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Report

# Energy and the Circular Economy: Filling the gap through new business models within the EGD

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# Energy and the Circular Economy: Filling the gap through new business models within the EGD

FONDAZIONE ENI ENRICO MATTEI

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# Aknowledgments

The report has been produced within a cooperation agreement between FEEM and SEEDS – Sustainability, Environmental Economics, and Dynamics Studies[1]. The research work has been coordinated by Stefano Pareglio (FACTS Program Scientific Coordinator at FEEM). The report has been coordinated by Roberto Zoboli (Catholic University and SEEDS) and Massimiliano Mazzanti (University of Ferrara and SEEDS), and has been written by Laura Bonacorsi (FEEM), Elisa Chioatto (University of Ferrara and SEEDS), Alessio D’Amato (University of Rome Tor Vergata and SEEDS), Claudia Ghisetti (Catholic University and SEEDS), Mario A. Maggioni (Catholic University), Massimiliano Mazzanti (University of Ferrara and SEEDS), Susanna Paleari (IRCrES-CNR), Emy Zecca (University of Ferrara and SEEDS), Roberto Zoboli (Catholic University and SEEDS).

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The responsibility on what presented in the report is to be attributed only to the authors.

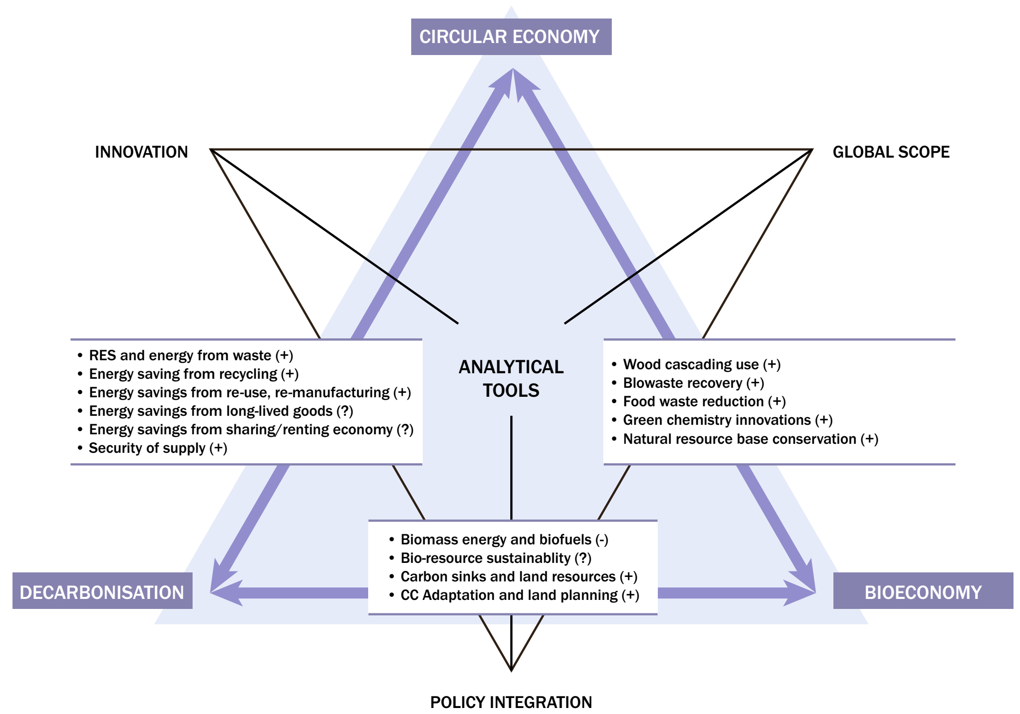
1 SEEDS is an inter-university research centre that gathers the competencies in environmental economics and policy of researchers from eight Italian Universities (University of Ferrara, Catholic University, University of Bologna, University of Rome 3, University of Rome Tor Vergata, University of Udine, University of Urbino, and University of Siena), http://www.sustainability-seeds.org/

# 01 Introduction and key conclusions

The FEEM report 2019 (Zoboli et al. 2019) proposed to embed the Circular Economy (CE) into a broader NEXUS framework, in which the relationships between the CE transition, the decarbonization transition, and the bioeconomy transition have to be considered in sustainability transition strategies (see Figure 1.1).

In this report, the focus is on the CE-Decarbonisation nexus, in particular the energy-CE links, taking into consideration also those links to the bioeconomy that can be relevant for the energy-CE link.

**Figure 1.1 The CE. decarbonization, bioeconomy NEXUS**




**Source: Zoboli et al. 2019**

We will highlight how, in spite of the very broad policy vision emerging from the European Green Deal (EGD) and the continuously increasing industrial interest for the CE, there are still missing, or not completely deployed, links between CE and energy/ decarbonization. In particular, there are missing links within the EU policy framework, in which legislation on CE and energy/climate are still delinked. The wide range of specific strategies triggered by the EGD, including the new EU Circular Economy Action Plan 2020 (EC 2020c), are going towards a deeper integration between CE and energy/decarbonization, and this can provide new opportunities. At the same time, the CE-related new business models are more and more holistic and flexibly encompass the CE-energy/decarbonizations links. In this framework, the energy industry is undertaking broad strategies for the CE that emphasize these links and move in the direction of integrated business models.

The report first presents the CE-energy/decarbonizations links. Then it takes stock of the evolving policy framework for these links. The other sections address the CE-energy/decarbonizations links in the energy industry, also presenting the range of initiatives of some major players, and the CE measurement at the company level.

## Key conclusions

- **Key conclusion 1:** The CE can save large amounts of energy in 'closing the material loops' (recycling), but the net effects of business models in the 'slowing down' and 'narrowing' resource loops (e.g. sharing economy) can be uncertain depending on technologies or systemic effects. Energy production within the CE loops is still much based on virgin biomaterials, which can have more values in innovative non-energy uses (e.g. green chemistry), while the production of energy from waste arising from 'closing the loops' is limited.
- **Key conclusion 2:** Before the EGD, there is a weak integration between energy and the CE within the EU legislation. The EU-level definitions of CE criteria for funding businesses suffers for a 'material circularity' bias, which gives little attention to energy production from CE loops. However, CE and energy are increasingly connected within the EGD.
- **Key conclusion 3:** The concepts of CE and 'CE business models' are increasingly holistic. Direct surveys indicate that this approach prevails in practice and firms adopt CE strategies that involve materials and energy co-production in an integrated way.
- **Key conclusion 4:** The energy industry shows a mounting interest in the CE, both as an internal management practice and as a source of new market opportunities. Approaches and initiatives from major market players are heterogeneous and largely based on the appropriation of specific innovative businesses.
- **Key coclusion 5:** The measurement of CE inside the companies is still challenging, and this issue must be addressed in front of the future adoption of 'CE criteria' by European policies and the financial system.
- **Key conclusion 6:** The development of 'integrated' CE-energy business models can be needed to get the opportunities arising from the increasing CE-energy integration expected from the EGD.

# 02 Circular Economy and energy

***Key conclusion: The CE can save large amounts of energy in 'closing the material loops' (recycling), but the net effects of business models in the 'slowing down' and 'narrowing' resource loops (e.g. sharing economy) can be uncertain depending on technologies or systemic effects. Energy production within the CE loops is still much based on virgin biomaterials, which can have more values in innovative non-energy uses (e.g. green chemistry), while the energy production from waste arising from 'closing the loops' is limited.***

## 2.1 Energy efficiency and saving from the CE

The energy and GHG emissions savings from the CE can be seen at the three nested levels of the CE proposed by Bocken et al. (2016) (see also OECD 2017, and Zoboli et al. 2019):

*Closing the resource loops* The first level is the (increasing) 'closure of the use loops' of resources (waste and materials) through the (increasing) degree of material recycling and energy recovery from waste, and the increase of materials and products reuse, also after 're-manufacturing' of complex products or their parts (e.g. in the automotive sector).

*Slowing down resource loops* The second level of circularity is about 'slowing down' the use-loops of resources (materials), and it is mainly about the useful life of products. This level of CE is at the boundaries of, or even involves, the 'sharing and renting economy' and similar organizational innovations that can intensify the use of goods/capitals and give them a longer life.

*Narrowing resource flow* The third level of the CE is the 'narrowing' of resource flows through a higher efficiency of resource use, which can be based on innovation and behavioral change. It 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.

**Energy and carbon-emission savings from 'closing the loops'**

There is robust evidence that closing the loop of materials, in particular through recycling, can save resources, energy and emissions with respect to production from primary resources.

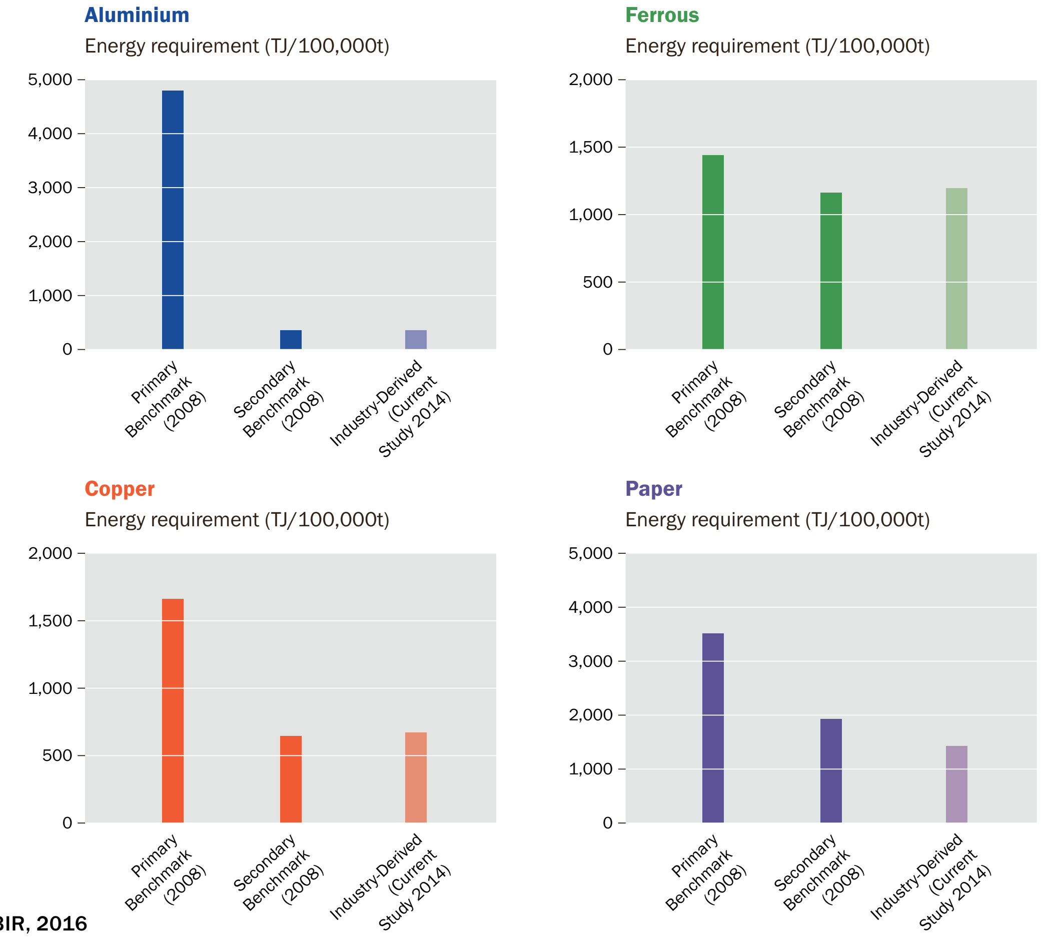
In a report by BIR (2016), based on detailed methodologies and industrial information, the energy and GHG savings are measured for aluminium, copper, ferrous metals and paper production.

In the case of aluminium, the energy and carbon footprint savings achieved by recycling with respect to the primary production would be, for 100,000 tons, 4,434TJ in energy and 627kt$CO_2$e in $CO_2$ emissions, respectively.

In the case of copper, for 100,000 tons, estimated savings are 1033TJ in energy and 146kt$CO_2$e in $CO_2$ emissions, respectively. In the case of ferrous metals production, for 100,000 tons, savings are 206TJ in energy and 29kt$CO_2$e in $CO_2$ emissions, respectively.

Finally, in the case of paper, for 100,000 tons, savings are estimated 1,979TJ in energy and 280kt$CO_2$e in $CO_2$ emissions, respectively (Figure 2.1). Scaling these unit savings to the worldwide secondary production of the three metals gives a total savings of 572 million tons of $CO_2$ (Figure 2.2).

**Figure 2.1 Energy savings from secondary production with respect to primary production in aluminium, copper, ferrous metals and paper**




**Source: BIR, 2016**

**Figure 2.2 Energy and CO2 savings from the secondary production of aluminium, copper, and ferrous metals**

| Material | Energy Savings (achieved by industry against Primary Benchmark) (TJ/100,000t) | Annual Worldwide Secondary Production* | Estimated Savings in Annual $CO_2$ Emissions (Mt) |
|---|---|---|---|
| Aluminium | 4434 | 18 | 63.3 |
| Copper | 1033 | 6 | 4.8 |
| Ferrous | 206 | 580 | 503.9 |
| Total Estimated Savings in Annual $CO_2$ Emissions for the Production of the Secondary Metal Studied (Current Study) | | | **572.0** |

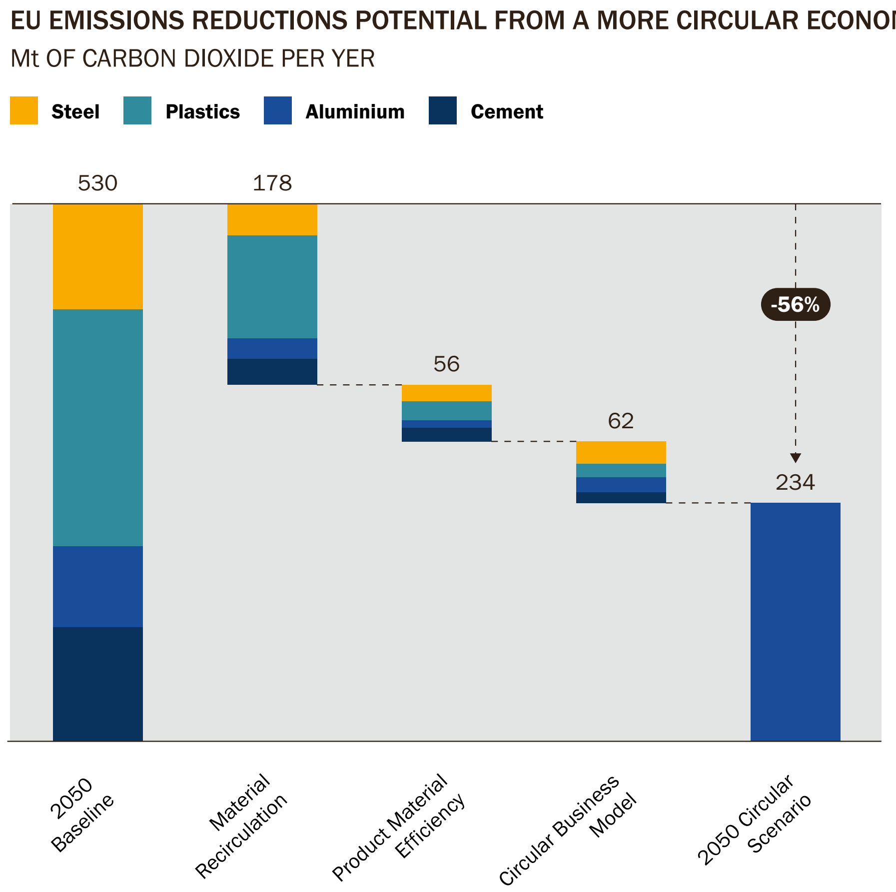
* Annual worldwide secondary production (Mt) as quoted in 2014 for Aluminium and 2013 for Copper and Ferrous

**Source: BIR, 2016**

Even though these materials already have high rates of recycling, there are additional potential energy/$CO_2$ savings from futher developing the recycling chains. For example, in the case of aluminium, large quantities are currently in stock and will be available for recycling in future. Globally, the increase of new capacity of primary aluminium is low, but the demand for secondary aluminium processing is expected to grow. At present, around 20% of the aluminium demand worldwide is covered by old scrap. Major sources of aluminium scrap are construction and demolition, transport and automotive machinery, mechanical engineering, electrical appliances and packaging.

According to Material Economics (2018) "*a more circular economy can make deep cuts to emissions from heavy industry: in an ambitious scenario, as much as 296 million tonnes $CO_2$ per year in the EU by 2050, out of 530 in total – and some 3.6 billion tonnes per year globally*" (see Figure 2.3). This potential can be achieved mainly by material re-circulation opportunities (recycling) and by material efficiency, especially in the use sectors.

**Figure 2.3 Emission reduction potential from more CE in selected industries**




**Source: Material Economics, 2018**

Waste management, and in particular recycling, can be a relevant source of energy savings compared to other resource-efficient solutions. According to the European Commission (2016), at the EU level "*enhanced recycling efforts as part of waste management suggest the largest identified CED [cumulative energy demand] reduction potentials, as high as 3 500 PJ annually. Reducing food waste offers strong potential for energy savings, too, calculated here with up to 2 000 PJ per year. Savings from the food sector might be even higher if a broader set of measures were envisaged, including, for example, reduced meat consumption. Reducing CED by nearly as much, technical and behavioural changes in the water sector could account for up to 1 700 PJ per year and annually 73 000 Mm3 of saved water. On the other end of the spectrum, though still contributing to an overall potential CED reduction, minimal CED reductions are offered through improvements in WEEE recycling in the ICT sector (up to 1.4 PJ per year) and through integrated aquaculture (0.5 PJ per year).*" (Table 2.1).

**Table 2.1 Summary of main quantitative results (CED, CRD and water savings) in specific sectors, goods and industrial symbioses**

| Case study | CED reduction (PJ/yr) | CRD reduction (1000 t/yr) | Water ($Mm^3$/yr) |
|---|---|---|---|
| Waste management: additional recycling | 2,900 - 3,500 | | |
| Domestic water sector: irrigation and industry sectors including behavioural changes | 1,060 - 1,700 | | 73,000 |
| Domestic water sector, irrigation and industry sectors: excluding behavioural changes | 360 - 685 | | 64,300 |
| Road construction - reclaimed asphalt | 254 | 56,000 | 0.1 |
| Buildings - clinker optimisation in building concrete | 104 | 11,000 | 0 |
| Building - increased wood construction | 484 | 439,000 | 0.5 |
| Building - reduced new-building construction | 619 | 495,000 | 0.9 |
| Buildings - increased building rehabilitation and lifetime | 60 | 48,000 | 0.7 |
| Modal shift in urban transport | 510 | 7,800 | 19 |
| ICT: Thin / zero clients | 8 | 4,092 | n.a. |
| ICT: Recycling plastics from WEEE | 1.4 | 23 | n.a. |
| Food waste | 1,000 - 2,000 | | 4.7 |
| Integrated aquaculture | 0.5 | | |
| Ferrous sector | 290 | | |
| Industrial symbiosis for by-products and reused components for computer manufacturing | 21 | | |
| Industrial symbiosis for fermentation residues from biogas plants as raw material for the woodworking industry | 1 | | |

**CED = cumulative energy demand; CRD = cumulative raw-material demand**

**Source: EC, 2016**

**Energy and carbon savings from 'slowing down' and 'narrowing' the loops**

It is generally demonstrated that a longer life of goods in use can save environmental resources, although the net benefits can be uncertain in some cases.

Shorter lifespan of goods can create 'inter-temporal excess consumption'. If the 'technical' life of a computer is 5 years, and rapid innovation brings its economic/social obsolescence life to 4 years (-20%), the increase of goods production and waste needed to keep a constant stock in use is +25%. As a consequence, longer life can be environmentally beneficial. According to Truttmann and Rechberger (2006), to have a constant stock of 1.000 washing machines (WM), each year 100 new WMs must enter the process "Use", and 100 WMs must leave it to waste (10-years product life). Increasing lifetime to 15, with 5-years reuse with the same stock of 1.000 WMs, reduces the number of WMs to 67 produced and wasted each year (1.000 in stock divided by 15 years of product life). The energy implication is that the system without reuse consumes 22,000 GJ in 15 years, while reuse reduces this consumption to 19,900GJ (−10%).

ETC/WMGE (2020) reports that, based on Bakker and Schuit (2017) "*Extending product lifetimes usually leads to environmental benefits, because it saves the energy and resources that would otherwise be consumed in manufacturing new products*" and, according to the EEB (2019) "*extending the lifetime of all washing machines, smartphones, laptops and vacuum cleaners in the EU by one year would lead to annual savings of around 4 million tonnes of carbon dioxide by 2030, which is equivalent to taking over 2 million cars off the roads for a year*". From the same studies "*a 1-year lifetime extension of all smartphones in Europe would save 2.1 million tonnes of carbon dioxide per year by 2030: in other words, a reduction of the overall carbon footprint from smartphones of 31 per cent, the equivalent of taking more than 1 million cars off the road for a year*" (EEB, 2019). Other results suggest that "*with one-year extension of a smartphone's lifetime, 27 per cent of its primary energy consumption could be saved along with 29 per cent of its water consumption*" (Benton et al., 2015).

