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Brief

Energy and the Circular Economy: How to fill the integration gap?

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Abstract

FEEM Policy Brief[1]

The Circular Economy can be seen in a broader NEXUS framework, in which the relationships between the CE transition, the decarbonization transition, and the bioeconomy transition are at the core of sustainability strategies and policies. 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' 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 value in innovative non-energy uses (e.g. green chemistry), while the production of energy from waste arising from 'closing the loops' is limited also as a consequence of EU policies. Before

[1] This brief is based on the report 'Energy and the Circular Economy: Filling the gap through new business models within the EGD'. The report has been produced in cooperation between FEEM and SEEDS – the interuniversity research centre on Sustainability, Environmental Economics, and Dynamics Studies.

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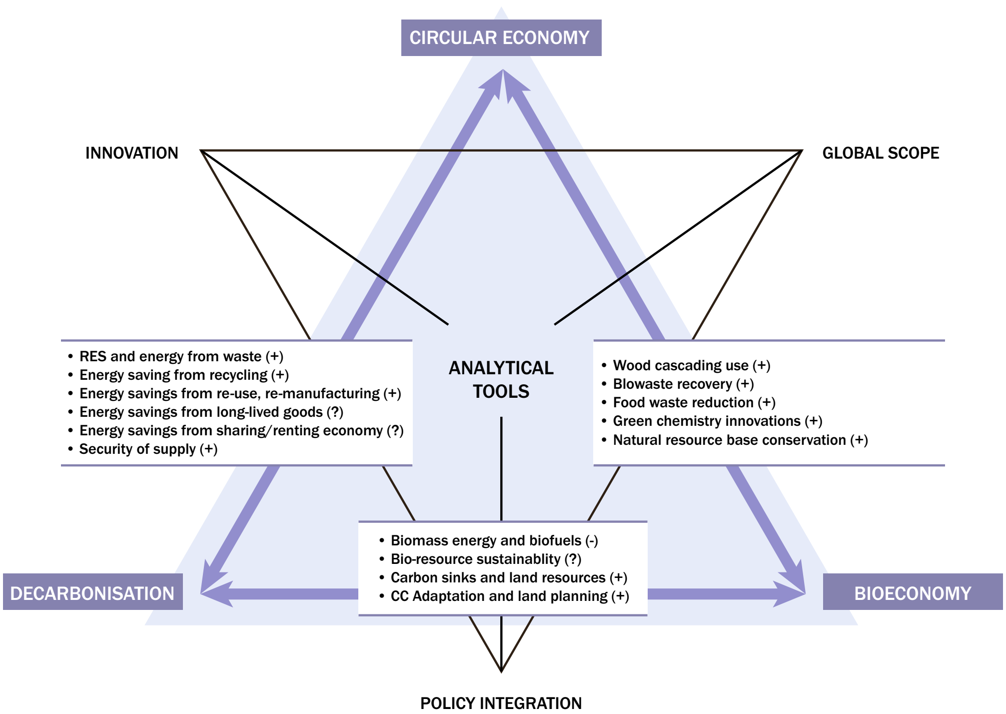
the EGD, there was a weak integration between energy and the CE within the EU legislation. The EU-level definitions of CE criteria for funding business suffers for a 'material circularity' bias, which gives little attention to energy production from CE loops. However, CE and energy are increasingly connected within the EGD. 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 energy management and materials in an integrated way. 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. 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.

01 The energy - circular economy Nexus

The Circular Economy can be seen in a broader NEXUS framework, in which the relationships between the CE transition, the decarbonization transition, and the bioeconomy transition are at the core of sustainability strategies and policies (Zoboli et al. 2019) (Figure 1.1). In this framework, there are still weak links between CE and energy/ decarbonization.

Although the wide range of strategies triggered by the EGD pushes towards a deeper integration between CE and energy/ decarbonisation, legislation on CE and energy/ climate are still weakly linked. However, at the same time, the CE-related new business models are more and more holistic and flexibly encompass integration between CE and energy/decarbonization. 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 implementation of the EGD should move towards a more flexible attitude on energy from waste together with a lower pressure on virgin bioresources as a source of energy, thus leaving these resources for higher value added uses.

