Biocircularcities unlocked!
The Brussels stop
Final conference of the Biocircularcities project
Brussels, 28 September 2023

This project has received funding from the Bio-based Industries Joint Undertaking (JU) under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101023516. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and the Bio-based Industries Consortium.
Why and how to unlock a local and circular bioeconomy – Barriers and solutions

Moderated by Jean-Benoit Bel (ACR+)

Amalia Zucaro (ENEA)
Karin Meisterl (ENT)
Laurène Chochois (LIST)
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The Biocircularcities project in a nutshell

Karin Meisterl, Fundació ENT
28 September 2023

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BIOCIRCULARCITIES (BCC)
Exploring the circular bioeconomy potential in cities. Proactive tools for implementation by policy makers and stakeholders.

Coordination and Support Action

Aims
➢ Supporting the development of innovative regulatory frameworks aligned with circular bioeconomy principles
➢ Exploring the CBE potential of unexploited bio-based waste streams in 3 pilot areas

8 consortium partners
3 BCC pilot areas with different value chains

Metropolitan Area of Barcelona (MAB, Spain)
Separately collected biowaste

- Improving separate biowaste collection
- Upgrading biogas from anaerobic digestion into biomethane for the local gas grid

Metropolitan City of Naples (MCN, Italy)
Agro-industrial organic waste

- Processing coffee roasting residues (coffee silverskin) into functional ingredients

Pazardzhik Province (PP, Bulgaria)
Forestry residues

- Lignocellulosic valorisation (production of bio-based chemicals)
- CHP plant (bioenergy)
BBC Main outcomes

➢ LCA and LCC of the 3 selected pilot value chains to compare the current state with the alternative scenarios.

➢ Policy recommendations based on drivers and barriers identified in the policy framework of the 3 selected value chains.

➢ Web-based tool (guidelines) to assist policy makers and industry in designing biowaste management strategies.

➔ Multi-actor approach: Continuous involvement of local and international stakeholders in the project outcomes.
BCC multi-actor contribution

- Metropolitan Area of Barcelona (MAB)
  - Municipal biowaste
  - Living Labs #1-3

- Metropolitan City of Naples (MCN)
  - Agro-industrial organic waste
  - Living Labs #1-3

- Province of Pazardzhik (PP)
  - Forestry residues
  - Living Labs #1-3

- Peer Review Sessions & Advisory Board Meetings #1-3

Pilot Areas
Selected Value Chains
Local Level
International Level
Discover Biocircularcities in video: https://youtu.be/kMQp_vmlWqE (EN)
Watch this video also in Bulgarian, Catalan, Italian, or Spanish.
Roundtable: Why and how to unlock a local and circular bioeconomy – Barriers and solutions

Moderated by Jean-Benoit Bel (ACR+)
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The benefit of unlocking local bioeconomy

Amalia Zucaro, ENEA
28 September 2023
LIFE CYCLE THINKING (LCT)

- **PRE-PRODUCTION** (procurement of raw materials)
- **PRODUCTION** (transformation of materials, assembly and finish)
- **DISTRIBUTION** (logistics, sales and packaging)
- **USE AND CONSUMPTION** (including maintenance)
- **END OF LIFE** (Reuse, Recycle, Recovery, Disposal)
The forestry residues chain in Pazardzhik Province (PP)

Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) results
The selected chain in PP

**CURRENT SITUATION**
- Forest residues: 25,239 t (35%)
  - Unused in forest
- Pellet production plant:
  - 1,611 t
  - 60%
  - 5%

**ALTERNATIVE SCENARIO**
- So far unused forestry residues: 22,715 t (25%)
- Lignocellulosic valorisation:
  - 2,524 t (10%)*
- To remain in the forest

*Recommended amount to be left on the forest floor in order not to disturb the nutrient balance of the soil (Pergola et al., 2020)

What is changing compared to the current situation?
(The other steps of the current value chain stay the same)
Net environmental impacts of the three scenarios

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>BaU</th>
<th>Alternative scenario - CHP</th>
<th>Alternative scenario - Biorefinery</th>
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<td>-8.32E+01</td>
<td>-3.91E+02</td>
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</table>

