BIOCIRCULARCITIES project: circular bioeconomy in urban contexts

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ABSTRACT: The BBI-JU Biocircularcities project proposes to unlock the circular economy potential of unexploited bio-based waste streams by exploring the development of economically and environmentally efficient models for organic waste (food and kitchen waste, garden waste, agricultural waste from agro-based industrial sector, wood waste and forestry residues, etc.) in three pilot areas: Napoli (Italy), Barcelona (Spain) and Pazardzhik (Bulgaria). In particular, the aim of the project is to identify regulatory and business opportunities as well as shortcomings for the introduction of bio-based processes and products into local and international markets. In each investigated territory, the state of the art of organic waste management is analysed to identify unexploited bio-based waste streams and implement new circular economy strategies. Local stakeholders are involved in participatory processes to obtain insights and concretely address the problems that limit the implementation of circular solutions within the identified chains. Boosting circular bioeconomy in pilot territories will raise awareness on sustainability issue in urban contexts and facilitate the replicability of the project's results on national and European scale.

Keywords: Bio-waste, Circular Bioeconomy, Organic waste, Sustainability assessment, Urban systems.

1. INTRODUCTION

In the current transition to more sustainable production and consumption models, concepts such as Circular Economy (CE), bioeconomy and circular bioeconomy are becoming increasingly popular. Despite some potential overlaps and differences, these frameworks complement each other. While circular economy aims at increasing the resource efficiency of processes and the use of recycled materials to reduce consumption of finite resources and minimize waste, bioeconomy promotes the use of biological resources to produce renewable products such as biofuels, bioproducts and biopower (European Commission, 2018). Biomass from agriculture, forestry and marine environment (including byproducts and waste) can become feedstock for the processing industry to produce 1) food and feed, 2) fibres, 3) chemical and materials that later on will be transformed into "bio-based products", 4) bioenergy and biofuels substituting fossil feedstock. Circular bioeconomy arises from the intersection between CE and bioeconomy and can be defined as a framework to reduce the reliance on fossil and mineral resources and promote sustainable production of renewable resources from land, fisheries and aquaculture, promoting the bio-waste conversion into various bio-based products and bioenergy, while growing new jobs and industries (Ellen MacArthur Foundation, 2012; WEF, 2014). Circular bioeconomy appears to

bring economic and environmental growth benefits. However, circular bioeconomy is not intrinsically sustainable just because it is based on the reuse of bio-waste (Oliveira et al., 2021). Negative environmental impacts can be generated by the production of bio-based material and bioenergy products. Therefore, the environmental opportuneness of bio-based products, in terms of lower impacts over the entire production chain, needs to be carefully assessed on a case-by-case basis (Wang et al., 2021, Birner, 2017; Sodano, 2013).

With the application of the principles of circular economy and in compliance with the waste hierarchy, bio-based waste (or simply bio-waste and bio-based by-products) can be reduced, reused, recovered or recycled within the same sector or in other sectors (industrial symbiosis). In fact, through waste prevention measures and mechanisms of industrial symbiosis, the volume of bio-waste to be disposed of can be reduced, the problem of biomass losses can be resized and the bio-based waste streams can be used again in cascading and organic recycling as feedstock for the bio-based industry (The Nature Conservancy, 2018; US Environmental Protection Agency, 2021). Finally, unavoidable bio-waste can be regarded as a resource (not anymore as waste) and be reintroduced into the production cycle, leading to a more resource-efficient and sustainable production (Bracco et al., 2018).

Bio-waste based products chains involve multiple players: biomass producers, manufacturing and processing industries, wholesalers, retailers, restaurants, supermarkets, consumers, bio-waste management companies, companies recovering bio-waste, innovation SMEs, researchers, investors and policy-makers. Due to diversity of stakeholders, they have legitimate but often contrasting points of view about strategies to adopt for managing bio-waste. In such a diverging context, it is challenging to find alternatives accepted from all visions.