Figure 1.1 The CE. decarbonization, bioeconomy NEXUS



Source Zoboli et al. 2019

Key conclusions of the FEEM-SEEDS report:

- **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' 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 also as a consequences of policy choices.
- **Key conclusion 2:** Before the EGD, there was a weak integration between energy and the CE within the EU legislation. The EU-level definitions of CE criteria for funding business 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 energy management and materials in an integrated way.
- **Key conclusion 4:** 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.
- **Key conclusion 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 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' 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 also as a consequences of policy choices.*

2.1 Energy efficiency and savings from the CE

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

There is robust evidence that closing the loop of materials, in particular through recycling, 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.

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"*. This potential can be achieved mainly by material re-circulation opportunities (recycling) and by material efficiency, especially in the use sectors.

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.

For example, 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 could be car scrappage schemes implemented in many countries, which increases the average energy/emission efficiency of car stock but reduce its average age by accelerating scrappage.

According to Material Economics (2018), new circular business models in mobility and buildings, in particular sharing, can save 62 Mt of CO_2 equivalent 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%.

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

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 e Novel, 2019) and higher utilization rates (Cho, Park e Kim, 2017).

However, according to the International Energy Agency, the overall environmental and climate implications are rather ambiguous.

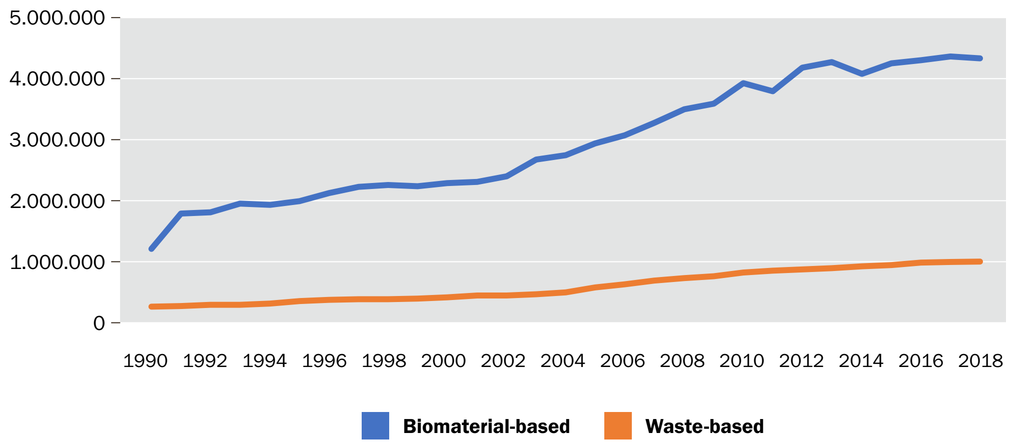
2.2 Energy production from CE loops

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.

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 2.1. 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 2.2). 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.

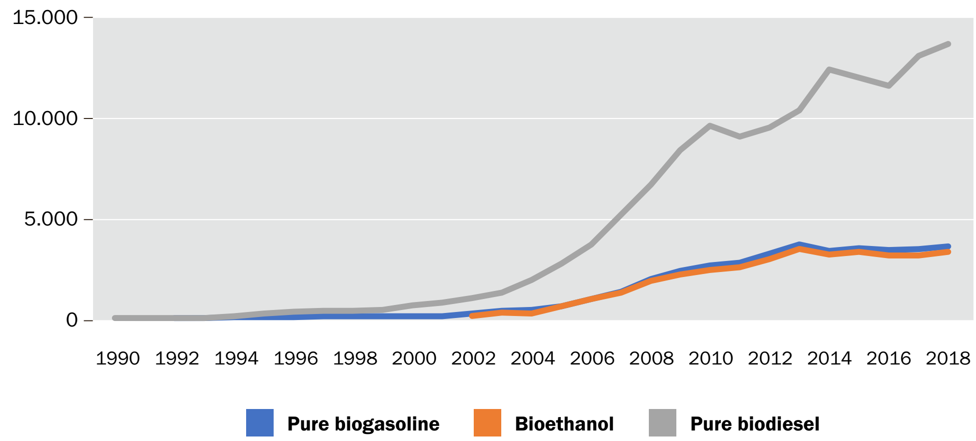
Figure 2.1 Domestic production of energy from bio-based and waste-based feedstock, EU27, 1990-2018, Terajoule