Environmental loads

Envir. benefits
Net environmental impacts of the Biorefinery scenario

- Acidification
- Climate change
- Particulate matter
- Eutrophication, marine
- Eutrophication, freshwater
- Eutrophication, terrestrial
- Human toxicity, cancer
- Human toxicity, non-cancer
- Ozone depletion
- Photochemical ozone formation
- Resource use, fossils
- Resource use, minerals and metals
- Water use

**Environmental loads**

- Biorefinery Succinc acid
- Biorefinery Ethyl levulinate
- Biorefinery BDO

**Avoided benefits**

- Avoided fossil BDO
- Avoided fossil Succinic acid

Legend:
- Pellets
- Biorefinery - Succinc acid
- Avoided fossil Butane-1,4-diol (BDO)
- Compost
- Transport
- Biorefinery-Ethyl levulinate
- Avoided Inorganic fertiliser (N, P2O5, K2O)
- Biorefinery - BDO
- Avoided fossil Ethyl levulinate
### eLCC: Total economic costs for PP system (F.U. 1 ton of forestry residues)

**Total BaU scenario economic costs**

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit</th>
<th>Cost</th>
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</thead>
<tbody>
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<td>€/ton</td>
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**Total Alternative scenario (Biorefinery) economic costs**

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<th>Category</th>
<th>Unit</th>
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**Total Alternative scenario (CHP) economic costs**

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<tr>
<td>NET EXTERNAL COSTS (savings)</td>
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<td>39.3</td>
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<tr>
<td>TOTAL NET BALANCE</td>
<td>€/ton</td>
<td>39.3</td>
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</table>
Conclusions from LCA & LCC in PP chain

➢ The **Biorefinery scenario** turns out to be the most sustainable, thanks to the benefits deriving from the production of bio-based chemicals.

➢ The greatest environmental **advantages** come from the **avoided production** of fossil BDO.

➢ The **highest impact** (hotspot) is due to **electricity** consumption.

➢ The valorization of 25% of currently unused forest waste, through its conversion into biochemicals (**Alternative scenario** - Biorefinery), would **allow to quadruple the economic benefits**, considering both the earnings from all the valorization activities and the **savings of environmental remediation costs**.

**These results suggest:**

➢ Increasing the production of bio-based BDO.

➢ Increasing the use of renewable energy and/or of low energy consumption machinery.
The agro-industrial organic waste chain in the Metropolitan City of Naples (MCN)

Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) results
The selected chain in MCN

**According to the Ecoinvent LCA database**

1 t 100%
---
Biowaste from Coffee Roasting (Coffee Silverskin*)

Pneumatic conveying system

Pelletiser

1 t Collection + Transport

Composting (mixed with pretreated green waste)

** 50%

0.5 t

Compost

Supply & Demand

“Losses” (CO₂, H₂O,..)

Incineration + Landfilling

100%

---

1 t 100%

Biowaste from Coffee Roasting (Coffee Silverskin*)

Pneumatic conveying system

Pelletiser

1 t Collection + Transport

Sterilisation, sieving, washing, drying, homogenisation

Functional ingredient for baked goods

Bakery

0.95 t

Supply & Demand

**95%

1 t 100%

Biowaste from Coffee Roasting (Coffee Silverskin*)

Pneumatic conveying system

Pelletiser

1 t Collection + Transport

Composting (mixed with pretreated green waste)

** 50%

0.5 t

Compost

Supply & Demand

“Losses” (CO₂, H₂O,..)

Incineration + Landfilling

100%

---

ALTERNATIVE SCENARIO

1 t

Biowaste from Coffee Roasting (Coffee Silverskin*)

Pneumatic conveying system

Pelletiser

1 t Collection + Transport

Sterilisation, sieving, washing, drying, homogenisation

Functional ingredient for baked goods

Bakery

0.95 t

Supply & Demand

**95%

---

* About 90% of total biowaste from coffee roasting (besides discarded beans)
### Net environmental impacts of BaU and Alternative scenarios

