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POWER4BIO
REGIONS FOR
BIOECONOMY

Catalogue with bio-based solutions

Deliverable 3.3

MAIN AUTHORS: WAGENINGEN RESEARCH, BZN, CIRCE, DBFZ

DATE: 31 DECEMBER 2019

PUBLIC

Project POWER4BIO “emPOWERing regional stakeholders for realising the full potential of European BIOeconomy”

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| Main Author | Martien van den Oever, Johan van Groenestijn, Arnoud Togtema, Jan Broeze (WR), Nora Hatvani (BZN), Javier Marcos Gonzalez, Ignacio Martin Jimenez (CIRCE), Bomin Yuan (DBFZ) |
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Table 1 Document Factsheet

| Document History | | | |
|------------------|------------|---|--|
| Version | Date | Main modification | Entity |
| Draft 1 | 19/06/2019 | Draft approach document sent to RTOs | WR |
| Draft 2 | 13/08/2019 | Long list of solutions complete, results combined | CIRCE, DBFZ, WR, AKI, BZN, UNFU, CAPDER, MAE, CCB, SPRING, EWI, USB, SUA |
| Draft 3 | 16/09/2019 | Short list of solutions selected | BZN, CIRCE, DBFZ, WR |
| Draft 4 | 20/09/2019 | Guidelines for filling database | WR |
| D3.3 Draft | 18/11/2019 | Draft description of approach, activities & results. Sent to BZN, CIRCE & DBFZ for review | WR, BZN, CIRCE, DBFZ |



| | | | |
|------------------|------------|--|----------------------|
| Online catalogue | 28/11/2019 | Info for selected bio-based solutions partly filled out in online database. Start of mutual reviewing | WR, BZN, CIRCE, DBFZ |
| D3.3 Draft-2 | 11/12/2019 | Updated draft. Sent to BZN, CIRCE & DBFZ for review | WR, BZN, CIRCE, DBFZ |
| Online catalogue | 20/12/2019 | Catalogue of bio-based solutions published and searchable | WR, BZN, CIRCE, DBFZ |
| D3.3 Final Draft | 20/12/2019 | Conclusions & Summary | WR, CIRCE |
| D3.3 Final | 30/12/2019 | Final review by CIRCE and WR | CIRCE, WR |

Table 2: Document History

ABBREVIATIONS

BSAT: Bioregional Strategy Accelerator Toolkit

CAPEX: Capital expenditure

CO₂: Carbon dioxide

DM: Dry matter content

DoA: Description of Action

ERD: Entity relationship diagram

FOB: Free on board

GA: Grant Agreement

GHG: Greenhouse gas

GJ: Giga joule

ha: Hectare (10.000 m²)

HMF: Hydroxymethylfurfural

HTP: Hydrothermal processing

kg: Kilogram

PWA: Progressive web applications

RTO: Research and Technology Organisation

tonne: 1000 kg

TRL: Technology readiness level

WP: Work package



CLARIFICATIONS

Database webtool: Edit module and user module of the database

Field: Box in database webtool to enter information of solutions

Solutions factsheet: The information of each solution which is included in the database and which can be viewed and also printed in PDF format by end-users.

Biomaterials: Means 'bio-based materials', based on recently harvested plant feedstock. The same holds for 'biochemicals' and 'bioenergy'. This does not necessarily mean that the materials are biodegradable.

PROJECT PARTNERS

CIRCE: Fundación CIRCE Centro de Investigación de Recursos y Consumos Energéticos

DBFZ: DBFZ DEUTSCHES BIOMASSEFORSCHUNGSZENTRUM GEMEINNUETZIGE GMBH

WR: STICHTING WAGENINGEN RESEARCH

META: META GROUP SRL

AKI: NEMZETI AGRARKUTATASI ES INNOVACIOSKOZPONT (National Agricultural Research and Innovation Center)

EPC: EPC Project Corporation Climate. Sustainability. Communications. mbH

DRAXIS: DRAXIS ENVIRONMENTAL S.A.

BZN: Bay Zoltán Nonprofit Ltd. for Applied Research

UNFU: Ukrainian National Forestry University

CAGPDS (former CAPDER): Junta de Andalucía – Consejería de Agricultura, Pesca y Desarrollo Rural

MAE: Mazovia Energy Agency

USB: University of South Bohemia

CCB: Chemie Cluster Bayern GMBH

SPRING: Sustainable Processes and Resources for Innovation and National Growth

EWI: VLAAMS GEWEST (Government of Flanders)

SUA: Slovak University of Agriculture in Nitra

ECRN: European Chemical Regions Network (ECRN) e.V.



SUMMARY

One of the aims of the Power4Bio project is to compile a catalogue containing factsheets on existing bio-based solutions towards resource-efficient biorefineries with tested potential for market uptake (high TRL) for bioenergy production, biomaterials, biochemicals and food and feed. The catalogue intends to be used by stakeholders in a region to get an overview of available promising options to convert a wide range of biomass feedstock into an array of bio-based products.

The factsheet information is stored in an online accessible database which has been developed in a previous task of the Power4Bio project (Deliverable 3.2). The list of most relevant content topics to be addressed in the factsheets has been jointly established by all partners of the project, keeping regional policy makers, industry (associations) and consultants in mind, and by actually involving stakeholders from these targeted end-user groups (Deliverable 3.1). The selected content topics of the factsheets were combined into the following sections/themes: General, Feedstock, Technology, Products, Environment and Impacts.

The factsheets contain a short description and several characteristics of the solution, as well as info regarding suitability of biomass feedstock for production of the target product, benefits of the solution related to the value chain and specific constraints for implementation.

This deliverable report describes the activities performed to fill the catalogue database with the info for the selected bioeconomy solutions:

- Project partners have proposed most promising solutions having $TRL \geq 6$, resulting in a substantial list of about 150 solutions, mainly from the regions participating in POWER4BIO, but also from other EU regions.
- The RTOs have selected a limited list of high potential solutions covering 4 product groups: biomaterials, biochemicals, bioenergy and food & feed. And covering a wide range of feedstocks.
- Info and data for key topics per solution has been collected from online sources, bibliographic references and expert knowledge from project partners, as well as from solution owners. The info has been stored in the online catalogue database.
- Synergies between solutions were identified.

The online catalogue is designed to be of interest to policy makers, industry and other interested parties and is available via a simple interface at <https://power4bio.draxis.gr>. At present it contains 26 solutions which can be searched by the following fields: Feedstock, Technology, TRL and Products, as well as via words in the Summary and Technology Description. Once a solution is selected for viewing, the user may navigate to other solutions with similar content via keywords. Guidelines on how to use and search the catalogue have been placed on the catalogue website.

The database will be maintained and made available during the duration of the project in order to guarantee its functionality in the POWER4BIO project website. The catalogue will be harmonized with the Bioregional Strategy Accelerator Toolkit, the overall online webtool that will be developed and delivered in POWER4BIO Deliverable 2.5.



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1 INTRODUCTION

One of the aims of the Power4Bio project is to compile a catalogue containing factsheets on existing bioeconomy solutions for the production of bioenergy, biomaterials, biochemicals, and food & feed. The catalogue intends to be used by stakeholders in a region to get an overview of available promising options to convert a wide range of biomass feedstock into an array of bio-based products. 'Promising options' means resource-efficient biorefineries with tested potential for market uptake, i.e. high technology readiness level (TRL).

The factsheet information is stored in an online accessible database which has been developed by DRAXIS with the help of WR, BZN, CIRCE and DBFZ in a previous task of the Power4Bio project (Deliverable 3.2). The list of most relevant content topics to be addressed in the factsheets has been jointly established by all partners of the project, keeping regional policy makers, industry (associations) and consultants in mind, and by actually involving stakeholders from these targeted end-user groups (Deliverable 3.1). The selected content topics of the factsheets were combined into the following sections/themes: General, Feedstock, Technology, Products, Environment and Impacts.

The solution factsheets contain a short description and several characteristics of the solution, as well as info regarding suitability of biomass feedstock for production of the target product, benefits of the solution related to the value chain and specific constraints for implementation.

This deliverable report describes the activities performed to fill the catalogue database with the info for the selected bioeconomy solutions.

The approach for the description of the bio-based solutions in the catalogue was as follows:

- Preparation of a template to collect interesting regional bioeconomy solutions.
- All region partners and research partners (RTOs) of Power4Bio have submitted their suggestions for solutions, and input has been combined in a substantial list of solutions in an Excel file.
- Considerations to select a limited list of high potential solutions have been discussed.
- Selection of the limited list of high potential solutions to be elaborated in the catalogue was made.
- Collection of info from bibliographic references and expert knowledge from project partners, and storage of the info in the online database. Contacting solution owners for further info.
- Optimisation of uniformity and comparability of data and information in the catalogue for the end-user is achieved through a guidelines document.
- Mutual reviewing of solutions is performed to further align quality and achieve uniformity of data in factsheets.
- Synergies between solutions were identified.
- Guidelines how to use the database webtool are prepared and connected to the catalogue website.