The results of a UN Environment's review of lifecycle assessment (LCA) studies suggest that "*washing machines and refrigerators should be used for at least 10 years before they are replaced with a more energy-efficient models, while vacuum cleaners, mobile phones and laptops are typically replaced prematurely and should be used for longer, although it is difficult to suggest an exact replacement moment for these products.*"

Referring to Prakash et al. (2016, in German), the ETC/WMGE reports that "*an LCD television with a ten-year lifetime consumes 28 per cent less energy demand and has a 25 per cent lower global warming potential than a television with a short lifetime (5.6 years) over a 10-year reference period. Over the given study period of 10 years, televisions with long lifetimes produce almost 600 kilograms less carbon dioxide than the short lifetime televisions.*"

The higher energy and emission efficiency of new products can be compensated for by the impact of a quicker turnover and a shorter life of goods on resource use and waste.

A case in point can the be car scrappage schemes implemented in many countries, which increase the average energy/emission efficiency of car stock but reduce its average age by accelerating scrappage. According to Wee et al. (2000): "*reducing the age of the current car feet may result in an increase of life-cycle $CO_2$ emissions. This will probably also be true for cars to be produced in future unless the fuel efficiency of new cars improves much faster than the historical trend indicates*". Similarly, according to Kim et al. (2004), "*From a life cycle perspective, the emissions from both the additional vehicle production and scrapping need to be addressed when evaluating the benefits of scrapping older vehicles. According to the simulation results, accelerated scrapping policies are generally recommended to reduce regulated emissions, but they may increase greenhouse gases*".

Kagawa et al. (2013) use an input-output approach to quantify $CO_2$ emission in the car scrapping phase in Japan and conclude: "*the $CO_2$ emissions resulting from the disposal of passenger cars is 58 kg $CO_2$-eq/vehicle. Since $CO_2$ emission associated with vehicle production is 6.426 kg $CO_2$-eq/vehicle, the $CO_2$ emission associated with vehicle production and the disposal for passenger cars is 6.500 kg $CO_2$-eq/vehicle in Japan*". In the case of Italy, referring to the scrappage scheme of 2009, Marin and Zoboli (2019) estimate that 485k additional cars were produced to respond to the net demand increase, and this caused a total additional about 2 million tons of emissions of $CO_2$-equivalent. These results suggest that the possible energy and emission benefits from stock renovation can be weighted against the effects of a shorter life of goods.

According to Material Economics (2018), new circular business models in mobility and buildings, in particular sharing, can save 62 Mt $CO_2$-eq per year by 2050 by making greater use of vehicles and buildings, which together represent a majority of European demand for steel, cement and aluminium. In the 'circular scenario' of Material Economics, the materials input to mobility can fall by 75%.

However, the net energy and emission effects of the sharing-based business models are ambiguous in theory and very uncertain in practice.

Recently, Ranjbari et al. (2018) produced a systematic review of the papers published on the Sharing Economy (SE) from 2013 to 2018 (Web of Science, Scopus and Google Scholar). The environmental and sustainability dimension of the SE is cited in almost a quarter of the definitions (15 out of 67), and, in the period considered, there has not been a year in which at least one published paper did not cite the environmental implications of the SE in terms of resource efficiency and pollution reduction. For example, for Muñoz and Cohen (2017) the objective of the SE is to augment the efficiency and the optimization of underutilized resources. Similar conclusions are suggested by different studies that suggest a positive environmental outcome through a longer duration of goods (for example Demailly and Novel, 2019) and higher utilization rates (Cho, Park e Kim, 2017). Firnkorn e Müller (2011), referring to the case of Car2go in Germany, conclude that this platform has positive effects on $CO_2$ emissions and land consumption. Schor e Fitzmaurice (2015) claim that the future expansion of the SE will increase the environmental sustainability of economic processes.



However, other researchers arrive at the opposite conclusion and suggest there can be a net increase in resource consumption, as a result of a 'sustainability paradox'. In particular, according to Verboven and Vanherck (2016), there is "*a contradiction between the visible positive effects of a sustainable business model and the less visible or disregarded negative externalities. This is the case of the 'rebound effects' that are always associated to the transition from an old to a new model of production, both in terms of individual behaviours and at the level of macro and systemic consequences*". They define the rebound effect as "*a collateral not intentional effect that takes place when efficiency is improved, and this brings to a price reduction that causes use and consumption to be higher than before*". In general, following Demailly and Novel (2014) and Bocken et al. (2014), in the case of the SE, there is a rebound effect when sharing reduces the price of a good or service and this cause an increase in consumption. Actually, while the SE seems to cause lower demand for goods, the actual outcome will depend on the elasticity of demand and supply. Therefore, there is not a clear-cut effect also on the environmental and resource side.

According to EEA (2019) "*An expansion in the mobility-sharing sector will decrease negative environmental pressures because of the reduced number of individual vehicles and consumption of fossil fuels (McKinsey, 2017; Thomä et al., 2018). However, according to analyses by the International Energy Agency of the links between energy, transport and digital technologies, the overall environmental and climate implications are rather ambiguous. For example, under a best-case scenario of improved efficiency through automation and ride-sharing, road transport energy use could halve compared with current levels. Conversely, if efficiency improvements do not materialize and rebound effects from automation result in substantially more travel, energy use could more than double (Kamiya et al., 2018).*"

In addition, "*More sharing economy companies, such as Uber, Lyft and Airbnb, are expected in the future. These companies' platform-based business models are probably some of the most disruptive innovations of the past two decades. Whether they lead to environmental benefits, however, cannot be stated unequivocally because of potential rebound effects. An analysis of San Francisco, for example, concludes that companies such as Uber and Lyft are the biggest contributors to growing traffic congestion (Erhardt et al., 2019). Between 2010 and 2016, hours of delay during the week increased by 62% compared with 22% in the absence of these companies, based on a counterfactual scenario*".

## 2.2 Energy production from CE loops

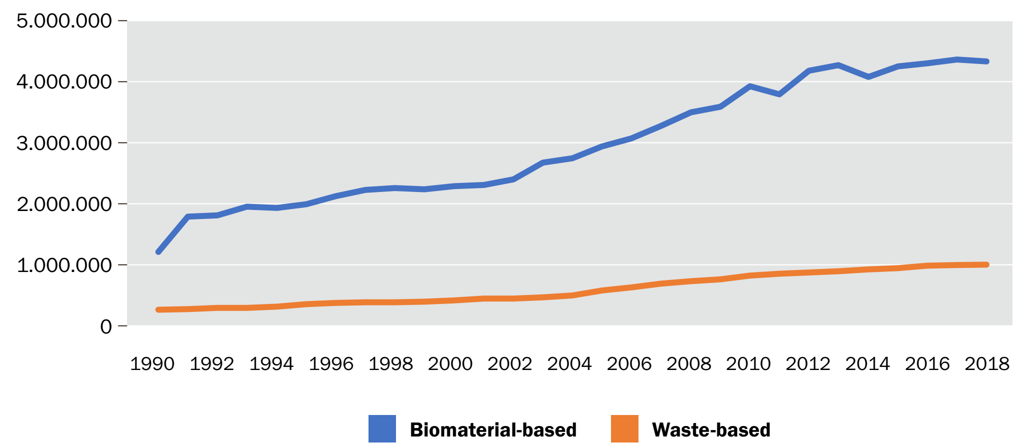
**Too much energy from virgin biomass (and too little from waste?)**

Closing the material loops within the CE paradigm can produce a significant flow of energy feedstocks and energy production within industrial and consumption/post-consumption value chains.

However, a major trend in Europe in the last two decades has been the fast-growing production of energy from bio-based feedstock. Even though materials classified as 'waste' from agroforestry activities contribute to this trend, the most part of these bio-materials have the features of virgin biomass (e.g. fuelwood, virgin wood residues). At the same time, the contribution of properly defined 'waste' from closed-loops of materials (households and industry) to energy production grew less, and it is still a minor source. This can be the combined results of very strong incentives to renewables to achieve the ambitious EU policy targets in a short time, which found in the biomass sector a fertile ground, and of the imprinting of EU Waste Hierarchy that gives priority to material recovery from waste.

The trend of energy production from bio-based and waste-based feedstock from 1990 to 2018 in the EU27 (without the UK) is presented in Figure 2.4. While waste-based energy production increased significantly from the early-2000s, the growth trend for bio-based energy production has been very strong. In 2018, the production from bio (about 4,4 million/terajoule) was about 4,6 times the production from waste. A very strong trend in using virgin bioresources for energy took place in the biofuel sector (Figure 2.5). This happened on lands and crops that can have a food use and with production techniques whose sustainability and emission balances stimulated the concerns of the European Commission, as suggested by the requirements embodied in the most recent EU directive on RES. The same concerns are addressed by the EU Biodiversity strategy of 2020.

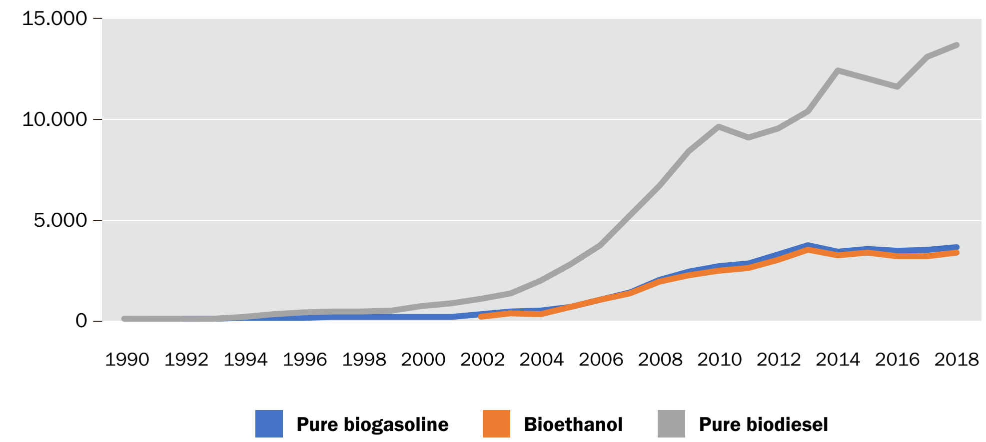
**Figure 2.4 Domestic production of energy from bio-based and waste-based feedstock, EU27, 1990-2018, Terajoule**




**Bio-based feedstock: 'Fuelwood, wood residues and byproducts' and 'Biogases'; Waste-based feedstock: 'Renewable fraction of industrial waste'; 'Industrial waste (non-renewable)'; 'Renewable municipal waste'; 'Non-renewable municipal waste'.**

**Source: own elaboration on Eurostat data**

**Figure 2.5 Domestic production of biofuels, EU27, thousand tons**



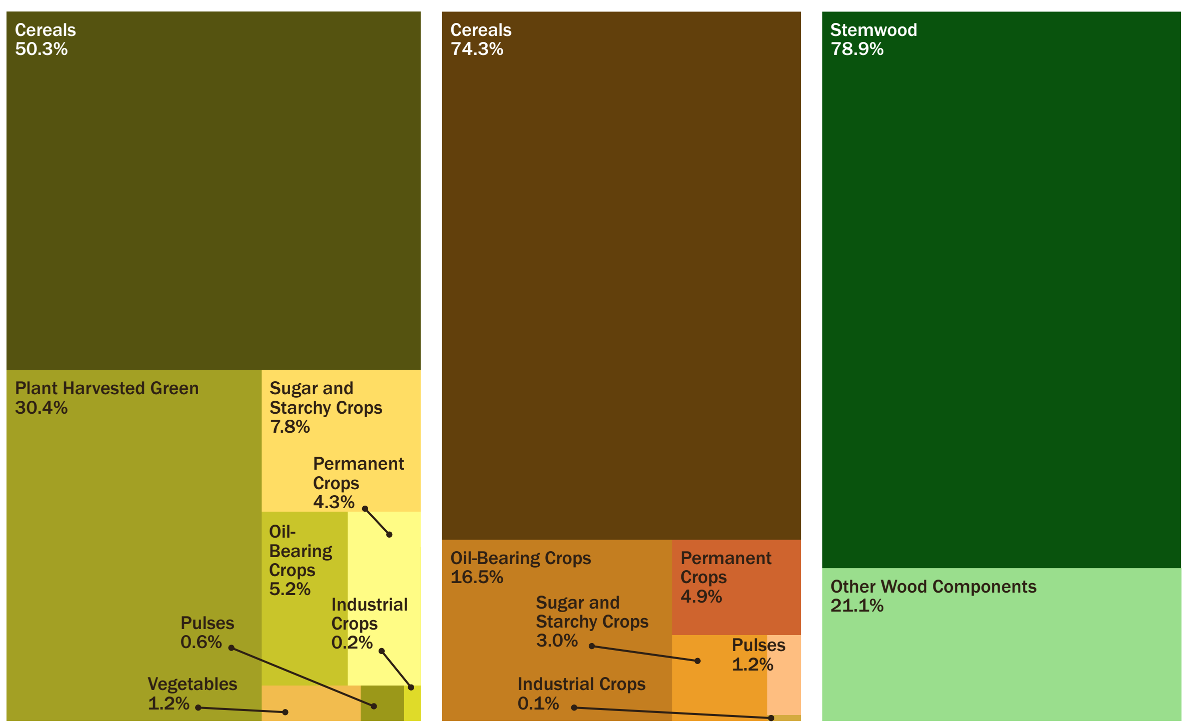

**Source: own elaboration on Eurostat data**

While accepting the EU Waste Hierarchy principle on the priority to be assigned material recovery, is the dominance of, and the policy in favour to, energy production from virgin biomass with respect to energy from waste, justified?

### Giving value to virgin bioresources

The European potential for biomass is huge, but subject to sustainability concerns. Data from Camia et al. (2018) indicate that, in front of annual 540 million/tons of crop production, there are 420 million/tons of bio-residues, and 510 million/tons of wood production (Figure 2.6). This potential from agricultural resdues is largely unexploited or wasted, whereas in some sectors, in particular wood residues, there is a high demand pressure coming from the combination of industrial and subsidized energy demands. Over one-third of primary biomass sourced from forests in Europe is directly used to produce energy (EEA 2018).

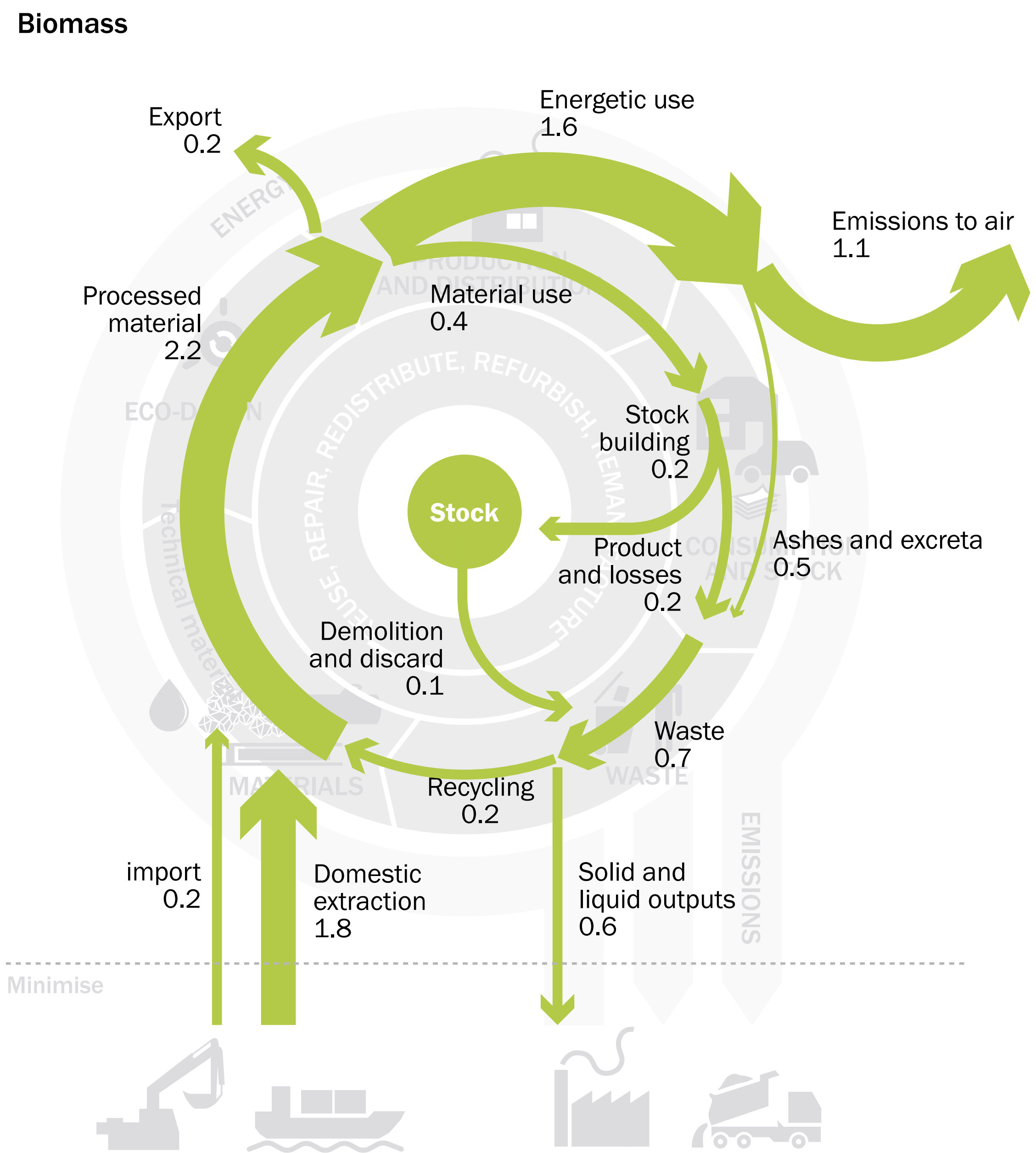
Figure 2.6 EU-28 annual biomass production from land-based sectors, excluding pastures (10-year averages, Mt dry matter)




Source: Camia et al. 2018

Looking at the material flow of biomass in the EU elaborated by the EEA (2018), it is clear that biomass is too much wasted or used in low-value processes. Energy use is 72% of total uses, and four times the material use, with large emissions. Recycling is just 28% of total waste and just 11% of extraction from nature. Non-recycled waste is twice the import, and about 38% of domestic extraction (Figure 2.7).

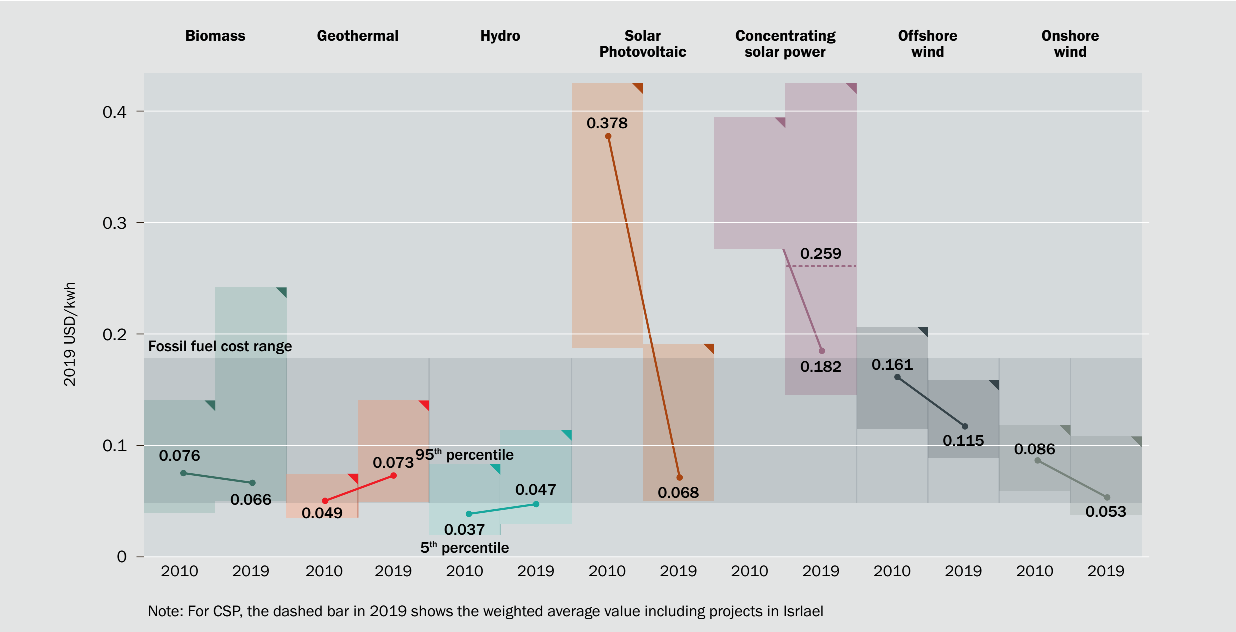
Figure 2.7 Biomaterial flows through the EU economy, gigatonnes per year, 2014




Source: EEA 2018

The economic and environmental misallocation of virgin biomass resources is worsened by the fact that energy production from biomass has low rates of innovation. A crucial factor for the future of renewable energies is their 'learning curves', which relate the unit cost of the energy produced to the market penetration rate or the capacity installed. According to IRENA (2020), electricity from biomass is cheap with respect to fossil-based production, which can explain its quick response to incentive-based policies of the last decades, but it has weak 'learning curves', whereas other technologies have better performances (Figure 2.8).