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Alternative scenario</th>
<th>BaU scenario</th>
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<td>Acidification</td>
<td>mol H+ eq</td>
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<td>Climate change</td>
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<td>Particulate matter</td>
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<td>Eutrophication, marine</td>
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<tr>
<td>Eutrophication, freshwater</td>
<td>kg P eq</td>
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<td>Eutrophication, terrestrial</td>
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<td>Human toxicity, non-cancer</td>
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<td>Ozone depletion</td>
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<td>Photochemical ozone formation</td>
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<td>Resource use, fossils</td>
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<td>Water use</td>
<td>m³ depriv.</td>
<td>-7.02E+03</td>
<td>1.17E+01</td>
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</table>
Net environmental impacts of the Alternative scenario

Environmental loads

Environmental benefits

TREATMENT (Bakery)

Avoided wheat flour

Electricity

Transport to Bakery
Machinery
Electricity
Waste disposal
Tap water
Avoided Wheat flour

Acidification
Climate change
Particulate matter
Exhaustion
Extrapolation
Extrapolation, human toxicity
Extrapolation, cancer
Extrapolation, non-cancer
Dose elevation
Precipitation
Air emissions
Energy use
Minerals and metals
Water use

Benefits

loads

Environmental
loads

Environmental
benefits

Net environmental impacts of the Alternative scenario

Avoided wheat flour

Electricity
eLCC: Total economic costs for MCN system (F.U. 1 ton of C.S.)

### Total BaU scenario economic costs

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit</th>
<th>Cost</th>
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<tbody>
<tr>
<td>NET INTERNAL COSTS</td>
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<tr>
<td>NET EXTERNAL COSTS</td>
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<td>€/ton</td>
<td>-593.8</td>
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### Total Alternative scenario economic costs

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<th>Unit</th>
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<td>NET INTERNAL COSTS (expenditures)</td>
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<tr>
<td>NET EXTERNAL COSTS (savings)</td>
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<td>545.8</td>
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<tr>
<td>TOTAL NET BALANCE</td>
<td>€/ton</td>
<td>+357.8</td>
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Conclusions from LCA & LCC in the MCN chain

➢ The Alternative scenario turns out to be the most sustainable, thanks to the benefits deriving from the avoided production of flour.

➢ The most impacting processes are electricity consumption and transport.

➢ The Alternative scenario results to be more economically convenient than the BaU, in terms of savings in both biowaste disposal costs and environmental remediation costs.

These results suggest:

➢ increasing the use of renewable energy and/or of low energy consumption machinery;

➢ having local treatment facilities (less transport);

➢ there are more economically convenient solutions than the public system for disposing of biowaste from the agro-industrial sector.
The municipal biowaste chain in the Metropolitan Area of Barcelona (MAB)

Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) results
The selected chain in the MAB

**Current Situation**
- Kitchen waste
- Green waste (small size)

**Selected Chain**
- Private & Industry BIOWASTE (8,396 t)
- Transport
- Municipal BIOWASTE
- Open containers — problem: low biowaste quality (77,244 t)
- Pretreatment
- Digestate (16,271 t)
- Composting
- Biogas (9,954,367 m³)
- Energy self-consumption
- Electricity production
- Supply & Demand

**Alternative Scenario**
- Private & Industry BIOWASTE (8,396 t)
- Transport
- Municipal BIOWASTE (Net increase: 25%)
- Door to Door — Smart Bin — higher biowaste quality (96,555 t)
- Pretreatment
- Digestate (5,248 t)
- Composting
- Biogas (14,307,424 m³)
- Biogas upgrading
- Biomethane for gas network / waste trucks
- Supply & Demand

**Current/Not Changing Situation vs. New Situation**
Environmental impacts of the two scenarios

- Reduction of impacts from 43% in PM and CC up to 96% in WU

<table>
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<tr>
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<th>BaU scenario</th>
<th>Alternative scenario</th>
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Environmental impacts of the Alternative scenario

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<td>EM</td>
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Environmental benefits
### Life Cycle Costing (LCC) analysis

**Total economic costs: internal costs and environmental damage costs (externalities) (F.U. 1 ton of collected biowaste).**

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit</th>
<th>Cost</th>
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<td>External costs</td>
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<td><strong>TOTAL COSTS</strong></td>
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</tr>
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<td><strong>TOTAL COSTS</strong></td>
<td>€/ton</td>
<td><strong>1,61E+03</strong></td>
</tr>
</tbody>
</table>
Conclusions from LCA & LCC in the MAB chain

➢ The solutions proposed (prevention measures, different collection systems and treatment) in the Alternative scenario resulted 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 generated by the collection activities, in both investigated scenarios, are greater than those generated by the treatment processes.