The outcome of this task is:

- An online catalogue with 26 bioeconomy solutions which can be searched by multiple criteria: feedstock, technology, TRL and product, as well as via search words in the free text fields of summary and technology description.



- The catalogue is designed to be of interest to policy makers, industry and other interested parties via a simple interface at <https://power4bio.draxis.gr>.
- The webtool comprises the option to go from one solution factsheet to a related one comprising similar aspects via keywords included in the solution factsheets.

The catalogue will be harmonised with the Bioregional strategy accelerator toolkit (BSAT), the overall online webtool that will be developed and delivered by the Power4Bio project.



2 COLLECTION OF SUBSTANTIAL LIST OF REGIONAL SOLUTIONS

2.1 Approach

In order to allow all partners to provide their input for regional bioeconomy solutions, a draft template was prepared. During a Telcon meeting with the task partners in June 2019, the template was discussed and suggestions for slight modifications were made. The template was adapted accordingly and sent to all Power4Bio partners end of June.

All region partners and research partners of Power4Bio project have submitted their suggestions by end of July. Input has been combined in a substantial list of solutions in an Excel file.

2.2 Template to collect solutions

The template to collect interesting bioeconomy solutions contained the following items:

- Name of solution
- Location of the solution (country – region)
- Feedstock in
- Products out
- Website and other sources for info
- Name of contact person
- Other key info like amount of info publicly available and TRL.

The template included an explanation of the objective of the Power4Bio catalogue and guidelines for suggesting solutions. For instance, during the Telcon meeting in June 2019 task partners decided that solutions should have TRL ≥ 6 in order to meet the requirement ‘with tested potential for market uptake’ as indicated in the Annex 1 of the Grant Agreement (GA). Another key aspect is the amount of info publicly available. The full template with explanation is presented in Annex A. A snapshot of the template with 2 examples filled out, as sent out to Power4Bio partners, is presented in Figure 1.

| Partner suggesting the solution | Name of solution | Location of solution (Country – Region) | Feedstocks in | Products out | Website name / Other info source | Name contact person | Comments |
|---------------------------------|--|---|-------------------|--|---|--|---|
| WR | Wood biorefinery | Norway | Spruce wood chips | Lignosulphonate + Cellulose + Ethanol + Vanillin | www.borregaard.com http://www.susvaluewaste.no/2017/09/07/one-of-the-worlds-most-advanced-biorefineries/ | Martin Lersch, CTO Business Development Borregaard, martin.lersch@borregaard.com | Regular business (TRL 9+). Significant GHG reduction reported |
| WR | Extraction of native protein from green vegetables | Netherlands | Vegetable losses | Protein + biogas | http://greenproteinproject.eu/ https://www.greenproteinbv.com/ | Paul Bussmann, Senior scientist WFBR, paul.bussmann@wur.nl | Food waste reduction. Significant Environmental footprint reduction. TRL 6. |

Figure 1: Snapshot of template to collect bioeconomy solutions with 2 examples filled out.



2.3 Long list of solutions

All region partners and RTOs have submitted their suggestions. WR has combined all the input in an Excel table, about 150 solutions in total. The suggested solutions originated in particular from the partner regions, but also from other EU regions/countries. The entire long list of solutions is included in Annex B.



3 SELECTION OF LIMITED LIST OF HIGH POTENTIAL SOLUTIONS

3.1 Considerations for selection

During a kick-off Telcon meeting in June 2019, task partners have discussed criteria to select a limited list of high potential solutions. During a second Telcon early September, it was decided to apply the following considerations for selecting high potential solutions:

- Representative spreading over the 4 product groups: energy, materials, chemicals and food & feed
- TRL \geq 6
- Covering different types of feedstock
- Reasonable amount of data for the solutions can be collected
- Covering the regions in the project

Quick scans were performed in order to see whether a minimum amount of info for suggested solutions could be found on public sources like company websites or is available within the RTO organisations as a result of previous projects and contacts.

The qualification 'high potential' is considered to link to high TRL as well as promising related to market potential in different EU regions. Whether a solution is actually high potential for an individual stakeholder depends on many aspects like feedstock available, infrastructure, (regional) demand for products, wish to implement solutions that are fully mature already (TRL 9) or wish to make own development (lower TRL).

3.2 Selection of high potential solutions

Selection of the limited list of high potential solutions was done by each RTO for their specific product group (as indicated in the task description of the Annex 1 of the GA) by prioritising the solutions on the long list with the above mentioned considerations in mind. Division of the solutions over the 4 product groups was arranged by using the following clusters:

- Bioenergy: Biofuels, Bio-power and heat, Advanced biofuels
- Bio-based chemicals: Compounds which react further to materials and products, Solvents, Surfactants, Fertilisers, etc.
- Bio-based materials: Polymers, Plastics, Packaging, Textiles, etc.
- Food & feed: Focus on conversion of residues

As conventional food/feed solutions are known for many decades (e.g. production of sugar from sugar beet), partners decided to keep these out of scope and focus on the conversion of residues from food & feed industry into new products like 'extraction of native protein from green vegetables (residues)', etc.



Partners have each selected 10 most interesting solutions within their product group for elaboration in the catalogue database:

- Bioenergy (CIRCE)
- Biochemicals (DBFZ)
- Biomaterials (BZN)
- Food & Feed (WR)

As some products may fit in more than one product group, e.g. ethanol may be used as a chemical or as a biofuel, attribution of elaboration of solutions to an RTO was done on individual basis. Final attribution of solutions to RTOs also considered existing knowledge about the solutions at an RTO or existing contacts between the solution owner and an RTO, so in a few cases the existing contact or specific knowledge 'overruled' the division into product groups as mentioned in the Annex 1 of the GA. In total, 26 solutions with a reasonable amount of info to inspire stakeholders were elaborated in the catalogue database.



4 SEARCHING KEY DATA AND STORING IN ONLINE CATALOGUE DATABASE

4.1 Searching key data

Information about the selected most relevant content topics (D3.1, D3.2) in first instance is collected from bibliographic references and from expert knowledge from project partners.

- Company websites
- Conference presentations
- Scientific literature
- Public private partnership projects

Specific references have been included in particular in the ‘technology description’ field. In case of missing info, solution owners were contacted to ask for further info. For several topics, it was difficult to find data from public sources or acquire info from companies. Therefore, partners have composed a list of key topics which are considered most relevant for stakeholders, in order to focus effort in finding info and data. These key topics have been listed below for the subsequent themes: Feedstock, etc.:

Feedstock

- Feedstock quality
- Feedstock price
 - Typical value is location specific, so trade spot and location are relevant
- Type of feedstock
 - This topic indicates whether or not the feedstock is also used in other applications, like e.g. food or material that is currently being recycled already
 - This topic is meant as a ‘simple’ indicator
- Competition for feedstock
 - This topic indicates whether specific competition or synergies with other value chains is expected. One out of 5 options needs to be indicated.
 - This topic is meant as a ‘simple’ indicator.

Technology

- TRL
- Technology Description
- Capacity
- Investment cost (CAPEX)
 - Bridgwater method to estimate.
- Cumulative Energy Demand

Products

- Product Name
- Application
- Product quality
- Capacity
- Alternative options for purpose/application



- This relates to Product. This topic indicates whether no, one or more alternative products/options are present to fulfil the purpose for which this product is used.
- This topic is meant as a 'simple' indicator for the need for this Product.

Environment and Impacts

- Job creation
- GHG emissions savings

In case no info could be found for CAPEX, job creation and GHG emissions savings, estimates have been established, as far as possible, by using simplified model calculations. The methods to determine estimations for these topics are discussed in the next sections.

4.1.1 Estimating CAPEX using Bridgwater

4.1.1.1 Background

To avoid a time consuming conceptual design and costing, the capital cost is estimated using the Bridgwater's method for new green field factories, which is based on the number of unit operations and the throughput of the factory (tonnes/year).

The equipment price (purchase costs) is mostly a small part of the capital costs; the other costs are design, engineering and creating facilities and infrastructure (foundation, building), instalment. Capital costs (CAPEX) are the installed costs. Between equipment price and installed costs a factor 4-5 (Lang factor) can be found.

The Capital cost for plants producing less than 60,000 tonnes products per year is estimated:

$$C = 169,560 N \left(\frac{Q}{S} \right)^{0.3}$$

If more than 60,000 tonnes products/year then use:

$$C = 1930 N \left(\frac{Q}{S} \right)^{0.675}$$

in which:

C is the capital cost in pound (GBP) in the year 2000 (see section 4.1.1.4)

N is the number of unit operations (section 4.1.1.3)

Q is the throughput capacity in tonnes of all (by)products together per year

S is the yield factor of the reactor conversion: the weight of all (by)products divided by the weight of feedstock.



4.1.1.2 Translation to bio-based processes

The Bridgwater method was developed for chemical, petrochemical and thermochemical (e.g. pyrolysis) processes. In our POWER4BIO project we use biomass and we get many products. Best is to use the mass flow of wet/fresh biomass (feedstock) in tonnes per year for throughput capacity, Q. In case a lot of water is already lost by the first few unit operations, e.g. by filtration, and the many remaining unit operations only process a small part of the original mass flow, the plant may be cut into two pieces: plant part 1 with a high mass flow and plant part 2 with a low mass flow. As the aim of biorefineries is to utilise all components of the biomass feedstock, the conversion factor, S, is assumed to be 1.