**Figure 2.8 Learning curves in renewable-based electricity production**




*Note: This data is for the year of commissioning. The thick lines are the global weighted-average LCOE value derived from the individual plants commissioned in each year. The project-level LCOE is calculated with a real weighted average cost of capital (EWACC) is 7.5% for OECD countries and China and 10% for the rest of the world. The single band represent the fossil fuel-fired power generation cost range, while the bands for each technology and year represent the 5th and the 95th percentile bands for renewable projects.*

**Note: Global weighted average levelised cost of electricity from utility-scale renewable power generation technologies, 2010 and 2019**

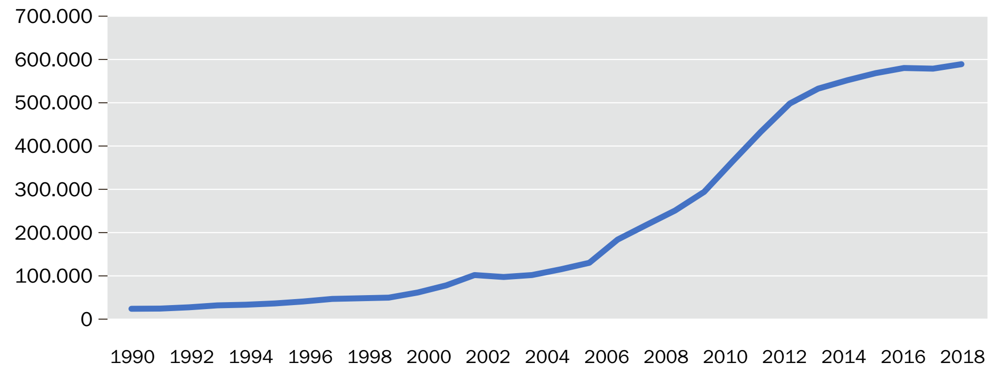
**Source: IRENA, 2020**

Further, within energy production from biomass, the use of biowaste can be better than using virgin biomass. A case in point is biogas, which boomed in the EU during the last few decades, passing from about 20.000 terajoules of 1990 to about 590.000 terajoules in 2019 (Figure 2.9). The result of the Horizon 2020 project ISAAC[2] clearly shows that better economic and environmental results arise for those biogas plants that use agricultural residues and biowaste (e.g. manure), and not dedicated crops. In this framework, a relevant development is the creation of biogas/biomethane plants based on bio municipal waste, once the NIBY syndrome is faced with well-designed participatory processes of the local population. An example is presented in the Box.

2 See http://www.isaac-project.it/wp-content/uploads/2017/07/D6.2-Methodological-report-on-the-socio-economic-analysis.pdf



**Figure 2.9 Biogas production in the EU27, 1990-2019, terajoule**




**Source: our elaboration on Eurostat data**

**Biogas/biomethane from municipal waste in Italy**

The Acea Pinerolese plant (Pinerolo, Italy) is a biowaste treatment facility based on the integration of aerobic and anaerobic digestion processes.
The plant consists of four sections: two for solid biowaste treatment by aerobic and anaerobic digestion, a section for waste water treatment and a landfill area equipped for biogas collection.
Biogas production at the facility exceeds the plant's own energy consumption, generating a net yield of electricity for the grid and for heat, which is used in nearby residential areas (Morone et al., 2017).
Operational costs are covered by, in almost equal parts, tipping fees and sales of the derived power and heat.
Work has also started for turning the plant into a biorefinery producing biogas and added-value chemicals, based on compost hydrolysate for use in fertilizers (Montoneri and Mainero, 2016)
**http://www.isaac-project.it/en/**

At the same time, significant developments are expected to take place in green chemistry, including bio-based plastics, that can give value especially to virgin biomaterials. The production capacity for bio-based platform chemicals is expected to grow faster than for bio-based plastics. After the 1st generation feedstock (sugar cane or oilseed plants), there is a growing industrial interest in non-food 2nd and 3rd generation renewable feedstock, that is wood residues, dairy, fruit and vegetable by-products, waste streams and algae the are abundant and low cost.

**Integrated business models including energy: Biorefineries**

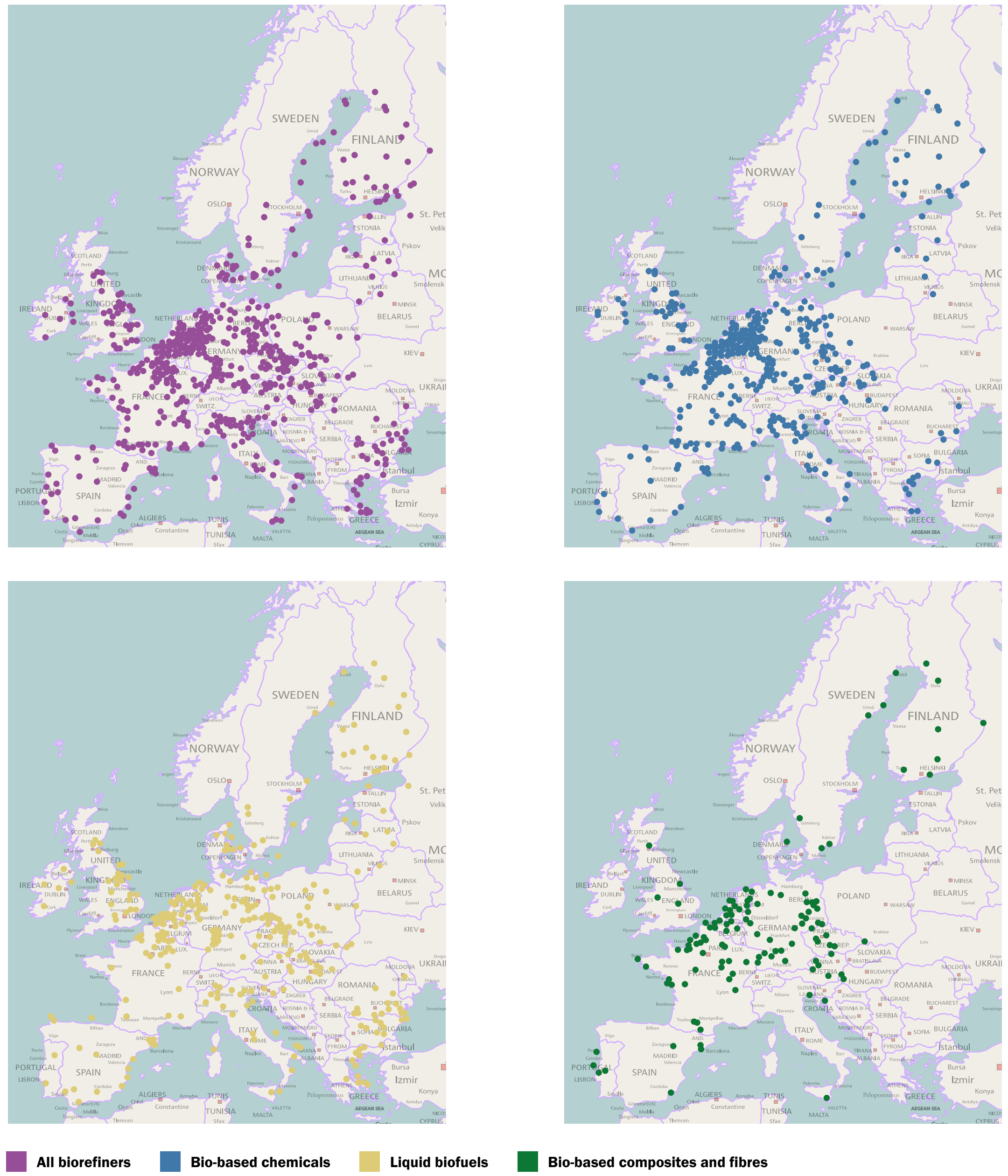
Biorefinery plants process a variety of bio-based raw materials, residues and waste in highly integrated and resource-efficient processes. They provide the opportunity for joining bio- and circular economy principles, especially when using 2nd-generation feedstocks from outside the food and feed sector (harvest residues and biowaste) (Figure 2.10).

According to the BIO-TIC project, by 2030 in the EU the scenario is for 310 biorefineries: 185 for 2nd generation ethanol, 50 for bio-based jet fuel, 30 for bio-based chemical building block and 45 for bio-based plastics[3]. A report by OECD indicates that in order to make the

3 The bioeconomy enabled - A roadmap to a thriving industrial biotechnology sector in Europe (2015) http://www.industrialbiotech-europe.eu/wp-content/uploads/2015/08/BIO-TIC-roadmap.pdf

industrial bioeconomy a success, the number of biorefineries, both in the United States and Europe, would have to be increased to between 300 and 400[4].

**Figure 2.10 Biorefineries in the EU in 2018**




*Biorefineries distribution in the EU as of March 2018. Purple dots indicate all biorefineiries (803 in total) Blue dots indicate the 507 biorefineries producing bio-based chemicals, Yellow dots indicate the 363 biorefineries producing liquid biofuels and the green dots indicvates the 141 biorefineries producing bio-based composites and fibres. It has to be noted that some biorefineries produce more than one product category and are thus shown in more than one map. Dots in lighter colour in three last figures indicate taht are currently inactive (but not necessarily as permanent status). Most birefineries correspond with location of chemical industry clusters and location of ports. Highest density of facilities is in Belgium, Netherland and some highly industrialised regions of Germany, France and Italy. Source: Parisi, C. 2018. Research Brief on biorefineries distribution in the EU. Joint Research Centre.*

**Source: BIOTIC project**

4 OECD (2018), http://dx.doi.org/10.1787/9789264292345-en



**Aquatic biorefinery**

An aquatic biorefinery is based on aquaculture and includes marine, freshwater and dryland fisheries, and the algae industry. In addition to producing resources for the food and feed industries, aquaculture can also provide aquatic biomass for other industries and end uses, such as the production of biofuels, chemicals and nutrients and the extraction of dietary supplements, such as omega-3 oils, from fish waste and algae.
Nutrient recycling can be supported by converting residues and organic waste from aquaculture into biogas and agricultural fertilizers. The biogas can then be transformed into biofuels, power or heat, for example, to heat a nearby greenhouse. This way, an industrial symbiosis cluster can be organized around aquaculture, so that all raw materials are fully used in a wide variety of products.
For many value chains in an aquatic biorefinery, it is essential that the aquatic feedstock harvesting and the biorefining installations are located close to one another, as the raw materials need to be fresh when processed. This means that aquaculture biorefineries have a positive effect on local job creation.
Sybimar is a Finnish SME producing fish in specially constructed inland fish farms. In addition to fish for the food industry, Sybimar also produces biogas from fish waste and food industry side streams for the generation of biofuels, power and heat. In addition to biogas production, Sybimar is synergistically connected to greenhouse farming. In this way, Sybimar meets part of its own electricity and heat demands, while also taking care of its own waste treatment. Nutrients, water, waste heat and CO2 are recycled back into the production process
**(Rönnlund et al., 2014; Sybimar, 2017)**

## Conclusion

In a systemic perspective of macro and meso (sectoral) interactions, a sustainable increase of energy or energy feed-stocks production from properly defined ‘waste’ can:

- Contribute to reducing the pressure on virgin bioresources for the production of energy, thus helping the conservation of ecosystems and nature;
- Reduce the competition in the biomass sector, in particular wood, between the renewable energy industry and the wood industry that uses wood as a structural material, in particular, the one entirely based on recycling of wood residues (MDF panels, particleboard panels);
- Favour the diversion of virgin biomass, in particular wood and agroforestry biomass residues, to uses with higher economic and environmental value, e.g. in green chemistry, or critically needed products, like bioplastics, within the innovative part of the Bioeconomy;
- Of course, contribute to the reduction of landfill of valuable materials, which is still too much high in many EU countries.

This re-balancing process can deliver results also within the EGD’s carbon neutrality strategy, which needs carbon sinks and carbon accumulation in ecosystems, as well as the Bioeconomy Strategy and the Farm-to-fork Strategy (see below).

# 03 The policy web linking CE and energy

***Key conclusion: Before the EGD, there is a weak integration between energy and the CE in the EU legislation. The definition of CE criteria for funding businesses at the official EU level suffers for a 'material circularity' bias, which given little attention to energy production from CE loops. However, CE and energy are increasingly connected within the EGD.***

## 3.1 CE and energy: Weak integration in EU legislation

How much CE and energy/climate are integrated across EU environmental and energy policies before the EGD?

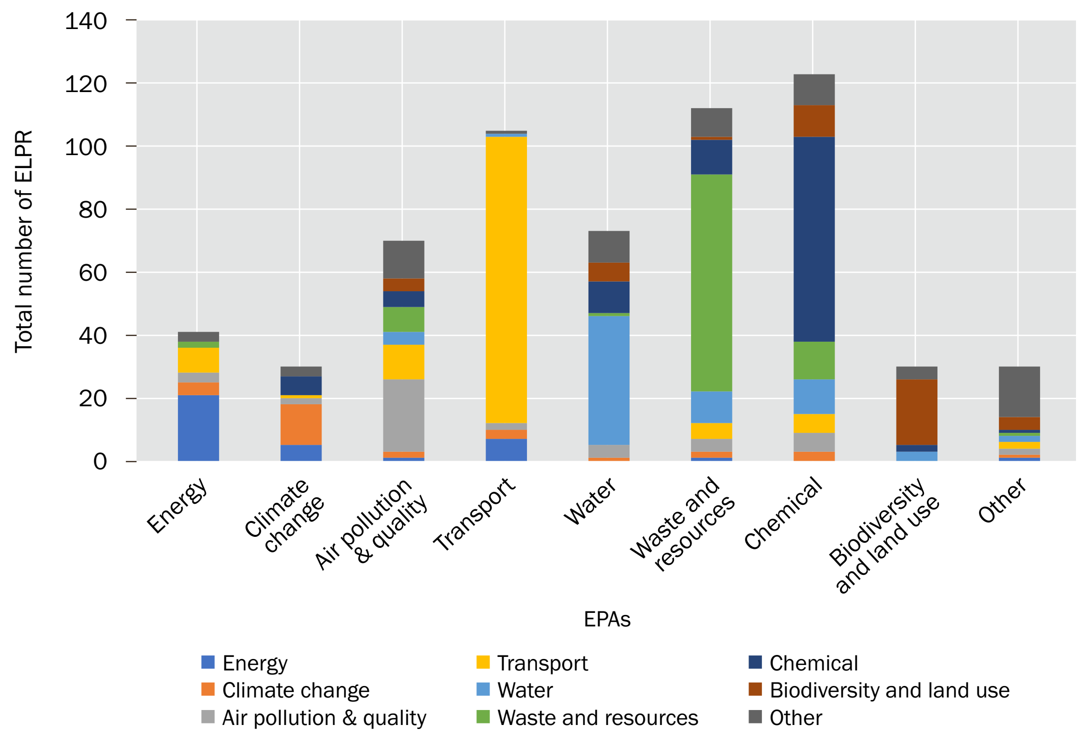
Building on works by the EEA (2013 and 2016b) and ETC/WMGE (2019), an analysis of cross-references among the most important pieces of EU environmental legislation in force in 9 policy areas (Paleari, forthcoming) shows that policies on energy and climate legislation are weakly integrated with CE/bioresources legislation[5].

With regard to environmental legislative and policy references (ELPR), the most relevant environmental policy areas (EPAs) as a source of references to other areas are 'chemicals' (123 ELPR), followed by 'waste and resources' (112 ELPR) and 'transport' (105 ELPR) in absolute terms (Figure 3.1). Apart from a few exceptions ('climate change' and 'air pollution and air quality'), more than a half of the referred environmental legislation/policy in each EPA belongs to the same area, as expected, but with some significant cross-referencing to other areas.

5 The environmental policy areas (EPAs) are: 'energy', 'climate change' (excluding GHG emissions from transport), 'air pollution & air quality' (excluding air pollution from transport), 'transport' (including GHG and air pollution from transport and transport noise), 'water' (freshwater, marine water & environment), 'waste & resources', 'chemicals', 'biodiversity & land use', and 'other' (which collects the pieces of environmental legislation that do not fall under the other EPAs or have a cross-sectoral nature). Overall, the analysis addresses 70 environmental directives/regulations/decisions. Each piece of legislation has been assigned to a single EPA (to avoid double-counting). See EEA (2013 and 2016), ETC/WMGE (2019), and Paleari (forthcoming) for the methodology and the details.



**Figure 3.1 Total number of ELPR contained in environmental legislation pertaining to different EPAs**

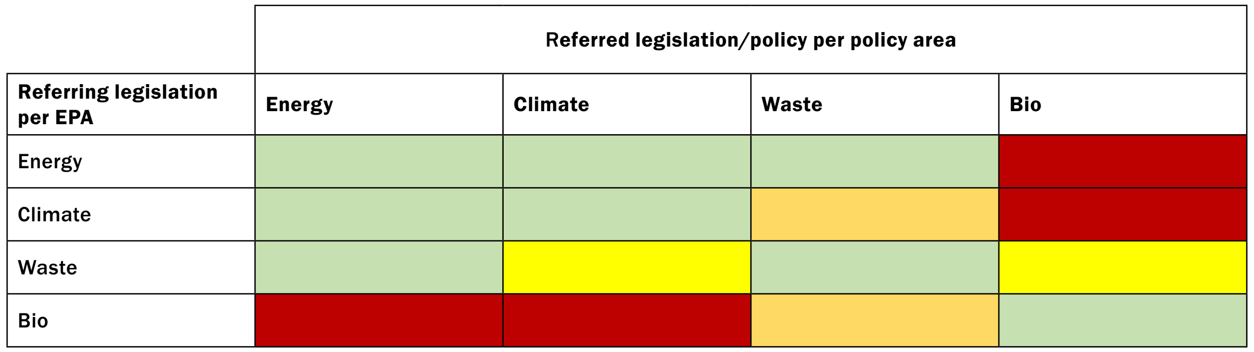



**Source: own elaboration**

However, in the case of energy/climate and waste/biodiversity, out of 4 pieces of energy legislation, 2 refer to waste legislation and none to biodiversity legislation, and out of 6 pieces of climate legislation, none refers to both waste and biodiversity legislation. From the other side, out of 13 pieces of waste legislation, only one refers to energy legislation and 2 to climate legislation, while out of 5 pieces of biodiversity legislation none refers to both energy and climate legislation (Figure 3.2).

The matrix in the table illustrates, in a visual way, the relationship between the environmental legislation pertaining to these EPAs. It shows that in most cases, there are not crosslinkages (red cells) or they are not bi-univocal (orange/yellow cells). These results highlight that, in spite of the systemic approach claimed in environmental policy strategies of the EU, the actual degree of integration between energy/climate legislation and CE-related legislation (broad perspective) is very limited. This limited integration risks missing the areas of positive interactions between the two domains.

**Figure 3.2 Qualitative relationship between selected EPAs (ELPR)**




**Green cells: mutual relationship (the environmental legislation belonging to EPA 'A' makes reference to the environmental legislation belonging to the policy area 'B' and the EPA 'B' makes reference to the environmental legislation belonging to the policy area 'A'. Orange and white cells: univocal relationship (the environmental legislation belonging to EPA 'A' makes reference to the environmental legislation belonging to the policy area 'B' – yellow cell- but the environmental legislation belonging to EPA 'B' does not make reference to the environmental legislation belonging to the policy area 'A' – orange cell- ). Red cells: no relationship (the environmental legislation belonging to EPA 'A' does not make reference to the environmental legislation belonging to the policy area 'B' and the EPA 'B' does not make reference to the environmental legislation belonging to the policy area 'A').**

**Source: own elaboration**

## 3.2 A 'material circularity' bias for waste?

Within the institutional process of categorizing CE models, in particular for defining CE-related eligibility criteria within the process of EU Sustainable Finance, energy receives an ambiguous consideration.

In March 2019, the Circular Finance Expert Group produced the report on "Accelerating the transition to the Circular Economy" (EC, 2019a). Besides the main goal of the report, that of improving access to finance for circular economy projects, the document highlighted the lack of a common understanding of what the circular economy is in terms of eligibility criteria for financial decisions and the need to properly monitor the circularity (versus the linearity) of projects to be financed. This led to the creation of a task force of the CE Finance Expert Group for developing a circular economy categorization system and criteria to define activities contributing to the circular economy (European Commission, 2020m).

