to ensure that upstream and downstream decisions in the value chain are coordinated (EC, 2014) and guided by two principles:
Cradle-to-cradle: i) design is oriented to durability, disassembly and refurbishment (Bicket et al., 2014: 12); and ii) regenerative forms of production and consumption are favoured (EMF, 2012).
Industrial symbiosis: i) cross-cycle and cross-sector cooperation is adopted along the whole supply chain in order to optimise life-cycles of materials and goods (Bicket et al., 2014), so that companies operating in the same area (spatial clustering) can exploit links in the supply chain thus making the exchange of production residuals easier (TNO, 2013).
We can differentiate between the following four business models: (i) product design; (ii) service & function based offerings; (iii) collaborative consumption; and (iv) 'waste-as-a-resource' business models[49].
Product design business models deliver eco-designed products made with fewer resources, less hazardous material, as well as with longer lasting and easier to maintain, repair, and upgrade components. Two approaches can be distinguished (UNEP/TU Delft, 2009): product redesign based on incremental improvements to existing products; or new product design representing the development of new resource efficient products suitable for repairing, upgrading, and recycling. These business models foster the introduction of policies and strategies improving environmental performance of energy related products, and approaches for standardised labelling (e.g. ISO 14021, 14024 and 14035).
Service and Function based business models provide the functions of a product instead of its physical ownership (Mont, 2004; Ölundh and Ritzén, 2001). Various types of these models (also referred to as 'product service systems') can be distinguished: Product-oriented services centred around product sales including additional services (e.g. maintenance contracts, take-back agreements); User-oriented services based on product lease, renting, sharing, and pooling; Result-oriented services supply specific outcomes, such as the creation of 'a pleasant climate' in offices, rather than simply selling products (Tukker, 2006).
Collaborative consumption business models are based on sharing, swapping, bartering, trading or renting access to products with idling capacity (or other commodities such as land or time) as opposed to ownership (Botsman and Rogers, 2010). The most widespread models take the form of an online sharing marketplace through which the demand for certain assets, products or services is matched with their supply usually through C2C channels.
'Waste as a resource' business models promote cross-sector and cross-cycle linkages by creating markets for secondary raw materials (recyclates). They can reduce the use of energy and materials in the production and use phases (efficiency) and also facilitate locally clustered activities to prevent by-products from becoming wastes (i.e. industrial symbiosis). "

** ETC/WMGE, 2015, Transition to a circular economy: the potential of innovative business models, F. Grossi, N. Brüggemann, R. Zoboli, mimeo*

49 *A more extensive and detailed analysis is presented in ETC/SCP & ETC/WGME (2014), 'Focusing on innovative business models supporting sustainable lifestyles'.*

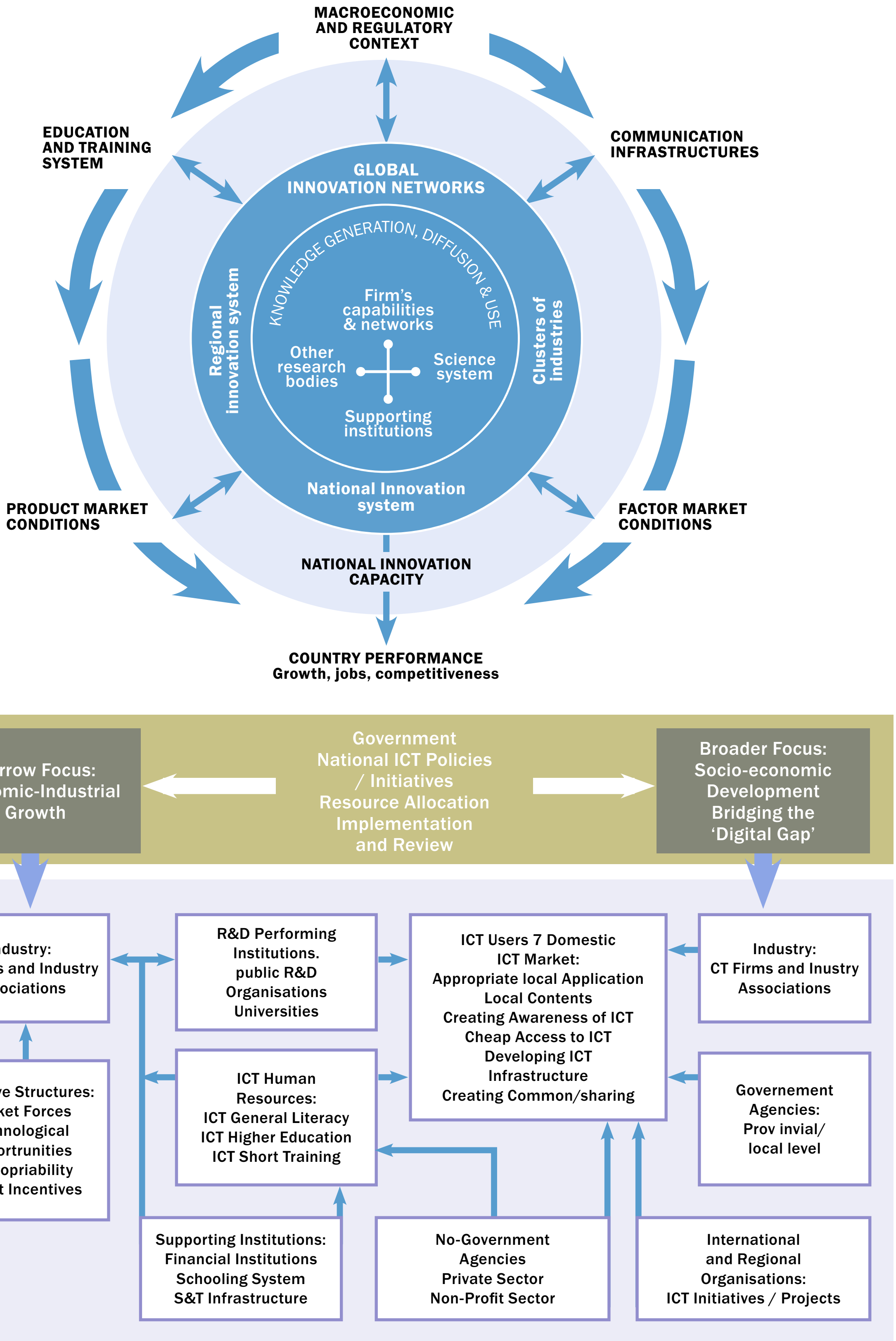
Therefore, the present setting of CE innovation encompasses a full range of innovation types and interests within the enlarged scope and vision of the 'New Circular Economy'.

In Figure 6.3, the other features of CE innovation (third column) include the reference to different types of 'Systems of innovation', that is 'Sectoral' and 'Regional/National'. The concept of 'National System of innovation' belongs to the analytical tools of the economics of innovation and has been developed from the 1990s to highlight the systemic nature of innovation processes, which arise from the interactions between different actors playing a different but complementary functional role in the system (see Freeman 1995; Lundvall 1992; OECD 1997 and 1999).

Figure 6.4 presents a picture of a NSI (which can apply also to the regional level) in which private enterprises of different types (usually: major companies, Schumpeterian innovators, and SMEs) are at the core of the system, while other major actors (public actors, also acting as buyers through procurement, the financial system, and the university/research system) act in a way that can support innovation and can give it economic value.

The 'Sectoral system of Innovation' approach, exploits a similar conceptual framework for application to large-scale complex industrial sectors (e.g. chemical industry) that have a significant intensity of innovation or are science-based (see Schrempf et al 2013; Malerba 2002; Oltra and Saint Jean 2009). A picture for a Sectoral System of Innovation is exemplified in Figure 6.4 in the case of the ICT sector.

Figure 6.4. A National System of Innovation (upper part) and an Example of a Sectoral System of Innovation (lower part)



Source: OECD, 1999; Baskaran and Muchie, 2016

In the scheme of Figure 6.3, we suggest that innovation in the narrower inner circle ('Closing the resource loops') and the central larger circle ('Slowing the resource loops') could be generally related to a concept of 'Sectoral System of Innovation', with the second level ('Slowing the resource loops') having a broader sectoral coverage by involving innovations not only in waste management/recycling/recovery but also in re-manufacturing and product durability. The reason is that, in spite of the large variety of sectors, materials, technologies, and actors involved, the waste system and the recycling/recovery industries are recognised as a 'sector' of the economy with a large body of specific policies, legislations, administrative and planning instruments, and well-defined, albeit strongly evolving (e.g. by 'Management options' innovations), inter-industry interactions and sectoral organisations that support the 'Old Circular Economy'. This same 'sector', however, is generally not a main focus industrial policies and innovation policies, at least before the CE Package and the birth of the 'New Innovation-intensive Circular Economy'.

The outer larger circle ('Narrowing resource flows') instead, would lose the features of a 'Sectoral Innovation System' and should be reasonably embodied in the framework of the 'National/Regional Innovation System' because its scope encompasses a large number of sectors (possibly all) that optimise materials/resources use and many service or product-service innovations ('Servitisation') that provide general resource efficiency results.

Both conceptual frameworks and innovation policies push the 'New Innovation-intensive Circular Economy' in a double direction: (i) to assign circularity the role of a horizontal requirement/attribute of production processes, products, and behaviours in the whole economic and social system; (ii) 'de-specialising' the CE by diverting it from the traditional domain of the 'waste system' and putting it in the general domain of industrial strategies and policies - also giving waste policy, which remains a key driver, an explicit role as industrial policy in addition to – or instead of – being an 'environmental' policy.

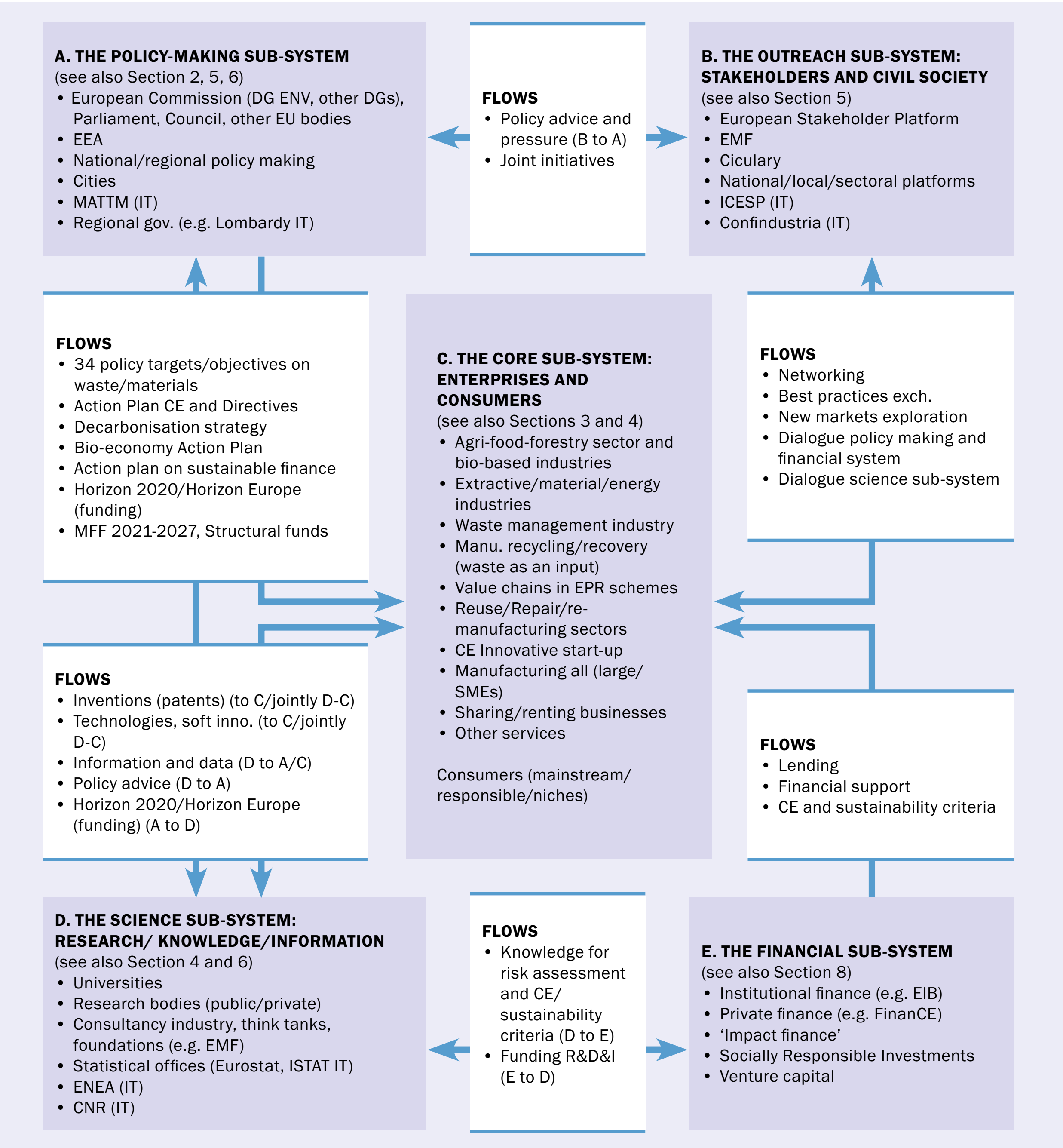
To better understand and govern this dynamics, which risks to be dominated by fragmentation, we suggest to reorganise the policy and strategic vision of the CE around the conceptual framework of the 'Innovation systems'. In the discussion above, we have suggested that the present evolution of the CE, or the 'New Innovation-intensive CE', places the CE itself in between a 'Sectoral system of innovation' and the 'National System of Innovation', given the possible pervasiveness of the CE-related changes across the industrial and consumption system.