For circular bioeconomy to become a reality and foster the introduction of bio-waste and bioprocesses into the economy, several conditions should be met:

- More alignment, dialogue and cooperation should exist among different industrial sectors, not only to link their material flows but also to draw a common strategy.
- Stakeholders with different knowledge areas and interests should be engaged to facilitate exchanges and collaboration and find alternatives that could serve all of them.
- Long-term investments are needed. These investments could partly come from bio-based private sector; however, stable and long-term policies are needed to invest in “risky” projects.
- A regulatory and legislative framework to overcome barriers and exploit potentials is necessary.
- Multi-level governments need to share the vision and potentials of circular bioeconomy and adapt current policies to make circular bioeconomy approaches economically and environmentally sustainable.

2. A CASE STUDY

2.1 The BIOCIRCULARCITIES project

The BIOCIRCULARCITIES project (Horizon 2020 Framework Programme. “Funding & tender opportunities”, BBI-2020-SO4-S4 Type of action “BBI-CSA) aims at supporting the development of innovative and comprehensive regulatory frameworks and roadmaps aligned with circular bioeconomy principles, centred on bio-waste and based on feedback from multi-stakeholder participatory processes. The BIOCIRCULARCITIES project will:

- Work on the interaction between “circular economy” and “bioeconomy” as well as combine different policy regulations, such as taxation, waste management, innovation, industry, agriculture and trade.
- Consider not only supply-side (feedstock generation) but also demand-side (market of bio-based products) policy measures to achieve effective actions.

- Coordinate multi-level actions including measures from local waste management plans, through regional infrastructures and planning (e.g. biorefinery deployment), to national and EU initiatives.
- Consider the expectations and the perceptions of the different actors involved in the bioeconomy value chain to have a holistic view of the circular bioeconomy in the specific analysed context.

In order to support the project's aims it is necessary to generate information that encompass different aspects (environmental, economic, technical, socio-cultural, legal and political) and different perceptions about the state of the art and the evolution of circular bioeconomy to overcome existing barriers and propose new sustainable opportunities.

The project is in line with the orientations of the Updated Bioeconomy Strategy 2018 and the Farm to Fork Strategy (2020) and it will seek synergies and collaboration with the upcoming Circular Cities and Regions Initiative (CCRI), which will focus at local and regional level.

2.2 The pilot areas: Napoli, Barcelona and Pazardzhik

Within the BIOCIRCULARCITIES project (GA, 2021) three case studies, in which bio-waste is not fully exploited according to the principles of the circular bioeconomy, were selected (Figure 1) and possible pathways of achieving a sustainable and circular bio-waste management were analysed.