4.1.1.3 Number of unit operations

Unit operations are the important process steps such as grinding, mashing, cutting, mixing (mixer), reactor, distillation column, rectification column, molecular sieve, solvent extraction, filtration, sedimentation, centrifuge, dryer, evaporator, absorber, etc.

No small equipment such as pump, compressor, blower, pipe, storage tank, conveyor, logistic/ transport equipment, packaging.

No environmental equipment such as biofilters and wastewater treatment plants. Waste (water) processing costs can be separately expressed in the yearly costs, as a part of the OPEX.

4.1.1.4 Correction for currency type and devaluation

The formulas are made for the year 2000 and C is expressed in pound Sterling. The convert it to 2019 and EURO:

1 EURO = 0.90 GBP

The equipment costs in chemical engineering has increased since the year 2000. The price index is followed using the Chemical Engineering Plant Cost Index (CEPCI). In 2000 the index was 394.1 and the latest information is from 2018. In 2018 the index was 603.1. The equipment prices have increased with a factor 1.53.

Combining both factors: capital cost C has to be multiplied with a factor 1.7.

4.1.1.5 Resulting equations for Power4Bio

The Capital cost for plants producing less than 60,000 tonnes products per year is estimated¹:

$$C = 1.7 \times 169,560 \times N \times (\text{tonnes wet biomass per year})^{0.3}$$

If more than 60,000 tonnes products/year then use:

$$C = 1.7 \times 1930 \times N \times (\text{tonnes wet biomass per year})^{0.675}$$

¹ Guide to capital cost estimating, 4th edition, A.M. Gerrard, Inst. of Chemical Engineers, 2000, ISBN 978 0 85295 399 0



4.1.2 Estimating GHG emission savings

4.1.2.1 Background

We aim to indicate the GHG effect of switching from fossil-derived materials to bio-based sources.

Estimates of GHG emissions allocated to fossil fuels (and other fossil-derived materials) include:

- 1) the emissions due to the extraction of the fossil source, processing and supply (transport) of the material (for fuels referred to as “Well-to-Tank”)
- 2) the emissions generated at combustion (for fuels referred to as “Tank-to-Wheel”).

The combination of both is referred to as “Well-to-Wheel”.

For bio-based materials and fuels the emission related to combustion are defined at 0, because the actual emissions are mainly releasing the carbon that was fixed in agricultural production. Hence, you could say that only the ‘Well-to-Tank’ emissions are to be taken into consideration: emissions related to agricultural production (fuels for machinery, emissions due to artificial fertilizer production, non-CO₂-GHG emissions like methane and nitrogen oxides) and post-harvest chain are to be taken into consideration.²

However, detailed analysis of such a processing chain is not obvious. We assume that the largest difference between fossil based and bio-based products is at the end-of-life (“Tank-to-Wheel”). With that assumption the GHG emissions savings are the emissions due to combustion of the material.

4.1.2.2 Procedure

Determination of a reasonable fossil reference for the bio-based product(s) that is produced with the solution, and the amount of bio-based product which is required to replace 1 tonne of fossil reference product.

The “GHG emission savings” is estimated as the amount of CO₂ that is emitted by incineration of the fossil equivalent of 1 tonne of bio-based product.

4.1.2.3 Example

Suppose that one tonne of polystyrene (PS) can be replaced by one tonne of polylactic acid (PLA). Such replacement saves the greenhouse emission created at the end of life of PS. At the end of life PS is incinerated and since this material is fossil-based, the CO₂ produced by this incineration is adding to the greenhouse effect. The amount of CO₂ produced by incineration of PS can be calculated. PS has the chemical formula (C₈H₈)_n and each C₈H₈ will produce 8 CO₂. The weight ratio 8 CO₂ / C₈H₈ is 352/104.

² <https://www.mizuho-ir.co.jp/english/knowledge/report/wtwghg041130.html>



Therefore, 1 tonne of PS creates 3.38 tonnes CO₂ GHG emission. The consequence is that one tonne of PLA can save 3.38 tonnes CO₂ GHG emission end-of-life.

4.1.3 Estimating job creation potential

4.1.3.1 Background

Dedicated estimates of job creation in a bio-based process will only be possible for dedicated solutions. Preferably, estimation of job creation is provided by solution owners.

If no data can be obtained through solution owners, a rule-of-thumb may be used. In a search for jobs creation in the bioeconomy domain we encountered some studies detailing on job creation in biotechnology, but not the generic field of bio-based industries in Europe. The most useful information source found was a report by USDA, “An Economic Impact Analysis of the U.S. Bio-based Product Industry”³ which gives the total number of direct jobs and added economic value of the US bio-based industry sectors: Agriculture and Forestry, Biobased Chemicals, Biorefining, Forest Products, Textiles, Enzymes (see Table 3). Next to that, overall number of indirect jobs is indicated, being 1.76 times the direct jobs.

Table 3: Number direct jobs and added economic value for various bioeconomy sectors in US.

| Sector | Direct jobs (-) | Added economic value (M\$) | Added economic value/Direct job (\$/job) | Jobs/Added economic value (jobs/M\$) |
|--------------------------|--------------------|----------------------------------|--|--|
| Agriculture and Forestry | 263,500 | 15,800 | 59,962 | 16.7 |
| Forest Products | 1,059,660 | 93,300 | 88,047 | 11.4 |
| Biobased Chemicals | 17,690 | 5,000 | 282,646 | 3.5 |
| Biorefining | 570 | 155 | 271,930 | 3.7 |
| Textiles | 164,370 | 9,600 | 58,405 | 17.1 |
| Enzymes | 3,000 | 874 | 291,333 | 3.4 |

4.1.3.2 Procedure

The added economic value of a solution may be estimated by subtracting the product of feedstock volume and cost from the product of products volume and price.

The number of potentially created jobs, both direct and indirect, may be calculated by multiplying 1) the value in the last column of Table 3, 2) the added economic value of the solution in million €, 3) the factor 2.76 to include indirect jobs and 4) the conversion rate of dollar over euro: 1.10 on October 13th 2019.

³ <https://www.biopreferred.gov/BPResources/files/BiobasedProductsEconomicAnalysis2016.pdf>



4.1.3.3 Example

Suppose the Borregaard solution produces which produces 160 ktonnes of lignosulfonate at 300 €/tonne, 20 ktonnes of ethanol at 550 €/tonne and 160 ktonnes of cellulose at 1100 €/tonne, requiring 400 ktonnes of Spruce wood chips at 80 €/tonne. And considering the Borregaard solution a biorefinery requiring 3.7 jobs per 1 million \$ of added economic value. Then the estimated total number of direct jobs for the solution =

$$3.7 * \{[(160,000 * 300 + 20,000 * 550 + 160,000 * 1100) - (400,000 * 80)]/1,000,000\} * 1.1 = 826.$$

The estimated total number of direct and indirect jobs is $2.76 * 826 = 2280$.

The actual number of direct jobs posted on the Borregaard website is 750.

4.2 Indicators for sustainability

Based on the Deliverable 2.6 report prepared in the IEE 12 835: Strategic Initiative for Resource Efficient Biomass Policies project, a number of indicators were included in the solution factsheets. These indicators present a quick evaluation of sustainability and resource use efficiency of biomass value chains. In the following sub-sections, the last bullet refers to the highest score regarding sustainability.

4.2.1 Type of feedstock

This indicator distinguishes in the range 'fresh material suitable for food/feed' going to 'non-recyclable waste':

- Fresh material (high value), which can also be used for material / food
- Residues, which can also be used/recycled for material or animal feed
- Fresh material, but difficult to use for material / food
- Residues, difficult to use for material / food
- Non-recyclable waste

4.2.2 Competition for the main feedstock

Promoted use of specific biomass (e.g. subsidies) may distort markets, i.e. draw away from other applications, or increase prices for those applications. New use of (residual) biomass may also create synergies which improve the business case for other applications. The sustainability aspect of the solution is scored in the range from 1) Competition is very likely ... to 5) Clear synergies with existing value chains:

- Competition is very likely for this type of feedstock (e.g. stem wood, recyclable waste) in case of policy support (subsidies)
- Some competition with existing value chains
- Market distortion unlikely / enough room in markets
- Some synergies with existing value chains



- Clear synergies with existing value chains

4.2.3 Size of the worldwide market for the main product

Distinguishes in the range '< 1000 tonnes/year worldwide (niche market)' to '> 100 million tonnes/year worldwide (large worldwide market)':

- < 1000 tonnes/year worldwide (niche market)
- 1000 - 100.000 tonnes/year worldwide
- 0.1 - 10 million tonnes/year worldwide (worldwide market)
- 10 - 100 million tonnes/year worldwide
- > 100 million tonnes/year worldwide (large worldwide market)

4.2.4 Sustainable alternatives to fossil counterpart of the product

Some applications can be fulfilled by several means (e.g. electricity by PV, wind, or geothermal); for other applications options are more limited (fuels, materials). Markets and policy makers are likely to focus their efforts in biomass applications where there are limited other options. The indicator distinguishes in the range 'No other alternative to fossil' to '> 5 Alternatives':

- > 5 Alternatives
- 4-5 Alternatives
- 2-3 Alternatives
- 1 Alternative
- No other alternative to fossil

4.3 Storing data in online database

Info was stored in the online database of the catalogue. In order to achieve optimised uniformity and comparability of data and information for the end-user, a guidelines document was prepared, suggesting which, how and how much info to fill out for each of the different topics. The info in the solution factsheets is clustered in the following themes: General, Feedstock, Technology, Products, Environment and Impacts.