In the 'Categorization System for the Circular Economy' produced by the 'Special task force' created by the CE Finance Expert Group to contribute to the future work of the Sustainable Finance Platform on developing the EU sustainable finance taxonomy[6], after defining the 9R 'strategies and principles' of CE, it is stated:

*"A further R-strategy often mentioned in combination with the above 9Rs, sometimes even as part of a circular economy definition, is the recovery of (embodied) energy from wastes and residues. The CE Finance Expert Group acknowledges that from a waste management angle, energy recovery is an environmentally preferable option to landfill disposal in accordance with the waste hierarchy principle. Additionally, the recovery of energy from organic wastes and residues of renewable origin, including the production of fuels therefrom, may contribute substantially to climate change mitigation by displacing consumption of fossil fuels. However, a majority of CE Finance Expert Group members considers that the resource efficiency gains from waste-to-energy and waste-to-fuel strategies are fairly modest in comparison with the other 9Rs, particularly when considering the loss in economic value of potentially recyclable materials through incineration. Hence, the activities primarily aimed at the energetic use of wastes and residues are excluded from the circular economy categorization system. Nevertheless, the CE Finance Expert Group considers that both the production of renewable energy (including biomass, but also solar, wind and hydro) and the efficient use of energy, which are not included in the circular economy categorization system, have a key role to play and constitute important ingredients in a circular economy. Moreover, the application of the 9R strategies in the design, manufacture and development of energy systems and infrastructure may also result in significant resource efficiency gains that can contribute substantially to the circular economy."*

This mixed inclusion/exclusion of energy, in particular energy production, from the core supporting elements of the CE, is reflected in the very limited role energy has in the specific components of the CE 'Categorization'. In particular:

- Within 'Circular Use', the category *"2.b. Refurbishment and repurposing of end-of design life or redundant immovable assets (buildings/infrastructure/facilities)"* mentions among the specific circularity criteria *"the activity is deliberately circular by design; meaning that it prioritizes strategies that prioritize resource efficiency gains, while simultaneously promoting other objectives such as increasing energy efficiency and/or the quality/resilience of the immovable asset"*;
- Within 'Circular value recovery', the category *"3.c Recovery and valorization of biomass waste and residues as food, feed, nutrients, fertilizers, biobased materials or chemical feedstock"* mentions among the specific circularity criteria *"energetic use of by-products and residues of the recovery process is allowed to cover own energy needs or where there is no other economically viable higher use for these"*.

The same limited consideration of energy as a contributor to circular economy emerges for the June 2020 EU regulation on the *"criteria for determining whether an economic activity qualifies as environmentally sustainable for the purposes of establishing the degree to which an investment is environmentally sustainable"* in the framework of the Sustainable Finance strategy[7]. In particular, the Article 13 of the criteria for activities giving a *"substantial contribution to the transition to a circular economy"*, mentions the *"adoption of energy efficiency measures"*, but also the *'minimization*

6 The special task force of the CE Finance Expert Group was composed of the following organisations: EIB, EBRD, ENEL, EEA, ICLEI, OVAM, and Bank Gospodarstwa Krajowego.

7 Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088. The regulation "applies to: (a) measures adopted by Member States or by the Union that set out requirements for financial market participants or issuers in respect of financial products or corporate bonds that are made available as environmentally sustainable; (b) financial market participants that make available financial products; (c) undertakings which are subject to the obligation to publish a non-financial statement or a consolidated non-financial statement pursuant to Article 19a or Article 29a of Directive 2013/34/EU of the European Parliament and of the Council(68), respectively" (Art. 1).

*of incineration of waste*' (see Box). This means that, in the process towards specific regulatory criteria to qualify circular activities, energy efficiency measures are considered whereas energy production from waste-based feedstocks is disfavoured.

This 'material circularity bias' with respect to circular resources for energy production clearly reflects the European 'Waste hierarchy', in which material recovery is ranked above energy recovery. However, this is not always supported by LCA analyses as, in some cases, it is appropriate to consider energy production as a better solution for waste recovery (see Zoboli et al. 2019 for a discussion). In a systemic perspective, a more flexible attitude towards energy from waste can reduce the pressure on burning virgin biomaterials as arising from policies on renewable energy sources.

**The CE criteria in Article 13 of EU Regulation/2020/852**

Article 13 Substantial contribution to the transition to a circular economy

1. An economic activity shall qualify as contributing substantially to the transition to a circular economy, including waste prevention, re-use and recycling, where that activity:
   (a) uses natural resources, including sustainably sourced bio-based and other raw materials, in production more efficiently, including by: (i) reducing the use of primary raw materials or increasing the use of by-products and secondary raw materials; or (ii) resource and energy efficiency measures;
   (b) increases the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities;
   (c) increases the recyclability of products, including the recyclability of individual materials contained in those products, inter alia, by substitution or reduced use of products and materials that are not recyclable, in particular in designing and manufacturing activities;
   (d) substantially reduces the content of hazardous substances and substitutes substances of very high concern in materials and products throughout their life cycle, in line with the objectives set out in Union law, including by replacing such substances with safer alternatives and ensuring traceability;
   (e) prolongs the use of products, including through reuse, design for longevity, repurposing, disassembly, remanufacturing, upgrades and repair, and sharing products;
   (f) increases the use of secondary raw materials and their quality, including by high-quality recycling of waste;
   (g) prevents or reduces waste generation, including the generation of waste from the extraction of minerals and waste from the construction and demolition of buildings;
   (h) increases preparing for the re-use and recycling of waste;
   (i) increases the development of the waste management infrastructure needed for prevention, for preparing for re-use and for recycling, while ensuring that the recovered materials are recycled as high-quality secondary raw material input in production, thereby avoiding downcycling;
   (j) minimizes the incineration of waste and avoids the disposal of waste, including landfilling, in accordance with the principles of the waste hierarchy;
   (k) avoids and reduces litter; or
   (l) enables any of the activities listed in points (a) to (k) of this paragraph in accordance with Article 16.
2. The Commission shall adopt a delegated act in accordance with Article 23 to:
   (a) supplement paragraph 1 of this Article by establishing technical screening criteria for determining the conditions under which a specific economic activity qualifies as contributing substantially to the transition to a circular economy; and
   (b) supplement Article 17 by establishing, for each relevant environmental objective, technical screening criteria for determining whether an economic activity in respect of which technical screening criteria have established pursuant to point (a) of this paragraph causes significant harm to one or more of those objectives.
3. Prior to adopting the delegated act referred to in paragraph 2 of this Article, the Commission shall consult the Platform referred to in Article 20 regarding the technical screening criteria referred to in paragraph 2 of this Article.
4. The Commission shall establish the technical screening criteria referred to in paragraph 2 of this Article in one delegated act, taking into account the requirements of Article 19.
5. The Commission shall adopt the delegated act referred to in paragraph 2 by 31 December 2021, with a view to ensuring its application from 1 January 2023.

## 3.3 Increasing integration from the EGD

The European Green Deal (EGD) was adopted in December 2019 by the European Commission (EC, 2019c). The Communication includes an initial roadmap of key measures aimed at:

- ensuring that there are no net emissions of greenhouse gases (GHG) by 2050;
- boosting the efficient use of resources by moving to a clean, circular economy;
- restoring biodiversity and cut pollution.

The roadmap will be updated as needs evolve, and this has been the case with the COVID-19 crisis.

What are the high-level strategic and policy links between energy/climate and the CE emerging from the EDG?

The EC has proposed a European Climate Law in March 2020 (EC, 2020a). The Law sets out a binding objective of climate neutrality in the EU by 2050. By June 2021, the Commission will assess how the EU legislation implementing the Union's 2030 target[8] would need to be amended, in order to enable the achievement of the new emission reductions target and carbon neutrality.

The annual renovation rate of the building stock shall be doubled, and a power sector shall be developed that is largely based on renewable energy sources (RES). In the transport sector, a 90% reduction in emissions is needed by 2050 (with contribution from the road, rail, aviation and waterborne transport). A wide range of measures and actions have been identified to meet these objectives that have an indirect implication for the CE (e.g. C&D waste from renovation, bio residues for renewable fuels in transport).

Achieving carbon neutrality requires the full mobilization of industry.

A new broad Industrial Strategy has been adopted in March 2020, along with a new Circular Economy (CE) Action Plan. The Industrial Strategy (EC, 2020b) aims at supporting both the ecological and digital transitions. It shapes comprehensive measures to modernize and decarbonize energy-intensive industries, support sustainable and smart mobility industries, promote energy efficiency, strengthen current carbon leakage tools and secure a sufficient and constant supply of low-carbon energy at competitive prices.

The EGD considers the CE as a key enabler of climate neutrality. Indeed, it points out that *"about a half of total GHG emissions come from resource extraction and processing of materials, fuels and food"*, so that an increased circularity may open significant new opportunities to reducing GHG emissions. With specific regard to the new CE Action Plan (EC, 2020c), the EGD states that *"a key aim of the new policy framework will be to stimulate the development of lead markets for climate-neutral and circular products, in the EU and beyond*". The analysis of the 2020 CE AP shows that DEC is expected to benefit from many measures listed in the plan.

The CE Action Plan shapes measures to make sustainable products, services and business models the norm in the EU. In 2021, the EC will

8 Directive 2003/87/EC on ETS; LULUCF Regulation EU 2018/841; Regulation EU 2018/842 on non-ETS sectors.

propose a sustainable product policy legislative initiative. The core of this legislative initiative will be to widen the Ecodesign Directive (EU, 2009) beyond energy-related products, but the EC will also consider establishing a set of sustainability principles (where appropriate, also through complementary legislative proposals; see Box).

**Sustainability principles to be eventually established by the EC**

- Improving product durability, reusability, upgradability and reparability;
- Addressing the presence of hazardous chemicals in products;
- Increasing the energy and resource efficiency of products;
- Increasing recycled content in products, while ensuring their performance and safety;
- Enabling remanufacturing and high-quality recycling;
- Reducing carbon and environmental footprints;
- Restricting single-use and countering premature obsolescence;
- Introducing a ban on the destruction of unsold durable goods;
- Incentivising product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle;
- Mobilizing the potential of digitalization of product information, including solutions such as digital passports, tagging and watermarks;
- Rewarding products based on their different sustainability performance, including by linking high performance levels to incentives.

**Source: EC 2020c**

Moreover, the CE AP 2020 states that:
*"In order to achieve climate neutrality, the synergies between circularity and reduction of greenhouse gas emissions need to be stepped up. The Commission will:*

- *analyze how the impact of circularity on climate change mitigation and adaptation can be measured in a systematic way;*
- *improve modelling tools to capture the benefits of the circular economy on greenhouse gas emission reduction at EU and national levels;*
- *promote strengthening the role of circularity in future revisions of the National Energy and Climate Plans and, where appropriate, in other climate policies.*

*Next to reducing greenhouse gas emissions, achieving climate neutrality will also require carbon be removed from the atmosphere, used in our economy without being released, and stored for longer periods of time. Carbon removals can be nature-based, including through restoration of ecosystems, forest protection, afforestation, sustainable forest management and carbon farming sequestration, or based on increased circularity, for instance through long term storage in wood construction, re-use and storage of carbon in products such as mineralization in building material.*

*To incentivize the uptake of carbon removal and increased circularity of carbon, in full respect of the biodiversity objectives, the Commission will explore the development of a regulatory framework for certification of carbon removals based on robust and transparent carbon accounting to monitor and verify the authenticity of carbon removals."*

The EC will revise the Industrial Emissions Directive (EU, 2010), so that circular economy practices will be integrated in upcoming Best Available Techniques reference documents. The EC will also develop an industry-led reporting and certification system; support the use of digital technologies for tracking, tracing and mapping of resource; and promote the uptake of green technologies by registering the EU Environmental Technology Verification scheme as an EU certification mark.

The CE Action Plan focuses on selected product value chains that are resource-intensive and for which the potential for circularity is high, namely: electronics and ICT; batteries and vehicles; packaging, plastics; textiles, construction and buildings; food. Among these priorities, however, the only one having a direct implication for energy and CE is the one on constructions and buildings. Together with the Revision of the Construction Product Regulation (including the introduction of recycled content requirements), measures will be promoted to improve the durability and adaptability of built assets and develop digital logbooks for buildings and to integrate life cycle assessment in public procurement.

Other measures, shaped by the CE Action Plan, are aimed at steering financing towards more sustainable production and consumption patterns. Some relevant initiatives have already been undertaken by the EC, including: integrating the CE objective under the EU Taxonomy Regulation (EC, 2018a); carrying out preparatory work on EU Ecolabel criteria for financial products; offering guidance to project promoters on circular incentives, capacity building and financial risk management; providing EU financial instruments, such as SME guarantees under the current framework and InvestEU as of 2021, to mobilize private financing in support of the circular economy. In 2020-2021, the Commission will:

- Enhance disclosure of environmental data by companies in the upcoming review of the Non-Financial Reporting Directive (EU, 2014);
- Support a business-led initiative to develop environmental accounting principles that complement financial data with circular economy performance data;
- Encourage the integration of sustainability criteria into business strategies by improving the corporate governance framework;
- Reflect objectives linked to the CE as part of the refocusing of the European Semester and in the context of the forthcoming revision of the State Aid Guidelines in the field of the environment and energy;
- Continue to encourage the broader application of well-designed economic instruments, such as environmental taxation, including landfill and incineration taxes, and enable Member States to use value-added tax rates to promote CE activities that target final consumers, notably repair services.

In May 2020, the EU has adopted the 'Farm to Fork' Strategy (EC, 2020d). Based on the Strategy, before the end of 2023, the EC will propose a legal framework for a sustainable food system to enhance policy coherence, mainstreaming sustainability in all food-related policies; work on common definitions and general principles/requirements; and address the responsibilities of all the actors involved.

The CE-related and energy-related measures are, by 2023: prioritize investments in RES and energy efficiency solutions in the future CAP Strategic Plans (e.g. to promote biogas production); development of a regulatory framework for certifying carbon removals (to promote carbon sequestration by farmers/foresters). In the '2030 Biodiversity Strategy' (EC, 2020e), three billion new trees will be planted in the EU, along the lines indicated in the EU Forest Strategy to be adopted in 2021.

Moreover, the Biodiversity Strategy promotes the shift to bioenergy based on residues and non-reusable and non-recyclable waste, which should be preferred to the use of whole trees and food and feed crops (whether produced in the EU or imported) to avoid pressure on land and the decline of natural sinks.

In September 2020, the EC has issued the Communication 'Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people' ('Climate Target Plan 2030'; EC, 2020f), which presents an EU-wide, economy-wide GHG emissions reduction target by 2030, compared to 1990, of at least 55%, including emissions and removals. Moreover, it previews a set of actions required across all sectors of the economy and the launch of revisions of the key legislative instruments to achieve this increased ambition. Indeed, based on Impact Assessment projections, by 2030:

- renewable energy would reach 38% to 40% of gross final consumption;
- the share of EU renewable electricity production would at least double from today's levels of 32% of renewable electricity to around 65% or more;
- renewables in heating and cooling would achieve around 40% penetration;
- the share of renewable energy in the transport sector would increase to around 24%;
- coal consumption would be reduced by more than 70% compared to 2015, and oil and gas by more than 30% and 25%, respectively;
- final and primary energy consumption would further reduce in 2030, achieving savings of 36-37% for final energy consumption (total energy consumed by end-users) and 39-41% for primary energy consumption (total energy used to meet final energy needs);
- the renovation rate of buildings, which is around 1% today, would double and more.

The 'Climate Target Plan 2030' emphasizes the role of CE in:

- reducing GHG emissions across the entire industrial value chain (to reach the 55% GHG emissions reduction target, industry should reduce its emissions up to around 25% by 2030 compared to 2015);
- reducing GHG (non-$CO_2$) emissions from waste management, by turning waste into a resource and specifically through measures addressing biowaste (collection/landfilling ban) and, possibly, sewage sludge;
- promoting energy efficiency, e.g. through the Sustainable Product Legislative Initiative announced in the CE Action Plan.

With regard to biomass, the 'Climate Target Plan 2030' projects an increase of RES by 2030, but with a limited role of bioenergy. In line with the 'Biodiversity Strategy', the use of whole trees and food and feed crops for energy should be minimized, which should also encourage the use of biowaste/residues in a circular perspective.

The Chemical Strategy for Sustainability (EC, 2020g), '*strives for a toxic-free environment, where chemicals are produced and used in a way that maximizes their contribution to society including achieving the green and digital transition, while avoiding harm to the planet and to current and future generations*'. According to the Strategy, although chemical pollution amplifies climate change, the EU is still lacking a comprehensive information base on all substances placed on the market and on their overall impact on climate. Therefore, the Commission will assess how to introduce information requirements under REACH (EU, 2006) on the overall environmental footprint of chemicals, including on emissions of GHG.

With regard to energy, energy efficiency is prioritized, as chemical production is one of the most energy and resource-intensive sectors. The Strategy highlights that CE can contribute to the transition to a toxic-free environment in different ways. For instance, it can promote the development of safe and sustainable-by-design chemicals, such as sustainable bio-based chemicals. On the other hand, the implementation of the Strategy will boost the production and uptake of secondary raw materials, by limiting the presence of substances of concern in products and ensuring the availability of information on chemical content and safe use.

The Renovation Wave Initiative, adopted in October 2020 (EC, 2020h), aims at doubling the annual energy renovation rate of residential and non-residential buildings by 2030, as buildings are responsible for about 40% of the EU's total energy consumption and for 36% of its GHG emissions from energy. The EC Communication lists 'life-cycle thinking and circularity' as one of its key principles and states that "*minimizing the footprint of buildings requires resource efficiency and circularity combined with turning parts of the construction sector into a carbon sink, for example through the promotion of green infrastructure and the use of organic building materials that can store carbon, such as sustainably-sourced wood*".

Under the EU Methane Strategy (EC, 2020j), the EC has proposed a set of actions to reduce methane emissions by 35%-37% compared to 2005 levels by 2030 (in line with the 55% GHG emissions reduction target established for 2030). Methane is a powerful GHG gas, second only to $CO_2$ in its overall contribution to climate change. These actions include the development of the market for biogas from sustainable sources such as manure or organic waste and residues via upcoming policy initiatives. Indeed, the biogas resulting from such feedstock is a source of highly sustainable RES, while the material that remains after anaerobic digestion (digestate) can be used as a soil improver, which, in turn, reduces the need for alternative soil improving products, such as synthetic fertilizers of fossil origin. With regard to waste, uncontrolled emissions of landfill gas in landfill sites are another relevant source of methane emissions. The Strategy, therefore, highlights that "*minimizing the disposal of biodegradable waste in landfills and its utilization for climate-neutral circular bio-based materials and chemicals is critical to avoid the formation of methane*". The EC has also announced that it will consider taking measures to limit the emission of GHG from sewage sludge.

With reference to industry and business, the EC will put forward a new initiative in 2021 (which may take the form of a legislative proposal) on sustainable corporate governance. This initiative will address human rights and environmental duty of care and due diligence across economic value chains in a proportionate way according to different sizes of enterprises. Moreover, the current review of the reporting obligations of businesses under the Non-Financial Reporting Directive (EU, 2014) is aimed, inter alia, to improve the quality and scope of non-financial disclosures, including on environmental aspects.

**Finance and investments for the EGD**

The Green Deal announced the adoption, by the EC of a Sustainable Europe Investment Plan, to help meet its funding needs. The Plan was presented in January 2020 (EC, 2020l) and aims at mobilizing at least €1 trillion of sustainable investments (from the EU budget, national budgets and the private sector) over the next decade. The EC had already estimated that achieving the current 2030 climate and energy targets requires €260 billion of additional annual investment (about 1.5% of 2018 GDP), compared to a baseline scenario (EC, 2019c). This figure mainly includes energy-related investments, buildings and part of the transport sector (vehicles). The average investment needs per sector are most significant in the renovation of buildings. According to the plan, the transformation to a low carbon economy, envisaged by the Green Deal, may require additional investments of up to 2% of GDP by 2040.

Since the private sector will be key to financing the green transition, the Green Deal shapes a set of measures to direct financial and capital flows to green investment. In particular, the EC will present a renewed sustainable finance strategy in the fourth quarter of 2020 that will focus on the following:

- the EC will: adopt the taxonomy for classifying sustainable activities (EC, 2018a); work to embed sustainability into the corporate governance framework; support businesses and other stakeholders in developing standardized natural capital accounting practices, so that environmental risks and mitigation opportunities are appropriately managed; increase the disclosure on climate and environmental data by companies and financial institutions, through the review of the Non-Financial Reporting Directive (EU, 2014).
- Increase opportunities for investors and companies by making it easier for them to identify sustainable investments and ensuring that they are credible. This could be done via clear labels for retail investment products and by developing an EU green bond standard.
- Manage climate and environmental risks and integrate them into the financial system. This means better integrating such risks into the EU prudential framework and assessing the suitability of the existing capital requirements for green assets.