Although not fully developed here, an organising framework that integrates the 'Sectoral system of innovation' elements and the 'National System of Innovation' elements of the 'New Innovation-intensive CE' can be elaborated, and can be mapped at different levels, from the European to the regional level.

The major blocks/actors to map are the industrial/economic actors according to innovativeness or other criteria, the relevant policy system (all levels), the university/research system, the financial system. In addition to the actors, mapping must address the flows inside and outside the system, e.g. the inter-industry relationships, both material and economic, and the flows of public and private investments and funding. Policy processes can similarly be mapped and monitored.

In Figure 6.5, we sketch a simplified picture of a CE ‘System of Innovation’ also exploiting the stock-taking exercise carried out in Part 1.

Figure 6.5. A ‘circular’ sketch of the CE ‘System of Innovation’ - also based on ‘stock taking’ in Part 1



Source: own elaboration

The system is made of five major sub-systems.

The 'Enterprises and consumer' sub-system is at the core - as it is in any 'System of Innovation', - and it is the attractor of flows from other sub-systems. It is made by the resource/materials/waste-related industries and, in the 'New CE', by the whole manufacturing sectors and many service sectors linked to 'non-material' CE business models (see the scheme in Figure 6.3). The 'Policy making sub-system' determines the policy impulses and the funding resources from public budgets, going both to the 'core' and to the 'Research/knowledge/information sub-system'. The latter is central in producing new and adapted knowledge for the 'core', and for the 'Policy making sub-system'. The 'Research/knowledge/information sub-system' also receives resources from the 'Finance sub-system', and gives the latter the knowledge base to assess risks and criteria relevant to sustainable finance. The 'Finance sub-system', as composed by both institutional and private finance actors - including fund managers, SRI investors, venture capitalists – lends money to the 'core', possibly adopting specific sustainability and CE criteria (see Section 8). The 'Finance sub-system' also operates under policy prescriptions (e.g. Action Plan on Sustainable Finance) from the 'Policy making sub-system'. The 'Stakeholders and civil society' sub-system is made, in the case of the CE, by a number of actors from business and other parts of the society in the 'core', and it develops networking, policy pressure, knowledge diffusion and communication. The role of this sub-system is increasingly important in the 'New CE' in that it works as a 'systemic glue' by working with other sub-systems, like science and knowledge, and finance.

Although very sketchy, the scheme shows the wealth of 'circular' interactions involved in the 'New Innovation-intensive CE' and could provide, when properly developed, an easy way to identify relevant actors and flows in support to CE strategies.

6.3. Pushing innovation for the CE: European R&I programmes

The described approach to the New CE as an innovation system can be seen vis à vis a real-world picture in which, before the European CE Package, 'formal' 'Micro-invention/innovation' (patents) in waste and circularity were not on an upward trend, the diffusion of 'Management option innovations' (e.g. non-landfill technologies) was slow and highly differentiated across countries and regions, 'Prevention innovation' adoption was slow in industry, and other barriers emerged for a 'New innovation-intensive CE' '(see Part 1, Section 4).

A possible policy push towards a 'New Innovation-intensive CE' can be expected from the implementation of CE Package of 2015 and the revised waste directives of 2018 and 2019, as well as the announced revision of the Action Plan for the CE in 2020.

These policy pushes can be augmented in the direction of a 'New innovation-intensive CE' by the present activism in the allocation of European R&I funding, as well as funds in other policy areas, to the CE transition (interactions between the A and D sub-systems in Figure 6.5).

According to data from the European Commission[50], the total spending of EU-level programmes to support the CE has been more than 10 billion/€ since 2016, of which: 1,4 billion/€ from Horizon 2020 until 2018; 7,1 billion/€ from Cohesion Policy; 2,1 billion/€ from European Fund for Strategic Investments and InnovFin; about 100 million/€ through LIFE.

In particular, environment-related R&I represents a substantial part of the European public funds allocated under the EU R&I Framework Programs (FPs). Within Horizon 2020 (FP8, 2014-2020), the allocations most directly related to the environment are inside the Pillar 'Societal Challenges' under the programmes: (i) 'Food security, sustainable agriculture and forestry, marine maritime and inland water research and the Bioeconomy', 3.851 million/€; (ii) 'Secure, clean and efficient energy', 5.931 million/€; (iii) 'Smart, green and integrated transport', 6.339 million/€; (iv) 'Climate action, environment resource efficiency and raw materials', 3.081 million/€. These programmes amount together to 19.202 million/€, or about 72% of the total budget for the pillar 'Societal Challenges' and about 26% of total Horizon 2020 budget (74.015 million/€). Environment-related R&I can be found, of course, all across Horizon 2020 as a part of the specific calls and projects, for example inside ERC grants, MSC Actions, and the programmes on 'Enabling and Industrial Technologies', 'Innovation in SMEs', 'Health, demographic change and wellbeing'.

The Interim evaluation of Horizon 2020[51] highlights that, based on the results of the study by PPMI (2017)[52], *"Regarding the wider impact of European projects, an especially large proportion of Horizon 2020 projects are expected to have an effect on 'Climate action, environment, resource efficiency and raw materials' (51%) and 'Health, demographic change and wellbeing' (47%), followed closely by 'Secure, Clean and Efficient Energy' (42%)".* However, the same 2017 Interim evaluation reports that *"The results of tracking Horizon 2020 expenditure for sustainable development and climate change show that for the first years of Horizon 2020 activity, the sums spent have fallen behind the expected expenditure for these objectives as of 1 January 2017. For climate action, expenditure was 27% compared to a target of 35% applicable to the whole period of Horizon 2020, and for sustainable development it was 53.3% versus a target of 60%."*.

Within Horizon 2020, in the last few years (from 2015), the projects strictly related to the CE (i.e. explicitly referring to 'circular economy' in their title) that received funding under different calls have been 61, for a total cost of 345 million/€. Eight of them are coordinated by Italian partners, and Italy is represented in the partnership of many projects. Appendix 2 presents the essential information on the above-mentioned projects. Many other Horizon 2020 projects can have a relationship with the CE through parts/links within their program of work.

50 *Presentation by Paola Migliorini (EC DG Environment) at the workshop 'Circular Economy – How to connect policy, research and business?, 10th May 2019, Fondazione Eni Enrico Mattei, Milan.*

51 *See European Commission (2017), Interim Evaluation of Horizon 2020, https://ec.europa.eu/research/evaluations/index.cfm?pg=h2020evaluation*

52 *PPMI, 2017, Assessment of the Union Added Value and the Economic Impact of the EU Framework Programmes (FP7, Horizon 2020), http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/assessment_of_the_union_added_value_and_the_economic_impact_of_the_eu_framework_programmes.pdf ,*

In the European Commission's 'Research and Innovation Participant Portal'[53], the Focus Area "Connecting economic and environmental gains – the Circular Economy" includes 381 occurrences with reference to open and forthcoming calls in the Work Programme 2018-2020. However, many of these open and forthcoming calls are not easily referable in a direct way to the CE.

A clearer indication on the role of CE research within Horizon 2020 in the next few years is presented in the Work Programme 2018-2020[54]. 'Focus areas' of the programme are considered in the Digital Single Market, the Energy Union, Mobility, Space, and the Circular Economy, which together attract an allocated budget of about €7.2 billion. In particular, the focus area - 'Connecting economic and environmental gains – the Circular Economy' receives a total budget 964 million/€.

According to the Work Programme: *"Realising the circular economy needs more than traditional R&D or a piecemeal approach to technologies. It needs changes in entire systems and joint efforts by researchers, technology centres, industry and SMEs, the primary sector, entrepreneurs, users, governments and civil society. It needs enabling regulatory frameworks; and additional public and private investments", and "the contribution of this focus area will be in renewing Europe's industrial capacities and boosting growth, in a world of resource constraints. This will need new technologies, new business models, and their uptake by industry and SMEs; linking different sectors and public bodies; developing integrated value chains; and better communication to engage society and consumers. Success will be seen in: A measurable improvement in the efficiency and effectiveness of the use of resources (primary and secondary), including energy; Measurable reductions in waste generation, environmental pollution and greenhouse gas emissions; transforming recyclable waste into a flourishing market of secondary raw materials; Competitive advantages for existing businesses; New businesses opportunities, including disruptive innovation; Security of raw materials supply" (p. 24).*

The main components of the Focus Area are presented in Table 6.1. It can be seen that the two major components are about industrial technologies and business models, and these components also link the CE to climate and decarbonisation research and to the bioeconomy research (see, on these links, the Section 7 below on the NEXUS). In general, it is clear that, under the heading 'circular economy' is now encompassed a significant part of EU-funded industrial and technological research, in particular in important manufacturing sectors.

53 *https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/focus-area/circular_econonmy.html#c,topics=callStatus/t/Forthcoming/1/1/0/default-group&callStatus/t/Open/1/1/0/default-group&callStatus/t/Closed/0/1/0/default-group&+identifier/desc*

54 *European Commission, Horizon 2020- Work Programme 2018 – 2020, European Commission Decision C(2019)1849 of 18 March 2019, http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-intro_en.pdf.*

Table 6.1. Components of the Focus Area - 'Connecting economic and environmental gains – the Circular Economy'

Component	Budget
Leadership in enabling and industrial technologies - Nanotechnologies, Advanced Materials, Advanced Manufacturing and Processing, and Biotechnology (LEIT-NMBP): European high-tech building blocks serving the circular economy (Sustainable Process Industries (SPIRE) initiative)	€370 million
Societal Challenge 2 'Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy' (SC2): the bio-economy aspects of the circular economy	€256 million, including €100 million for access to risk finance
Societal Challenge 3 'Secure, clean and efficient energy' (SC3): reuse of carbon dioxide	€12 million
Societal Challenge 5 'Climate action, environment, resource efficiency and raw materials' (SC5): transition to circular economy business models and practices, and sustainable sourcing or raw materials, also from secondary sources	€326 million

Source: adapted from EC H2020 Work Programme 2018-2020.

Other focus areas can encompass CE-related research. It is the case with Focus Area - 'Building a low-carbon, climate resilient future', in which it is claimed that *"Many synergies also exist with actions under the Focus Area 'Circular Economy', including the Sustainable Process Industries (SPIRE) initiative, since improving the efficiency and effectiveness of resource use (both primary and secondary) will help boost energy efficiency while also leading to a reduction in greenhouse gas emissions."* (p. 22).

Within the FP programmes, the EIT – European Institute of Innovation and Technology has started the experience of EIT Communities and KICs – Knowledge and Innovation Communities, which represent platforms of cooperation between research and industry[55]. Among the various EIT/KICs, the 'EIT Raw Materials' (created in 2014) is the closest one to the CE by addressing the following R&I themes:

- Exploration and raw materials resource assessment;
- Mining in challenging environments;
- Increased resource efficiency in mineral and metallurgical processes;
- Substitution of critical and toxic materials in products and substitutions for optimised performance;
- Recycling and materials chain optimisation of end-of-life products;
- Design of products and services for the circular economy[56].

Research-industry cooperation on the CE is also encompassed in the action of the other EIT Communities: (i) 'EIT Manufacturing', which has inter alia the objective of having 30% of materials in industry that are 'circular'); (ii) 'EIT Food', which has inter alia the objective to develop solutions to transform the traditional 'produce-use-dispose' model into a circular bio-economy; (iii) 'EIT Climate-KIC', which has inter alia the objective of creating low-carbon value chains based on the circular economy and bio-economy.

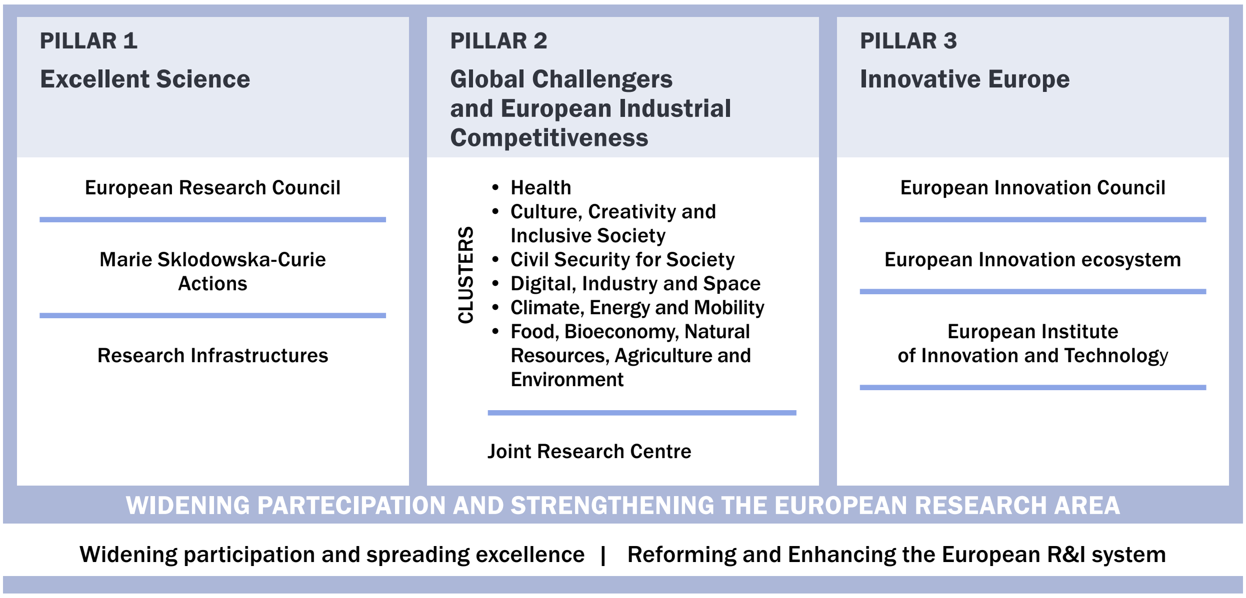
In May 2018, the Commission presented the proposal for the new FP9 'Horizon Europe', 2021-2027 (Figure 6.6). The proposed budget is 100/120 billion/€, and it is part of the

55 See *https://eit.europa.eu/eit-community*

56 *https://eit.europa.eu/eit-community/eit-raw-materials*

negotiations on the new Multiannual Financial Framework of the Union 2021-2027[57]. The major societal objectives are: (i) Tackling climate change (35% budgetary target); (ii) Helping to achieve Sustainable Development Goals; (iii) Boosting the Union's competitiveness and growth.