In order to harmonise the stored info, some fields only allow numbers, others have a maximum number of characters, and for some topics a pre-defined characterisation from a list of 5 options is included.

Because the end-user will be able to search the database by Feedstock, Technology and Products names, TRL, as well as by words in the free text Summary and Technology Description fields, keywords have been introduced to allow the end-user to navigate from one solution to another solutions with similar keywords.

4.4 Quality check

RTO partners have mutually reviewed each other's solutions in order to align quality and achieve optimal uniformity of data in the factsheets. Distribution for reviewing solutions was based on:

- Existing contacts
- Language and country



- Product group as in task 3.3 description (BZN Materials, etc.)
- Personal expertise and background: DBFZ Energy, WR Chemicals
- Each RTO reviews solutions of all 3 other RTOs

The review in particular focussed on:

- Further additions to missing info the reviewer is aware of.
- Unifying the info per topic.
 - Aligning of terminology. E.g. Feedstock names, etc.
 - Type and amount of info. The Guidelines-document presents a reference, but cannot cover all possibilities to fill out information.
- Factual inaccuracies.

RTO partners have discussed whether a minimum number of specific topics would need to be covered before publishing a solution. A reason to apply such a standard is that the catalogue will not be filled with many solutions containing insufficient amount of info to be useful for end-users. However, it was considered that solutions may be inspiring very much even if some key info could not be found or reasonably calculated. Therefore it was decided to use the 'minimum number of topics' list (see section 4.1) not to determine which solution factsheets may be published or not, but basically to focus effort in finding info and data.

Collection of information was done and referenced at the best of researchers' knowledge. For an additional check, solution owners were asked to provide eventual feedback to the information stored in the online catalogue by sending PDF exports of the info presented in the solution factsheets. Eventual comments were addressed.

4.5 Bioeconomy solutions in the online catalogue

The catalogue can be accessed via the following link: <https://power4bio.draxis.gr> and contains key info of 26 bioeconomy solutions. Guidelines on how the catalogue can be used and searched are presented in Chapter 6 of this report, as well as under a button on the website.

Overall, 6 solutions deliver biomaterials, 5 biochemicals, 10 bioenergy and 9 food & feed products. Several of these solutions may be regarded as biorefineries which produce more than 1 type of product:

- 'Meadow grass silage biorefinery producing grass fibre enhanced plastic granulates and natural insulation material', in combination with 'Biogas plant producing electrical energy from grass juice and food residue'
- 'Sugar production from lignocellulosic biomass through hydrolysis', also producing ethanol and lignin
- 'Bio-coal production via Hydrothermal Carbonization of Sewage Sludge', also producing nutrients as fertilizer
- 'Oyster mushroom and oyster mushroom substrate production on cereal crop straw', in combination with 'Biogas plant producing electrical energy from spent mushroom substrate and other agricultural and food industrial waste'



- ‘Production of food additives from olive oil industry by-products by extraction’ yields polyphenols and triterpenes
- ‘Borregaard wood biorefinery for cellulose and lignosulfonate’, also producing ethanol and power

| Title ↑ | Feedstock | Technology | TRL | Products |
|--|---|--------------------------|--------|---|
| 01. Oyster mushroom and oyster mushroom substrate production on cereal crop straw | - Cereal straw - Alfalfa residues - Crop stalk | Mushroom growing | TRL 9+ | - Oyster mushroom - Oyster mushroom substrate (growth substrate inoculated with oyster mushroom spawn) |
| 02. Converting vegetable oils and lignocellulosic material derived from grape marc into coated technical textile | - Grape marc - Oil seed rape | Polymerization | TRL 8 | - Coated technical textile |
| 03. Construction material created by using hemp hurds | - Hemp hurds - Lime | Mixing | TRL 8 | - Insulation material |
| 04. Insulation and construction material created by using hemp hurds | - Hemp hurds - Lime | Mixing | TRL 9+ | - Insulation material - Lime based binder |
| 05. Biogas plant producing electrical energy from spent mushroom substrate and other agricultural and food industrial wastes | Cattle manure substrate (FERAC) Food waste Other food processing residues Kerf and other by products of distillation process Distillation residue Food waste Other food processing residues Food industrial wastes | Anaerobic digestion | TRL 9+ | - Electrical energy |
| 06. Conversion of sugars and nutritional values into pure cellulose form | - Biowaste separately collected | Nanocellulose production | TRL 6 | - Pulp materials and sheets |

Figure 2: Example list of solutions stored in the catalogue as displayed on the opening screen of the webpage.

Titles of solutions stored in the catalogue:

- Bio-coal production via Hydrothermal Carbonization of Sewage Sludge
- Bioconversion of organic side streams by black soldier fly larvae - being bio-refined to e.g. lipid & protein
- Biodiesel from vegetable oils and animal fats through transesterification process
- Biogas plant producing electrical energy from grass juice and food residues
- Biogas plant producing electrical energy from spent mushroom substrate and other agricultural and food industrial wastes
- Biogas production from cattle manure via anaerobic digestion
- Borregaard wood biorefinery for cellulose and lignosulfonate
- Conversion of bio-waste into pure nanocellulose form by a bacterial fermentation process
- Extracting specialty oils, additives (eg anti-oxidants) for food & cosmetics from fruit side streams
- Extraction of native protein from green vegetables
- Fermentation of carbohydrates into lactic acid
- Fluidised Bed Combustion to convert poultry manure into heat and electricity
- Growing mushrooms on coffee residues
- Heat and power production via cogeneration from wood chips and agricultural residues
- Hydrothermal Processing technology to convert carbohydrates into 5-Hydroxymethylfurfural
- Meadow grass silage biorefinery producing grass fibre enhanced plastic granulates and natural insulation material



- Oyster mushroom and oyster mushroom substrate production on cereal crop straw
- Production of 1,4-Butanediol (1,4-BDO) from sugar by fermentation
- Production of beer from unsold bread by alcoholic fermentation
- Production of food additives from olive oil industry by-products by extraction
- Production of medium chain fatty acids from food residues by chain elongation
- Production of polyhydroxyalkanoates (PHAs) using waste cooking oil by HYDAL fermentation process
- Production of phycocyanin solution by extraction of Spirulina
- Renewable hydrogen production from biomass via thermolysis
- Sugar production from lignocellulosic biomass through hydrolysis
- Sustainable construction material made by using hemp hurds

4.6 Reference to BE-Rural project

BE-Rural is a project which has been funded under the same call (RUR-09-2018) as POWER4BIO. Although both projects have different timelines and specific scopes, both projects aim at supporting the development of sustainable bioeconomy strategies and business models, and at empowering regional stakeholders to boost the transition towards bioeconomy regions, by disclosing the potential of existing (small-scale biorefinery) technologies. The BE-Rural project has delivered a report⁴ in October 2019 addressing 16 small-scale technology options (called 'solutions' in POWER4BIO). Only one solution appears to be overlapping: 'Disposable tableware and packaging (Bio-Lutions)'.

⁴ https://be-rural.eu/wp-content/uploads/2019/10/BE-Rural_D2.1_Small-scale_technology_options.pdf



5 SYNERGIES BETWEEN BIOREFINERIES

Technological solutions aim at producing one or more key products. However, biorefinery solutions often result in even more products, which are then referred to as side products. These side products can be used as feedstock for conversion into other products by another technology solution. Such possible synergies between biorefinery type of solutions have been reviewed in section 5.1.

Further, some solutions may be designed in such a way that they can produce more than one type of main product (section 5.2). In other words, a fixed assembly of equipment in a factory may produce different products, depending on feedstock and technology parameter settings. For instance, next to producing ethanol from corn, the same technology solution could also produce lactic acid from pre-treated lignocellulose if considered during the design phase of the plant.

The examples of potential synergies within the selection of solutions addressed in the catalogue have been addressed in the following sections.

5.1 Synergies between biorefineries

Many solutions addressed in the catalogue use feedstocks which are the (side) products of traditional technology solutions which have been in place for many years or even decades. Actually, many of the solutions were selected for the catalogue because of their synergy with existing technologies, mostly from food industry:

- Cereals
- Vegetables
- Fruits
- Sugar
- Potatoes
- Bread
- Meat
- Dairy products
- Juices
- Beer

Other biorefinery solutions focus on valorisation of waste streams arising from households:

- Waste cooking oil
- Sewage
- Paper recycling is in place in some countries for several decades



- Conventional plastic packaging recycling is established in some countries for several years, but still needs to transform to optimise recycling benefits. This transformation should include addressing non-drop in bio-based plastics and biodegradable plastics⁵.

and farms:

- Manure

Finally, selected solutions are based on residues from (2nd generation) wood and other fibre based industries. The indicated lists of feedstock is not an exhaustive list of all the possibilities.