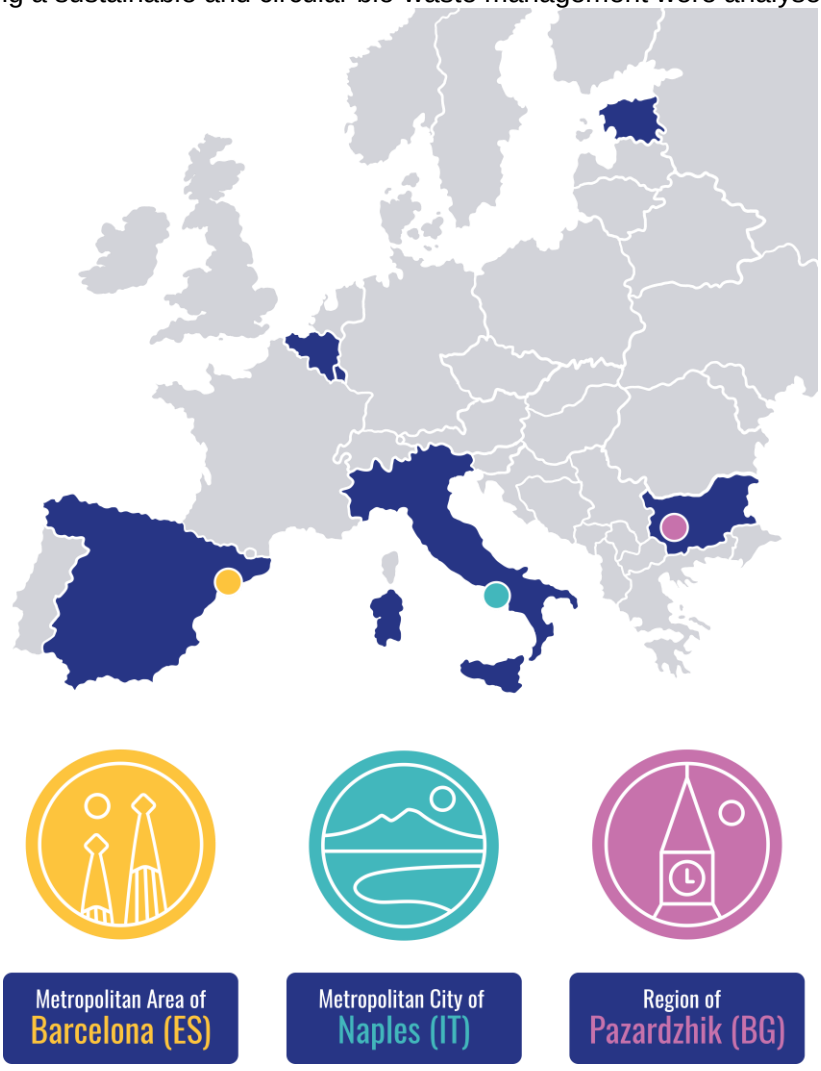

Figure 1. The selected urban areas analysed into the BIOCIRCULARCITIES project (https://www.biocircularcities.eu).

The potential solutions are derived primarily from a search for existing best practices, relating to: (i) production models that lead to a reduction in the waste generation (waste prevention measures) and (ii) the valorisation of bio-waste, through the reinjection into the production cycle and the marketing of the obtained products, considering the potential opportunities for industrial symbiosis and integrated biorefinery implementation.

The case studies analysed were selected in three European urban contexts surrounding the municipalities of Barcelona (Spain), Napoli (Italy) and Pazardzhik (Bulgaria) that will act as pilot-cities whose results can support the replication of the approach in other urban contexts across the EU. These cities were chosen since they represent different contexts and situations in relation to bio-waste management (an advanced, medium and early stage bio-waste management system) and their nature and demography (two coastal metropolitan areas with high population density and an internal rural territory with a low population density).

2.2.1 Barcelona Metropolitan Area - AMB

Barcelona was selected as a pilot city due to its advanced position in Europe, related to the bio-waste management and the implementation policy measures for sustainable bio-based chains.

The Barcelona Metropolitan Area (AMB) includes 36 municipalities, with 3,339,279 inhabitants and an average population density of 4.7 inhabitants/km^2 (data are referred to year 2020).

In 2020 in this pilot area, the bio-waste (from households and commercial activities plus green waste) per capita amounts to 0.37 kg/inhabitant/day, for a total of 453.480,4 ton/year of bio-waste generated. The source separated bio-waste has been increasing constantly since 2002.

In the pilot area there are 4 facilities treating the separately collected bio-waste: 2 composting plants that exclusively receive bio-waste separated at source and produce compost as a final product. The other two plants (Ecoparc 1 and Ecoparc 2) have anaerobic digestion facilities, followed by a composting step to obtain compost. In a separate biological treatment line, the organic output from the mechanical treatment of residual waste is stabilised. The resulting material cannot be used as compost, as it does not meet the requirements for application in agriculture. However, the high rate of impurities in the bio-waste and the high rate of bio-waste still present in the residual waste indicate that an improvement is possible and there are bio-waste flows underexploited in line with biocircular economy principles.