➢ The highest environmental and economic benefits come from the biomethane production and the consequently avoided supply of fossil methane.

➢ The Ozone depletion and Resource use (fossils) impact categories record a NET benefit from the proposed solutions.

➢ The Alternative scenario allows for an average reduction of 70% in the environmental impacts.
This project has received funding from the Bio-based Industries Joint Undertaking (JU) under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101023516. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and the Bio-based Industries Consortium.

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Policy recommendations

Karin Meisterl, Fundació ENT
28 September 2023
LCA/LCC based Policy recommendations

- Use renewable energy sources in the valorisation processes
- Purchase energy-efficient machinery
- Optimise transport
- Reuse and recycle, take action against planned obsolescence, and promote the spread of eco-design (to facilitate repair and recycling)
- Fiscal and financial incentives to realize these actions
Methodology: Policy Recommendations (PR)

- BCC Database on Policy Framework for the CBE (144 documents: D3.1)
- Analysis of the most relevant CBE documents by the local partners (72 documents)
- Definition of divers and barriers for the implementation of circular bioeconomy (D3.2)
- Policy recommendations for the 3 pilot areas

LCT based PR

- Existing legislations + policy instruments (in other countries than BG, ESP, IT)
- Good Practice examples

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94 BCC policy recommendations

In total 30 general PR relevant to all three pilot areas on the topics of:

- Data management
- Organic waste treatment and sustainable biorefineries
- Market incentives for bio-based products
- Public awareness and support
- Stakeholder involvement
- (Bioplastics)

In total 64 PR specific to different pilot areas, including:

- Forestry residues (collection; biochemicals & bioenergy production)
- Agro-industrial organic waste & novel food
- Municipal biowaste (food waste prevention, separate collection. AD/biogas/biomethane)
Data management

➢ At EU level, introduce standardised guidelines for data collection and analysis for all types of organic waste.

➢ At national and regional level, introduce into law annually updated, comprehensive, transparent, and freely accessible databases on municipal biowaste streams using European standardised guidelines.

➢ At national level, consolidate and accelerate the development of national electronic platforms for waste management regarding the documentation, registration, and reporting obligations in the waste management sector and data exchange between all regions in one country.
Organic waste treatment and sustainable biorefineries

➢ At EU and national level, ensure planning security with regard to legal framework conditions and subsidies, and phase out subsidies not consistent with the EU waste hierarchy and CBE targets.

➢ At regional level, introduce financial incentives for technical improvements of existing treatment plants, the use of BAT and for the construction of new biorefineries, giving preference to bio-based products according to the "cascading use of biomass principle".

➢ At national level, build capacity in the municipalities to speed up the permitting process for new biorefineries.

Market incentives for sustainable bio-based products

➢ At national, regional, and local level, support Green Public Procurement to stimulate the growth of the sustainable bio-based product market, using the EU guidance for bio-based products in procurement.

➢ At EU or national level, introduce VAT reductions for bio-based products (e.g., biochemicals) and other environmentally friendly products and services produced in the EU compared to fossil-based alternatives (integrated approach) and products from outside the EU.
Public awareness and support

➢ At regional and local level, finance well-developed, continuous environmental education programmes on food waste prevention, separate collection, and the benefits of bio-based products.

➢ At regional and local level, monitor the success of awareness raising campaigns using common indicators for MSW management.

Stakeholder involvement

➢ At regional or local level, promote the participative approach by enshrining stakeholder involvement in legislation.

➢ At EU and regional level, promote technology and innovation clusters and networking platforms (e.g., Biomethane Industrial Partnership) for policy makers, researchers, and market players.
Pazardzhik Province

- At national level, funding should be made available for local environmental impact assessments to determine the range between forestry residues that must remain on the ground to preserve soil quality and biodiversity and residues that can be used to produce new bio-based products.

- At national level, introduce a fee and incentive scheme to promote the pre-treatment and sustainable collection of forestry waste for biorefineries – especially in difficult terrain – also with a view to reducing the costs of firefighting and reforestation after fires.