A limited number of solutions within this catalogue exhibit synergies:

- The spent mushroom substrate resulting from the solution on 'Oyster mushroom production on cereal crop straw' is used as feedstock in the 'Biogas plant producing electrical energy'.
- One solution involves 'Sugar production from lignocellulosic biomass', which can be converted in other solutions into chemicals.

Other solutions deliver (co-)products which can be used in a range of applications and technology solutions not covered in this catalogue:

- Food ingredients: Food, pharma
- Feed and feed ingredients
- Chemicals: e.g. bio-based plastics and resins materials, coatings, solvents, etc.
- Cellulose based fibres: Composites, insulation materials, textiles, paper, packaging
- Lignin: Resin binder systems (panels & boards), bitumen applications (asphalt roads, roofing membranes), compounds
- Bio-based energy carriers: Fuels, power, heat
- Nutrient rich residues: Soil improvement. Taking into account that the bioeconomy tends to collect an increasing amount of biomass from the land, e.g. crop straw and leaves, it needs to be considered that a healthy soil requires nutrients. Sustainability requires biorefineries to address returning sufficient amount and quality of nutrients to the soil.

5.2 Synergy within solutions

A number of solutions can produce alternative products using the same technology:

Further, some solutions may be designed in such a way that they can produce more than one type of main product. In other words, a fixed assembly of equipment in a factory may produce different products, depending on feedstock and technology parameter settings. For instance, next to producing ethanol from corn, the same technology solution could also produce lactic acid from pre-treated lignocellulose if considered during the design phase of the plant.

⁵ M. van den Oever, K. Molenveld, M. van der Zee, H. Bos, 2017. Bio-based and biodegradable plastics : facts and figures : focus on food packaging in the Netherlands, <https://library.wur.nl/WebQuery/wurpubs/519929>



- ‘Sugar production from lignocellulosic biomass through hydrolysis’ could also produce Glucose, Xylose, Furfural, 5-HMF
- ‘Fermentation of carbohydrates into lactic acid’ could also produce Ethanol and Carboxylic acids
- ‘Hydrothermal Processing technology to convert carbohydrates into 5-Hydroxymethylfurfural’ could also produce Furfural and Biocoal



6 GUIDELINES TO USE THE CATALOGUE

The information in the catalogue aims to provide inspiration and an orientation for stakeholders, whether policy maker, industry or other parties interested in bioeconomy. The info is provided with mentioned restrictions (see section 6.1) with the purpose to facilitate stakeholders to screen their options. Each stakeholder will need to find, review and verify the exact data/info that is applicable for their specific conditions and situation.

A button with 'View Disclaimer & Guidelines to use the Catalogue' will be included in the top bar of the webpage, next to the 'View demo' button.

6.1 Disclaimer

All info has been retrieved from public sources or supplied by Power4Bio experts, unless specific sources have been indicated in the Technology Description field, under the Technology section.

A short description of the methods used to estimate CAPEX, GHG emission savings and job creation are provided in section 4.1 of D3.3, available at <https://power4bio.eu/project-material>.

The info in this database is publicly available for any party interested in bioeconomy solutions, and the info is meant as an orientation point for users' own further study and considerations, and indicative only.

This database is part of the POWER4BIO project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 818351. Responsibility for the information and views set out in this document lies entirely with the authors. Although the authors have collected and stored the info with utmost care, they cannot guarantee completeness, correctness or actuality of the information. The authors accept no liability for any damage or harm arising from the use of information in this database.

6.2 Overview how the catalogue can be used

The catalogue website contains a demo video which shows in 2:35 minutes how the end-user may search and view the data of the catalogue. Data for the bioeconomy solutions can be viewed in so called factsheets. The following steps can be distinguished:

- Finding data using search criteria
- Viewing factsheets with thematically grouped information per solution
- Finding solutions with similar aspects as the solution found already

In the next sections, these steps will be explained in more detail.

6.3 Searching data via multiple criteria

The user can search through the database using following criteria:

- Feedstocks: Searches and retrieves all solution factsheets that contain the indicated feedstock(s). Choosing multiple feedstocks, all solution that contain any or all of the selected searchable feedstock(s) will be retrieved.



- **Technologies:** Searches and retrieves all solutions that contain the indicated technology (-ies). If more than one technology is selected, any or all solutions containing the technologies selected will be retrieved.
- **TRL:** Retrieves all solutions meeting the TRL selected.
- **Products:** Searches and retrieves all solutions containing the indicated product as a primary product or as a by-product. Choosing multiple products, all solution that contain any or all of the selected searchable product(s) will be retrieved.
- **Word(s) in Summary:** Searches and retrieves solutions that contain all the words (or part of words) in its summary text. Each word (or part of a word) is searched separately and not as a phrase. All indicated words (or part of words) must be included in the summary of the same solution.
- **Word(s) in Technology Description:** Searches and retrieves solutions that contain all the words (or part of the words) in its Technology Description text. Each word (or part of a word) is searched separately and not as a phrase. All indicated words (or parts of words) must be included in the technology description field of the same solution.
- Using a combination of search criteria, the user will retrieve results which meet all criteria in a single solution.

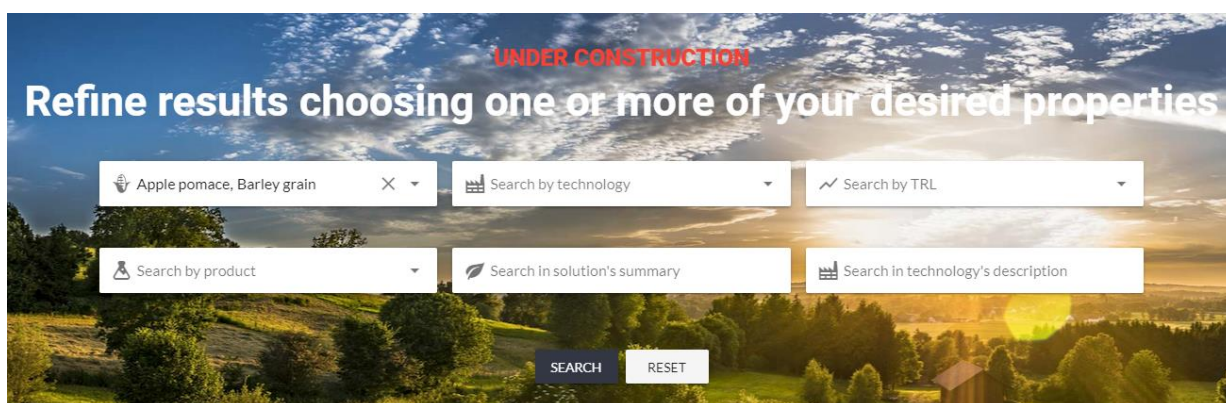


Figure 3: Catalogue search page.

Summary information of the solutions retrieved as a result of the search is presented in table or grid format, according to the user's preference. Details of a solution can be viewed by clicking the title in table display or by clicking 'view solution' in grid display. Solutions can be sorted ascending/descending by title, feedstock, technology, TRL and product.



| Title | Feedstock | Technology | TRL | Products |
|---|---|---|--------|---|
| Borregaard wood biorefinery for cellulose and lignosulfonate | - Spruce wood chips - Sawdust (conifers) - Sawdust (nonconifers) - Wood waste - Residues from further woodprocessing | Techniques from pulp and paper industry | TRL 9+ | - lignosulfonate - Ethanol - Cellulose - Electrical energy |
| Biogas plant producing electrical energy from grass juice and food residues | - Food residues - Grass juice | Anaerobic digestion | TRL 9+ | - Electrical energy - Organic fertilizer |
| Production of beer from unsold bread by alcoholic fermentation | - Unsold bread - Barley grain - Wheat grain - Bread & rolls losses (Surplus product Retail Processing Breadcrusts Dough) | Fermentation | TRL 9+ | - Beer |
| Meadow grass silage biorefinery producing grass fibre enhanced plastic granulates and natural insulation material | - Meadow grass silage | Mechanical treatment of fibres | TRL 9+ | - grass fibre enhanced plastic granulates - Insulation material |

Figure 4: Catalogue results page, table display.

Searching data using a mobile device basically works identical to described above for using a large screen from monitor or laptop, the lay-out is vertically oriented though.

6.4 Structure of factsheets in view mode

When viewing the solution factsheet, the user obtains an overview of the solution with general information at the top, followed by indicative data for each section/theme in the following sequence: feedstock, technology, product, environment and impacts (Figure 5).

By clicking 'Show more' on either section/theme (arrows), further details for the section are revealed. To view more details of General content topics, 'Show more' in the centre of the top can be clicked.

← BACK Creation Date: Oct 14, 2019

Borregaard wood biorefinery for cellulose and lignosulfonate
Wood chips are subjected to sulfite pulping and subsequently to separation and conversion processes yielding at least 5 products. TRL 9.