Figure 6.6. The structure of 'Horizon Europe' 2021-2027



Source: European Commission, 2019.

The most direct environment-related allocations can be found inside the Pillar 2 'Global challenges and Industrial Competitiveness'. The approach pursued in Horizon Europe, especially for Pillar 2, is shaped by 'clusters', which will be based on 'missions' and 'partnerships' beyond the usual calls.

More specifically, in the preparatory document of the European Council on Horizon Europe (March 2019), the terms 'Energy', 'Environment', 'Sustainable Development' occur, respectively, 325, 202 and 52 times, and the same applies to the 'Proposal for a Decision of the Council on establishing the specific programme implementing Horizon Europe (March 2019). In this second document, the phrase 'circular economy' is mentioned in 20 sentences.

According to Art. 9 (Budget), *"the financial envelope for the implementation of the Framework Programme for the period 2021 – 2027 shall consist of [EUR 94 100 000 000 in current prices] for the specific programme referred to in Article 1(3)(a) and for the European Institute of Innovation and Technology (EIT) and [EUR13 000 000 000 in current prices] for the specific programme referred to in Article 1(3)(b)."* The indicative distribution of the budget for the programme (Article 1(3)(a) and for the EIT is reported in

57 In the present negotiations on the MFF at the European Parliament there are proposals to rise the Horizon Europe budget to 120 billion/€.

Table 6.2. The clusters closer to the CE are 'Climate, Energy and Mobility' (15 billion7€) and 'Food and Natural Resources' (10 billion/€), also via the bio-economy, but other clusters and actions can include CE-related research. A 35% target is confirmed for expenses allocated to climate-related action across the different programmes/projects.

Table 6.2. Indicative distribution of the budget in Horizon Europe, 2021-2027

a)	[EUR 25 800 000 000] for Pillar I 'Open Science' for the period 2021-2027, of which
(1)	[EUR 16 600 000 000] for the European Research Council;
(2)	[EUR 6 800 000 000] for Marie Skłodowska-Curie Actions;
(3)	[EUR 2 400 000 000] for research infrastructures
(b)	[EUR 52 700 000 000] for Pillar II 'Global Challenges and Industrial Competitiveness' for the period 2021-2027, of which
(1)	[EUR 7 700 000 000] for cluster 'Health';
(2)	[EUR 2 800 000 000] for cluster 'Inclusive and Secure Society';
(3)	[EUR 15 000 000 000] for cluster 'Digital and Industry';
(4)	[EUR 15 000 000 000] for cluster 'Climate, Energy and Mobility';
(5)	[EUR 10 000 000 000] for cluster 'Food and Natural Resources';
(6)	[EUR 2 200 000 000] for the non-nuclear direct actions of the Joint Research Centre (JRC)
(c)	[EUR 13 500 000 000] for Pillar III 'Open Innovation' for the period 2021-2027, of which
(1)	[EUR 10 500 000 000] for the European Innovation Council, including up to [EUR 500 000 000] for European Innovation Ecosystems;
(2)	[EUR 3 000 000 000] for the European Institute of Innovation and Technology (EIT)
(d)	[EUR 2 100 000 000] for Part 'Strengthening the European Research Area' for the period 2021-2027, of which:
(1)	[EUR 1 700 000 000] for 'sharing excellence';
(2)	[EUR 400 000 000] for 'reforming and enhancing the European R&I System'.

Source: European Council, March 2019.

Horizon Europe is part of the Multiannual Financial Framework for 2021-2027 (MFF) proposed in May 2018 by the European Commission and now under negotiation[58]. The total size of the MFF is 1,279 billion/€ (1,134 billion/€ in 2008 prices), which represents 1.11% of the estimated GNI of the EU27 (after Brexit). The major areas of the MFF 2021-2027 are: 'Single market, Innovation and Digital' (including Horizon Europe for research and innovation): 14,8% of total MFF; 'Cohesion and Values' (including Regional Development Fund and Social Fund): 34,6%; 'Natural Resources and Environment' (including Agricultural and Maritime Policy): 29,6% - these three areas together covering 79% of the total MFF.

While it is difficult to estimate the resources committed to the environment within the MFF, financial resources for the environment-related areas can be found within, for example, 'Cohesion and values', through many parts of the European Regional Development Fund (226,3 billion/€), and 'Natural resources and the environment', though many parts of the Agricultural and Maritime Policy, and the Programme for Environment and Climate Action (Life), receiving 5,4 billion/€.

58 *European Commission (2018e), A modern budget for a Union that protects, empowers and defends. The Multiannual Financial Framework for 2021-2027, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2018)321 final, 2 May 2018.*

Among the 'new and reinforced priorities' receiving significant additional budget with respect to the previous MFF 2014-2020, those more directly related to the environment are 'Research and Innovation' (Horizon Europe), with an increase of 60%, and LIFE, with an increase of 70%. However, climate change is a central concern within the whole MFF 2021-2027, and the commitment to 'mainstreaming climate change' has been increased, from 20% of total resources in MFF 2014-2020 to 25% in the new MFF under negotiation (proposals for a 30% share are under discussion). This commitment would shift the total allocation to climate change from 206 billion/€ under MFF 2014-2020 to 320 billion/€ under the new MFF, or +114 billion/€[59].

In Italy, the process of revision of the Italian National Research Programme 2021-2025 (NRP) has been started and led to the draft of the thematic foundations of the new Programme. The previous NRP 2015-2020 was dominated by competitiveness objectives and was based on the definition of priority areas and actions according to Italian industrial specialisations and strengths[60]. The programme was endowed with 2,5 billion/€ for the first three years, largely wrapped up from already existing funding channels. One of the outcomes of the programme has been the enlargement of Technological Industrial Clusters (national and regional) aimed at connecting research with industry, already started in 2012. The first 8 clusters were: Aerospace; Agrofood; Green Chemistry; Intelligent Factory; Mobility; Life Sciences; Technologies for living environments; Smart Communities. The NRP added the following clusters: Technologies for the Cultural Heritage; Design and Made in Italy; Marine Economy; Energy[61].

According to available information, the revised PNR 2021-2025 aims to the alignment to Horizon Europe, and is based on 14 key areas: 1. Health; 2. Culture and Cultural Heritage; 3. Design, creativity and Made in Italy; 4. Social transformation; 5. Electronics telecommunications and Digital Technologies; 6. High Performance Computing and Big Data; 7. Artificial Intelligence Cibersecurity and Robotics; 8. Quantum technologies and enabling key technologies; 9. Space; 10. Sustainable Mobility; 11. Climate, Energy; 12. Green Technologies; 13. Bioeconomy, Food and Blue growth; 14. Natural Resources, Environment and Disasters risk reduction. Resource endowment is still unknown.

Both the old NRP and the outline of the new NRP (though) the areas, do not include the Circular Economy as a specific key area/cluster. However, CE-related research could be partly found within: Sustainable Mobility; Climate, Energy; Green Technologies; Bioeconomy, Food and Blue growth; Natural Resources, Environment and Disasters risk reduction.

59 *According to DG Clima "The EU is broadly on track towards the 20% target, but further efforts are needed. Based on the current trend, the climate-related spending under the 2014-2020 budget is projected to amount to 200 billion or 18.8% of the EU operational spending" commitments", https://ec.europa.eu/clima/policies/budget/mainstreaming_en*

60 *See http://www.istruzione.it/allegati/2016/PNR_2015-2020.pdf*

61 *For a more detailed and complete picture of the Italian innovation system and the resources allocated to research in Italy, see ANVUR, 2018, Rapporto biennale sullo stato del sistema universitario e delle ricerca 2018, http://www.anvur.it/rapporto-biennale/rapporto-biennale-2018/, and Nascia L., Pianta M., 2018, Research and Innovation Policy in Italy, https://mpra.ub.uni-muenchen.de/89510/1/MPRA_paper_89510.pdf*

In Italy, in addition to the work by ENEA on CE-related innovations[62], a number of scientific research institutes of the Italian National Research Council (CNR) –the major public research body in Italy - work, as their main mission, on CE-related innovations and bioeconomy innovations, like innovative industrial materials and and bio-based materials. Appendix 3 reports the list of CNR institutes working in these areas.

7. Integrative approach 2: A NEXUS linking CE, decarbonisation, and the bioeconomy

7.1. The NEXUS approach

The NEXUS approach is promoted by the UN and other organisations (e.g. Future Earth[63]) as a useful way to overcome the fragmentation and separation of sectoral policies that generally pervades even systemic multi-sectoral problems. The most extensive application of the NEXUS approach is in the framework of development policies in LDCs for the critical interdependency between water, energy, and food (IRENA 2015; WEF 2011; Perrone et al. 2011). However, the NEXUS approach can be used for different areas and policy/management problems when there are interconnections - of a technical/technological, ecological, social, economic and political nature - that make conventional sectoral approaches and policies not effective or not efficient.

This can be the case with the Circular Economy. In the present setting of EU policies, and national/regional/local policies, the CE, decarbonisation, and the bioeconomy are largely seen as specific strategies/policies with their own main scopes, targets and objectives, and instruments. While the connections between the three areas are often recognised and cross-referenced, and sometimes emphasised in the case of the links between CE and decarbonisation (see Part 1, Section 2), this is done as a collateral link of each policy area taken separately, and it is not considered as reciprocally conditional on the design and implementation of each policy. This may be a source of ineffectiveness and inefficiency in that synergies can be lost and potential conflicts between different policies are not fixed neither ex ante nor ex post. The undue separation runs against the EU Treaty provisions on 'policy integration' and it is a permanent point of attention in the debate on EU environmental policies in relation to other policies. The opportunity to recognise the NEXUS-like interactions between the CE, the decarbonisation transition, and the bioeconomy has been recently suggested by the EEA (see EEA 2019).

The full development of such a NEXUS approach would require, first of all, steps forward from the analytical point of view, in particular in terms of identifying and measuring connections between the involved materials and energy flows, natural resources, industrial sectors, social and policy processes.

The present state of modelling and other analytical tools are just partly suited to provide a complete knowledge basis. For example, CGE and other energy/climate-economy models do not encompass a detailed waste/material flow component, nor the present state of large scale

62 See www.enea.it

63 http://www.futureearth.org/

waste/materials (MFA) models is advanced enough to compete with the advanced state of energy/climate-economy models that are officially used to support and shape climate and energy policies at the global and European level (decarbonisation) (see Part 1, Section 3). At the same time, the knowledge basis for bioeconomy strategies/policies is more advanced with respect to the one available to support waste/circularity strategies and policies. In fact, the only experience of a large scale waste model in Europe is the European Waste Model developed by the EC to support the CE strategy proposal and managed by the EEA (see Part 1, Section 3). However, while demanding the support of analytical models, the possible advantage of the NEXUS approach is that it allows simplifying by focusing just on the essential major inter-sectoral links.

