BIO CIRCULAR CITIES

Exploring the circular bioeconomy potential in cities

LCA and LCC analyses of the selected systems producing and managing biowaste in the pilot areas

Public summary

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This is the public summary of the confidential report "LCA and LCC analyses of the selected systems producing and managing biowaste in the pilot areas" which results from the work carried out within the Biocircularcities project to explore, according to a Life Cycle Thinking approach, the environmental and economic sustainability of the biowaste systems selected by the project and compare them with alternative scenarios, in each pilot area. These assessments allowed to develop recommendations for enhancing organic waste (biowaste) prevention, valorisation, and management optimisation. The evaluation of the different scenarios will also support the development of circular pathways, based on the current legislation, at local, national and European level and be used in the development of the Biocircularcities Webtool to rank suitable biocircular technologies.

If you are interested in accessing the complete report, please address your request to contact@biocircularcities.eu. Find out more on the Biocircularcities pilot territories on https://biocircularcities.eu/live-from-pilots/.

Why and how assess environmental and economic impacts of biowaste management

A thorough assessment of the environmental and economic impacts of biowaste management is a decisive factor in helping European cities to achieve sustainable development, based on the integration of environmental sustainability, economic growth and welfare into decision-making processes. Indeed, raising awareness about the potential positive impacts is a fundamental step to foster the transition towards the circular bioeconomy. This can be conducted by adopting a Life Cycle Thinking approach, which is a structured and comprehensive approach spread worldwide, supported by the ISO standards 14040-44:2006.

Life Cycle Assessment and Life Cycle Costing methodologies were used for the three pilot territories. The Life Cycle Assessment considers factors such as greenhouse gas emissions, resource use, water and soil pollution. It enables the identification of the most environmentally sustainable biowaste management option. The Life Cycle Costing, which includes the assessment of internal costs over the different stages of the biowaste management chain and costs of environmental impacts (external costs or externalities), aims at assessing the economic efficiency of the different scenarios and identifying those that offer the best cost-benefit ratio in the long term. They also include the identification of the environmental and economic critical aspects (hotspots), which also allows targeted interventions to overcome or reduce them.

Therefore, Life Cycle Assessment (environmental perspective) and Life Cycle Costing (economic perspective) together provide a holistic perspective of the selected biowaste management chains in the three pilot areas with regard to their environmental and economic impacts.

Three pilot areas, three biowaste management systems and two methodologies

For each pilot territory, a specific biowaste management value-chain has been selected with the support of local stakeholders. They are described in detail in the report "State of the art of biowaste production and management in the pilot areas" (public summary available here).

These biowaste chains are:

- Separately collected municipal biowaste in the Metropolitan Area of Barcelona (MAB, Spain), since it is the most abundant biowaste stream in the pilot area.
- Forestry residues and wood processing waste, due to the strong forestry vocation of the Pazardzhik Province (PP, Bulgaria) pilot area; they represent the most challenging biowaste stream, in terms of urgency to be dealt with.
- Organic waste from the agro-industrial sector, in Metropolitan City of Naples (MCN, Italy), an underexplored stream. In particular, organic waste (coffee silverskin - CS) from the coffee chain has been selected for further investigation, due to the novelty of the process and the possibility of using primary data from local coffee roasting industries.

For each system, a Business as Usual (BaU) scenario, representing the current situation, and one or more Alternative scenarios, in line with the principles of the circular bioeconomy and the needs of local stakeholders, have been analysed. In detail, the environmental and economic performances of the three selected value chains have been evaluated through Life Cycle Assessment and Life Cycle Costing methodologies.

These analyses are based on the qualitative and quantitative data provided directly by the local partners (Área Metropolitana de Barcelona – AMB, Città Metropolitana di Napoli – CMNA, and Regional Energy Agency of Pazardzhik – REAP) and were completed with data from pertinent scientific literature and specialised databases such as EcoInvent 3.8. The time reference for BaU primary data is 2021 for MAB, 2019 for PP and 2019 for MCN. For the secondary data retrieved from EcoInvent, the available datasets relating to the year closest to the reference one were selected.

The results of the analyses show that, for all BCC pilot areas, the Alternative scenarios always turn out to be a more sustainable option thanks to the production of sustainable bio-based products that can replace their fossil counterparts.

In addition, the analyses highlighted that the most impacting processes from an environmental point of view are electricity consumption and transport. These results are useful for local stakeholders and policymakers to understand the importance of focusing on: (i) energy efficiency strategies and (ii) valorisation at territorial level to support the local economy and reduce transport.

Metropolitan Area of Barcelona

The BaU scenario for the Metropolitan Area of Barcelona involves the current voluntary separate collection in open containers, followed by transport and treatment of the biowaste through anaerobic digestion to produce biogas and digestate in a local facility, namely ECOPARC 2. The digestate and biogas are respectively converted into compost (in a composter) and electricity (in a Combined Heat and Power (CHP) plant).

In the Alternative scenario, prevention measures and mandatory biowaste separation through door-to-door or smart bins were considered. Moreover, the collected biowaste is transported only four times per week to the local facility (ECOPARC 2), where it is processed into biomethane (by upgrading the biogas from anaerobic digestion) to be injected into the national grid.