- At EU level, introduce incentives for bioenergy compared to fossil energy through measures such disincentives for the use of fossil energy (e.g., increasing taxes) or an incentive mechanism based on carbon footprint assessment.* The lower the carbon footprint [CO₂ g/MJ], the higher the price/incentive should be for this product/energy source.

*according to the International Sustainability and Carbon Certification (ISCC).
Metropolitan City of Naples

- At national level, introduce financial incentives and administrative and technical support for companies to use their by-products (e.g., coffee silverskin) internally for the production of new products (e.g., functional food) to avoid classification as waste.

- At regional and local level, incentivise local industrial symbiosis, i.e., the physical exchange of resources, energy and/or by-products among different industries.

- At national level, set up collection systems for agro-industrial organic waste: Give financial incentives to companies or businesses to collect and store a certain waste stream (e.g., collection of spent coffee grounds in cafeterias).

- **Novel food:** At national level, provide financial support for laboratory analyses in support of risks assessments for EFSA (European Food Safety Authority), which provides independent scientific advice and informs on existing and emerging risks in the food chain with a view to granting market authorisation (minimum 2-year process).
At national level, introduce mandatory door-to-door (DtD) or smart bin collection systems. The introduction of new "open bins" should be prohibited.

At the local level, DtD collection controls should be introduced - with fines for non-compliance.

At national level, introduce the mandatory application of the pay-as-you-throw (PAYT) principle.
Metropolitan Area of Barcelona

➢ At national and regional level, introduce stricter limits for biowaste impurities (CAT: 5%; ESP: 10% by 2027) → Low impurity levels are important for obtaining high-quality compost!

➢ At national level, integrate a higher minimum biogas target (at least 5 bcm by 2030) and biomethane target (at least 5% of the total gas consumed) linked to the target for new plants to be built into the Spanish Biogas Roadmap 2022.[1]

➢ At national level, promoting biomethane demand by awareness raising campaigns about the guarantee of origin certificate (by Enagás) [2] for energy produced from renewable sources (when and where it was produced, the type of production facility and energy source).

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BIO CIRCULAR CITIES

BioCircularCities guidelines (webtool)

Laurène Chochois, LIST
28 September 2023
BCC guidelines: Methodological approach

BCC webtool: https://bcc.list.lu/

✓ Analysis of the scope of the global Circularity and Bioeconomy concepts, the associated European targets and incentives, and the correlations which can be established between them.

✓ Analysis of the main drivers and barriers towards the development of sustainable circular bioeconomy value chains (D4.1 literature review; D3.2 policy framework analysis at EU and pilot level).

✓ Review of the existing supporting approaches, guidelines and tools in order to position the BCC guidelines and clearly define its objectives.

✓ D4.2 “Report documenting the definition of the decision tree background logic”.

Objective and scope of the BCC Guidelines

**Target group:** Biowaste managers/technicians reporting to public/private decision makers.

**Different feedstock**
- Municipal biowaste
- Forestry residues
- Agro-industrial organic waste

**How to avoid landfill and create added-value?**

**Which valorisation option is the most suitable?**

- Recycling into high-value biochemicals
- Recycling into biogas or biomethane and/or compost
- Incineration with energy recovery

**BBC webtool** -> Identification of the most suitable bio-circular valorisation technology considering the specific context
Setting guidelines for identifying the most suitable biowaste treatment options

➢ **BCC Guidelines format:**

Webtool supporting the identification of the most relevant options in terms of biowaste management and valorisation technologies.

https://bcc.list.lu/
Setting guidelines for identifying the most suitable biowaste treatment options

➢ **BCC Guidelines format: Webtool** supporting the identification of the most relevant options in terms of biowaste management and valorisation technologies.
# BCC webtool: 14 technologies considered