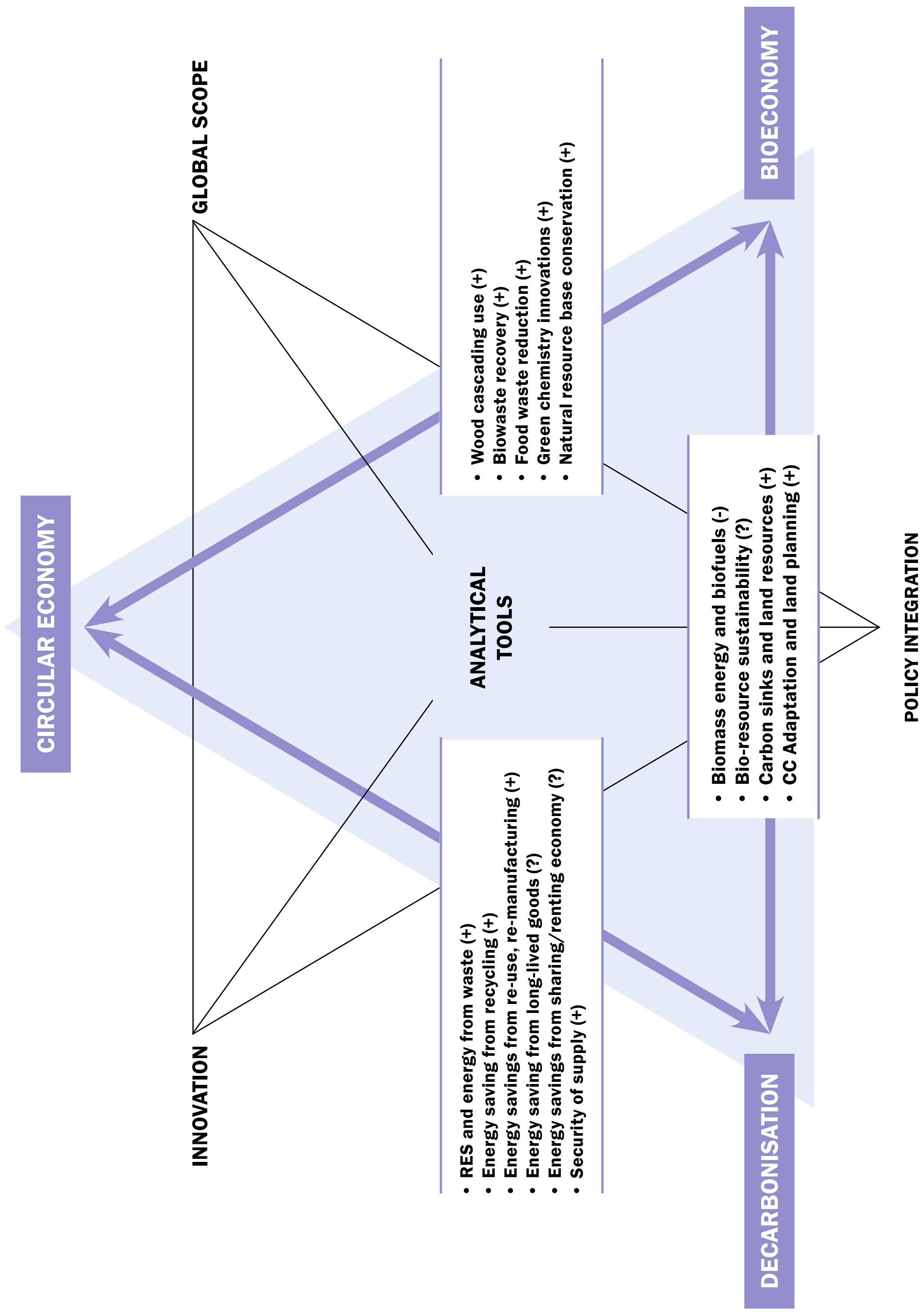
The second major step of a NEXUS approach is policy synergy and integration. While in the case of CE strategy and the Bioeconomy strategy there is dialogue and a set of recognised interlinkages (see EEA 2018 and 2019), these linkages are still weak in the case of climate-energy policies and the EU decarbonisation strategy. While the CE is included among the options to achieve a 'carbon neutral economy' in the EU, it is done as a sort of external contribution, and the bioeconomy strategy is not much emphasised in the decarbonisation strategy (see Part 1, Section 2).

The third dimension of such a NEXUS can be at the level of enterprises. Most companies, even SMEs, have to manage in a naturally or necessarily integrated way materials, waste, energy, emissions in their operations and strategies, and even outside the sectors designated as bioeconomy, they have to deal with natural resources and ecosystems (e.g. water). This can be particularly important for those companies operating on a large geographical scale or in multiple sectors.

7.2 Sketching a CE-DEC-BIO NEXUS

A NEXUS approach to Circular Economy, Decarbonisation, and Bioeconomy (CE-DEC-BIO NEXUS) is sketched in Figure 7.1.

Figure 7.1. A sketch of the CE-DEC-BIO NEXUS



An immediate link between CE and DEC is provided by the contribution of waste to energy production, even in the framework of Renewable Energy Sources (RES) policies. 'Non-renewable waste' (municipal and industrial) represents an increasing source of energy in the EU28 with a strong upward trend that doubled the figure from 2002 to 2016 (Figure 7.2).

Figure 7.2. Gross inland energy consumption from non-renewable waste (municipal and industrial, EU28, 1990-2016, thousands TOE)

Source: own elaborations on Eurostat data.

In spite of the limited consideration that energy from waste receives in CE strategies at almost all levels, also consistently with the 'Waste Hierarchy', this link cannot be disregarded as it is part of the reality of the CE, and energy from waste can be an important transitional option towards 'zero landfill' objectives. Another effect of energy from waste, as is the case with RES in general, is the possible improvement of security of supply for energy, which is in line with the potential overall effects of DEC strategies. An analysis of the CE-DEC link (climate change mitigation) in some sectors has been recently provided by Material Economics (2018).

A second CE-DEC link, even taking a narrow definition of CE, is the decarbonisation effect implied in the move towards secondary materials, which substitute for more energy/ emission intensive processes based on virgin materials. This effect also includes the fact that the CE is 'inward looking' and the procurement and transportation chains can be geographically shorter, possibly national or local - leaving aside transitional problems, like the long-range trade of plastic waste (see ETC/ WMGE 2019). When considering also re-use and re-manufacturing, the decarbonisation effect can be even higher, given that re-use/ re-manufacturing requires relatively lighter production process compared to those (possibly energy intensive) of new production and also of recycling/recovery.

When taking a broader perspective to the CE by including longer life of goods, sharing economy and renting economy, the decarbonisation effect can be, in principle, even higher. However, there are open issues about the net energy/emissions effects because gains in energy efficiency from innovations in new equipment/goods (e.g. cars) might be higher than those from longer life, re-use, sharing and renting (i.e. accelerated obsolescence might be good). At the same time, sharing and renting can create 'rebound effects' (i.e. cheap services that stimulate additional demand) thus finally increasing, and not reducing, the demand of services and then increasing net energy consumption and emissions (see, for example, Maggioni 2017).

A set of links between CE and DEC are correctly stated in the Commission's 'European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy' of 2018[64]:

"The EU industry is already today one of the most efficient globally and this is expected to continue. A competitive resource-efficient and circular economy will need to develop to keep it so. The production of many industrial goods like glass, steel and plastics will see further significant reductions in energy needs and process emissions, particularly with increasing recycling rates. Raw materials are indispensable enablers for carbon-neutral solutions in all sectors of the economy. Given the scale of fast growing material demand, primary raw materials will continue to provide a large part of the demand. But a reduction of materials input through re-use and recycling will improve competitiveness, create business opportunities and jobs, and require less energy, in turn reducing pollution and greenhouse gas emissions. Recovery and recycling of raw materials will be of particular importance in those sectors and technologies where new dependencies might emerge, such as a reliance on critical materials like cobalt, rare earths or graphite, whose production is concentrated in a few countries outside Europe. But also strengthened EU trade policy has a role to ensure sustainable and secure supply of these materials to the EU. New materials will play an important role as well, whether rediscovering traditional uses such as wood in construction, or new composites replacing energy intensive materials. Consumer choices will also matter for product demand. Some may come from other ongoing transformations, such as digitalisation reducing paper demand. Others will be more climate conscious choices, such as customers increasingly asking for climate and environmentally friendly products and services. This requires more transparent information to consumers about carbon and environmental footprints of products and services so that they can make informed choices." (p. 12).

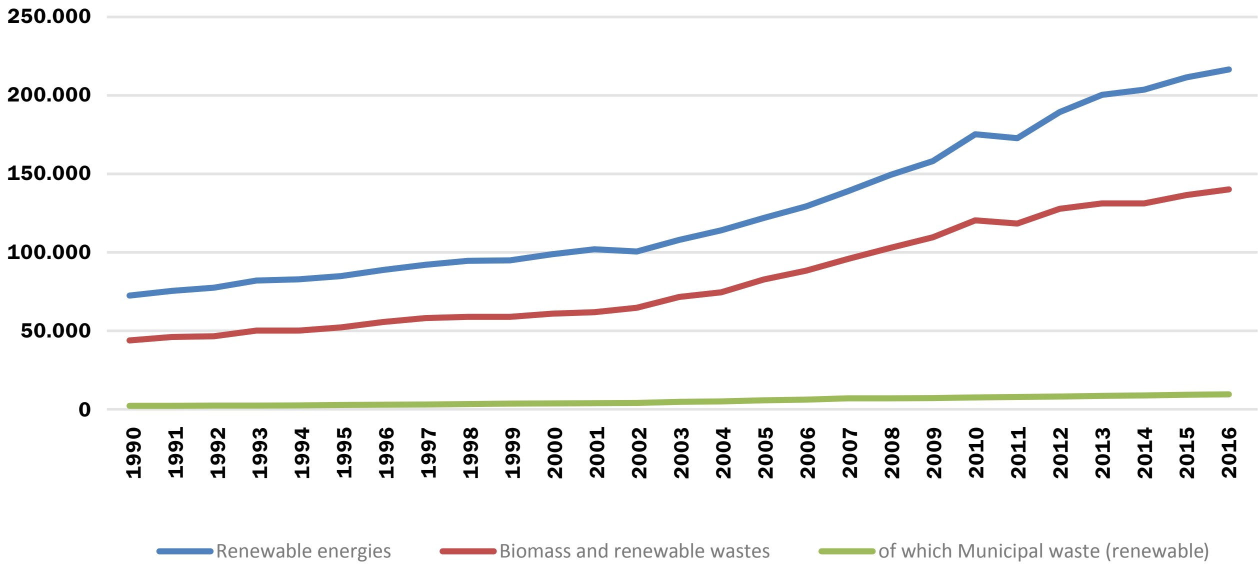
Another micro-level connection between CE and DEC is that, in general, companies do not face trade-offs in (eco)innovating in energy efficiency and materials/waste savings. The eco-innovation literature based on direct surveys or EU level institutional surveys (e.g. Community Innovation Surveys, Eurobarometer) highlights that a large part of eco-innovation activities (even in SMEs) jointly involve saving energy, materials, water and other inputs (see

64 *European Commission, 2018a, A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018) 773 final, Brussels 28.11.2018.*

Marin, Marzucchi and Zoboli 2015) also in a framework of innovation 'complementarity' and even without trade-off between material/ energy efficiency and economic performance. The increasing adoption of comprehensive sustainability strategies by companies can be a channel for synergy between CE and DEC, even though specific industrial opportunities may differ in this respect.

However, there can also be channels of inconsistency – even policy inconsistency – between CE and DEC when ambitious targets for decarbonisation via RES can displace recycling and CE development. This can be the case of large bioeconomy sectors, like the European forest-based industry for which the strong growth of biomass demand induced by RES policies created a competition for biomass materials (wood chip and particles, wood waste and residues) used as the main input in the wood-panel based industry, i.e. wood recycling (see Gargiulo and Zoboli, 2007, for the Italian experience). This can be seen also as an inconsistency with the Waste Hierarchy which ranks material recovery/recycling above energy recovery of the same waste. However, in the same forest-based industries, there is large use of own wood residuals (from processes) for energy self-production, in particular in CHP plants, also getting benefits from favourable RES and CHP incentive regimes. In the EU, 'biomass and renewable waste' represent about 65% of total RES final inland consumption in 2016, closely reflecting the strong upward trend of total RES consumption since 1990 and its doubling from 2002 to 2016 (Figure 7.3).

Figure 7.3. Gross inland energy consumption from Renewable Energy Sources and from 'biomass and renewable municipal waste', EU28, 1990-2016, thousands TOE

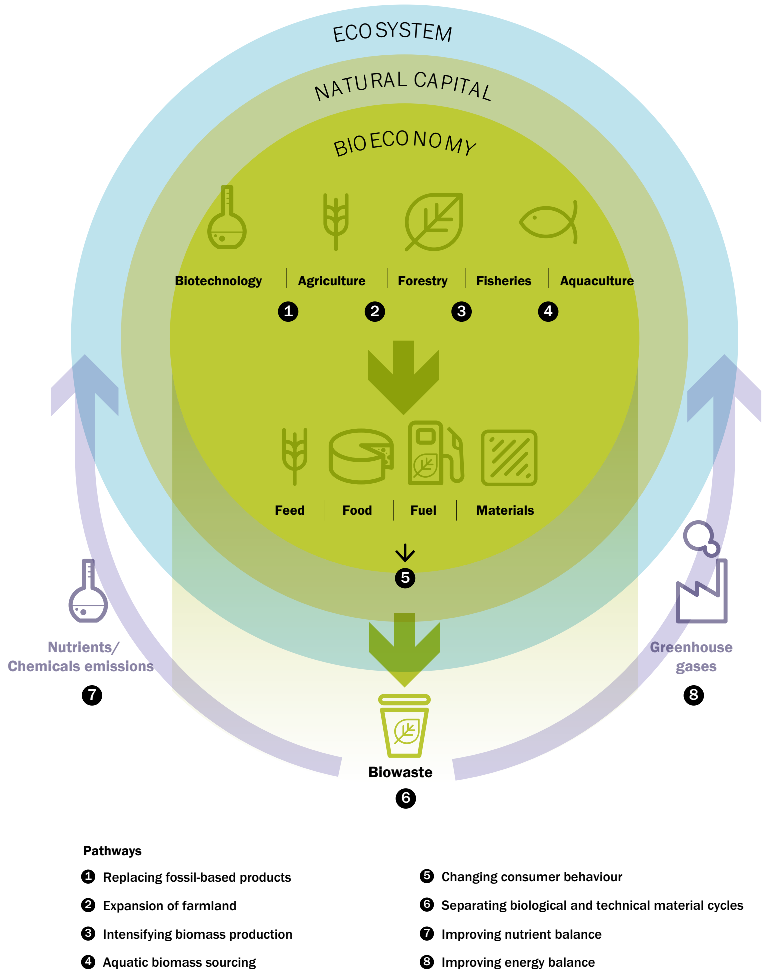


Source: own elaborations on Eurostat data.