In response to the deep economic recession caused the COVID-19 crisis, in May 2020, the EC adopted the 'Next Generation EU', the recovery Plan for Europe (EC, 2020n). Based on estimates, at least €1.5 trillion of additional public and private investment will be required in 2021 and 2022 to get Europe on the road to a sustainable recovery. To meet these financial needs, the EC proposed: A new €750 billion recovery instrument, called 'Next Generation EU', to boost the EU budget with new financing raised on the financial markets for 2021-2024 and to be channeled to the Member States in support of investment and reform priorities; Targeted reinforcements to the MFF for 2021-2027, amounting to some €1,100 billion, to bring the total financial power of the EU budget to €1.85 trillion in support of key EU programs.

The political agreement reached, at the level of the European Council, in July 2020 largely confirmed these proposals[9]. The package will be made of 1.070 billion MFF and 750 billion 'Next Generation EU', the latter made of 360 billion loans and 390 billion grants.

The imprinting of the recovery plan will be very aligned to the EGD. According to the Council conclusions, "A21. Climate action will be mainstreamed in policies and programmes financed under the MFF and NGEU. An overall climate target of 30% will apply to the total amount of expenditure from the MFF and NGEU and be reflected in appropriate targets in sectoral legislation. They shall comply with the objective of EU climate neutrality by 2050 and contribute to achieving the Union's new 2030 climate targets, which will be updated by the end of the year. As a general principle, all EU expenditure should be consistent with the Paris Agreement objectives."

9 See the Council conclusions at https://www.consilium.europa.eu/media/45109/210720-euco-final-conclusions-en.pdf



# 04 Holistic CE business models and energy

***Key conclusion: The concepts of CE and of 'CE business models' are increasingly holistic. Direct surveys indicate that this happens in practice and firms adopt strategies that involve materials management and energy co-production in an integrated way***

## 4.1 Evolving concepts

While few concepts of CE dominate the European policy discourse (see EC 2015, EEA 2016a; WEF 2014, EMF, 2015), the concept and definitions proliferate at the research and academic level (see also Zoboli et al., 2019) and an open pluralism still prevails: "cradle-to-cradle" (McDonough and Braungart, 2002), "industrial ecology" (Graedel and Allenby, 1995), "industrial metabolism" (Ayres, 1994), "biomimicry" (Benyus, 2002), "blue economy" (Pauli, 2010), and "natural capitalism" (Lovins et al., 1999; Homrich et al., 2018).

According to a recent study, there are more than 100 definitions (Kirchherr et al., 2017), but also about 90 different approaches on business models for the circular economy (Pieroni et al. 2019) and about 270 leading indicators (Kravchenko et al., 2019). Certain works have been focused more on the need to create closed loops of materials flows, such as using waste as a resource and reduce pollution throughout the life cycle of products. Others have expanded the scope of the concept beyond the management of material resources assessing aspects such as energy supply efficiency and conservation, land management, soil protection and water (Rizos et al. 2018).

According to the expert group of 44 members representing Member States, industry, and the research community defined "Strategic Forum for Important Projects of Common European Commission", there are strong inter-linkages across sectors that make circular economy more of a need. For instance, all energy-intensive industries already depend highly on recycled materials as raw materials input, and in other sectors it is indispensable to reach the security of raw materials supply.

The recommendations of the Strategic Forum are:

i) improve the circularity of materials by requiring the design of products makes them reusable, repairable and recyclable (including eco-design);
ii) improve the traceability of materials and chemicals in the supply chain to enhance recyclability;
iii) Facilitate transfer and valorization of waste, $CO_2$ and CO and facilitate industrial symbiosis;
iv) Optimize pre-treatments for reducing production costs;
v) Improve existing sorting technologies and facilitate the deployment of new and more efficient technologies for the treatment of end-of-life material streams (e.g. copper

removal from ferrous scrap);
vi) Facilitate access to waste streams. Facilitate chemical, cement and steel recycling;
vii) Establish a level playing field for environmental requirements between European installations and installations located in third countries that use ferrous scrap (i.e. full application of the waste shipment regulation);
viii) Ensure regulation on waste that supports material circularity and prioritizes reuse, repair, recycling, and re-manufacturing over waste incineration;
ix) Reduce contamination of end of life materials streams;
x) Harmonization across Member States of end of life and end of waste criteria, definition of by-products and hazardous waste;
xi) Simplification of the permitting process. (EC, 2019b: 59)

It is thus clear that a shift in the concept of CE has occurred that makes it much broader than purely materials and product centered. To the CE concept refer multiple processes spanning from recycling; using resources efficiently; shifting to renewable energy sources; remanufacturing, reuse of products and components; product life extension; up to a shift in consumption patterns that change the way products are consumed, including the so called sharing economy. It thus pertains also to multiple disciplines. Clearly, the same activity can pertain to different processes. For instance, activities such as recycling may pertain to different processes: either traditional mechanical recycling or (also) chemical recycling.

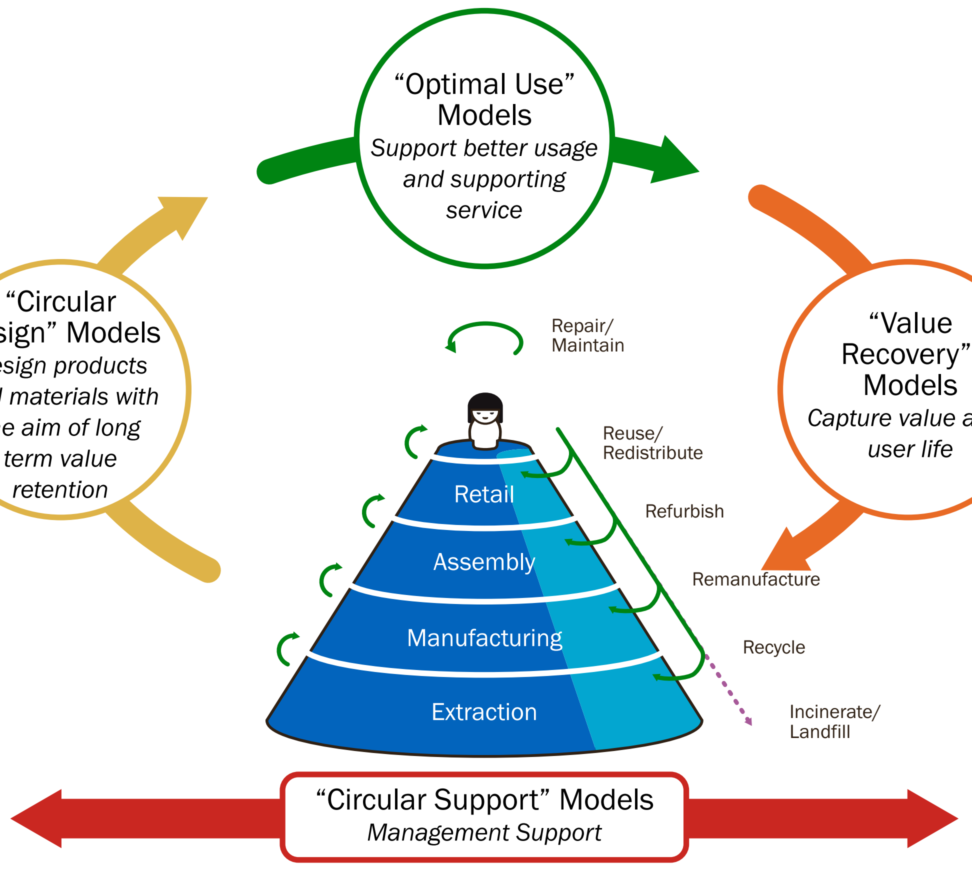
Enhancing the circularity of the economy is thus not simply an environmental strategy to be conceived at the product level, as it covers other related aspects as well such as the reduction in material use and thus the maintenance of the security in their supply as well as the enhancement of production and growth of the whole value chains.

In the available literature, there is an incremental trend moving from the achieved goals in increasing material circularity up to a more recent conceptual shift towards a more central role of technological and social innovation, that includes sectors that were traditionally not meant to be included by the CE concept. It is indeed discussed that earlier works on CE focused on concrete metrics, tools, instruments, and computations, leaving considerations on values, societal structures, cultures, and more broadly systemic shifts less investigated and more recent (Korhonen et al. 2018).

This enlargement of the scope of the CE concept is reflected in more recent documents and recommendations at the policy level. The so-called 9R of the CE have been defined and exploited to further conceive the concept (Kirchherr et al., 2017):
1) Refuse
2) Rethink
3) Reduce
4) Re-use
5) Repair
6) Refurbish
7) Remanufacture
8) Repurpose
9) Recycle

Overall, multiple categories of circular activities that contribute to increasing resource efficiency and decreasing environmental impacts throughout value chains have been identified and structured into four groups, as summarized in Figure 4.1.

**Figure 4.1 Business model categories in the 'value hill'**




**Source: EC, 2020**

## 4.2 Holistic business models

Moving towards an alternative economic system requires a transformation of all production and consumption patterns, value chains and sectors. The circular economy is not limited to the way specific products and services are created, designed, re-used and recycled, and it involves business models, or, in other words, the way production and consumption can create value. Circular economy policies then affect novel ways firms can choose for doing business (Potting et al., 2017).

New business models are therefore crucial to facilitate the CE transition, as economic agents are central actors in driving this process. There is agreement on the fact that businesses have a key role to play in driving this transition and that some of them have already started implementing new circular business models.

For several years, the literature on strategic management has studied the role of the Business Model as a means to shape the strategy of companies, driving their competitiveness, defining how to positioning in the market (Chesbrough, 2010).

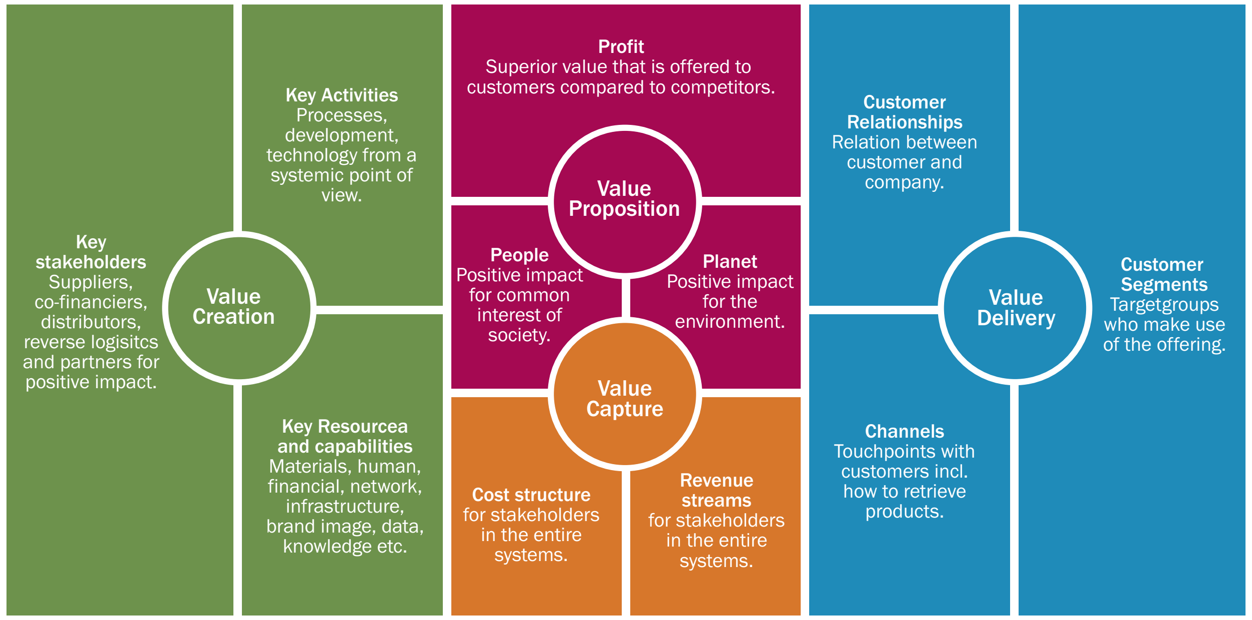
The move towards a CE requires firms to adapt their business model or create a new one (Mathews and Tan, 2011; Yang and Feng, 2008). At a strategic level, for example, companies should adopt a systemic approach in order to understand where the value is created in the supply chain and the role in the value creation of the entire network of suppliers, manufacturers, retailers and customers, also using available tools for example of Life Cycle Assessment (LCA) and Product Lifecycle Management (PLM) (Urbinati et al. 2017).

As it was already clear from the conceptualization of the CE, which involves many layers and aspects, also the conceptualization of circular business models can become rather complex.

Ranta et al. (2018) summarize existing views on business models by highlighting those components they are focusing on, such as the value proposition, the value creation, the financial structure, the market, the competitive strategy, the value capture, the value creation and delivery, the customer interface or the infrastructure management.

More systematically, Bocken et al. (2018) try to schematize circular business models around the building blocks of value creation, value proposition, value capture and value delivery to encompass all the layers and actors involved in their definitions, as summarized in Figure 4.2.

**Figure 4.2 Business model canvas for the CE**




**Source: Bocken et al. 2018**

Linder and Williander (2017) define a circular business model as one in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings. Thus, it entails a reverse logistics to return products from users to the producer, to facilitate its reuse, repair, remanufacturing, refurbishment and recycling. A hierarchy among these activities has also been suggested, whereby reuse is preferable to recycling since much of the value remains with the components contrarily to the case of recycling.

More in detail, existing literature allows mapping available circular business model according to the different strategies and impacts when looking at business model strategies that allow slowing resource loops, Bocken et al. 2016 and allow identifying multiple strategies and case studies.

Business models may pertain to providing access to services that satisfy consumer needs without owning the physical products, as it happens in the case of car sharing, or document management system for Xerox, Kyocera. Or, more broadly, to the sharing economy. They may also pertain to the extension of product value when they aim at exploiting the residual value of products, as it happens in the automotive industry when remanufacturing parts of cars or in the case of clothing return initiative (such as by H&M). Also those models that deliver long-product life products designed for durability and repair, as it is done by Miele appliances with longer than usual warranty over their products. Lastly, they can be classified as sustainable business models those solutions that seek to reduce end-user consumption, again by increasing durability, upgradability, and services.

Business models can also be leading to closing resource loops. This is the case for business models that extend resource value by exploiting the residual value of resources through the collection and use of otherwise wasted materials. Recyclebank, for instance, is a Business model that provides customers with rewards points for recycling activities and belongs to this type of business model. Industrial symbiosis is a business model that allows closing resource loops. Using residual outputs from one process as feedstocks for another process taking advantage of the proximity of businesses as in the AB Sugar case, the UK's sugar producer. It has turned its waste from its core business (manufacturing of food, sugar) into feedstocks for new product lines such as producing animal feed from by-products, the use of heat and $CO_2$ from sugar refining to heat greenhouses and grow tomatoes near its sugar refining facilities, and the fermentation of sugar (by-) products for heating[10].

It is quite clear that the vagueness that characterized the definition of CE is fully reflected by the multiple taxonomies available to define what circular business models are and how to taxonomize the existing ones.

10 Wissington is a beet sugar plant established in 1925, as part of British Sugar. The plant supplies 420,000 tonnes of sugar a year in various formats, extracting it from the sugar beet grown around the East of England. To produce all of that sugar requires 3.5 million tonnes of raw material much of which could be destined for landfill.

## 4.3 Firms' holistic approaches towards the CE: Results from surveys

While policy has been so far mostly directed towards material use (re-use and reduction), firms are directing their innovation strategies towards combining different trajectories, which not only do include innovations aimed at the material or waste reduction, but also at water or energy reduction, as well as to energy production, or increasing renewables as well as changing the design of products towards "eco-design" or abating greenhouse gases emissions. When analyzing original firm-level data from a CAWI/CATI survey conducted in 2020 by IZI SpA for the University of Ferrara on a representative sample of Italian firms in different sectors, interesting evidence emerges.

As summarized into Table 4.1, the largest share of CE- innovations adopters pertains the domain of 'Waste reuse', namely including innovations that allow the re-use of waste into own or other production processes (23% of firms have adopted such innovations in the period 2017-2019) but also the domain of 'Energy reduction', namely including innovations that reduce firm's energy use (23% of adopters). More interestingly, it can be observed the broadness of CE-related innovation experiences, which do also include (in order of importance in the share of adopters): Innovations that reduce waste (per unit of output); Innovations that reduce raw materials (including energy); Innovations that change the design to minimize energy use or maximize products' recyclability; Innovations towards renewable energy use. Lastly, to a lesser extent, come innovations precisely aimed at reducing water use and innovations aimed at abating greenhouse gas emissions (although most of the GHG abatement will be captured by innovations at abating energy use, being energy consumption responsible for most GHG emissions).

**Table 4.1: Share of adopters of CE-related innovations**

| Category | Share of adopters | |
|---|---|---|
| WATER | Innovations that reduce water use in production | 8% |
| RAWMATERIAL | Innovations that reduce raw materials (incl. energy) | 18% |
| RENENERGY | Innovations towards renewable energy use | 13% |
| ENERGY | Innovations that reduce energy use | 23% |
| WASTE | Innovations that reduce waste (per unit of output) | 19% |
| WASTE_REUSE | Innovations that allow the re-use of waste into owns or others production processes | 23% |
| ECO_DESIGN | Innovations that change the design to minimize energy use or maximize products' recyclability | 14% |
| GHG | Innovations to abate greenhouse gases emissions | 7% |

**Source: own elaboration on direct survey**

Overall, this evidence allows observing that firms are undertaking business models that already encompass multiple dimensions of activities related to the circular economy and that those are not explicitly suffering from the previously discussed circularity bias.



In the years 2017-2019, Italian firms have, on average, chose to combine internally different CE-related strategy, embracing a holist approach towards the CE, stemming from the adoption of multiple typologies of innovation activities.

Out of the 44% of the firms in the sample (i.e. 1.981 firms out of the 4.565 responding firms) that declared having introduced at least one of the possible CE-innovations in the period, we can analyse how likely it is that innovations happen in isolation or, rather happen across multiple domains. Only 25% of the innovators have only focused on one single typology of innovation to be adopted, whereas the remaining 75% of innovative firms have focused on a more holistic approach, and have combined the adoption of CE related innovations to either 1 additional type (23%), to 2 types (20%), to 3 types (14%) or to more than 3 types (19%).

When looking at those intersections among innovations, again once excluding those firms that have not introduced any CE-innovation, and once focusing on how the adoption of WASTE_REUSE (i.e. the one with the largest share of adopters) is combined with the remaining categories we observe that:

1. 11% of the innovators jointly adopt WASTE_REUSE and WATER related innovations;
2. 24% of the innovators jointly adopt WASTE_REUSE and innovations that reduce RAW MATERIALS (including energy);
3. 15% of the innovators jointly adopt WASTE_REUSE and RENEWABLE ENERGY use innovations;
4. 27% of the innovators jointly adopt WASTE_REUSE and ENERGY reduction innovations;
5. 28% of the innovators jointly adopt WASTE_REUSE and WASTE reduction innovations;
6. 17% of the innovators jointly adopt WASTE_REUSE and ECO-DESIGN related innovations;
7. 11% of the innovators jointly adopt WASTE_REUSE and GHG abatement innovations.

These results provide support to the intersection between energy and material reduction and efficiency into a firm's business models.

Notwithstanding the general idea that a CE approach is widely welcomed by industries, the current structure of the supply chains is largely conservative, and the CE transition is still restricted to a business niche (Kirchherr et al. 2018). Indeed, *"If you talk about circular economy, these players only glance at you with a question mark in their eyes"* (Kirchherr et al. 2018, p. 269). Understanding which role the sustainability transition plays in firms' business choices represents a way to understand the points of failure/success of this path.

In light of this, Chioatto et al. (2020) have conducted a series of video interviews with eight companies in the Emilia Romagna region, one of the most lively Italian regions from a CE point of view[11]. The aim was to investigate firms' progress in the implementation of new CE approaches, in line with the use of regenerative sources of energy, the extension of product life and their recovery, and the elimination of toxic materials (Wilts 2017). The interviews covered different sectors (i.e. wood, fiberglass, agribusiness, packaging, and FM transmitters)[12]

11 According to the recent data of the ART-ER (2020) in the three-year period 2016-2019, Emilia-Romagna has activated over 430 research and innovation initiatives on circular economy issues.

12 Companies vary also in terms of size and age.

and processes in order to give an overview of what happens to the business models when different companies try to embrace a circular perspective. The main questions asked to firms were related to their decision to undertake an innovation path and the relevant areas of innovation.

The study reveals a positive engagement of these firms in the implementation of circular-oriented BMs. The introduction of practices aimed at achieving a “cleaner” production is of interest for all firms taking part in the survey. In particular, six of them suggested a specific interest/involvement in the energy field. This may partially derive from the positive impulses given by recent relevant legislation. The last decade has indeed been characterized by policy actions against plastics and emissions increase with decisive support for alternative sources of energy/ materials. In this context, companies increased their attention towards the environment in terms of packaging (reduction in the impacts of single-use plastic bottles, recycled cardboard), with important positive spillovers in terms of lower $CO_2$ emissions and reduction in weight, volumes and number of transport trips. The significant subsidies to renewable energy have also led to firms’ energy-related innovative practices in different sectors (including the food sector), for example in terms of a reduction in the impact of bio-waste generated, the installation of photovoltaic systems and the delivery of organic waste for methane production. Actions related to reductions in $CO_2$ emissions were also exploited by trading on the EU Emission Trading System. Other relevant actions, although not directly linked to the energy sector, include the development of new, more sustainable materials, including plastics.