<table>
<thead>
<tr>
<th>Type of bio-based product</th>
<th>Biochemical processes</th>
<th>Thermochemical processes</th>
<th>Chemical processes</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk/Specialty chemicals</td>
<td>Enzymatic hydrolysis</td>
<td>Gasification</td>
<td>Heterogeneous catalysis</td>
<td>Pulping</td>
</tr>
<tr>
<td></td>
<td>Industrial fermentation</td>
<td>Hydrothermal process</td>
<td></td>
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<tr>
<td></td>
<td>Solid state fermentation</td>
<td>Pyrolysis**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bio-based functional ingredients (novel) food</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biogas</td>
<td></td>
<td>Anaerobic digestion (AD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical Biological Treatment (MBT) + AD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomethane</td>
<td></td>
<td>Anaerobic digestion + Biomethanation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compost</td>
<td></td>
<td>MBT + Composting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>Landfilling</td>
<td>Incineration of MSW (containing biowaste) + energy recovery</td>
<td></td>
</tr>
</tbody>
</table>

*only applicable to food related waste
**only applicable to wood processing waste and forestry residues
BCC webtool: data entry by the user

Access: https://bcc.list.lu/

Step 1: Feedstock and current system characterisation
Step 2: Type of bio-based product targeted
Step 3: Environmental performances
Step 4: Political and economic incentives

RESULTS: Technology ranking
BCC webtool: database and results

**BACKGROUND DATABASE** for technology selection
- Valorisation technologies portfolio
- Significant technical parameters
- Associated EU policy framework
- Significant environmental & economic parameters
- Data for sustainability comparisons

**RESULTS: Ranking** of the 14 integrated technologies, depending on the:
- Type, quantity and quality of feedstock
- Specification of environmental performances
- Available political and economic incentives
- Job creation potential
- The possibility to recycle/recover/reuse a product (end-of-life stage) etc.

### BioCircularities app

#### Home
- Name: Gasification
- Score: 6

#### Step 1: Characterisation of a technology
- Heterogenous catalysis
- Industrial fermentation
- Mechanical Biological Treatment (MBT) with Composting
- Anaerobic digestion

#### RESULTS: Ranking
- Type, quantity and quality of feedstock
- Specification of environmental performances
- Available political and economic incentives
- Job creation potential
- The possibility to recycle/recover/reuse a product (end-of-life stage) etc.

#### Economic viability:
The economic feasibility of biomethane plants is evaluated as a function of the feedstock used and the plant size. For instance, the operating costs would be higher for treating waste-based materials than for food waste. The profitability of biomethane plants is strongly linked to the subsidies available (Kouchella & D’Alessio, 2016).

#### Anaerobic Digestion:
- Anaerobic Digestion can be considered as a cost-effective technology.
- Operating costs for Anaerobic Digestion are lower than costs of industrial composting (Fan et al., 2018). González-Costallo et al., 2021 estimate that subsidies required in order to reach profitability varied from 10.5 €/MWh to 19.3 €/MWh. It was found that Digestate selling price is below 2 EUR/L.
- Although pre-treatments may increase the biodegradability of the substrate and the conversion yields, these processes may increase overall costs and limit its economic feasibility (Ignjatović et al., 2021).

#### Environmental burdens and advantages:
- Several authors demonstrated that the main environmental benefits of Anaerobic Digestion are realised in terms of lower energy demand, global warming potential (GWP), and resource consumption (RC) due to energy production from biogas instead of natural gas, and to the replacement of chemical fertilisers by digestate.
- For other impact categories such as acidification potential (AP), eutrophication potential (EP), photochemical oxidant formation (POF), human health impacts (HHI), and ozone depletion potential (ODP), several studies found that the environmental impacts of Anaerobic Digestion processing vary mainly depending on the technological specifics, the plant geographical location, and other assumptions and choices made for the environmental impact calculation.

#### Social benefits:
- Anaerobic Digestion create employment by highly skilled plant contractors, operators and related service providers. A study from 2018 elaborated by Navigant Netherlands B.V. estimates the employment linked to both biomethane and hydrogen deployment according to a specific “optimised gas” scenario defined in their “Gas for Climate study”, based on investments in renewable gas across different sectors of the economy in 2030. The estimated number of jobs per unit of energy produced, was estimated around 775 to 1,650 jobs / TWh.

#### N.B.
The model does not estimate the net employment effects across the overall energy system because the focus was on the renewable gas supply chains, employment factor.

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Why and how to unlock a local and circular bioeconomy – Barriers and solutions