In general, a strong push towards biomass energy targets (electricity/heating) for DEC purposes can exert pressures on bio-resources, on which the Bioeconomy is based. Even beyond the above-mentioned case of competition for wood waste between energy and industrial uses, there is a general issue of increasing pressure of energy production over natural ecosystems. In European countries, this issue involves both forest ecosystems as linked to the biomass energy sector, the agro-food sector as linked to biofuels production, and water ecosystems as linked to the hydropower sector (in particular mini-hydro). Different studies alerted the EU policy makers on the potential limitations of domestic natural ecosystems in sustainably supporting the multiple and increasing demands of use and exploitation coming from industry and energy production (RES), including the demands from the same Bioeconomy sectors (for example INDUFOR 2013).

Important links between DEC and the Bioeconomy arise through land-based resources (see Dodd 2017). In addition to the possible conflicts highlighted above, there can be positive connections in that DEC strategies, as the one proposed by the Commission for a ‘carbon neutral economy’, require the contribution by carbon sinks. Natural environments that are the basis of the Bioeconomy (agro-forestry systems and water ecosystems) must be properly managed and preserved to complement energy-technology trajectories in carbon-neutral strategies. This implies ex ante interconnections between DEC-oriented policies and BIO policies to avoid conflicts and competitions and to exploit synergies. In particular, land planning and territorial management must be addressed to combined objectives of contributing to climate change mitigation, in the framework of ‘carbon neutrality’, and to preserve the resource basis of the Bioeconomy (in addition to the main objectives of nature preservation and ecosystem integrity). According to the EEA (2018), even the increase of circularity inside the Bioeconomy can be an important achievement of CE itself while contributing to sustainable Bioeconomy in general (see Figure 7.4).

Figure 7.4. The 'Circular bioeconomy' according to EEA, 2018



Source: EEA, 2018

A complementary additional synergy between the bioeconomy sectors (i.e. their natural resources base) and DEC/carbon-neutrality can be Climate Change Adaptation. As designed by global climate policies (the Cancun Framework, the Paris Agreement and subsequent COPs), as prescribed by the European Commission, and as planned by the majority of EU countries (and some regions), adaptation strategies involve a radical revision of development planning approaches that must incorporate climate risk in public and private decisions, a prudential approach in land use change, water management, agricultural practices and strategies, prevention of the effects of climate-related disasters. This re-direction of planning involves in multiple ways also energy production and distribution facilities, and the resource-base of many RES (e.g. water). From the other side, it involves a balanced pressure from industry and energy production on natural ecosystems and land.

The development of the CE can alleviate some of the problems to be faced for the preservation of the ecosystem and natural-resource base for the Bioeconomy. This positive link between CE and BIO can arise, first of all, from the significant role of biomaterials within the system of municipal and industrial waste. Organic waste represents a significant share of total municipal waste; a significant part of packaging is biological (paper, wood), and the corresponding forest-based industries are a significant part of the Bioeconomy, already achieving a very high degree of circularity, including self-production of energy from biomass. Food waste is estimated to be 100 million/tons/year tons in Europe, thus representing a significant opportunity cost for industry, retailers and households. The reduction of food waste receives a very high attention in the CE package and waste directives revision (50% reduction objectives in line with the SDGs, while no binding targets have been adopted).

A significant part of biowaste is recycled in composting, and it can be used as a feedstock for biogas/biomethane[65]. In addition, waste management and biomaterials strategies share hierarchical approaches, as 'cascading' biomaterials cycles are not too distant from the approach of the 'Waste Hierarchy' (see Mantau 2012; Vis et al. 2016; EEA 2018).

Finally, the most important innovation perspectives within the CE, especially in terms of economic value added, are those linked to biowaste/materials, like in the very dynamic sector of the 'green chemistry' (e.g. biopolymers, biochemical feedstock in cosmetics, etc.). In general, the overall objective of the CE to reach a total diversion of waste from landfills (in itself a bad use of land resources and then a cost to the bioeconomy) will bring back to the production system hundred million tons of materials, a large part of which are bio-waste/materials; this can reduce the pressure over land-based resources and virgin materials, and this can keep and enlarge the resource base for the Bioeconomy.

These sketched relationships in the NEXUS, although often mentioned, are neither fully understood nor systematically documented in their working and for their implications, and even less they are fully covered by consistent modelling/analytical tools. In addition, they are just partly considered in ex ante policy design and implementation in the three areas. The CE-DEC-BIO NEXUS can then represent a wide area of research to support industrial and public policy strategies.

7.3 Horizontal dimensions of the CE-DEC-BIO NEXUS

Four additional horizontal scoping elements can be added.

Firstly, the CE-DEC-BIO NEXUS has a global scope. The CE is, in general, 'inward looking' in terms of resources and this can have large implications by reducing the external dependence of Europe for materials and energy thus increasing its security of supply. This does not mean that there are no trade issues in the CE, also linking DEC and BIO in the NEXUS. Actually, the implementation of waste/CE policies of the past created large imbalances in domestic supply and demand of waste materials (treatment and recycling capacity, different pace of landfill policies, etc.) thus generating increasing trade flows of waste materials for recycling and energy recovery, both intra and extra-EU (see ETC/WMGE,

65 See the results of the H2020 project 'ISAAC' on biogas in Italy, http://www.isaac-project.it/

2017a; Mazzanti and Zoboli 2013; EEA 2012). The large international trade system of wood residues for recycling and energy production, the flows of waste for incineration (energy) and recycling to Germany, and the flows of WEEE and plastic waste to China and Asia are well known examples of consequences of both CE and DEC strategies. However, they can be seen as possibly 'transitional' in certain phases of the CE and RES policies, with dramatic changes accelerated by, for example, the recent Chinese ban on plastic waste import, which is creating a strong pressure on the plastic recycling sector in the EU (see ETC/WMGE 2019). In general, the development of the CE can change international trade of resources, materials, and products (e.g. through re-use, re-manufacturing, sharing), making Europe more reliant on domestic resources. This can also raise economic issues on relative domestic vs foreign costs and prices, and then the role of policies in balancing possible cost dis-advantages for Europe.

A second horizontal element of the CE-DEC-BIO NEXUS can be innovation. CE-oriented innovations, in the framework of the 'New Innovation-intensive CE' (see Section 6), can influence the link between the CE and DEC by, for example, changing the pay-off of material recycling compared to energy recovery, or by improving the energy efficiency of recycling/recovery processes (or re-use and re-manufacturing), or by making available for energy recovery materials that are now directed to disposal in landfills. Innovations in the CE can change the links with the Bioeconomy, by, as mentioned above, giving very high value added to poor waste materials through green chemistry, or by facilitating the recovery of food before wasting (e.g. conservation technologies), or by reducing material losses in the food producing industries and in agriculture, or by increasing the durability of biomaterials in different use areas. More in general, if the CE is seen as an 'Innovation System' (see Section 6), the NEXUS can provide a good additional key to identify the relevant components of the system, e.g. the actors, the policy channels, the economic flows.

A third horizontal dimension is policy integration. There are not robust tools and systematic exercises of checking ex ante the implication of, for example, DEC policies for the CE and the Bioeconomy, and vice versa. Even less developed is the state ex post policy assessment, both in general, and in particular for the implications of a certain policy on other policy areas, with possible 'externality' mechanisms. Policy consistency analysis can be better done outside the policy making arena. It can require, in an evolving way, different types of analytical instruments, from qualitative approaches to integrated assessment and modelling tools. The NEXUS approach can provide a framework to make policy integration analysis circumscribed and focused mainly on major connections and links. It can then avoid the ambition of assessing the whole complexity of a policy/strategy while allowing policy makers to have a specific window for ex ante and ex post assessment of 'external' consequences and implications. This can pave the way to 'internalisation' of the external effects.

A fourth horizontal dimension is, as mentioned, the need of analytical tools able to represent the inter-sectoral linkages of the CE. While a NEXUS approach, by focusing on major linkages, can 'economize' with respect to full and detailed inter-sectoral tools, like

Environmentally Extended Input Output data and models, nonetheless more advanced tools allowing to see the waste system integrated within the material flow system of the economy, and both waste and materials flows integrated in the inter-industry system of relationships are still needed. The NEXUS approach can stimulate and catalyse these advancements.

8 Open and emerging issues

The present emphasis on the CE as a sort of 'self-regenerative economy for free' seems to hide a number of well-known issues and potential barriers to the CE arising in the economics of waste and recycling. While these issues and barriers seem to belong to the 'old' CE, they are actually persisting in the 'new' CE (see also Massarutto (2019) for a very good discussion on the economics of the CE). At the same time, there are new opportunities for the (old and new) CE coming from the evolving attitudes of the financial sector.

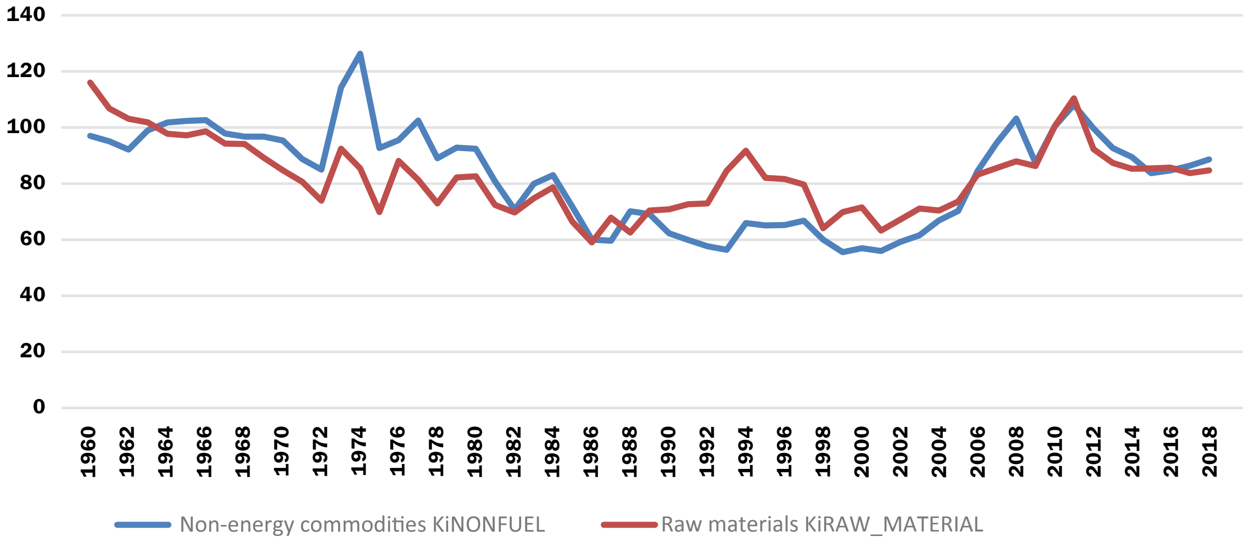
We present below arguments on the need to carefully consider the economic, legal, and financial sides of the CE transition.

8.1 Prices, costs-benefits, taxes, consumers

One of the fundamental barriers to develop a CE is the phase of low price of material resources and commodities. Non-fuel and raw materials real-price indexes of the World Bank (Figure 8.1) clearly show that the level in 2018 is, in spite of a recovery during the 2000s, well below the level of 1960. Markets by themselves do not provide scarcity signals to support the closing-the-loop of materials (and energy) and to implement resource efficiency as a response to resource scarcity. This implies that the burden of developing the CE is assigned to policies, industrial innovation opportunities, and people choices and behaviours.

Waste and recycling policies has been largely based on 'command and control' approaches and regulatory tools associated to policy targets adoption. Even though these policies of 'command and control' have triggered a large number of CE achievements and industrial innovations, the areas of major CE success have been those subject to the application of 'economic instruments', like EPR-based policies (see Part 1, Section 2 and 4), while landfill taxes adopted in many countries (see EEA 2016a) also had a role in triggering the closure of the material loops.

Figure 8.1. Indexes of real prices of non-energy commodities and raw materials



Source: own elaborations on World Bank data

In general, however, the economics of waste/recycling markets and industries is not well understood, and transparent public information on these markets is scant: many waste flows and secondary materials are still exchanged at 'negative prices' (the waste 'owner' pays for delivering the waste) or very low positive prices in incomplete-information markets, which makes the economics of the recycling industries - and even the circulation of economic values within the EPR-based 'compliance schemes' (distribution effects) - far from being clear in many cases. The lack of systematic sources of information on the main micro-economic dimensions of the 'Closing Materials Loop' of the CE (costs and prices) can prevent from more effective policies and even from understanding the economic potential of many industrial inventions/innovations in the 'New CE'.

A recurrent proposal to create incentives to resource saving and to boost recycling/reuse has been the introduction of material resource taxation. Mirroring the economics arguments in favour to carbon taxation in climate change policies, a resource tax is expected to restore the 'right price' when market price does not reflect the 'true scarcity' of the resource. A resource taxation policy has been proposed by a number of authors (for example Barker et al., 2011; Baumol, 2010; Ekins et al., 2009).