Keywords (find related solutions)
 fermentation ethanol Borregaard wood spruce sulfite pulping
 vanillin cellulose lignosulfonate

Show more

| Show More... | Technology | Show More... | Show More... |
|--|--|--|---|
| Feedstock Spruce wood chips Price: 80 (€/ton DM) Country: Norway Trade Spot: Market Energy Content: 18.9 (GJ/tonne) Competitive use: Power plants | Techniques from pulp and paper industry TRL: TRL 9+ Capacity: 400000 (ton DM/year) Other inputs: Water, Salt, Sulfur, | Products lignosulfonate Price: 300 (€/ton DM) Capacity: 160000 (ton DM/year) Standards: Country: China Trade Spot: Market | Environment and Impacts Benefits Drawbacks Regulations requirements Challenges Socio economic |

Technology
Techniques from pulp and paper industry

Description
Process steps: Spruce chips is separated into bark and wood. The bark is used as a fuel to produce electricity and heat. The wood is subjected to sulfite pulping (hemicellulose and lignin dissolves) and separation. The solid is cellulose. The black liquor contains lignosulfonate which is recovered from the aqueous phase. A part of the lignosulfonate is converted by chemical modification into vanillin. The remaining liquid is used to produce ethanol by fermentation with yeast. The effluent, still containing C5 sugars, is used to produce biogas. Feedstock flexibility: Spruce wood is preferred. Other types of wood can be used as well, including waste wood such as saw dust. hardwood species are less suitable. Products: Overall, each ton of Spruce Wood chips is converted into 400 kg of lignosulfonate, 400 kg of cellulose pulp, 50 kg of ethanol and 23 kg of vanillin and heat and electricity. Innovativeness: Sulfite pulping is standard in pulp making, but the further processing of the pulp and black liquor is unique. That makes the process a real biorefinery.

Figure 5: Solution factsheet view page.

Under 'Technology', the Technology Description field contains (bibliographic) references, as well as base data for estimates presented.



All information of a solution can be exported to PDF file using a button at the top right corner of the solution view window.

Viewing factsheets using a mobile device basically works identical to described above when using a large screen from monitor or laptop, the lay-out is vertically oriented though.

6.5 Finding solutions with similar aspects as solution found already

Once a solution is selected for viewing, the user may navigate to other solutions with similar content via 'keywords', which are in the top section of the factsheet view.

This option works similar for large screens from laptop or monitor and smaller screens of mobile devices.

6.6 Operating on any device

The catalogue can be accessed on any device (PC, tablet, smartphone) using any kind of operating system (Windows, Apple, Android, etc.), auto adapting its content to the size and resolution of the device.

At the moment of access, the tool stores a snapshot of the database locally on the device, which allows to browse and search the catalogue even offline.



7 CONCLUSIONS AND RECOMMENDATIONS

A long list of about 150 bio-based technology solutions has been composed by the partners of the POWER4BIO project. From this list, 26 high potential solutions were elaborated in the catalogue. For each of these solutions, the RTO partners have collected info for content topics defined by all POWER4BIO project partners in Deliverable 3.1. The info has been stored in the database developed by DRAXIS with the help of WR, BZN, CIRCE and DBFZ in Deliverable 3.2.

The info in the solution factsheets has subdivided into the following sections: General, Feedstock, Technology, Products, Environment and impacts. Each of the sections contains a number of content topics. It appeared that data for several content topics defined in D3.1 were difficult to find. Therefore, RTO partners decided to establish a list of topics which were most relevant for stakeholders to focus their effort in finding data. Also, methods to estimate data for some topics were defined.

Each RTO has focussed on a specific product group (bioenergy, biochemical, biomaterial, food & feed). In order to optimise regarding uniformity and comparability of data and information, guidelines were drafted to align feeding of info into the database by the several RTOs. Next to that, a review and checking procedure has been implemented such that the 4 RTOs have reviewed solutions filled out by all other 3 RTOs in order to check quality and introduce a mechanism to align data input among all 4 partners.

As the catalogue of bioeconomy solutions relates to the POWER4BIO Deliverable 3.4 on best practices and Deliverable 4.1 on business models, a thorough analysis on how these activities could be aligned has been carried out.

As in Deliverable 3.2, special attention has been paid to the potential user's profiles. This has resulted in a pragmatic approach in facilitating the access to the data collected in this Deliverable 3.3 by means of a tailor-made tool design in the catalogue. The end-user will be able to search the database by the following fields: Feedstock, Technology, TRL and Products, as well as the Summary and Technology Description. Once a solution is selected for viewing, the end-user may navigate to other solutions with similar content via keywords. Guidelines on how to use and search the catalogue have been placed on the catalogue website.

The database will be maintained and made available during the duration of the project in order to guarantee its functionality in the POWER4BIO project website. The catalogue and its IT architecture will be integrated in the Bioregional Strategy Accelerator Toolkit (BSAT) which will be developed in POWER4BIO Deliverable 2.5. As part of the BSAT, POWER4BIO will explore how to exploit this tool.

The biorefineries identified and depicted in this Deliverable 3.3 will also be of high interest to the POWER4BIO regions in the development of their bioeconomy strategies (Deliverable 5.3). The compilation of those cases will inspire the 5 CEE regions in this exercise as a very important input for their internal evaluation and discussions.



8 ANNEXES

Annex A: Template to collect bioeconomy solutions for long list

Power4Bio

Template to collect regional solutions

WR, 28/06/2019

Objective

One of the key goals of WP3 is to deliver a so called Catalogue of bioeconomy solutions (technologies) with a tested potential for market uptake. With this template we ask you to share with us the solutions you are aware of in your region (or even outside) operating on TRL6 (demonstrated in relevant environment) or higher TRL and that potentially may be interesting for other regions in Europe.

In a next stage of the WP3, task 3.3 partners we will collect data for the key topics defined in task 3.1 for a selection of the listed solutions to be stored in the catalogue.

Explanation to the template

- Column 1: Please indicate the name of your organisation
- Column 2: Official name if available. Otherwise a short description may be very useful, e.g. <name of technology> to convert <feedstock> to <product(s)>
- Column 3: Please indicate in which country and/or region the solution/technology is implemented or studied.
- Column 4: More than 1 (type of) feedstocks may be entered if applicable. Please start with the feedstock that is mainly applied/studied.
- Column 5: Please mention all relevant products, starting with the most relevant one regarding value/volume. If a solution/technology delivers 2 or 3 products, please indicate like this: Lignosulphonate + Cellulose fibre + Ethanol. If a technology may deliver either one or another product, please indicate like this: Cellulose. Ethanol.
- Column 6: More detailed information on the solution/technology may depend on the development stage. That can be a website. Or a scientific publication. Or other type of publication. Please indicated what is available: website(s), reference to publications.
- Column 7: Contact person may be the responsible person at a (pilot) plant or of an R&D group.
- Column 8: Please indicate whatever you think relevant for us to know when selecting solutions for detailed data collection for the catalogue. E.g.: Reasonable amount of data of the solution are available or can be collected. Or: Significant greenhouse gas reduction reported.
- Please add as many lines as required.

We have provided an example in the template table below.

Planning

Can you please send us your input by Friday July 19th?



Template to collect bioeconomy solutions for long list, Continued.

Template to collect long list of 'regional solutions'

| Partner suggesting the solution | Name of solution | Location of solution (Country – Region) | Feedstocks in | Products out | Website name / Other info source | Name contact person | Comments |
|---------------------------------|--|---|-------------------|--|---|--|---|
| WR | Wood biorefinery | Norway | Spruce wood chips | Lignosulphonate + Cellulose + Ethanol + <u>Vanilin</u> | www.borregaard.com http://www.susvaluewaste.no/2017/09/07/one-of-the-worlds-most-advanced-biorefineries/ | Martin Lersch, CTO Business Development Borregaard, martin.lersch@borregaard.com | Regular business (TRL 9+). Significant GHG reduction reported |
| WR | Extraction of native protein from green vegetables | Netherlands | Vegetable losses | Protein + biogas | http://greenproteinproject.eu/ https://www.greenproteinbv.com/ | Paul Bussmann, Senior scientist WFBR, paul.bussmann@wur.nl | Food waste reduction. Significant Environmental footprint reduction. TRL 6. |
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Annex B: Long list of solutions

| Short description of solution | Location of solution (Country, region) | Website |
|---|--|---|
| Conversion of hemicellulosic biomass into furfural | Belgium | https://www.polyfurfurylalcohol.com/products |
| Making beer by replacing 20% of the malt with unsold fresh bread | Belgium | https://www.beerproject.be/en/beer/babylone/ |
| Dry anaerobic digestion of organic household waste into biogas and compost | Belgium | www.ows.be |
| Extraction of specialty oils and anti-oxidants for the food industry and cosmetics from fruit wastes (EcoTreasures) | Belgium, Flanders | http://www.ecotreasures.be |
| Conversion of organic waste streams via cultivation of black soldier fly larvae into proteins, fat and chitin as base chemicals (Millibeter/Agroproteins) | Belgium, Flanders | https://www.flandersinvestmentandtrade.com/invest/en/news/agriprotein-uk-acquires-insect-firm-millibeter |
| Conversion of vegetable oils and animal fats into a broad range of natural chemicals and ingredients | Belgium, Flanders | https://www.oleon.com/ |
| Hemp cultivation and processing into food products | Czech Republic, Jihlava | https://hempoint.cz/en/ |
| Ointment based on hemp seed extract and hemp seed oil | Czech Republic, Olomouc | https://www.annabis.cz/ |