2.2.2 Città Metropolitana di Napoli - CMNA

The Città Metropolitana di Napoli (CMNA) was selected as pilot area because in the past it was a clear example of waste mismanagement in Europe. The CMNA has a population of about 3.2 million people and a population density of 5,093 inhabitant/km^2. This Metropolitan area includes 92 different municipalities with different waste management organization, such as door-to-door collection and dumpster collection. In 2020, the separate collection rate was 48.4% of the total production of Municipal Solid Waste (MSW). The CMNA is an area where bio-waste processing capacity is currently insufficient to treat the total amount of waste generated. Local waste-processing capacity for the organic fraction is limited to only one composting plant and two integrated anaerobic and aerobic treatment plants. Most of bio-waste is sent outside the metropolitan boundaries for treatment.

The specific nature of the CMNA, including urban, agricultural and industrial areas with important biomass production activities, determines the production of a large fraction of bio-waste. In particular, the food supply chain (from agriculture to markets as well as to municipal waste collection and treatment) is an important source of residual biomass for bioenergy, biochemicals and biomaterials. Therefore, the agro-industrial sector faces the challenge of correct and environmentally sound disposal of residues (food markets, industrial food manufacture such as oil and grape pomace, cheese production, among others).

2.2.3 Pazardzhik Region

The Pazardzhik Region is one of the 28 administrative regions in Bulgaria, according to the administrative-territorial division as of 1999. Following the accession of Bulgaria to the European Union (2007), for the purposes of strategic planning the country was divided into six areas: Northeast, North Central, Northwest, Southeast, South Central, and Southwest. The Pazardzhik Region is located in the west part of the South Central planning area. It comprises 12 self-governing municipalities, which include 117 settlements and 96 mayoralties situated on 4,458 km^2, which is 4% of the total country territory. The Region has a population of 310,723 inhabitants, with a low population density (68 inhabitants/km^2). The greater part (56%) consists of forested areas and 36% of agricultural lands. The Pazardzhik Region represents a typical rural region with a well-developed agricultural sector, including forestry and farming. The Region provides very good opportunities for the development of sustainable agro-energy chains based on local agricultural residues and local agro-forestry waste. In the Pazardzhik Region, as well as in Bulgaria in general, separate collection of bio-waste is at its very early stage and only few pilot projects are in place. Therefore, a significant unexploited potential of agricultural wastes and residual wood biomass can be valorised.

2.3 BIOCIRCULARCITIES: a conceptual framework for circular bioeconomy.

The aim of the BIOCIRCULARCITIES conceptual framework is to develop a procedure that can be replicated in different EU contexts.

The first step of the proposed procedure is a survey of the waste management in the involved territories in order to raise awareness of: (i) the existing sectors dealing with (i.e. producing, collecting, treating, processing, valorizing) bio-waste, (ii) the local, national and European regulatory frameworks and (iii) the existing best practices.

In the second step, in each investigated urban context, the main underexploited bio-waste streams are identified and the relevant stakeholders in the field of bio-waste management and circular bioeconomy are involved by means of interactive sessions in dedicated local living labs.

The following step foresees the evaluation of environmental and economic performance of the alternative (best practices) and current (Business as Usual - BaU) bio-waste management scenarios. The sustainability of the selected bio-waste streams is explored in a Life Cycle Thinking (LCT) perspective. In particular, the environmental and economic performance of the studied systems are evaluated through Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) methodologies.

Finally, regulatory and market gaps detected together with best practices assessment will contribute to provide a set of proposed policy recommendations to foster the expansion of circular bioeconomy, consequently reorienting investments and creating green jobs. Outcomes obtained at local level will be used to develop roadmaps to transfer the BIOCIRCULARCITIES approach to other European contexts.