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 2.2 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 to material recovery, is the dominance of, and the policy favour to, energy production from virgin biomass with respect to energy from waste, justified?

Giving value to virgin bioresources

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

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. The result of the Horizon 220 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.

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. 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).

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 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].

In a systemic perspective of 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

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

[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

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

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.

03 The policy web linking CE and energy

***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 business 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.*

3.1 CE and energy: Weak integration in EU legislation

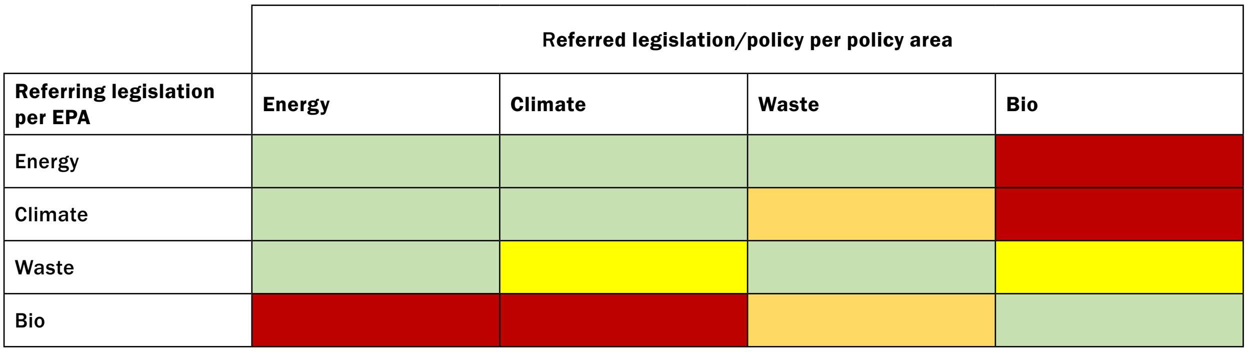
How much CE and energy/climate are integrated across EU environmental and energy policies *before* the EGD?

Building on works by the EEA (2013 and 2016) 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].

The matrix below 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.

[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 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 the 'Categorization System for the Circular Economy' (European Commission 2020f), after defining the 9R 'strategies and principles' of CE, it is stated that: *"[...] 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."*

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[6]. 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 of incineration of waste’. Then, 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’. However, 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.

3.3 Increasing integration from the EGD

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

The EGD (European Commission, 2019) 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. The new CE Action Plan (EC, 2020a) 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”*.

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*

[6] 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).

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."

In May 2020, the EU has adopted the 'Farm to Fork' Strategy (EC, 2020b). 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). Moreover, the Biodiversity Strategy (EC, 2020c) 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.

With regard to biomass, the 'Climate Target Plan 2030' (2020d) 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.

Under the EU Methane Strategy (EC, 2020e), 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). 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.

The Strategy 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.

04 Holistic CE business models and energy

***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 energy management and materials in an integrated way.*

4.1 Holistic business models

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).

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[7].

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. 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 CO2 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.

[7] 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.

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*

Changing approaches

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.

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.

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.

The FEEM report summarises these initiatives for four major energy players - ENI, Total, Shell, ENEL - as presented in their official communication, with a focus on industrial initiatives. A specific case study is developed based on interviews on Versalis.

The emerging strategies are different, but all are aimed at exploiting and exploring, with an increasingly robust commitment, the opportunities offered by the CE paradigm.

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