| | | |
|--|-------------------------------|---|
| Anti-cellulite and slimming body serum based on microalgae and CBD hemp extract | Czech Republic, Prague | https://www.ecofuel.cz/ |
| Production of PHA polyester from used frying oil (Hydal) | Czech Republic, Prague | https://www.nafigate.com/en/biotechnology-hydal |
| Building material made of hemp and lime (Hempcrete) | Czech Republic, Rousínov | http://www.mabeko.cz |
| Anaerobic decomposition of pig slurry in a wastewater treatment plant and cogeneration unit into biogas and heat | Czech Republic, South Bohemia | https://www.calla.cz/index.php?lang=eng&path=e_energy |
| Anaerobic decomposition of corn, grass silage and pig slurry in a wastewater treatment plant and cogeneration unit into power and heat | Czech Republic, South Bohemia | https://www.calla.cz/atlas/detail.php?id=1689 |
| Production of heat and electricity from wood biomass | Czech Republic, South Bohemia | https://www.carthamus.cz |
| Production of heat and electricity from straw and hay | Czech Republic, South Bohemia | https://www.ecjh.cz |
| Combustion of biomass into heat | Czech Republic, South Bohemia | https://www.eon.cz/elektrina-a-plyn-pro-mesta-a-verejnou-spravu/sluzby/kotle-na-biomasu-VS/teplarna-mydlovary-ii |
| Combustion of biomass (wood chips and straw pellets) into heat | Czech Republic, Třebíč | https://www.tts.cz/?lang=en |
| 2 nd generation biofuels from straw and other agricultural waste for future cars (DONG) | Denmark | www.lnbicon.com |



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| Ingredients for the cosmetic products, detergents and cleaning agents from Palm-based raw materials | France | https://www.basf.com/global/en/who-we-are/sustainability/whats-new/sustainability-news/2018/certified-palm-products.html |
| Integrated biorefinery for production of bioethanol, biogas, power and heat from sugar beets, straw and other biowaste | France | www.cristal-union.fr |
| Biodiesel production from vegetable oils and animal fats | France | https://www.engineering-airliquide.com/lurgi-biodiesel |
| Conversion of wood into charcoal and power (Carbonex) | France, Aube | http://carbonex.fr/technology---innovation.html |
| Resins from plant based tall oil, gum rosin and terpenes for many industry sectors | France, Dax | https://www.drt.fr/en/resins.html |
| Conversion of wood residues into phenolics (BIOPHENOL) | France, Essonne | https://www.biophenol.com/#products |
| Conversion of biomass (wheat straw, wood, miscanthus) into charcoal and heat (BIOLYSE) | France, Eure-et-loir | https://www.biolyse.fr/technologie/le-procede-biolyse |
| Conversion of wood, argi-wastes or recycled biomass into hydrogen (HYNOCA) | France, Marne | https://www.haffner-energy.com/hydrogen |
| Conversion of agro-industrial wastes into protein, oil and fertilizer using flies (Protifly) | France, Mont de Marsan | https://protifly.com/ |
| Anaerobic digestion of wet biomass like mais silage and residues into biogas | Germany | https://biogas.org/edcom/webfvb.nsf/id/Export-sortiert-nach-Firma?Open&sDS01=1 |
| Innovative process for converting lignocellulosic agricultural residues into bioethanol | Germany | https://www.clariant.com/en/Business-Units/New-Businesses/Biotech-and-Biobased-Chemicals/Sunliquid |



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| Conversion of discarded milk into casein textile fibres | Germany | https://www.qmilkfiber.eu/ |
| Conversion of agriculture residues into self-binding micro- and nano-fibrillated natural fibres through a mechanical process | Germany | www.bio-lutions.com |
| Extraction of the active ingredient (wet-green ⁰) from olive leaves | Germany | http://www.wet-green.com |
| Syngas, synfuel and fine chemicals production from dry biomass (Bioliq) | Germany | https://www.bioliq.de/english/24.php |
| Production of bio-aromatics from lignin | Germany North-West / Netherlands / Belgium | https://www.bigc-initiative.eu/align.php ; https://vito.be/en/news/lignovalue-pilot-launched |
| Plastic materials based on renewable feedstock | Germany, Baden-Württemberg | https://www.tecnaro.de/en/home.html |
| Production of functional cellulose fibres from plant biomass like wood, vegetables, fruits | Germany, Baden-Württemberg | https://www.jrs.de/ |
| Bacterial production of rhamnolipids for agriculture, pharmaceuticals, cosmetics, cleaners, nuclear decontamination and fire protection | Germany, Baden-Württemberg | https://biotensidon.com/en/home/ |
| Biotechnological conversion of organic waste and residues from food processing (cocoa bean shells, spent grains, rice husks) into food and bioenergy | Germany, Baden-Württemberg | https://www.novis.me/english-1/ |



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| Cellulosic ethanol and lignin production from straw (Sunliquid®) | Germany, Bavaria | https://www.clariant.com/de/Business-Units/New-Businesses/Biotech-and-Biobased-Chemicals/Sunliquid |
| Natural fibre reinforced bio-based plastic composites | Germany, Bavaria | https://biofibre.de/en/ |
| Production of cellulose and viscose from wood | Germany, Bavaria | http://www.kelheim-fibres.com/home/index_uk.php |
| Bio-based coatings | Germany, Bavaria | https://www.naturhaus.net/ueber-uns/ |
| Insulated food packages and bags | Germany, Bavaria | https://landpack.de/en |
| Adjustable optical frames from wood | Germany, Bavaria | https://www.freisicht-eyewear.com/ |
| Foam-moulded structure based on WPC material (ecopolytec®) | Germany, Bavaria | https://langmatz.de/en/wp-content/uploads/sites/2/2016/01/langmatz-company-image-broschure-en.pdf |
| Bio-based demulsifiers, flocculants, precipitators (WS eco®) for water treatment | Germany, Bavaria | https://www.ws-eco.de/en/ |
| Biological, non-toxic plant protection products based on insect-patogenic viruses and micro-encapsulation (Agrolytix) | Germany, Bavaria | https://www.agrolytix.com/en/ |
| Biochar products for soil improvement from biomass residues | Germany, Bavaria | https://www.circular-carbon.com/ |
| Biotechnological solidification of dusts (health protection, reduction of dust explosions) | Germany, Bavaria | http://dustbiosolutions.com/ |



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| Synthesis of complex peptides for cosmetics, agriculture and pharma by bacteria | Germany, Bavaria | https://www.mk2.bio/ |
| Thermal Catalytic Reforming of organic waste into biocrude oil, syngas, biochar, heat& power (Susteen) | Germany, Bavaria | https://susteen-tech.com/en/ |
| Biotechnological production of spider silk fibres for use in textile products, medical devices and cosmetics (Biosteel®) | Germany, Bavaria | https://www.amsilk.com/home/ |
| Biorefinery to convert potatoes into starches, starch derivatives, proteins and pulp for paper industry, food, chemicals, fodder, textiles | Germany, Bavaria | https://www.suedstaerke.de/index.php?Applications-en |
| Chemo-enzymatic cascade reaction conversion of sugars into fine chemicals and specialties (Cascat) | Germany, Bavaria | https://www.cascat.de/en/products/ |
| Production of regenerated cellulose fibres from wood (CORDENKA® rayon) | Germany, Bavaria | http://www.cordenka.com/en/cordenka/ |
| Enzymatic conversion of plant oils (coconut, sunflower, palm, peanut, rapeseed) into specialty chemicals for the fibre, textile and leather industries | Germany, Bavaria | https://www.pulcra-chemicals.com/sustainability |
| Production of bioethanol, proteins and CO2 from residues of sugar refineries | Germany, Bavaria and Baden-Württemberg | http://www.suedzucker.de/de/Unternehmen/Umwelt-Nachhaltigkeit/2015_Suedzucker_Vom_Rohstoff_zum_Produkt_de.pdf |
| Production of PHB polyester from renewable resources | Germany, Bavaria and Hessen | http://www.biomer.de/IndexE.html |