Life Cycle Assessment and Life Cycle Costing results show that:

- The solutions proposed (prevention measures, different collection systems and treatment) in the Alternative MAB scenario result to be more sustainable than the current solutions in the BaU scenario, from both the environmental and economic point of view.
- The environmental and economic impacts of collection are greater than those of treatment in both investigated scenarios. In particular, transportation is the main hotspot in both investigated scenarios.
- The highest environmental and economic benefits come from biomethane production and the resulting avoided production of fossil methane.
- For Ozone depletion and Resource use (fossils) impact categories there are NET benefits from the proposed Alternative solutions.
- The Alternative MAB scenario allows for an average reduction of environmental impacts by 70% and of external costs by about 46% compared to the BaU scenario.

As far as the economic performance is concerned, the internal costs (related to expenditures and revenues) for the Alternative scenario are slightly lower (a few euros per ton of biowaste) than for the BaU scenario. Moreover, also in terms of externalities, the Alternative scenario appears to be more advantageous, as the total environmental damage cost is almost halved compared to the BaU scenario. However, it should be noted that these are only indicative results, as they have been obtained using European average data, as no primary data were available.

Province of Pazardzhik

In the Province of Pazardzhik, 65% of the residues generated by forestry are valorised as pellets (60%) and as compost (5%) in both the BaU and Alternative scenarios. The remaining 35% of forestry residues are left on the forest ground (unused forestry residues) in the BaU scenario. Alternative scenarios should be designed considering a better forestry residues management to prevent frequent open fires and to safeguard the forest ecosystem. For these reasons, in the Alternative scenarios, 25% of the unused forestry residues is valorised as energy in a CHP plant (Bioenergy scenario), or converted into high-value biochemical products (Biochemicals scenario).

Life Cycle Assessment and Life Cycle Costing results show that:

- The "Biochemicals scenario" turns out to more sustainable for forestry residues valorisation, thanks to the benefits from the production of bio-based chemicals.
- The "Bioenergy scenario"; leads to greater advantages than the "Biochemicals scenario" only in the "Eutrophication of freshwater" impact category.
- The greatest environmental benefits come from the avoided production of fossil 1,4 butanediol (BDO) in the "Biochemicals scenario".
- The highest impact (hotspot) is due to the electricity consumption by the treatment phase for both the biochemicals production and the energy generation in a CHP plant. Therefore, an increased use of renewable energy and/or a lower energy consumption for the processes (e.g. by using the Best Available Technologies) is advisable.
- The environmental burdens of composting and pelletising processes are only partially balanced in the BaU scenario by the avoided production of N, P, K synthetic fertilizers; on the contrary, the environmental loads arising in the Alternative scenarios are negligible compared to the net benefits resulting from the avoided production of the fossil counterparts.
- When considering internal economic costs, the Biochemicals Alternative scenario is more profitable than the BaU scenario thanks to the high value of biochemical products, while it was not possible to evaluate the internal costs of the Bioenergy Alternative scenario due to a lack of data. In detail, the valorisation of 25% of the currently unused forestry residues through their conversion into biochemical products would allow to quadruple the economic benefits, considering both the revenues from all valorisation activities and the savings of environmental remediation costs.
- All three scenarios lead to savings in environmental damage costs, with the largest benefits observed for the Biochemicals Alternative scenario and the smallest ones for the BaU scenario.

Overall, the valorisation of the lignocellulosic fraction to produce biochemicals in a local biorefinery leads to greater benefits than the other valorisation scenarios (energy valorisation through CHP plants or composting).

Metropolitan City of Naples

The BaU scenario for the agro-industrial organic waste management system in the Metropolitan City of Naples (MCN), focuses on the coffee silverskin disposed of through the public service and sent to composting. In the Alternative scenario, coffee silverskin is sent to a bakery and transformed into a functional ingredient that is used for the production of bakery products, replacing the same quantity of wheat flour.

The Life Cycle Assessment and Life Cycle Costing results show that:

- A net environmental load is recorded for the BaU scenario. Conversely, the Alternative scenario results in a net environmental benefit thanks to the avoided production of wheat flour.
- The most environmentally impacting processes are electricity consumption in the treatment phase as well as transport. Therefore, an increased use of renewable energy and energy-efficient processes, as well as the use of local treatment facilities, would be necessary to improve the overall environmental performance.
- The Alternative scenario results to be more economically advantageous compared to the BaU one, both in terms of biowaste disposal costs (internal costs) and environmental damage costs (externalities). Indeed, the disposal of 1 tonne of coffee silverskin in the BaU scenario costs two times more than the Alternative scenario, for the coffee company. As far as externalities are concerned, the BaU scenario leads to a net environmental damage cost, while the Alternative scenario (silverskin as functional ingredient) allows avoiding a few hundred euros of environmental damage costs, for 1 tonne of coffee silverskin disposed of, thanks to the avoided production of wheat flour. It also results in economic advantages for the bakery.

Therefore, the valorisation of coffee silverskin as compost is less advantageous than its transformation into a functional ingredient for bakery products.

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