# 05 Circular economy in the energy industry

***Key conclusion: The energy industry shows a mounting interest in the CE both as an internal management approach and as a source of new market opportunities. Approaches and initiatives from major market players are heterogeneous and largely based on the appropriation of specific innovative businesses. The measurement of CE inside the companies is still challenging, and this issue must be addressed in front of the future adoption of ‘CE criteria’ by European policies and the financial system***

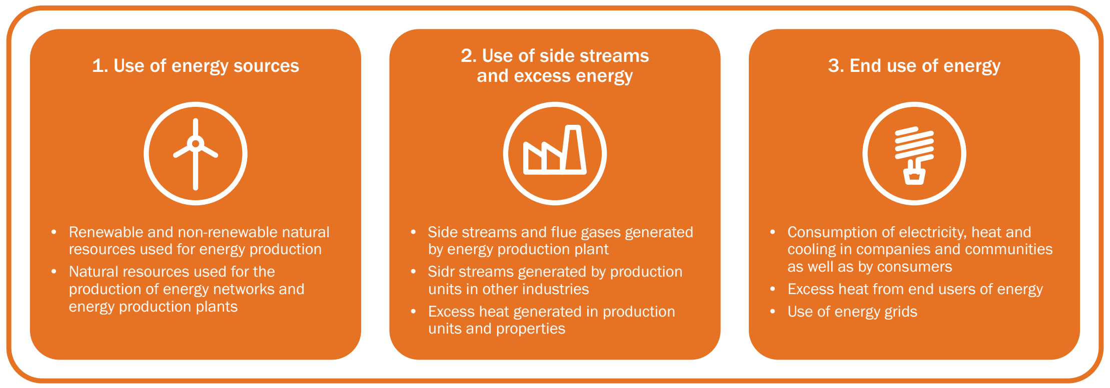
When looking at the energy industry, the CE transition involves many of the trajectories already outlined. Furthermore, due to the extreme interdependence of the energy sector within the whole economy, changes in this sector naturally affect the others towards the overall circularity of the economy.

According to Deloitte (2018), CE in the energy system consists of designs, processes and solutions that maximize the efficient use of natural resources for energy production, end-use of energy, and side streams. CE in the energy industry thus revolves around multiple phases of the value chain.

The CE concept can be extended to the energy sector by looking at the three segments that can be optimized in the energy system from a CE perspective. Those are, according to a recent study by Deloitte (2018):

1) the reduction in the use of natural resources related to primary energy production;
2) the use of excess resources from the energy industry in other industries;
3) the reduction in the use of energy by the end-user and the change in the energy service.

**Figure 4.3 CE for optimisation in the energy system**




**Source: Deloitte, 2018**

For a CE transition in the energy sector, at first, the use of natural resources related to primary energy production should be reduced by increasing the efficiency of energy production and replaced by renewable sources. The CE concept, however, needs systemic lenses to be operationalized and cannot be reduced to a matter of increasing renewable energy sources and efficiency. The energy production can thus be circular, through the use of renewable energy, through the exploitation of waste-to-energy, or through the recycling of materials from energy production plants.

Energy companies could also more actively develop new solutions or new services, changing the energy market radically. Then, secondly, the excess of energy, heat, or ashes from the industry can be utilized for other purposes, used in other industries and by developing an industrial symbiosis. This gives a central role to innovation, as developments in technology, such as heat pumps, and enable more profitable excess heat utilization (Deloitte, 2018).

Thirdly, CE can also occur in the way energy is used by the end-users and customers. Energy consumption can change for being more circular through new instruments such as energy-as-a-service business models, through an increase of energy efficiency for the end-users, or by means of a two-way district heat that integrates conventional district heating and the distribution of heat solutions via a smart grid. This third dimension reflects the importance of selling services rather than products, so that producers can retain greater control over the items they produce (enabling better maintenance, reconditioning and recovery) and customers only pay for the service they use.

Also in the case of the energy sector, the CE can entail different levels and can thus be more or less systemic, according to the different integration of each firm's choices with the different actors of the system, such as consumers, municipalities, energy companies. How to measure the circularity of this sector is thus not at all an easy task and, not surprisingly, we still lack unifying guidance. In Section 6.1, we provide some examples of CE strategies in by selected major energy players.

## 5.1 CE strategies and initiatives in large energy companies

During the last few years, large energy companies have adopted specific CE-related strategies and initiatives that range from adopting CE approaches in internal operations and management to initiatives in cooperation with suppliers and customers, from international research projects to the participation to CE networks.

We select and summarise these initiatives for four major energy players - ENI, Total, Shell, ENEL - as presented in their official communication, with a focus on industrial initiatives[13].

The emerging strategies are different, but all are aimed at exploiting and exploring the opportunities offered by the CE paradigm with an increasingly robust commitment. A specific case study is developed based on interviews on Versalis, which belongs to the ENI Group.

13 Information available as of August 2020.



**ENI**

At the governance level, the CE Programme is an inter-functional working group aimed at accelerating the process of identifying and implementing technological solutions, products and processes that minimize the consumption of resources and energy in all businesses and aim at reuse and exploitation of waste materials CE[14].

According to Eni Annual Report 2018, the company intended to invest more than €950 million in the subseqquent four years in CE initiatives (recovery of biomasses and waste, recycling of polymers, the extension of the useful life of the assets and products from a low carbon side). Further €220 million were addressed to research and development as well as to technological innovation.

Waste to Fuel is an important element of the Eni CE strategy. Eni has been producing high-quality biofuels from used cooking and frying oil, animal fat and other non-edible waste. A pilot plant has been built in Gela to test production of bio-oil and biomethane taken from the organic fraction of municipal solid waste. This is crucial in the announced production on an industrial scale at the plants in Ravenna, Porto Marghera and potential other disused industrial sites in Italy and even other countries.[15]

Several MoUs and cooperation agreements have been signed with various companies/institutions for the development of the CE. MoUs and cooperation agreements for the collection of waste cooking oils and the supply of Green Diesel were signed in 2018 in Rome with AMA, with Veritas in Venice, with Hera in Modena and with AMAT in Taranto[16]. In January 2019, Eni and Indonesia's state-run oil and firm Pertamina agreed to explore opportunities and discuss collaboration in waste transformation and biomass valorisation processes, low carbon products and RES development. In March 2019, Eni signed an agreement with COREPLA to launch research projects to produce hydrogen from non-recyclable plastic packaging waste.[17]

Specific MoUs and cooperation agreements have been: March 2019: Syndial, the environmental remediation arm of Eni, signed an MoU with waste services company Veritas to study the construction of a plant that will transform the organic fraction of solid municipal waste into bio-oil and bio-methane. The plant would be sited on an abandoned and reclaimed area within Eni's Porto Marghera petrochemical complex in Venice and will be able to process up to 150,000 t/year of organic waste. Specifically, Veritas should provide at least 100,000 t/year of OFSMW and other humid waste fractions collected separately from the Venice metropolitan area. June 2019: Eni and NextChem (Maire Tecnimont) have signed a partnership agreement to turn waste into energy by developing and implementing a conversion technology, which uses high-

14 Source: https://www.eni.com/docs/en_IT/enicom/sustainability/EniFor-2018-Decarbonization.pdf

15 Source: https://www.sipotra.it/wp-content/uploads/2019/04/Eni-Annual-Report-2018.pdf; https://www.eni.com/en_IT/innovation/technological-platforms/waste-to-fuel.page

16 ENI FOR 2018 – Path to decarbonisation

17 Source: https://www.eni.com/docs/en_IT/enicom/sustainability/EniFor-2018-Decarbonization.pdf; https://www.adnkronos.com/aki-en/business/2019/01/30/eni-indonesia-pertamina-ink-circular-economy-accord_pV5PnucfQCtCbyQ3MMM5DI.html; https://www.eni.com/docs/en_IT/enicom/media/press-release/2019/03/pr-Eni-COREPLA.pdf

temperature gasification to produce hydrogen and methanol from solid urban waste and non-recyclable plastic with minimal environmental impact.[18]

In July 2019, Eni and Lombardy Region signed an MoU on sustainability and CE to safeguard natural resources by using them efficiently and sustainably; promote waste recovery, reuse, and extension of products' useful life; produce sustainable energy products and promote biomass or waste products. In July 2019, Eni signed an MoU with Coldiretti, in order to implement joint initiatives in the following fields: using agricultural biomass to produce advanced biofuels for the energy sector, biochemicals, and by-products or inputs for agriculture like biofertilisers; researching and promoting crops that can be used as alternative sources for green refineries that do not compete with the food chain; promoting sustainable agriculture that focuses on optimising energy consumption, protecting environmental factors and promoting the sustainable use of water. In 2019, Eni signed an agreement with Cassa Depositi e Prestiti for the promotion of initiatives in Italy in the field of the CE, decarbonization and sustainability, also through the recovery of industrial sites, and for initiatives with a high socio-economic and environmental impact in partner countries in the energy sector and in the fight against climate change.[19]

The CE strategies of the ENI-controlled Versalis are: feedstock diversification to find the right balance between traditional sources, renewables and secondary raw materials; eco-design to enhance resource efficiency of products over their entire life-cycles; recycling of polymers through the development of innovative technologies. Several projects/initiatives have been developed to implement the CE strategy, such as: (i) an innovative type of expandable polystyrene was launched to prevent plastic leakage, under the trademark Extir® FL 3000; (ii) use of secondary raw materials deriving from end-of-life products (mainly from polystyrene packaging) to produce EPS; (iii) an agreement with Montello S.p.A., a leading European company focused on post-consumer plastic recovery and recycling technologies, was signed to develop a new range of polyethylene products made from recycled packaging.[20]

Eni Versalis is a member of the PolyStyreneLoop Cooperative, a non-profit organisation under Dutch law. Members of the foundation are industry representatives from the whole polystyrene foam value chain. The PolyStyreneLoop Cooperative is set up to demonstrate the feasibility of a large-scale demo plant as a closed-loop solution for the recycling of polystyrene (PS) insulation foam waste and the recovery of bromine. The planned demonstration plant in Terneuzen, Netherlands, will work with the CreaSolv® Technology. The PolystyreneLoop initiative is supported with a loan from RABO bank and has received a LIFE. It is mentioned as a good practice on the website of the European CE Stakeholder Platform.[21]

**TOTAL**

In 2015, Total announced plans to transform its La Mède refinery into one of Europe's largest biorefineries. Operational as from 2019, the biorefinery was designed to produce biofuels from various types of oils. La Mède's feedstock is made up of 60% to 70% crude vegetable oils (rapeseed, sunflower, soybean, oil palm, corn or new plants such as carinata) and 30% to 40% from CE chains, such as waste oils, byproducts from vegetable oil refining and animal fat.[22]

In France, Total helped found Valorplast (warrantor for the plastic packaging of French recycling organization Citeo). In partnership with Veolia, Total founded the Osilub plant in Le Havre, France. Since it opened in 2012, it has recycled 120,000 metric tons of used oil annually, equivalent to half of France's total output. These recycled oils are then used as feedstock by refineries to produce fuel or lubricants. In June 2018, Total has collaborated with Citeo, Saint-Gobain and the French Union of Fresh Dairy Product Manufacturers (Syndifrais) to create an industrial-scale polystyrene recycling channel in the country by 2020. The project will involve collecting post-consumer polystyrene packaging and finding the right technical solutions for recycling it. Total will use the sorted and prepared polystyrene in its plastic production units in Carling, France and Feluy, Belgium.[23]

Total is a member of the PolyStyreneLoop Cooperative, which is a non-profit organisation under Dutch law. Members of the foundation are industry representatives from the whole polystyrene foam value chain: PS foam manufacturers, raw material and additives suppliers, foam converters, and recyclers. The PolyStyreneLoop Cooperative is set up to demonstrate the feasibility of a large-scale demo plant as a closed-loop solution for the recycling of polystyrene insulation foam waste and the recovery of bromine. The planned demonstration plant in Terneuzen, Netherlands, will work with the CreaSolv® Technology. The PolystyreneLoop initiative is supported with a loan from RABO bank and has received a LIFE. It is mentioned as a good practice on the website of the European CE Stakeholder Platform.[24]

In 2017 Total successfully completed an industrial-scale test run of a proprietary recycling process for polystyrene on a European PS production line, following a series of pilot stage trials. The scale-up demonstrated the feasibility of sustainably incorporating about 20% of post-consumer recycled polystyrene with (80%) virgin polystyrene. Total is now planning to develop purification techniques that could treat a variety of post-consumer waste types with the objective of finding a process capable of handling complex PS waste streams on conventional polymerisation lines.[25]

18 Source: https://www.chemanager-online.com/en/news-opinions/headlines/eni-and-veritas-waste-fuel-pact ; https://www.eni.com/docs/en_IT/enicom/sustainability/EniFor-2018-Decarbonization.pdf; https://www.chemanager-online.com/en/news-opinions/headlines/eni-and-veritas-waste-fuel-pact

19 Source: https://www.eni.com/docs/en_IT/enicom/sustainability/EniFor-2018-Decarbonization.pdf ; https://bioenergyinternational.com/feedstock/eni-and-lombardy-region-sign-sustainability-and-circular-economy-dea; https://www.refiningandpetrochemicalsme.com/products-services/26050-eni-coldiretti-sign-mou-for-joint-projects-relating-to-the-circular-economy l

20 Source: https://www.versalis.eni.com/irj/portal/anonymous?guest_user=anon_en&NavigationTarget=ROLES://portal_content/z_eni_ve_fl_versalis/z_eni_ve_fl_roles/z_eni_ve_rl_gues_versalis/EconomiaCircolare

21 Source: https://polystyreneloop.org/; https://circulareconomy.europa.eu/platform/en

22 Source: https://www.total.com/en/commitment/environmental-issues-challenges/climate-change/sustainable-biofuels

23 Source: https://www.total.com/en/commitment/environmental-issues-challenges/environment-protection/waste; https://polystyreneloop.org/; https://circulareconomy.europa.eu/platform/en; https://www.plasticsnewseurope.com/article/20180629/PNE/180629895/consortium-to-create-polystyrene-recycling-channel-in-france

24 Source: https://www.total.com/en/commitment/environmental-issues-challenges/environment-protection/waste; https://polystyreneloop.org/; https://circulareconomy.europa.eu/platform/en; https://www.plasticsnewseurope.com/article/20180629/PNE/180629895/consortium-to-create-polystyrene-recycling-channel-in-france

25 Source: https://www.total.com/en/commitment/environmental-issues-challenges/environment-protection/waste; http://www.circulary.eu/project/total-recycled-polystyrene/

Total petrochemical teams have developed a new generation of polyolefins under the Lumicene® brand name. The result is thinner packaging manufactured using fewer materials, emitting fewer GHG gases and generating less waste after use. The Lumicene® range includes polyethylenes used for cosmetics packaging or artificial grass, and polypropylenes, which are frequently used to manufacture drinking cups and feeding bottles for babies.[26]

**Shell**

As stated in the 2019 Sustainability Report, Shell is starting to explore a circular economy approach in its operations and supply chains. For instance, Shell assessed a new waste management software to reduce the amount of waste generated. Shell has started to implement the system in its Australian business and plan to roll it out to major facilities across its businesses over the next few years. Shell facilities in Australia have been implementing a number of waste improvement projects aimed at reducing waste to landfill and providing benefits to local communities. For example, the contractor that collects and recycles waste oil from Shell facilities in rural Queensland now also collects waste oil from farms during these trips, allowing this oil to be recycled as well. Shell has also been working to improve the sustainability performance of its buildings by reducing consumption and waste. For example, Shell Business Operations centres in Kuala Lumpur, Malaysia, are aiming for zero food waste to landfill in 2020 and have implemented several waste projects. In 2019, they reduced total food waste at their offices by 70%.[27]

With specific regard to plastic/packaging, Shell is exploring how to make better use of them in the post-consumer phase (e.g. by turning them into useful liquids that could be used as a source of energy, as chemicals or as new products), based on a circular approach. In particular: In 2019 Shell announced its ambition to use 1 million tonnes of plastic waste as feedstock at its chemical plants by 2025. The first Shell plant to do this in 2019 was Norco in Louisiana, USA. Shell intends to scale up the technology and deploy it at its chemical plants in North America, Europe and Asia. Shell Retail is helping its service stations to reduce, reuse and repurpose food, paper and packaging waste across its operations and supply chain, for example, by incentivising the use of reusable bags and cups. For instance, In the Philippines, Shell is working with Green Antz, to transform used lubricant bottles and other plastic waste into eco-bricks, which are used to build Shell retail sites and, as a next step, affordable houses and schools.[28]

Shell Lubricants, which makes and sells engine and industrial oils, has a strategy to reduce, reuse and recycle packaging across its supply chains. Shell Lubricants is also exploring different and more sustainable packaging solutions, such as new packaging formats and dispensing and refill solutions. For instance: Shell companies that manufacture lubricants were the first to create a modern, reusable container for motor engine oil offered on the Loop shopping platform, which allows customers to buy everyday products in reusable containers. The container is designed to be reused at least 100 times before it is recycled into new lubricant bottles at the end of its life. In the Philippines, Shell is working with Green Antz to transform used lubricant bottles and other plastic waste into eco-bricks, which are used to build Shell retail sites and, as a next step, affordable houses and schools.[29]

Together with the Brazilian sugar and ethanol company Cosan SA Indústria e Comércio, Shell founded the joint venture called Raízen in 2011, which is mentioned as a CE case study by the Dutch Sustainable Growth Coalition Report (2015). During the sugar cane biofuel production process, all of the biowastes is reused. The crushed dry cane is burned for electricity, more ethanol can be converted from cane waste materials, and the liquid waste is returned to the field as a natural fertilizer. In 2017, Bio-bean has partnered with Shell and Argent Energy to create a coffee-based biofuel that will be used in London's diesel buses. In March 2019 Shell joined the W2C consortium which wants to build a factory that makes valuable chemicals and biofuels from non-recyclable waste. The plant will be built in the Botlek area of the port of Rotterdam and will have two production lines that can process up to 360 kt of waste. The project is supported by the Ministry of Economic Affairs and Climate Policy of the Netherlands. Shell is a member of the PolyStyreneLoop Cooperative, which is a non-profit organisation under Dutch law. Members of the foundation are industry representatives from the whole polystyrene foam value chain: PS foam manufacturers, raw material and additives suppliers, foam converters, and recyclers. The PolyStyreneLoop Cooperative is set up to demonstrate the feasibility of a large-scale demo plant as a closed-loop solution for the recycling of polystyrene insulation foam waste and the recovery of bromine. The planned demonstration plant in Terneuzen, Netherlands, will work with the CreaSolv® Technology. The PolystyreneLoop initiative is supported with a loan from RABO bank and has received a LIFE grant. It is mentioned as a good practice on the website of the European CE Stakeholder Platform.[30]

Launched before 2010, Shell Cariphalte RC is the leading cost-effective Polymer-modified bitumen designed for high-performance road applications in combination with Reclaimed Asphalt Pavement in base, upper and high-quality layers. It is an innovative, cost-effective solution that helps conserve natural resources in a circular perspective and reduce total asset cost.[31]

**ENEL**

The Futur-e project, which was launched in 2015, was aimed at repurposing 23 sites that had come to, or were approaching, the end of their productive lifespans (e.g. in Bari, La Spezia, Montalto di Castro and Porto Tolle) and

26 Source: https://www.total.com/en/commitment/environmental-issues-challenges/environment-protection/waste; http://www.circulary.eu/project/total-recycled-polystyrene/

27 Source: Shell Sustainability Report, 2019; https://reports.shell.com/sustainability-report/2019/responsible-business/environment/waste.html

28 Source: Shell Sustainability Report, 2018; www.shell.com/plasticwaste; ; www.shell.com/plasticwaste; https://reports.shell.com/sustainability-report/2019/responsible-business/environment/plastics.html

29 Source: Shell Sustainability Report, 2018; www.shell.com/plasticwaste; ; www.shell.com/plasticwaste; https://reports.shell.com/sustainability-report/2019/responsible-business/environment/plastics.html

30 Source: https://polystyreneloop.org/; https://circulareconomy.europa.eu/platform/en; https://www.agro-chemistry.com/news/shell-joins-waste-to-chemicals-consortium-rotterdam/; https://www.shell.nl/sustainability/dsgc-circular-economy/_jcr_content/par/textimage.stream/1456246067913/aa31422882cf1e59beb1476d65e2a8cbe197186d/dsgc-circular-economy-2015.pdf; https://www.shell.com/make-the-future/cleaner-mobility/bio-bean.html

31 Source: https://www.shell.com/business-customers/bitumen/news/news-and-media-2019/the-role-of-bitumen-technology-in-recycled-roads.html

a disused mining area. The objective of the project was to identify development pathways that give a new future to these plants according to the principles of sustainability and the CE. Key to the Futur-e project was the involvement of the local community in the various phases that led to the identification of sustainable projects that could affect positively on the surrounding area. The project is mentioned as a best practice by the WBCSD Report 'Scaling the circular built environment'. At Porto Tolle, for instance, redevelopment work will see the opening of Delta Farm on the site in 2023, creating a tourist, sports and agri-food park that will play an important role in the life of the Po Delta. Based on the sustainable worksite model, developed by Enel in 2014, everything done on the worksite shall take place with a focus on sustainability, from the selection of materials, the environmentally friendly management of the worksite once work begins and the plant's operations. This innovative model is currently applied by Enel Green Power, e.g., at its San Pellegrino and Mura hydropower facilities.[32]

To assess the reach and effectiveness of its actions in the field of CE, Enel has developed a method for measuring their circularity (the CirculAbility model) which also applies to its suppliers (see next section). The model takes into account all five pillars of CE, applied by using a number of sub-indicators.