A thorough analysis has been carried out by ETC/SCP et al. (2015) that question whether a tax on resources is an appropriate instrument to achieve the desired material efficiency. A first issue is the phase to be taxed (extraction, input of the material at the first industrial use, and final consumption of products embodying the material). The tax effects actually can differ according to the level of the value chain at which it is introduced because of the different innovation options and material-demand strategies industrial actors can take, different demand elasticity to price (and then to the tax), market power, and innovation possibilities prevailing at different levels of the chain.

Furthermore, to achieve a reaction from industrial users or consumers, tax rates need to be sufficiently high. The case studies in ETC/SCP et al. (2015) actually show that resources/materials have rather low price elasticity of demand – material resource costs often only constitute a small part of the overall cost. This would suggest high tax rates that, however, might cause considerable economic changes, adaptation costs, and opposition from stakeholders.

Even when protecting the domestic taxation schemes by means of Border Tax Adjustments (BTA), it is not easy to envisage a unilateral European-level or country-level tax on a single material resource: a unilateral tax raises the risk of cross-material substitution effects with uncertain resource and environmental implications. A global multilateral extraction tax on all non-renewable non-energy resources, however, could be considered.

Among the emerging issues associated to the CE is the consumer protection. Especially in the broader perspective to the CE, which includes longer life of goods and new CE business models - including 'products as services, rents of materials, the sharing economy, the repair economy - there are mounting issues in defining the property rights (to own and to use), the contracts, and guaranty/insurance aspects in a way that protect the consumer. These issues apply also to waste in that the collection and treatment chains are based on principles and definition (e.g. the same definition of 'waste') that can be challenged in the CE (see Micklitz 2019; Keirsbilck and Terryn 2019; De Franceschi 2018).

8.2 Production capacity, investments, finance

Developing the 'Old' and the 'New' CE needs investments in capacity creation, R&D, and innovative start-up businesses.

In the 'Old CE', in some sectors/countries there has been a fundamental mismatch between the domestic increasing 'preparation for recycling' (separate and dedicated collection) and the creation of domestic recycling/recovery/reuse industrial capacity. This has been at the root of a capacity map in which some countries in Europe have an excess capacity (e.g. Germany) and others with lacking capacity, thus giving rise to the increasing international trade of waste for recycling and hazardous waste (see for example ETC/WMGE 2017a). A dramatic example is plastic waste, for which the EU-level increase in domestic collection met an insufficient (largely non-economic) domestic demand for recycling; this created huge flows of plastic wastes towards China and Asia, which in 2018 introduced bans on import thus putting in disarray the EU plastics sector (see ETC/WMGE 2019).

Industrial capacity for the development of the 'Old CE' has a public policy side, given that a large part of waste collection and treatment capacity is still in the hands of the public sector in many European countries (including Italy), and has a private business side, given that the recycling industry (be it specialised or part of manufacturing industries) is largely made of private enterprises. Public and private investments, to be undertaken, require social and economic pay-offs and need financial resources in any case. In addition, investments in an 'Innovation-intensive New CE' can require a specific allocation within R&I funding, as illustrated in Section 6, especially if the perspective to the CE is a broad one (the 'outer circle' in Figure 6.3) which corresponds to an 'innovation system' or a new industrial and consumption paradigm.

Differently from the low-carbon economy, for which there are estimates of the total financial needs and their distance from actual investments in Europe (see European Commission 2018d), it is very difficult to estimate the financial needs for the CE transition because it is made of (even small) investments across a wide range of heterogeneous industries. Even the data on 'CE lending' by the EIB can be considered as the results of re-classifications, in terms of CE, of lending operations inside a number of different sectors, among which 'Industry and Services' play an important role with 33% of the 2.1 billion/€ total CE lending in 2013-2017 (see Table 8.1).[66]

Table 8.1. Circular Economy lending by the European Investment Bank, 2013-2017, million € and share

Sector	CE lending 2013-2017 (€ m)	Share
Industry and services	706	**33%**
Water management	554	**26%**
Agriculture and bioeconomy	366	**17%**
Waste management	331	**16%**
Mobility	95	**5%**
Urban development	50	**2%**
Energy	14	**1%**
TOTAL	2,116	**100%**

Source: EIB 2019.

Therefore, on the financial side of CE investments, it is very important the complex process recently started by the European financial system to define 'circularity' as a basis for a preferential treatment in lending while taking, at the same time, a *de facto* discriminatory attitude towards lending to 'linear' businesses. This process can be seen in the general framework of the pathways to 'sustainable finance' and the policy leading to the EU Action Plan on Sustainability Finance of 2018[67]. This process mirrors, on the side of financing the CE, what is happening with the increasing concerns of the banking system about 'climate risk'.

The EIB is defining and adopting criteria for the selection of CE projects, and the EIB 2019 Circular Economy Guide (EIB 2019) aims at promoting: "a common understanding of the circular economy concept and related challenges and opportunities among the EIB's financial and project partners; raising awareness of and promote circular solutions among project promoters and other stakeholders; facilitating and harmonising due

66 *As a joint initiative with European Commission, the EIB set up in 2017 the Circular Economy Finance Support Platform "to promote the coordination and knowledge exchange amongst key CE stakeholders and implement concrete actions needed to enhance investments in the circular economy", https://eiah.eib.org › about › initiative-circular-economy*

67 *https://ec.europa.eu/info/publications/sustainable-finance-resources_en*

diligence of and reporting on circular economy projects by the EIB financial and project partners".

The eligibility of CE projects must fulfil 'circularity criteria' in screening and assessment, and a project is deemed to contribute to the circular economy if it falls under any of the following categories: 1 Circular design & production; 2 Circular use & life extension; 3 Circular value recovery; 4 Circular support. In addition, the project should be 'intentional' in the sense of having a clearly communicated intention to contribute to CE goals and objective. A list of CE project types that falls under one of the Circularity Categories (which will be regularly updated) is provided by the EIB.

The EIB assessment and screening criteria for the project based on CE business models are interesting and somewhat 'extreme'. For example, in 'leasing models', it must be demonstrated product/service life extension, and the return to the producer/provider after the first and the last cycle for respectively refurbishing and recovery. In the case of projects on second-hand assets, resource efficiency, recycling and energy recovery, the screening and assessment criteria require to reduce materials and to consider "recycling as a measure of last resort in a circular economy" (sic!). It is also interesting that, in the assessment of risk, not only the commercial risks, including security of supply, are to be considered but also the 'supply chain risks'.

In the private sector, the FinanCE Working Group has been created in 2014 by PGGM, the Dutch pension fund manager[68]. It produced 'Linear risks' (May 2018) and the 'Circular economy finance guidelines' (July 2018)[69]. 'Linear risks' are defined as "exposure to the effects of linear business practices" and are exemplified by companies that "use non-renewable resources, prioritise sales of new products [sic!], fail to collaborate, fail to innovate/adapt". The Linear Risks Matrix is presented in Figure 8.2. The next steps are to develop specific metrics to quantify linear risks and "incorporate tools such as the True Value Methodology to put a money value to linear risks".

68 The other mebers are and the members are: ABN Amro, Banco Intesa San Paolo, BNP Paribas, CDC, Circle Economy, Circularity Capital, Danish Business Authority, EBRD, EIB, Ellen Macarthur Foundation, ING, KPMG, PGGM, Rabobank, Sitra, Suez.

69 http://fintecc.ebrd.com/insight/insight-circular-economy-finance-guidelines; https://assets.kpmg/content/dam/kpmg/nl/pdf/2018/advisory/linear-risks.pdf; see also ABN Ambro (2018)

Figure 8.2. Linear Risk Matrix

Risk factors	Linear business practices			
	Utilise non RE resources	**Prioritise sales of news products**	**Fail to collaborate**	**Fail to innovate or adapt**
Market	Scarcity of primary resources	Bans on trade of waste	Limited opportunities to expand to new markets	Scarcity of primary resources
	Volatility of resources prices	Volatility of resources prices		Volatility of resources prices
Operational	International process failures	Worker safety issues	Supply chain inefficiencies	Inability to hire new talent
Business	Changing demand for sustainable solutions	Disruptive new business models	Disruptive new technologies	Discruptive new technologies
	Decreasing cost of renewables	Decreasing margin from commodisation		Disruptive new business models
Legal	Fines for legal violations	Regolament for extended producer responsibility	Fines for legal violations	More stringent environmental laws
	More stringent environmental laws			

Source: FinanCE Working Group

The Commission Expert Group on CE financing has been recently created to provide advice on how barriers to financing the CE could be removed. The Expert Group can create Multidisciplinary working groups, coordinated by the European Commission and EIB, based on 2019 EIB Guide and 2018 FinanCE WG Guidelines. It produced a set of recommendations in 'Accelerating the transition to the CE' (March 2019).

Another initiative that addresses finance for the CE is based on the project SCREEN, a Horizon 2020 project aimed at "a replicable systemic approach towards a transition to Circular Economy in EU regions within the context of the Smart Specialization Strategy, thus contributing to novel future eco-innovative and horizontal business models across different value chains."[70] The project is largely aimed at regions and then at the system of Structural Funds. The project also includes the definition of criteria for CE projects

Overall, the picture is very lively and quickly evolving. Even though it seems that criteria are already well-defined, there are still large uncertainties and knowledge needs to arrive to a sound system of standards, indicators, measuring and assessment tools. The issues raised by the financing of the CE are discussed in Goovaerts et al. (2018).

Another relevant area of work can emerge at the intersection between the finance for CE and the inclusion of climate risk in financing operations. The two are progressing as separated streams but they have large connection possibilities. Criteria for climate risk and criteria for CE finance may be also conflicting in specific areas, i.e. fully circular business/projects can be at climate risk. To understand connections and potential contradictions even on the financial side can be part of a NEXUS approach to the CE (see Section 7).

70 https://ec.europa.eu/easme/en/tags/screen; http://www.screen-lab.eu/

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Appendix 1

EU policy targets and objectives on waste ad resources, 2015-2050

1 TARGETS AND OBJECTIVES RELEVANT TO THE 2015-2050 PERIOD (UPDATED TO 31ST DECEMBER 2018)	
1a General	
Reference	**Target/objective + deadline and info**
COM(2011) 571, Roadmap to a Resource Efficient Europe	Waste is managed as a resource (2020)
COM(2011) 571, Roadmap to a Resource Efficient Europe	Achieve an absolute and per capita decline of waste generated (2020)
COM(2011) 571, Roadmap to a Resource Efficient Europe	Ensure high quality recycling (2020)
COM(2011) 571, Roadmap to a Resource Efficient Europe	Limit energy recovery to non-recyclable materials (2020)
COM(2011) 571, Roadmap to a Resource Efficient Europe	Virtually eliminate landfilling (2020)
COM(2011) 571, Roadmap to a Resource Efficient Europe	Eradicate illegal shipments of waste (2020)
Decision 1386/2013/EU (7th EAP)	Landfilling is limited to non-recyclable and non-recoverable waste (2020)
1b Reuse, recycling and recovery targets	
Reference	**Target/objective + deadline and info**
Directive 2000/53/EC, ELV Directive	Targets for end-of-life vehicles (by average weight per vehicle per year):
	reuse and recovery: 95%
	reuse and recycling: 85%
	(2015) FIN
Directive 2012/19/EU, WEEE Directive	WEEE, with reference to Annex I categories:
	cat. 1 or 10: 85% recovery and 80% recycling
	cat. 3 or 4: 80% recovery and 70% recycling
	cat. 2, 5, 6, 7, 8 or 9: 75% recovery and 55% recycling
	Gas discharge lamps: 80% recycling (2015) INT
Directive 2012/19/EU, WEEE Directive	WEEE, with reference to Annex IIII categories:
	cat. 1 or 4: 85% recovery and 80% reuse and recycling
	cat. 2: 80% recovery and 70% reuse and recycling
	cat. 5 or 6: 75% recovery and 55% reuse and recycling
	cat. 3: 80% recycling
	(2018) FIN
Directive 2008/98/EC, Waste Framework Directive	Recycling and reuse of 70% by weight of non-hazardous construction and demolition waste (2020)
Directive 2008/98/EC, Waste Framework Directive	Recycling and reuse of 50% by weight of paper, plastic, glass and metal from households (2020)
Directive 2008/98/EC, Waste Framework Directive, as amended by Directive 2018/851/EU	Increase the reuse and recycling of municipal waste to a minimum of 55% (2025) INT
Packaging Waste Directive 94/62/EC as amended by Directive 2018/852/EU	Increase the recycling rate of packaging waste to 65% (2025) INT
Packaging Waste Directive 94/62/EC as amended by Directive 2018/852/EU	Achieve minimum targets by weight for recycling regarding specific materials contained in packaging waste: (i) 50 % of plastic; (ii) 25% of wood; (iii) 70% of ferrous metal; (iv) 50% of aluminium; (v) 70% of glass; (vi) 75% of paper and cardboard (2025) INT
COM(2018)28, EU Strategy for plastics in a circular economy	All plastics packaging is either reusable or can be recycled in a cost-effective manner and more than half of plastics waste generated in Europe is recycled (2030)
COM(2018)28, EU Strategy for plastics in a circular economy	Sorting and recycling capacity of plastics has increased fourfold since 2015, leading to the creation of 200,000 new jobs, spread all across Europe (2030)