The BIOCIRCULARCITIES framework is at the beginning of its implementation. At the moment, after the survey on bio-waste management in the three pilot areas, the following chains were selected (one in each territory based on its territorial vocation) for the promotion of preventive design within a circular bioeconomy perspective:

- **Barcelona (AMB)**: the selected chain is the management of organic fraction of MSW generated in the AMB. The BaU scenario includes: (i) the current separate collection (open containers), (ii) the transport of organic fraction and (iii) the treatments in Ecoparc 2 (including composting and anaerobic digestion). The alternative scenario differs in taking into account smart bins and door to door system for separate collection and a treatment for producing value added products (such as biosolvents), taking advantages of one of the chain investigated in the synergic on-going project WaysTUP (“WaysTUP! Value chains for disruptive transformation of urban bio-waste into biobased products in the city context" – Project funded from European Union’s Horizon 2020 research and innovation programme

under grant agreement No 818308, https://waystup.eu/).

- **Napoli (CMNA)**: the selected chain refers to the bio-waste from the agro-industrial sector in the CMNA. The BaU scenario starts from the quantification of the residues of interest (e.g. tomato processing waste, lemon processing waste, olive oil production waste, wine production waste etc.) and, taking into account their transport and final treatment, evaluates the impacts of the whole chain. As alternative scenario, the conventional treatment is compared with a conversion process to produce bio-based products (e.g. bioplastics, biochemicals, pharmaceutical and nutraceutical bioproducts).
- **Pazardzhik:** the selected chain is the agro-forestry chain, including forestry residues and wood processing waste. The BaU scenario includes the transportation of these residues to the final disposal, while the alternative scenario accounts for both the energy valorisation (e.g. CHP plant for electricity and heat generation) or/and a biorefinery valorisation for the production of biochemicals.

For an effective transition to circular bioeconomy patterns in the three study areas, the following groups of stakeholders were involved into the local living labs:

- Academic and Research institutions: institutions that perform research specialised in producing and disseminating scientific knowledge, in order to favour the transfer of knowledge.
- Local Authorities: responsible for developing local policies in order to improve the sustainability of waste management through incentives, resolution of logistic bottlenecks and specific regulations.
- Local Waste Management Authorities: technical staff supervising the local bio-waste management.
- Companies in charge of managing bio-waste: public or private bodies managing collection, recovery, recycling and disposal of bio-waste in the pilot areas.
- Companies valorising bio-waste: public or private bodies transforming the bio-waste in added value products.
- NGOs (including Trade Unions): organizations that operate independently from the government and engage concerned members of civil society, can mobilise and structure public opinion, and advocate for a multitude of issues, such as social rights, environmental preservation, consumer's rights, and many others.
- Communities: group of people that can be potentially affected by circular bioeconomy actions, unorganised citizens but also informal organisations like neighbourhood activists, indigenous communities, and a variety of civil society forms of activisms.
- Professional Associations: group of people engaged in the same profession, able to provide technical advice to achieve advancements in the prevention and management of bio-waste.
- Mass media: local mass media to promote the BIOCIRCULARCITIES initiatives.

The next steps will be: (i) the implementation of three living labs in each pilot territory in order to identify the main challenges encountered in each bio-waste selected chain, to support the best practices on circular bioeconomy and to promote the results dissemination, (ii) the assessment of the environmental and economic impacts of the three selected bio-waste chains and (iii) the definition of regulatory framework and/or business models to support decision makers in the management of bio-waste in line with circular bioeconomy prospective.

3. CONCLUSIONS

The strength of this project lies in the capability to bring together multiple actors belonging to the

quadruple helix (businesses, research institutions, public authorities and civil society) to build the collaborative knowledge needed to map the different perspectives about legislative and business shortcomings/opportunities for developing circular bioeconomy in a specific analysed context. Surveys, living labs and peer-review sessions, directed at local stakeholders of the three pilot cities, as well as local and regional authorities, will help to incorporate their input and visions, create awareness of the project and its results, increase knowledge among target groups about circular bioeconomy, build capacity to foster implementation of the project's results at local, but also at national and European levels.

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