It defines a single circularity index, whose calculation is based on two components: Flow Circularity, which takes into account all the components of materials and energy in the phases of: Input (whether renewable, recycled, reused, etc.); Output (recycle, reuse, landfill); Usage Circularity, which takes into account the material utilisation factor, either by extending its life cycle or by considering the application of the principles of sharing and 'product as a service' (see also next sections for details).[33]

FOIX was a Thermal Power Plant consisting of 1×520 MW unit, operating until 2010. In 2015, the Spanish Government authorized its closure and ordered the dismantling and demolition of the plant. Enel started in 2017 the carrying out of the process, where the value of materials and resources is maintained in the economy longer, and the generation of waste minimized. An extensive CE approach has been adopted through the implementation of a Selective Demolition Process that implies to segregate the materials at origin maximizing their reuse and recycling. About 70% of the demolished materials will be recovered. The 'Wood waste recycling for social purpose' is the name of a 2018 CE initiative Enel is using in South America and Africa, in order to help meet the UN's Sustainable Development Goal (SDG) Number 8: 'Decent work and economic growth'. As a result, communities, SMEs and local partners are now involved in specific programmes designed to create efficient ecosystems. For instance, in the Marcona area of Peru, where Enel built the nation's first and largest wind farm (with 132 MW of installed capacity), the company has launched eco-carpentry projects which improve infrastructure and homes in the communities involved.[34]

Within the context of the Global Battery Alliance, Enel and Nissan in Melilla (Spain) started in 2018 a pilot initiative operating a battery energy storage system composed of repurposed, reused 'second life' batteries from electric vehicles and of new electric vehicle packs. The purpose is to overcome technological performance challenges and demonstrate the financial viability of reused batteries. Enel launched the 'Circular Economy Initiative for Enel Suppliers Engagement' in the first months of 2018 (mentioned as a best practice by the EU CE Stakeholder Platform and winner of the Italian Procurement Award 2019). This project involved 30 significant global suppliers. It promotes circular procurement, which means tracking materials as they come and leave, having detailed knowledge about the flows of components, environmental impact and product recyclability. The project foresees the use of a web tool where the suppliers insert their data to determine the CE index of their company.[35]

In 2019 Enel and the European Space Agency (ESA) started cooperating to promote the development of space-applications in support of energy security as well as economic and environmental sustainability. Through this cooperation, in the first half of 2020, Enel and ESA will be launching a joint initiative related to CE and aimed at fostering the development of innovative services combining space data and other technology to monitor public lighting, building efficiency and traffic flows, seeking to improve mobility and environmental sustainability in cities. In February 2020, Enel X (the Enel Group business line dedicated to innovative products and digital solutions) and Federlegno-Arredo signed an agreement to develop joint initiatives and projects under the banner of innovation, sustainability (including CE), and comfortable housing. The agreement aims to identify synergies between the Federation's supply chain and Enel X's business development areas, home, businesses, cities, and condominiums, with a view to creating shared value for the territory and communities in the long term. In February 2020, Enel X signed an agreement with Cremonini Group (food sector) to build photovoltaic systems in eight of the company's industrial plants. Enel X will also carry out a detailed report analyzing the level of circularity of the Cremonini Group.[36]

## 5.2 Focus: The approach of Versalis

To achieve a better understanding of the main perceived hurdles and challenges arising at firm level from the Circular Economy (CE), this section presents the results from a detailed interview with Versalis (Eni Group).

For our purposes here, the activities of Versalis include the production of several plastic raw materials (Polyethylene, Polystyrene)

32 Source: https://corporate.enel.it/en/company/conventional-sources; https://www.enel.com/media/news/d/2019/01/economy-circular-enel-ce100; https://www.enel.com/media/news/d/2014/09/enel-sets-up-sustainable-worksites; https://corporate.enel.it/en/futur-e/news/d/2019/07/tourist-village-porto-tolle-redevelopment-station.

33 Source https://corporate.enel.it/en/circular-economy-sustainable-future/performance-indicators; https://corporate.enel.it/content/dam/enel-it/azienda/circular/KPI-Model_3.2018_it.pdf

34 Source: http://www.circulary.eu/project/enel-foix/; https://corporate.enel.it/en/circular-economy-sustainable-future; https://corporate.enel.it/en/media/news/d/2018/07/recycling-wood-circular-economy

35 Source: https://www.weforum.org/global-battery-alliance/action; https://www.enel.com/stories/a/2018/11/sustainability-report-2017-enel-seeding-energies-supply-chain; https://circulareconomy.europa.eu/platform/en/good-practices/getting-suppliers-involved-better-assess-circularity-throughout-value-chain-project-enel

36 Source: https://corporate.enel.it/en/media/press/d/2019/12/enel-and-the-european-space-agency-together-to-foster-space-applications-in-energy--, https://corporate.enel.it/en/media/press/d/2020/02/enel-x-and-federlegnoarredo-together-for-the-redevelopment-of-housing-stock; https://corporate.enel.it/en/media/press/d/2020/02/enel-x-and-cremonini-group-together-for-sustainable-energy-solutions-

and Elastomers. Although it is present all over the world, the main reference market of Versalis is the EU. Indeed, chemicals and plastics play a significant role in the evolution of the EU strategy for a Circular Economy. For example, chemicals are identified as a priority in sustainable design according to the 2020 European Circular Economy Action Plan (EC, 2020c), and plastics are included among the key value chains of the Action Plan[37]. The crucial role of industries is also suggested by the latest Eurobarometer survey on "Attitudes of European citizens towards the Environment"[38]. According to 80% of respondents, big companies are not doing enough for the environment, and special emphasis is given to the role of eco-design, to the effort by industry and retailers to reduce plastic packaging, but also to consumers' education and to available waste management facilities. It is therefore central to achieve a better understanding (with a focus here on the plastics sector) from a firm perspective.

Though not having specific CE patents in 2017-2018, Versalis has been involved in significant eco-innovation efforts, along the whole value chain, namely products, processes and organisational innovation.

Broadly speaking, innovation proposed by Versalis, according to the interview, is linked to the concrete transition towards a circular business model, always taking into account a Life Cycle Perspective, based on three main directions, namely eco-design, recycling technologies and raw materials diversification, the latter favoring the inclusion of renewable raw materials and secondary raw materials.

Table 4.2 reports the main innovation efforts that were highlighted during the interview, classified according to whether they mainly turn out to be product and/or process and/or organisational innovations and to whether they are relevant at a firm or at a sector level.

**Table 4.2. Eco-innovation efforts according to ENI Versalis**

| Eco-innovation type | Product | Process | Organisational | Relevant at firm (F) and/or sector (S) level |
|---|---|---|---|---|
| Reduction in water use in production | | X | | F |
| Reduction in material use | X | X | | F/S |
| Reduction in electricity consumption (any source) | | X | | F |
| Reduction in waste per unit of output | X | X | | F |
| Waste reuse in production | X | X | | F |
| Reuse of own waste by other firms in their production process | | | X | F |
| Change in the design of products aimed at reducing material use (including energy) | X | X | | F |
| Change in the design of products aimed at improving recyclability | X | X | | S |
| Changes in the production process aimed at reducing GHG emissions | X | X | | S |

**Source: own elaboration based on a direct interview.**

37 See also EC, 2018b.

38 Special Eurobarometer 501: http://data.europa.eu/88u/dataset/S2257_92_4_501_ENG

More specifically, the process innovation related to a reduction in water use is a broad firm-level practice in the context of Health, Safety and Environment (HSE) management, which appears as independent of (but coherent with) the CE transition. Similar conclusions are linked to the reduction in waste per unit of output, as a relevant part of Versalis HSE management (both at a process and at a product level). More generally, the strategies in relation to waste are also linked to the design of "innovative" products (in an eco-design perspective) which are aimed at increasing the durability of outputs, enhancing downstream improvements in plastic products. Relevant examples involve the use of secondary raw materials for new polymer grades, - including varying percentages of recycled (post-consumer) materials - aimed at agricultural, commercial packaging, or insulation uses.

Other relevant innovation efforts include the reduction in electricity consumption as well as increasing attempts to expand the reuse of waste in production processes. This appears to be part of a more general attitude towards waste as a value. Strictly linked to this point, also emissions of greenhouse gases are highlighted as a relevant field of innovative effort, linked to the more general improvements in the Life Cycle impact of products, coherently with a reduction in non-energy as well as energy-related indirect emissions, due to upstream and/or downstream phases of the production process, but also in line with reductions of direct emissions.

The specific mentioned efforts are in line with more general R&D effort performed; as part of this, the evolution of "chemical recycling" technologies, aimed at increasing the feasibility of recycling when standard mechanical technologies do not work (e.g. mixed plastic waste that cannot be used as inputs for mechanical recycling), is mentioned as an example of the intense and "circular" innovation endeavor.

Focusing on specific investments related to waste, namely reduction of waste per unit of output and waste reuse in internal or other firms' production processes, Versalis has experienced an increase in waste reduction investments in 2017/18; such investments are further expected to increase in 2019/20. This performance is in line with the performance of comparable large firms in the chemical sector and is not expected to be affected by the Covid-19 crisis.

When focusing specifically on the role of policies and on the degree of stringency, credibility, objectives, according to the interview responses, the regulatory and policy context that has emerged in recent years and that is still partly in an evolving phase, appears to be clear, credible and features challenging objectives. On the other hand, the role of policy design and implementation is outlined as very important, because poorly shaped and/or harmonized and/or implemented policies may hinder transformations and innovation. For this reason, the CE transition needs, according to the results of the interview, the involvement of industrial actors of the chemical industry in the definition of those policies. Overall, if properly shaped, policy is intended as a crucial driver. Versalis plays its active role by participating at several discussion fora and in national and international associations. It is part of the Circular Plastics Alliance, an initiative under the European Strategy for Plastics (EC, 2018b), launched by European Commission in December 2018 to help plastics value chains boost the EU market for recycled plastics to 10 million tonnes by 2025.

Focusing on bioplastics, Versalis is involved in the sector through innovative efforts in developing biopolymers, which can bring a big contribution to the development of a circular economy model. At the same time, there are still issues to be better evaluated and to be managed with clear methodologies, mostly due to the limited applications so far and to potential issues related to biodegradability and compostability, as currently the differences are very small in relation to the end of life management of bio-polymers (organic collection), which turns out to be close to identical to that of traditional plastics packaging and requires technical improvements.

In this perspective, the effort by Versalis is to consider in any case the whole products life-cycle, and to address the potential for the end of plastic waste, being part of the Alliance to End Plastic Waste (AEPW) involving operators across the whole chemical industry value chain and all over the world, from chemical and plastic producers, to transformers, brand owners and recyclers.

## 5.3 Measuring the CE in companies

The extreme amount of publications and documents on the CE has also lead to the emergence of a multitude of indicators, methods, and tools aimed at 'measuring' the CE.

At the meso and macro level, many activities have been undertaken to provide a deeper measurement of the CE to encompass multiple dimensions. To mention the most recent ones: Eurostat established ad hoc indicators to monitor the circular economy, and introduced the Resource Efficiency Scoreboard and Raw Materials Scoreboard[39]. The note by the Italian Circular Economy Stakeholders Platform provides an overview of all existing indicators in Europe that relate to the Circular Economy (ICESP, 2018; Zoboli et al. 2019).

Underlying datasets generally used for macro indicators are sometimes updated infrequently, especially for the ones based on input-output data, and thus, feedback to policy will not be delivered in the period in which the circular economy is emerging and in which steering would be most desirable (Potting et al., 2018).

Lacking a tool to assess CE in companies, EMF has developed and provides firms with a tool to evaluate each firms circularity[40]. By using a set of about 30 indicators around different themes of the CE, it is based on a survey in which firms can declare their CE actions over multiple dimensions. For instance, firms are asked to state the percentage share of total material mass inflow of materials (renewable) suitable for the biological cycle that is 'consumed' or otherwise degraded during use for each defined sub-unit, or the percentage share of total material mass inflow of materials (renewable and non-renewable) suitable for the technical cycle for each defined sub-unit. Energy consumption and use information are also collected for each firm, as well as the waste processing, landfilling or incineration.

The approach set forth by EMF is not simply related to products development, but it encompasses the dimensions of business models and strategical choices by the firm, but also their network and interrelation with policy and stakeholders. In other words, it reflects fully the systemic nature of the CE concept outlined in the literature.

More at the indicators level, the tool asks firms to list which of the following (directly CE) activities the firm undertakes:

- Innovation (including design)
- Corporate strategy
- Supply chain management (including procurement)
- Production (plant or process) management
- Sales and marketing
- Account management (customer relations)
- Circular economy/sustainability function or equivalent.

Among the EMF indicators, the Material Circularity Indicator (MCI) measures the level of circularity of a single product. It is represented by a score from zero to one, where one indicates the highest level of circularity, constructed using information on *input* in the production process, *utility* during the use phase, *destination* after use and *efficiency* of recycling. This indicator considers the effects of producing a good on the environment in terms of its "linear" life, accounting for the materials used, the length of its life span and ultimately its recyclability. This methodology is considered more specific than the LCA because as it focuses on the materials, their origin and their future after a product usage. For this reason, the main shortcoming of this indicator is its mostly exclusive focus on technical cycles and materials from non-renewable sources. On top of this, the very detailed "bill of materials" needed for computing the MCI can be hard to obtain on firms' part.

Looking in details at the mathematical formulation of the indicator, we can notice that two products exhibiting a high level of "linearity" (as opposed to "circularity") can be hardly compared to each other, as their MCIs would end up being both zeros (Bonacorsi, 2020). The Ellen MacArthur Foundation documentation states that "[...] *as it is not anticipated that this methodology would normally be used for these kinds of product, there should not be any problems with this approach*". In any case, when the goal is moving away from linearity, one would ideally have an indicator able to measure any meaningful departures from the old economic paradigm.

Alternatively, (and mostly related to resource use though) Figge et al. (2018) propose a model to measure the circularity of resource use based on 'initial use'; 'refurbishment'; 're-cycling' activities undertaken by firms and to aggregate and evaluate those activities.

The World Business Council for Sustainable Development (WBCSD), formed by the CEOs of 200 important companies, proposed some circularity indicators as part of its "Factor10" project, aimed at re-designing the production process in such a way to reduce dependence from virgin materials and reduce waste at the same time. A set of 21 Circular Transition Indicators (CTISs) was proposed in order to help companies in assessing their circularity level (WBCSD and KPMG, 2020), together with an

39 http://ec.europa.eu/environment/circular-economy/pdf/monitoring-framework.pdf
https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework
http://ec.europa.eu/environment/resource_efficiency/targets_indicators/scoreboard/index_en.htm

40 https://www.ellenmacarthurfoundation.org/resources/apply/circularity-indicators

online tool implemented for helping users in calculating their measures of circularity.

Donati et al. (2020) propose a model on how to perform CE analyses using Environmentally Extended Input-Output Analysis, and describe a python package (pycirk) for modelling Circular Economy scenarios in the context of the Environmentally Extended Multi-Regional Input-Output database EXIOBASE.

A recently published paper reviews the existing CE performance assessment methods proposed in literature (Sassanelli et al. 2019) such as:

- Life Cycle Assessment (LCA), Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA)
- Multi-Criteria Decision Making (MCDM) approach/fuzzy methods Design for X (DfX) and Guidelines
- Data Envelopment Analysis (DEA)/input-output
- Material Flow Analysis (MFA)/Material Cost Analysis (MCA)/Material Flow Cost Accounting (MFCA)
- Energy (emergy, exergy) approach
- Simulation/Discrete Event Simulation (DES)
- Factor analysis (FA)
- BIM-based approach (BWPE) and real estate
- Analytic Hierarchic Process (AHP)/Analytic Network Process (ANP)
- Social Network Analysis (SNA)
- Corporate Social Responsibility (CSR)
- Regression model (RM)
- Sustainable Product Development (SPD) and Sustainable Performance Assessment (SPA)
- Process modelling (PM)
- Longevity based method (LBM)
- Balanced Score Card (BSC)

In the same vein, Saidani et al. (2019) analyse 55 sets of CE-indicators, developed by scholars, consulting companies and government agencies based on levels of CE implementation (e.g. micro, meso, macro), the CE loops (maintain, reuse, remanufacture, recycle), the performance (intrinsic, impacts), the perspective of circularity (actual, potential) they are taking into account, or their degree of transversality (generic, sector-specific). The authors also propose a tool to assess those indicators, 'The C-Indicators Advisor'.

Corona et al. (2019) provide an overview of existing circularity metrics by scrutinizing existing literature, concluding that none of the existing ones is addressing the CE concept in full. In order to conduct the analysis, they list eight "CE validity requirements":

- Reducing input of resources, especially scarce ones;
- Reducing emission levels (pollutants and GHG emissions);
- Reducing material losses/waste;
- Increasing input of renewable and recycled resources;
- Maximising the utility and durability of products;
- Creating local jobs at all skill level;
- Value- added creation and distribution;
- Increase social wellbeing.

Based on the literature review of the authors, LCA was found to be the most used framework to assess circular strategies. However, it is not immediate the scale-up at of product or service level to a regional or global level, especially when gains on one scale can be losses at another scale of the system Korhonen et al. (2018). Overall, the major challenges identified for existing metrics relate to the difficulties in measuring the CE goals throughout the existing dimensions; the need to evaluate the scarcity of materials fully, and the difficulty of representing the complexities of multiple cycles. Coherently, Kristensen and Mosgaard (2020) point out there is no commonly accepted way of measuring circular economy in general at the micro- level but also that the majority of indicators focus on economic aspects, while environmental and social aspects are mostly ignored, and this would lead to a narrower approach to sustainability.

Being understood that there exist multiple metrics and approaches also to measure the CE, no specific measurement for the CE has been detailed to be scalable to the energy sector solely. The evidence is thus quite fragmented and no generalizable. However, interesting ways of measuring the CE in the energy sector emerge when focusing on single case studies.

The opacity in concepts, measurements and indicators that characterizes the CE concept is mirrored by the difficulty in finding clear-cut directions on how to conceptualize and measure CE in the energy sector. Most likely, we have to accept that no generalizable evidence on this matter can be found and that so far we are forced to rely on case-by-case evidence. The opacity in the concept of CE and vagueness of the measurement of the concept can however severely undermine the effectiveness of those policies, which, in the absence of a clear way of understanding the CE condition and evolution, can be designed in an un-coherent way and being ineffective.

We will thus outline, in what follows, the case of ENEL that adopted a specific methodology and applies it to its operations.

## 5.4 Focus: CE measurement in ENEL

Enel has embraced a CE Business Model revolving around multiple dimensions of the previously discussed CE in the energy sector.

At first, its business model aims at the reduction in the use of natural resources related to primary energy production, increasing the adoption of renewable energy sources. More related to the closing the loop, Enel incentivises the reuse and regeneration of electronic components used in its solutions nearing the end of their life cycle.

At second, it has embraced the dimension of the reduction in the use of energy by the end user by changing the way energy is provided to the end-users. Through the Enel X's Demand Response it remunerates commercial and industrial consumers if they modulate their consumption at the request of the electricity operator to respond to demand/supply peaks and guarantee greater grid flexibility and stability. At the same time, this business model enables more effective exploitation of renewable energy sources such as wind and solar, because the provider encourages (by prices) consumption when energy production is higher.

In the same line, Enel X introduced a Vehicle-to-Grid (V2G) bidirectional charging system for electric cars, which turns users into potential energy provider. This allows for also embracing the re-use of excess resources by the energy industry in other industries, as the Demand Response system allows charging electric vehicles in their grid.

Overall, the Enel approach seems to systemically embrace all the three dimensions that have been outlined in the Deloitte (2018) report.

Enel is also a case study that is of interest in the way it chose to report its "circularity" by developing a "Circularity Index", constructed from its circulability model. In a methodological note, it explains the methodology chosen to develop the selected key performance indicators used.

The strategy outlines from the very beginning the main critical issues of such measurement in their context. This is the need to mix physical indicators (material and energy use and waste) with indicators pertaining to the use of energy sources. The choice, for more uniformity, was to mix in a single composite indicator energy and material related dimensions, being conscious that materials and energy are different aspects pertaining to heterogeneous spheres.