Directive 2008/98/EC, Waste Framework Directive, as amended by Directive 2018/851/EU	Increase the reuse and recycling of municipal waste to a minimum of 60% (2030) INT
Packaging Waste Directive 94/62/EC, as amended by Directive 2018/852/EU	Increase the recycling rate of packaging waste to 70% (2030) FIN
Packaging Waste Directive 94/62/EC, as amended by Directive 2018/852/EU	Achieve minimum targets by weight for recycling regarding specific materials contained in packaging waste: (i) 55 % of plastic; (ii) 30% of wood; (iii) 80% of ferrous metal; (iv) 60% of aluminium; (v) 75% of glass; (vi) 85% of paper and cardboard (2030) FIN
Directive 2008/98/EC, Waste Framework Directive, as amended by Directive 2018/851/EU	Increase the reuse and recycling of municipal waste to a minimum of 65% (2035) FIN
1c Collection and disposal	
Reference	**Target/objective + deadline and info**
Directive 2008/98/EC, Waste Framework Directive	Separate collection for glass, plastic, metal, paper (2015)
Directive 2006/66/EC on waste batteries and accumulators	Collection target for batteries: 45% (2016) FIN
Directive 1999/31/EC on landfills	Disposal of biodegradable municipal waste: reduction to 35% of total 1995 biodegradable municipal waste (2016) FIN
Directive 2012/19/EU, WEEE Directive	Collection target for WEEE: 45% of the average weight of EEE placed on the market in the three preceding years in the Member State concerned (2016) INT
Directive 2012/19/EU, WEEE Directive	Collection target for WEEE:
	65% of the average weight of EEE placed on the market in the Member State in the three preceding years or
	85% of WEEE generated in the Member State.
	(2019) FIN
Directive 2008/98/EC, Waste Framework Directive, as amended by Directive 2018/851/EU	Bio-waste shall be either separated and recycled at source, or is collected separately and is not mixed with other types of waste (2023 – end)
Landfill Directive 1999/31/EC, as amended by Directive 2018/850/EU	Member States shall endeavour to ensure that as of 2030, all waste suitable for recycling or other recovery, in particular in municipal waste, shall not be accepted in a landfill, with the exception of waste for which landfilling delivers the best environmental outcome.
Landfill Directive 1999/31/EC, as amended by Directive 2018/850/EU	Ensure that the amount of municipal waste landfilled is reduced to 10% of the total amount of municipal waste generated (2035)
1d Products and product making	
Reference	**Target/objective + deadline and info**
Directive 2011/65/EU on the restriction of the use of certain hazardous substances in EEE	No heavy metals (Pb, Hg, Cd, hexavalent Cr, PBB and PBDE) in vitro medical devices (2016)
Directive 2011/65/EU on the restriction of the use of certain hazardous substances in EEE	No heavy metals (Pb, Hg, Cd, hexavalent Cr, PBB and PBDE) in industrial monitoring and control instruments (2017)
Directive 2011/65/EU on the restriction of the use of certain hazardous substances in EEE	No heavy metals (Pb, Hg, Cd, hexavalent Cr, PBB and PBDE) in all electrical and electronic equipment not covered by the previous Directive 2002/95/EC (2019)
Directive 94/62/EC on packaging and packaging waste,as amended by Directive 2015/720/EU	Reduction in the consumption of lightweight plastic carrier bags (2018 – 2025)[71]

71 *The measures taken by Member States shall include either or both of the following: the adoption of measures ensuring that the annual consumption level does not exceed 90 lightweight plastic carrier bags per person by 31 December 2019 and 40 lightweight plastic carrier bags per person by 31 December 2025, or equivalent targets set in weight. Very lightweight plastic carrier bags may be excluded from national consumption objectives; the adoption of instruments ensuring that, by 31 December 2018, lightweight plastic carrier bags are not provided free of charge at the point of sale of goods or products, unless equally effective instruments are implemented. Very lightweight plastic carrier bags may be excluded from these measures.*

1e SCP and resource efficiency	
Reference	**Target/objective + deadline and info**
COM(2011)571, Roadmap to a Resource Efficient Europe	Disposal of edible food waste should be halved (2020)
2 TARGETS/OBJECTIVES IN LEGISLATIVE PROPOSALS (PRESENTED BUT NOT YET ADOPTED BY 31st DECEMBER 2018)	
Reference	**Target/objective + deadline and info**
Proposal for a Directive on the reduction of the impact of certain plastic products on the environment, COM(2018)340[72]	Member States shall take the necessary measures to collect separately, by 2025, an amount of waste single-use plastic products listed in Part F of the Annex equal to 90% of such single-use plastic products placed on the market in a given year by weight.
Proposal for a Directive on the reduction of the impact of certain plastic products on the environment, COM(2018)340[73]	Member States shall take the necessary measures to achieve a significant reduction in the consumption of the single-use plastic products listed in Part A of the Annex on their territory by … [six years after the end-date for transposition of this Directive].
4 MAIN LEGISLATION IN FORCE AND POLICY DOCUMENTS, NOT SETTING ANY TARGET/OBJECTIVE, RELEVANT TO THE WASTE POLICY AREA AND INTERNATIONAL AGREEMENTS	
The environmental theme 'Waste and resources' is regulated and addressed by several pieces of environmental legislation and policy documents not setting any target/objective, including the following:	
Policy documents: Commission Communication COM(2005)666, Thematic Strategy on the prevention and recycling of waste; Commission Communication COM(2005)670, Thematic Strategy on the sustainable use of natural resources; Commission Communication COM(2008)767, An EU strategy for better ship dismantling; and Commission Communication COM(2017)334, The role of waste to energy in the circular economy.	
Environmental legislation in force: Sewage Sludge Directive 86/278/EEC; Directive 96/59/EC on the disposal of PCBs and PCTs; Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues; Directive 2006/21/EC on the management of waste from the extractive industries; Regulation (EC) No 1013/2006 on shipments of waste.	
It is also worth noting that some multilateral (or international) environmental agreements to which the EU and/or most of its Member States are parties, as well as the related protocols, are relevant to 'Waste and resources', although they fall outside the scope of this research work. These include, for instance, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (A: 22.03.1989; E.F.: 05.05.1992; ratified by the EU).	
Also the UN Sustainable Development Goals (SDGs) address waste and resources, particularly SDG 12: 'Ensure sustainable production and consumption patterns'.	

Note: Green rows represent non binding objectives, while pink rows represent binding targets. Targets/objectives are listed in chronological order of the deadlines for implementation. When provided with the same deadline for implementation, objectives are listed first, followed by targets. 'INT' means 'interim target'; 'FIN' means 'final target'.

Source: Paleari and Reichel, 2019.

72 *Based on the final compromise text adopted by the European Parliament and the Council in January 2019, the following targets/objectives have been established: 1) Member States shall achieve a measurable quantitative reduction in the consumption of Annex A single use plastic products (e.g. cups for beverage) by 2026, compared to 2022; 2) with regard to single use plastic products listed in Annex C (i.e. beverage containers with a capacity up to three liters): a) from 2025, PET bottles shall contain at least 25% recycled plastic, calculated as an average for all PET bottles placed on the market on the territory of that Member State; b) from 2030, beverage bottles shall contain at least 30% recycled plastic, calculated as an average for all beverage bottles placed on the market on the territory of that Member State; 3) the following separate collection targets for recycling shall be achieved with regard to single use plastic products listed in Annex C (i.e. mainly beverage bottles with a capacity of up to three liters, including their caps and lids, but the exclusion of plastic and beverage bottles that have caps and lids made from plastic): a) 77% by weight by 2025; b) 90% by weight by 2029.*

73 *See previous footnote.*

Appendix 2

Projects on 'circular economy' funded within Horizon 2020

From CORDIS database, keyword 'circular economy' in the title, information at 24 December 2018

acronym	title	startDate	totalCost	call	coordinator
CIRCUSOL	Circular business models for the solar power industry	2018-06-01	8255590	H2020-CIRC-2017TwoStage	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.
SmartShip	A data analytics, decision support and circular economy – based multi-layer optimisation platform towards a holistic energy efficiency, fuel consumption and emissions management of vessels	2019-04-01	1472000	H2020-MSCA-RISE-2018	DANAOS SHIPPING COMPANY LIMITED
ReTraCE	Realising the Transition to the Circular Economy: Models, Methods and Applications	2018-11-01	4039862	H2020-MSCA-ITN-2018	THE UNIVERSITY OF SHEFFIELD
CICERONE	CIrCular Economy platfoRm for eurOpeaN priorities strategic agEnda	2018-11-01	2027611,3	H2020-SC5-2018-1	EIT CLIMATE-KIC SL
Smartmushroom	Smart MAnagement of spent mushRoom subsTrate to lead the MUSHROOM sector towards a circular economy	2018-08-01	3002793,8	H2020-EIC-FTI-2018-2020	ASOCIACION PROFESIONAL DE PRODUCTORES DE SUSTRATOS Y HONGOS DE LA RIOJA NAVARRA Y ARAGON
EFFECTIVE	Advanced Eco-designed Fibres and Films for large consumer products from biobased polyamides and polyesters in a circular EConomy perspecTIVE	2018-06-01	11869648	H2020-BBI-JTI-2017	AQUAFILSLO PROIZVODNJA POLIAMIDNIH FILAMENTOV IN GRANULATOV DOO
CircuBED	Circular Built Environment Design - Applying the Circular Economy to the Design of Social Housing	2018-06-01	195454,8	H2020-MSCA-IF-2017	CARDIFF UNIVERSITY
CINDERELA	New Circular Economy Business Model for More Sustainable Urban Construction	2018-06-01	7635365,3	H2020-CIRC-2017TwoStage	ZAVOD ZA GRADBENISTVO SLOVENIJE

Project O	Project Ô: demonstration of planning and technology tools for a circular, integrated and symbiotic use of water	2018-06-01	10692938	H2020-CIRC-2017TwoStage	IRIS SRL
RECODE	Recycling carbon dioxide in the cement industry to produce added-value additives: a step towards a CO2 circular economy	2017-08-01	7904415	H2020-SPIRE-2017	FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA
AMBIENCE	disruptive capturing and revalorisation system of AMmonia for Blogas plants ENhancing Circular Economy	2018-08-01	71429	H2020-SMEInst-2018-2020-1	INGENIERIA Y DESARROLLOS RENOVABLESSOCIEDAD LIMITADA
cPET	Tackling the global plastic waste issue, by upcycling no value streams into 100% virgin material and enabling new plastic circular economy	2018-09-01	71429	H2020-SMEInst-2018-2020-1	GR3N SAGL
CABRISS	Implementation of a CirculAr economy Based on Recycled, reused and recovered Indium, Silicon and Silver materials for photovoltaic and other applications	2015-06-01	9266682,7	H2020-WASTE-2014-two-stage	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES
MOGU floor	Natural-Grown Flooring for Circular Buildings	2018-10-01	2147570	H2020-SMEInst-2018-2020-2	MOGU SRL
Madaster	Towards a circular economy: Eliminate waste through an open platform that facilitates material passports	2017-05-01	3539089,2	H2020-SMEINST-2-2016-2017	MADASTER SERVICES BV
SYSTEMIC	Systemic large scale eco-innovation to advance circular economy and mineral recovery from organic waste in Europe	2017-06-01	9723586,3	H2020-CIRC-2016TwoStage	STICHTING WAGENINGEN RESEARCH
R2PI	TRANSITION FROM LINEAR 2 CIRCULAR: POLICY AND INNOVATION	2016-11-01	3013475	H2020-CIRC-2016OneStage	COLLABORATING CENTRE ON SUSTAINABLE CONSUMPTION AND PRODUCTION GGMBH
CIRCULAR IMPACTS	Measuring the IMPACTS of the transition to the CIRCULAR economy	2016-10-01	501280	H2020-SC5-2016-OneStageB	ECOLOGIC INSTITUT gemeinnützige GmbH
NextGen	Towards a next generation of water systems and services for the circular economy.	2018-07-01	11389106	H2020-CIRC-2017TwoStage	KWR WATER B.V.