The circularity index thus combines a dimension called "Circular Flow" that measures how materials and energy are circular in terms of their inputs and outputs and a second component that measures the "non-circularity component", and it weighs it by their use. The intuition is of weighting the non-circular sources by the reuse and "circular use". In other words, the impact of non-circular sources on the indicator is lower the higher products' lifetime and usage, in such a way to account for the fact that some virgin materials could have been subtracted from the environment in a more efficient way than others.

The "circular flow" measures the circularity in the use of resources (combining material and energy). Overall it weights the use of non-sustainable inputs over the total use of inputs, and it weights the total waste over the total outputs.

Inputs are constructed as the sum of inputs from renewables, from virgin materials, recycled materials and reused materials. Outputs are constructed as the sum of outputs sent to recycling, to reuse and wasted, where wasted outputs allow differentiating between the phase in which waste has been generated.

With respect to energy inputs, the approach distinguishes the different sources, e.g. carbon, imports, renewables, and reconstructs their share of use based on Terna data on GWh for each source. With respect to energy outputs, the approach distinguishes between the waste of energy recycled or reused in a subsequent process from the waste that cannot be recovered as the energy is dispersed in the external environment.

The use, or "circular use", comes itself from a combination of indicators, that include the life expectancy of an asset or a good with respect to the standard life expectancy of that good (i.e. without any circular intervention); the time of use of the good (either in terms of sharing or in terms of service as a product) with respect to the business as usual of that good.

One could wonder why circular products -from a material perspective- with a very long life get score 1 as well as those products that are fully circular but not long-lasting. This issue, however, does not seem to be very concerning as the process towards a more circular production paradigm is taking its first steps.

The ENEL approach of measuring circularity is mostly centred around what previous literature would suggest belonging to a narrowing of resource loops. Furthermore, if we take the Deloitte (2018) three levels approach, we can observe that such a measurement exercise is certainly centered around the first dimension of circular inputs while it mostly neglects considerations about the second and the third dimension, i.e. the use of excess of heat/energy for the other sectors and about the end-user changes in consuming energy. Recalling that Enel business model does include all the three dimension, its measurement effort has been centered mostly on the first one, which is most likely the one in which is easier to construct a measurement framework.

# References


**Andersen, Mikael. (2006).** An introductory note on the environmental economics of the circular economy. Sustainability Science. 2. 133-140. 10.1007/s11625-006-0013-6.

**ART-ER (2020),** Accelerare la transizione verso l'Economia Circolare in Emilia Romagna, Marzo 2020.

**Ayres, R. U., and Simonis, U. E. (1994),** Industrial metabolism: Restructuring for sustainable development.

**Bakker, C.A. and Schuit, C.S.C. (2017),** The long view exploring product lifetime extension. UN Environment, Nairobi, Kenya.

**Benton, D., Coats, E. and Hazell, J. (2015),** A circular economy for smart devices. Published by Green Alliance, London, UK.

**Benyus, J. M. (2002),** Biomimicry: innovation inspired by nature. New York: Perennial.

**Bocken, N., Short, S., Rana, P., Evans, S. (2014),** A literature and practice review to develop sustainable business model archetypes. Journal of Clean Production 65, 42–56.

**Bocken, Nancy M.P., de Pauw, I., Bakker, C., and van der Grinten, B. (2016),** Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering, 33(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

**Bocken, N. M.P., Schuit, C.S.C., and Kraaijenhagen, C. (2018),** Experimenting with a circular business model: Lessons from eight cases. Environmental Innovation and Societal Transitions, 28 (December 2017), 79–95. https://doi.org/10.1016/j.eist.2018.02.001

**Boks, C., and McAloone, T. C. (2009),** The design of Eco Board Games as an umbrella approach to sustainable product design education. In 17th International Conference on Engineering Design (pp. 390-395). Design Society.

**Bonacorsi L. (2020),** "Measuring circularity: a critical analysis of some relevant indicators", FEEM report 2020.

**Bureau of International Recycling (BIR) (2016),** Report on the Environmental Benefits of Recycling – 2016 edition.

**Camia A., Robert N., Jonsson R., Pilli R., García-Condado S., López-Lozano R., van der Velde M., Ronzon T., Gurría P., M'Barek R., Tamosiunas S., Fiore G., Araujo R., Hoepffner N., Marelli L., Giuntoli J. (2018),** Biomass production, supply, uses and flows in the European Union, First results from an integrated assessment, Joint Research Centre, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC109869/jrc109869_biomass_report_final2pdf2.pdf

**Ceschin, F., and Gaziulusoy, I. (2016),** Evolution of design for sustainability: From product design to design for system innovations and transitions. Design Studies, 47, 118–163. https://doi.org/10.1016/j.destud.2016.09.002

**Chesbrough, H. (2010),.** Business model innovation: opportunities and barriers. Long. Range Plan. 43 (2e3), 354-363

**Chioatto, E., Mazzanti M., Zecca E. (2020),** Circular Business Models: a survey on Emilia Romagna firms. Unpublished Working Paper.

**Cho, S.; Park, C.; Kim, J. (2017),** Leveraging consumption intention with identity information on sharing economy platforms. Journal of Computer Information Systems.

**Corona, B., Shen, L., Reike, D., Rosales Carreón, J., and Worrell, E. (2019).** Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. Resources, Conservation and Recycling, 151(May), 104498. https://doi.org/10.1016/j.resconrec.2019.104498

**Deloitte (2018),** Circular economy in the energy industry. Summary of the final report available at https://energia.fi/files/2287/Deloitte_2018_-_Circular_economy_in_the_energy_industry_-_Summary_report....pdf

**Demailly, D.; Novel, A.-S. (2018),** The Sharing Economy: Make It Sustainable, Sustainability 2018, 10, 2336 20 of 24

**Donati, F., Aguilar-Hernandez, G. A., Sigüenza-Sánchez, C. P., de Koning, A., Rodrigues, J. F. D., and Tukker, A. (2020),** Modeling the circular economy in environmentally extended input-output tables: Methods, software and case study. Resources, Conservation and Recycling, 152 (November 2018). https://doi.org/10.1016/j.resconrec.2019.104508

**EEA (2013),** Towards a green economy in Europe — EU environmental policy targets and objectives 2010– 2050, EEA Report No 8/2013, European Environment Agency, Copenhagen.

**EEA (2016a),** Circular economy in Europe – developing the knowledge base. EEA, Copenhagen

**EEA (2016b),** Environmental taxation and EU environmental policies, EEA Report No 17/2016, European Environment Agency, Copenhagen.

**EEA (2018),** The circular economy and the bioeconomy, Partners in sustainability, EEA Report No 8/2018, Copenhagen

**EEA (2019),** The sustainability transition in Europe in an age of demographic and technological change. An exploration of implications for fiscal and financial strategies, EEA Report 23/2019, Copenhagen.

**EEB (2019),** Cool products don't cost the Earth. Full report. European Environmental Bureau, Brussels, Belgium.

**EMF Ellen MacArthur Foundation (2013),** Circular Economy Overview [WWW Document]. https://www.ellenmacarthurfoundation.org/circular-economy/ concept.

**EMF Ellen MacArthur Foundation (2015),** Circularity Indicators: an Approach to Measuring Circularity.

**Enel,** CirculAbility© Model, Nota Metodologica, 2018

**ETC/WMGE (2019),** EU Environmental Targets and Objectives 2015 – 2050, Eionet Report 2019/2.

**ETC/WMGE (2020),** Electronic products and obsolescence in a circular economy, Eionet Report 2020/3 (by John Bachér, Yoko Dams, Tom Duhoux, Yang Deng, Tuuli Teittinen, Lars Fogh Mortensen), 18 June 2020.

**EU (2006),** Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, OJ L 396, 30.12.2006, p. 1–849.

**EU (2009),** Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products, OJ L 285, 31.10.2009, p. 10–35.

**EU (2010),** Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), OJ L 334, 17.12.2010, p. 17–11.

**EU (2014),** Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups, OJ L 330, 15.11.2014, p. 1–9.

**EU (2020),** Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088, OJ L 198, 22.6.2020, p. 13–43.

**European Commission (2015)** Closing the loop – an EU action plan for the circular economy. COM(2015) 614 final

**European Commission (2016),** Study on the Energy Saving Potential of Increasing Resource Efficiency. Final Report (G. Mehlhart; I. Bakas; M. Herczeg; P. Strosser; C. Rynikiewicz; A. Agenais; T. Bergmann; M. Mottschall; A. Köhler; F. Antony; V. Bilsen; S. Greeven; P. Debergh; D. Hay), September 2016.

**European Commission (2018a),** Proposal for a Regulation of the European Parliament and of the Council on the establishment of a framework to facilitate sustainable investment; COM(2018)353 final.

**European Commission (2018b),** 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 'A European Strategy for Plastics in a Circular Economy', COM(2018)28 final.

**European Commission (2019a)** Accelerating the transition to the circular economy – Improving access to finance for circular economy projects. A report by the Informal Commission Expert Group "Support to Circular Economy Financing". Luxembourg: Publications Office of the European Union, 2019. ISBN 978-92-79-99324-4 doi:10.2777/983129 Available at https://ec.europa.eu/info/sites/info/files/research_and_innovation/knowledge_publications_tools_and_data/documents/accelerating_circular_economy_032019.pdf

**European Commission (2019b)** Strengthening Strategic Value Chains for a future-ready EU Industry - report of the Strategic Forum for Important Projects of Common European Interest. Report of the Strategic Forum for important projects of common European interest. Luxembourg: Publications Office of the European Union, 2019. Available at https://ec.europa.eu/docsroom/documents/37824

**European Commission (2019c).** 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 'The European Green Deal', COM (2019)640 final.

**European Commission (2019d).** 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 'United in delivering the Energy Union and Climate Action - Setting the foundations for a successful clean energy transition' COM(2019)285 final.

**European Commission (2020a),** 'Proposal for a Regulation of he European Parliament and of he Council establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law)', COM(2020)80 final.

**European Commission (2020b),** 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, 'A New Industrial Strategy for Europe', COM(2020)102 final.

**European Commission (2020c),** 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 'A new Circular Economy Action Plan For a cleaner and more competitive Europe', COM(2020)98 final.

**European Commission (2020d),** 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 A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system', COM(2020)381 final.

**European Commission (2020e),** 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 'EU Biodiversity Strategy for 2030 Bringing nature back into our lives', COM(2020)380 final.

**European Commission (2020f),** 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 'Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people', COM(2020)562 final.

**European Commission (2020g),** 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 'Chemicals Strategy for Sustainability Towards a Toxic-Free Environment, COM(2020)667 final.

**European Commission (2020h),** 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 'A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives', COM(2020)662 final.

**European Commission (2020i),** Annex to the 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 'Adjusted Commission Work Programme 2020', COM(2020)440 final.

**European Commission (2020j),** 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 'an EU strategy to reduce methane emissions', COM(2020)663 final.

**European Commission (2020k),** Proposal for a Regulation of the European Parliament and the Council establishing the Just Transition Fund, COM(2020)22 final.

**European Commission (2020l),** 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 'Sustainable Europe Investment Plan European Green Deal Investment Plan', COM(2020)21 final.

**European Commission (2020m),** Categorisation System for the Circular Economy. https://doi.org/10.2777/172128

**European Commissions (2020n),** 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 'Europe's moment: Repair and Prepare for the Next Generation', COM(2020)456 final.

**European Commissions (2020o),** Annex to the 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 'Europe's moment: Repair and Prepare for the Next Generation', COM(2020)442 final.

**European Commission website:** https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_66 (accessed June 2020).

**European Parliament (2020),** Briefing 'EU legislation in progress: MFF 2021-2027 – Just Transition Fund', EU.

**Figge, F., Thorpe, A. S., Givry, P., Canning, L., and Franklin-Johnson, E. (2018),** Longevity and Circularity as Indicators of Eco-Efficient Resource Use in the Circular Economy. Ecological Economics, 150(November 2017), 297–306. https://doi.org/10.1016/j.ecolecon.2018.04.030

**Firnkorn, J.; Müller, M. (2011),** What will be the environmental effects of new free-floating car-sharing systems? The case of car2go in Ulm. Ecological Economics, 70, 1519–1528.

**Ghisellini, P., Cialani, C., Ulgiati, S. (2016),** A review on circular economy: the ex- pected transition to a balanced interplay of environmental and economic sys- tems. J. Clean. Prod. 114, 11e32. https://doi.org/10.1016/j.jclepro.2015.09.007

**Graedel, T. E., and Allenby, B. R. (1995),** Matrix approaches to abridged life cycle assessment. Environmental Science and Technology, 29(3), 134A-139A.

**Hofmann, F. (2019),** Circular business models: Business approach as driver or obstructer of sustainability transitions? Journal of Cleaner Production, 224, 361–374. https://doi.org/10.1016/j.jclepro.2019.03.115

**Homrich, A.S., Galvao, G., Abadia, L.G.G., Carvalho, M.M., (2018),** The circular economy umbrella: trends and gaps on integrating pathways. J. Clean. Prod.175, 525e543. https://doi.org/10.1016/j.jclepro.2017.11.064.Korhonen et al. (2018)

**ICESP (2018),** Strumenti per la misurazione dell'economia circolare.

**IRENA (2019), ,** Renewable Power Generation Costs in 2019, https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

**Kagawa, S., Hubacek, K., Keisuke, N., Kataoka, M., Managi, S., Suh, S., Kudoh, Y. (2013),.** Better cars or older cars? Assessing CO2 emission reduction potential of passenger vehicle replacement programs. Glob. Environ. Chang. 23, 1807–1818.

**Kim Hyung Chul, Ross Marc H., Keoleian Gregory A. (2004),** Optimal fleet conversion policy from a life cycle perspective, Transportation Research Part D 9 (2004) 229–249

**Kirchherr, J., Piscicelli L., Bour, R. Kostense-Smit, E., Muller, J. Huibrechtse-Truijens A., Hekkert, M. (2018),** Barriers to the Circular Economy:Evidence from the European Union (EU). Ecological Economics, 150, 264-272. doi:https://doi.org/10.1016/j.ecolecon.2018.04.028

**Kirchherr, J., Reike, D., and Hekkert, M. (2017),** Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127(April), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

**Korhonen, J., Nuur, C., Feldmann, A., and Birkie, S. E. (2018).** Circular economy as an essentially contested concept. Journal of Cleaner Production, 175, 544–552. https://doi.org/10.1016/j.jclepro.2017.12.111

**Kravchenko, M., Pigosso, D. C., and McAloone, T. C. (2019),** Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: Consolidation of leading sustainability-related performance indicators. Journal of Cleaner Production, 241, 118318. https://doi.org/10.1016/j.jclepro.2019.118318

**Kristensen, H. S., and Mosgaard, M. A. (2020),** A review of micro level indicators for a circular economy – moving away from the three dimensions of sustainability? Journal of Cleaner Production, 243, 118531. https://doi.org/10.1016/j.jclepro.2019.118531

**Li, H., Bao, W., Xiu, C., Zhang, Y., Xu, H. (2010),** Energy conservation and circular economy in China's process industries. Energy 35, 4273e4281. https://doi.org/ 10.1016/j.energy.2009.04.021

**Linder, M., Williander, M., (2017),** Circular business model innovation: inherent un- certainties. Bus. Strateg. Environ. 26, 182e196.

**Lovins, A. B., Lovins, L. H., and Hawken, P. (1999),** A road map for natural capitalism.

**Marin G., Zoboli R. (2020),** Effectiveness of car scrappage schemes: Counterfactual-based evidence on the Italian experience, Economics of Transportation, 21 (2020) 100150

**Material Economics (2018),** The Circular Economy a Powerful Force for Climate Mitigation, https://materialeconomics.com/publications/the-circular-economy-a-powerful-force-for-climate-mitigation-1

**Mathews, J.A., Tan, H. (2011).,** Progress towards a circular economy in China: the drivers (and inhibitors) of eco-industrial initiative. J. Ind. Ecol. 15, 435-457.

**Mayyas, A., Qattawia, A., Omara, M., Shana, D. (2012),** Design for sustainability in automotive industry: a comprehensive review. Renew. Sustain. Energy Rev. 16, 1845-1862.

**McDonough, W., Braungart, M. (2002),** Cradle to Cradle: Remaking the Way We Make Things. New York: North Point.

**Muñoz, P.; Cohen, B. (2017),** Mapping out the sharing economy: A configurational approach to sharing business modeling. Technol. Forecast. Soc., 125, 21–37.

**Pan, S. Y., Du, M. A., Huang, I. T., Liu, I. H., Chang, E. E., & Chiang, P. C. (2015),** Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system: a review. Journal of Cleaner Production, 108, 409-421.

**Pauli, G. A. (2010),** The blue economy: 10 years, 100 innovations, 100 million jobs. Paradigm publications.

**Pieroni, M. P. P., McAloone, T. C., and Pigosso, D. C. A. (2019),** Business model innovation for circular economy and sustainability: A review of approaches. Journal of Cleaner Production, 215, 198–216. https://doi.org/10.1016/j.jclepro.2019.01.036

**Potting, J., Hekkert, M. P., Worrell, E., and Hanemaaijer, A. (2017),** Circular economy: measuring innovation in the product chain (No. 2544). PBL Publishers.

**Prakash, S., Dehoust, G., Gsell, M., Schleicher, T., Staminger, R. (2016),** Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz“. Texte | 11/2016. Umwelbundesamt, Dessau-Roßlau, Germany.

**Ranjbari, M., Morales-Alonso, G., Carrasco-Gallego, R. (2018),** Conceptualizing the sharing economy through presenting a comprehensive framework. Sustainability, 10(7), 2336.

**Ranta, V., Aarikka-Stenroos, L., and Mäkinen, S. J. (2018),** Creating value in the circular economy: A structured multiple-case analysis of business models. Journal of Cleaner Production, 201, 988–1000. https://doi.org/10.1016/j.jclepro.2018.08.072

**Rizos, V., K. Tuokko and A. Behrens (2017),** “The Circular Economy: A review of definitions, processes and impacts”, CEPS Research Report No. 2017/08, CEPS, Brussels, April.

**Rizos, Vasileios; Behrens, Arno; Drabik, Eleanor; Rinaldi, David; Tuokko, K. (2018),** The role of steel in the circular economy: markets, processes and enabling policies. In Report of a CEPS Task Force.

**Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., and Kendall, A. (2019),** A taxonomy of circular economy indicators. Journal of Cleaner Production, 207, 542–559. https://doi.org/10.1016/j.jclepro.2018.10.014

**Sassanelli, C., Rosa, P., Rocca, R., and Terzi, S. (2019),** Circular economy performance assessment methods: A systematic literature review. Journal of Cleaner Production, 229, 440–453. https://doi.org/10.1016/j.jclepro.2019.05.019

**Schor, J.; Fitzmaurice, C. (2015),** Collaborating and connecting: The emergence of the sharing economy. In Handbook of Research on Sustainable Consumption; Reisch, L., Thøgersen, J., Eds.; Edward Elgar: Cheltenham, UK Northampton, MA, USA.

**Teece, D.J. (2010),** Business models, business strategy and innovation. Long Range Plann. 43, 172–194, http://dx.doi.org/10.1016/j.lrp.2009.07.003.

**Truttmann N., Rechberger H. (2006),** Contribution to resource conservation by reuse of electrical and electronic household appliances, Resources Conservation and Recycling 48(3):249-262

**Urbinati, A., Chiaroni, D., & Chiesa, V. (2017),** Towards a new taxonomy of circular economy business models. Journal of Cleaner Production, 168, 487-498.

**Verboven, H.; Vanherck, L. (2016),** The sustainability paradox of the sharing economy. UWF, 24, 303–314.

**WBCSD and KPMG (2020),** Circular Transition Indicators V1.0 – Metrics for business, by business, Jan 2020.

**Wee, B. V., Moll, H. C., & Dirks, J. (2000),** Environmental impact of scrapping old cars. Transportation Research. Part D: Transport and Environment, 5(2), 137-143.

**WEF, World Economic Forum (in collaboration with Ellen MacArthur Foundation and McKinsey and Company) (2014),** Towards the circular economy: accelerating the scale-up across global supply chains. World Economic Forum, Geneva.

**Wilts, H. (2017),** Key Challenges for Transformations Towards a Circular Economy: The Status Quo in Germany. International Journal of Waste Resources, 7.1, 1-5.

**Wirtz, B. W., Pistoia, A., Ullrich, S., and Göttel, V. (2016),** Business models: Origin, development and future research perspectives. Long range planning, 49(1), 36-54.

**Yang, S., Feng, N.A. (2008),** Case study of industrial symbiosis: Nanning sugar Co., Ltd. in China. Resour. Conservate. Recycl. 52 (5), 813 e 820.

**Zachmann, G., Peruzzi, M., & Serwaah, A. (2014),** When and how to support renewables? Letting the data speak. Bruegel Working Paper 2014/01, February 2014.

**Zoboli R. et al. (2019),** Towards an Innovation-intensive Circular Economy. Integrating research, industry, and policy, FEEM Report, June 2019.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