RECYSMART	SMART CONTAINER AND BIG DATA PLATFORM TO INCREASE PACKAGING RECYCLING RATES AND BOOST THE CIRCULAR ECONOMY	2018-06-01	71429	H2020-SMEInst-2018-2020-1	RE-CIRCULA SOLUTIONS SL
SCREEN	Synergic Circular Economy across European Regions	2016-11-01	1771865	H2020-CIRC-2016OneStage	REGIONE LAZIO
LOOWATT	European Expansion for Circular Economy Off-Grid Toilets	2016-06-01	71429	H2020-SMEINST-1-2016-2017	LOOWATT LTD
PresConfLuxDec	Innovative Enterprise Conference on Circular Economy and Access to Risk Finance	2015-10-19	226810	H2020-Adhoc-2014-20	TEAM WORK
Mucky	MUCKY: The circular solution for the valorisation of mixed municipal waste streams.	2015-07-01	71429	H2020-SMEINST-1-2015	BI-ENERGY BV
TyRec process	TyRec process: Whole Tyre Recycling within 30 Minutes with Molten Zinc – towards a circular economy	2015-06-01	71429	H2020-SMEINST-1-2014	COMPOSITE RECYCLING LIMITED
ERIFORE	Research Infrastructure for Circular Forest Bioeconomy	2016-01-01	2630950	H2020-INFRADEV-1-2014-1	Teknologian tutkimuskeskus VTT Oy
Mubic	Mushroom and biogas production in a circular economy	2015-04-01	71429	H2020-SMEINST-1-2014	ADVANCED SUBSTRATE TECHNOLOGIES AS
HOUSEFUL	Innovative circular solutions and services for new business opportunities in the EU housing sector	2018-05-01	8535247,5	H2020-CIRC-2017TwoStage	ACONDICIONAMIENTO TARRASENSE ASSOCIACION
C-SERVEES	Activating Circular Services in the Electric and Electronic Sector	2018-05-01	8034707,3	H2020-CIRC-2017TwoStage	AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS
ReCiPSS	Resource-efficient Circular Product-Service Systems	2018-06-01	8833302,1	H2020-CIRC-2017TwoStage	KUNGLIGA TEKNISKA HOEGSKOLAN
C-VoUCHER	Circularize ValUe CHains across European Regional Innovation Strategies	2018-04-01	5210220,6	H2020-INNOSUP-01-2017-twoStage	FUNDINGBOX ACCELERATOR SP ZOO
PAPERCHAIN	New market niches for the Pulp and Paper Industry waste based on circular economy approaches	2017-06-01	9217196,2	H2020-CIRC-2016TwoStage	ACCIONA CONSTRUCCION SA

PolyCE	Post-Consumer High-tech Recycled Polymers for a Circular Economy – PolyCE	2017-06-01	9452964,6	H2020-CIRC-2016TwoStage	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
CIRC-PACK	Towards circular economy in the plastic packaging value chain	2017-05-01	9252466,3	H2020-CIRC-2016TwoStage	FUNDACION CIRCE CENTRO DE INVESTIGACION DE RECURSOS Y CONSUMOS ENERGETICOS
ECOBULK	Circular Process for Eco-Designed Bulky Products and Internal Car Parts	2017-06-01	12153947	H2020-CIRC-2016TwoStage	EXERGY LTD
FiberEUse	Large scale demonstration of new circular economy value-chains based on the reuse of end-of-life fiber reinforced composites.	2017-06-01	11943964	H2020-CIRC-2016TwoStage	POLITECNICO DI MILANO
EMBRACED	Establishing a Multi-purpose Biorefinery for the Recycling of the organic content of AHP waste in a Circular Economy Domain	2017-06-01	17334554	H2020-BBI-JTI-2016	Fater S.p.A.
ERA-MIN 2	Implement a European-wide coordination of research and innovation programs on raw materials to strengthen the industry competitiveness and the shift to a circular economy	2016-12-01	16058787	H2020-SC5-2016-OneStageB	FUNDACAO PARA A CIENCIA E A TECNOLOGIA
CRESTING	CiRcular Economy: SusTainability Implications and guidING progress	2018-01-01	3854797,6	H2020-MSCA-ITN-2017	UNIVERSITY OF HULL
CircEuit	Circular European Economy Innovative Training Network	2016-09-01	3995643,2	H2020-MSCA-ITN-2016	UNIVERSITEIT LEIDEN
CarE-Service	Circular Economy Business Models for innovative hybrid and electric mobility through advanced reuse and remanufacturing technologies and services	2018-06-01	7722365,8	H2020-CIRC-2017TwoStage	CONSIGLIO NAZIONALE DELLE RICERCHE
TRENSCRYBE	TRapped ENSembles of Circular RYdBErg atoms for quantum simulation	2018-11-01	2240000	ERC-2017-ADG	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS
FORCE	Cities Cooperating for Circular Economy	2016-09-01	11308118	H2020-WASTE-2015-two-stage	KOBENHAVNS KOMMUNE

BAMB	Buildings as Material Banks: Integrating Materials Passports with Reversible Building Design to Optimise Circular Industrial Value Chains	2015-09-01	9933112,1	H2020-WASTE-2014-two-stage	INSTITUT BRUXELLOIS POUR LA GESTION DE L ENVIRONNEMENT-BRUSSELS INSTITUUT VOOR MILIEUBEHEER
CIRC4Life	A circular economy approach for lifecycles of products and services	2018-05-01	7228773,8	H2020-CIRC-2017TwoStage	THE NOTTINGHAM TRENT UNIVERSITY
Circular Agronomics	CIRCULAR AGRONOMICS - Efficient Carbon, Nitrogen and Phosphorus cycling in the European Agri-food System and related up- and down-stream processes to mitigate emissions	2018-09-01	7032749	H2020-SFS-2017-2	INSTITUT DE RECERCA I TECNOLOGIA AGROALIMENTARIES
NEMO	Near-zero-waste recycling of low-grade sulphidic mining waste for critical-metal, mineral and construction raw-material production in a circular economy	2018-05-01	14941397	H2020-SC5-2017-TwoStage	Teknologian tutkimuskeskus VTT Oy
R3FIBER	Eco-innovation in Composites Recycling for a Resource-Efficient Circular Economy	2018-03-01	71429	H2020-SMEINST-1-2016-2017	THERMAL RECYCLING OF COMPOSITES, SOCIEDAD LIMITADA
PRS	PRS, a disruptive technology for the industrial repair of large series of reusable plastic articles in the circular economy	2018-02-01	71429	H2020-SMEINST-1-2016-2017	PLASTIC REPAIR SYSTEM 2011 SL
CELION	Circular Economy applied to LI-ION batteries for smart electric mobility in cities	2017-12-01	71429	H2020-SMEINST-1-2016-2017	ALBUFERA E-POWER SL
IDEAL-CITIES	Intelligence-Driven Urban Internet-of-Things Ecosystems for Trustworthy and Circular Smart Cities	2018-07-01	1611000	H2020-MSCA-RISE-2017	FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS
CE-IOT	A Framework for Pairing Circular Economy and IoT: IoT as an enabler of the Circular Economy circularity-by-design as an enabler for IoT (CE-IoT)	2018-07-01	1692000	H2020-MSCA-RISE-2017	ECOLE NATIONALE DES PONTS ET CHAUSSEES
CLIC	CLIC - Circular models Leveraging Investments in Cultural heritage adaptive reuse	2017-12-01	4957033	H2020-SC5-2017-OneStageB	CONSIGLIO NAZIONALE DELLE RICERCHE

MUBIC	Mushroom and biogas production in a circular economy	2017-08-01	4185022,5	H2020-SMEINST-2-2016-2017	ADVANCED SUBSTRATE TECHNOLOGIES AS
PLUG-N-HARVEST	PLUG-N-play passive and active multi-modal energy HARVESTing systems, circular economy by design, with high replicability for Self-sufficient Districts Near-Zero Buildings	2017-09-01	6896147,5	H2020-EEB-2017	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS
PlastiCircle	Improvement of the plastic packaging waste chain from a circular economy approach	2017-06-01	8674540,9	H2020-CIRC-2016TwoStage	INSTITUTO TECNOLOGICO DEL EMBALAJE, TRANSPORTE Y LOGISTICA
ZERO BRINE	Re-designing the value and supply chain of water and minerals: a circular economy approach for the recovery of resources from saline impaired effluent (brine) generated by process industries	2017-06-01	11081973	H2020-CIRC-2016TwoStage	TECHNISCHE UNIVERSITEIT DELFT
Water2REturn	REcovery and REcycling of nutrients TURNing wasteWATER into added-value products for a circular economy in agriculture	2017-07-01	7129322,5	H2020-CIRC-2016TwoStage	BIOAZUL
SCARCE	Sustainable Chemical Alternatives for Re-use in the Circular Economy	2017-04-01	1499655,9	ERC-2016-STG	CRANFIELD UNIVERSITY
BRINE MINING	Applying circular economy solutions in industrial wastewater management: request of SME Associate to develop the necessary energy simulation tools for recovery of waste heat from industrial operations	2017-09-01	82000	H2020-INNOSUP-02-2016	SEALEAU BV
RESYNTEX	A new circular economy concept: from textile waste towards chemical and textile industries feedstock	2015-06-01	11432356	H2020-WASTE-2014-two-stage	SOEX TEXTIL-VERMARK-TUNGSGESELLSCHAFT MBH VERMARKTUNGSGE-SELLSCHAFT MBH
	Total		**345545745**		

Appendix 3

Institutes of the Italian National Research Council (CNR) doing research on materials, industrial technologies, and bio-based sectors

Istituto	CDS	Città
Istituto dei materiali per l'elettronica ed il magnetismo (IMEM)	052.000	Parma
Istituto di Biomembrane, Bioenergetica e Biotecnologie Molecolari (IBIOM)	015.000	Bari
Istituto di biochimica delle proteine (IBP)	007.000	Napoli
Istituto di biofisica (IBF)	008.001	Genova
Istituto di bioimmagini e fisiologia molecolare (IBFM)	009.000	Segrate
Istituto di Biologia Cellulare e Neurobiologia (IBCN)	117.000	Monterotondo Scalo Roma
Istituto di biologia e biotecnologia agraria (IBBA)	012.000	Milano
Istituto di biologia e patologia molecolari (IBPM)	013.000	Roma
Istituto di Bioscienze e Biorisorse (IBBR)	041.000	Bari
Istituto di biostrutture e bioimmagini (IBB)	017.000	Napoli
Istituto di chimica biomolecolare (ICB)	019.000	Pozzuoli
Istituto di chimica dei composti organo metallici (ICCOM)	020.000	Sesto Fiorentino
Istituto di chimica del riconoscimento molecolare (ICRM)	021.000	Milano
Istituto di Chimica della Materia Condensata e di Tecnologie per l'Energia (ICMATE)	031.000	Padova
Istituto di cristallografia (IC)	027.000	Bari
Istituto di fisica applicata "Nello Carrara" (IFAC)	032.000	Sesto Fiorentino
Istituto di fisica del plasma "Piero Caldirola" (IFP)	033.000	Milano
Istituto di fotonica e nanotecnologie (IFN)	036.001	Milano
Istituto di informatica e telematica (IIT)	044.000	Pisa
Istituto di matematica applicata e tecnologie informatiche "Enrico Magenes" (IMATI)	050.000	Pavia
Istituto di metodologie per l'analisi ambientale (IMAA)	055.000	Tito Scalo
Istituto di Nanotecnologia (NANOTEC)	054.005	Lecce
Istituto di Ricerca su Innovazione e Servizi per lo Sviluppo (IRISS)	071.000	Napoli
Istituto di Ricerca sulla Crescita Economica Sostenibile (IRCRES)	067.000	Moncalieri
Istituto di ricerca sulle acque (IRSA)	069.000	Monterotondo Stazione
Istituto di scienza e tecnologia dei materiali ceramici (ISTEC)	073.000	Faenza
Istituto di scienze delle produzioni alimentari (ISPA)	077.000	Bari
Istituto di scienze e tecnologie molecolari (ISTM)	079.000	Milano
Istituto di Sistemi e Tecnologie Industriali Intelligenti per il Manifatturiero Avanzato (STIIMA)	103.000	Milano
Istituto di struttura della materia (ISM)	087.000	Roma
Istituto gas ionizzati (IGI)	037.000	Padova
Istituto motori (IM)	058.000	Napoli
Istituto Nanoscienze (NANO)	115.000	Pisa
Istituto nazionale di ottica (INO)	111.000	Firenze
Istituto officina dei materiali (IOM)	114.000	Trieste
Istituto per i Polimeri, Compositi e Biomateriali (IPCB)	119.000	Pozzuoli
Istituto per i processi chimico-fisici (IPCF)	063.000	Messina
Istituto per i sistemi agricoli e forestali del mediterraneo (ISAFoM)	084.000	Ercolano
Istituto per i Sistemi Biologici (ISB)	053.000	Monterotondo
Istituto per il sistema produzione animale in ambiente Mediterraneo (ISPAAM)	083.000	Napoli

Istituto per la Protezione Sostenibile delle Piante (IPSP)	121.000	Torino
Istituto per la sintesi organica e la fotoreattività (ISOF)	082.000	Bologna
Istituto per la tecnologia delle membrane (ITM)	097.000	Rende
Istituto per la valorizzazione del legno e delle specie arboree (IVALSA)	106.000	Sesto Fiorentino
Istituto per le macchine agricole e movimento terra (IMAMOTER)	049.000	Cassana
Istituto per le tecnologie della costruzione (ITC)	101.000	San Giuliano Milanese
Istituto per lo studio dei materiali nanostrutturati (ISMN)	095.000	Monterotondo Stazione
Istituto per lo studio delle macromolecole (ISMAC)	096.000	Milano
Istituto superconduttori, materiali innovativi e dispositivi (SPIN)	113.000	Genova

Source: own selection on information from https://www.cnr.it/it/istituti

The **Fondazione Eni Enrico Mattei (FEEM)**, founded in 1989, is a non profit, policy-oriented, international research center and a think-tank producing high-quality, innovative, interdisciplinary and scientifically sound research on sustainable development. It contributes to the quality of decision-making in public and private spheres through analytical studies, policy advice, scientific dissemination and high-level education. Thanks to its international network, FEEM integrates its research and dissemination activities with those of the best academic institutions and think tanks around the world.

Fondazione Eni Enrico Mattei
Corso Magenta 63, Milano – Italia

Tel. +39 02.520.36934
Fax. +39.02.520.36946

E-mail: letter@feem.it
www.feem.it

FEEM
FONDAZIONE ENI
ENRICO MATTEI