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| Hydrothermal carbonization of wood or agri-waste to produce technical carbons, chemicals and fuels | Germany, Brandenburg | https://www.suncoal.com/ |
| Biorefinery of lignocellulosic biomass into cellulose, lignin and biogas | Germany, Brandenburg | https://lxp-group.com/ |
| Fermentation of bakery industry waste products into lactic acid for PLA production | Germany, Brandenburg | https://www.atb-potsdam.de/nc/forschungsprogramme/stoffliche-und-energetische-nutzung-von-biomasse/stoffliche-nutzung-von-biomasse/biotechnologische-stoffwandlung.html#CID1679 |
| Production of super absorbing cellulose and modified starch from potatoes for diapers | Germany, Brandenburg | https://fairwindel.de/ |
| Combustion of residual forest wood and materials from landscape management for heating and power | Germany, Braunschweig | https://www.bs-energy.de/privatkunden/ |
| Health-promoting ingredients (Spirulina) from Microalgae | Germany, Niedersachsen | http://mial.eu/en/ |
| Bio-based Polyamides from castor bean plants | Germany, Nordrhein- Westfalen | https://www.vestamid.com/product/peek-industrial/downloads/vestamid-terra-applications-en.pdf ; https://www.vestamid.com/sites/lists/re/documentshp/vestamid-processing-en.pdf |
| Hydrothermal carbonisation (HTC) of biomass into power, heat and biochar | Germany, Nordrhein- Westfalen | http://www.grenol.org/index.php?id=16 |
| Carbonization of sewage sludge into power, heat and biochar | Germany, Nordrhein- Westfalen | https://terranova-energy.com/ |



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| Transesterification of rape and soy oil into biodiesel and glycerine | Germany, Rostock | www.glencore.com ; https://es-es.facebook.com/pg/BPRostock/about/ |
| Transesterification of rape into biodiesel and rapeseed meal | Germany, Rudolstadt | https://www.bkk-biodiesel.de/ |
| Biotech process development and scale up for production of different bio-based chemicals from sugar | Germany, Sachsen-Anhalt | https://ew-biotech.com/ |
| Sugar production from lignocellulosic biomass | Germany, Saxony | www.green-sugar.eu |
| Anaerobic digestion of organic residue streams into biogas and bioenergy | Germany, Saxony | www.wabio.de |
| Production of compounds based on bio-based plastics and fibres | Germany, Saxony | https://fkur.com |
| Recycled engineering polymers (ECONAMID®) | Germany, Saxony Anhalt | https://www.domochemicals.com/en/products/engineering-plastics/econamid-pa6-pa66 |
| Production of isobutene through fermentation and purification of sugar or starch | Germany, Saxony-Anhalt | www.global-bioenergies.com |
| Production of cellulose pulp, bioenergy and biochemicals from wood biomass | Germany, Saxony-Anhalt | www.zellstoff-stendal.de |
| 2 nd Generation bioethanol production (Sunliquid®) from straw | Germany, Straubing | https://www.clariant.com/de/Business-Units/New-Businesses/Biotech-and-Biobased-Chemicals/Sunliquid |
| Cold-pressed vegetable oils from wine production pomace | Hungary | http://www.grapoila.hu/en/zero-waste-gyartastechnologiank/ |



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| Biorefinery producing mainly bioethanol from corn | Hungary | https://pannoniabio.com |
| Integrated complex producing mushroom growing on agricultural residues and biogas production | Hungary | http://pleurotus.hu/ |
| Production of grape seed oil and grape seed extract from grape seeds and skin | Hungary | https://pincszet.gere.hu/en/grape-seed/csodalatos-szolomag/ |
| Biorefinery producing pectin, biogas and compost from by-products of fruit juice industry | Hungary | https://www.rauch.cc/hu/ |
| Production of biogas and windscreen cleaner liquid from mash and herbal residues | Hungary | https://www.zwackunicum.hu |
| Combustion of straw, agricultural residues and Christmas trees for cogeneration in power plant | Hungary, Pécs | https://www.veolia.hu/hu |
| Building material made of hemp and lime (Hempcrete) | Hungary, Southern Great Plain | http://www.kenderhaz.hu |
| Production of heat and steam based on forest biomass | Ireland | https://www.coillte.ie/our-business/our-products/biomass/ |
| Syngas and biochar production from agricultural and forestry residues | Ireland | https://www.pge.ie/technology/ |
| Fluidised Bed Combustion (FBC) technology to convert poultry manure into heat and electricity for use on the poultry farm | Ireland, Limerick | http://www.bhslhydro.com/ |
| Biochemicals and biopolymers plant | Italia | www.coldiretti.it |



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| Production of leather-like fabric and biopolymers from the wastes of wine production | Italy | www.vegeacompany.com |
| Production of active cross-linking agents (ACL) from animal waste for formaldehyde and phenol-free tanning purposes | Italy | http://www.crossing-srl.com/en/applications/leather-tanning/ |
| Production of active cross-linking agents (ACL) from vegetable and agricultural waste for formaldehyde and phenol-free tanning purposes | Italy | http://www.crossing-srl.com/en/applications/leather-tanning/ |
| Bio-based thermoplastic compound based on different biomass sources: plants, wood, natural oils | Italy | www.nadir-tech.it ; |
| Production of PHA polyesters from wastewater sludge (B-PLAS Demo) | Italy | https://site.unibo.it/b-plas/en |
| Production of PHA polyester from agricultural wastes | Italy | https://noaw2020.eu/ |
| Supercritical fluids extraction (SFE) and fractionation of nutraceuticals, food additives, antioxidants from wine making by-products | Italy | https://www.progettoager.it (Italian only) |
| Production of levulinic acid from wood waste | Italy | http://www.gfbiochemicals.com/company/ ; https://greenchemicalsblog.com/2015/12/14/gf-biochemicals-to-start-using-wood-waste-feedstock-in-2016/ |
| Yeast-based conversion of sugars and starch into succinic acid for various applications | Italy / Netherlands | https://www.roquette.com/industries/selected-products/industry-performance-materials-biosuccinum/ |
| Bio-based polymers from algae, shrimp shells, lignin and cellulose (BioApp) | Italy and Slovenia | http://www.biopolife.com/ |



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| Transesterification of waste cooking oil into biodiesel | Italy, Aprilia | https://www.dplubrificanti.eu |
| Transesterification and Hydrogenation of olive oil derivatives, tallow and vegetable oils into chemicals | Italy, Cremona | http://www.greenoleo.com/index.php?Mod=HomePage |
| Biorefinery to produce chemical intermediates and pharmaceuticals from vegetable oil | Italy, Sardenga | http://www.matrica.it ; https://www.chemietechnik.de/matrica-nimmt-pflanzenoel-raffinerie-in-italien-in-betrieb/ ; https://www.chemengonline.com/versalisnovamont-joint-venture-matrica-starts-up-biorefinery-in-italy/?printmode=1 |
| Extraction of native protein from green vegetables | Netherlands | http://greenproteinproject.eu/ ; https://www.greenproteinbv.com/ |
| Production of medium chain fatty acids from food residues by chain elongation | Netherlands | www.chaincraft.nl |
| Incineration of wood prunings for heating residences | Netherlands | www.warmtebedrijfede.nl |
| Anaerobic digestion of cattle manure into biogas | Netherlands | https://www.host.nl/en/case/kampen-the-netherlands/ |
| Pyrolysis of non-food biomass into oil | Netherlands | https://www.btg-btl.com/en |
| Torrefaction of wood into pellets (fuel) | Netherlands | www.blackwood-technology.com |
| PHA polyester production from sewage | Netherlands | https://en.paques.nl/news/news/paques-hvc-and-water-boards-continue-developing-bioplastics-with-demo-installation-pha2use/2 |
| Insect breeding based on food residues for feed 1 | Netherlands | www.protix.eu |
| Insect breeding based on food residues for feed 2 | Netherlands | www.bestico.nl |
| Grass biorefinery into protein for feed and fibres | Netherlands | www.grassa.nl |
| Production of oil from waste citrus fruit peelings | Netherlands | https://www.meerlanden.nl/tag/citrusbrandstof |



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| Mono-saccharide production from lignocellulose residues (DAWN Technology) | Netherlands | www.avantium.com ; https://www.avantium.com/wp-content/uploads/2018/07/About-DAWN-Technology.pdf |
| Making paper from tomato stems | Netherlands | https://www.schutpapier.nl/en/news/first-book-printed-on-paper-with-tomato-fibers/ |
| Extraction of cellulose fibre from sewage for application as asphalt drip inhibitor | Netherlands | https://www.cell-vation.com/ |
| Fermentation of potato steam peels into pig feed | Netherlands | www.duynie.nl |
| Fermentation of brewers' spent grains into cattle feed | Netherlands | www.duynie.nl |
| Acidification of residue starch and protein from wheat processing into pig feed | Netherlands | www.duynie.nl |
| Processing of rejected shell fish into animal feed | Netherlands | www.seafarm.nl |
| Panels and boards based on residue cellulose fibres without using resins (Noble) | Netherlands | www.ecorglobal.com |
| Producing prepared foods from food surpluses and rejects in fresh supply chains | Netherlands | www.deverspillingsfabriek.nl |
| Separation of food processing by-products into food ingredients like fibres, juices and carotenoids | Netherlands | www.vanrijsingeningredients.com |
| Growing Oyster mushrooms on coffee residues | Netherlands | www.rotterzwam.nl/en_US |
| Rendering of slaughter residues into meat meal, blood meal and feather meal for feed | Netherlands | https://www.sonac.biz/ www.noblesseproteins.nl |
| Rendering of slaughter residues into proteins and fat | Netherlands | https://www.sonac.biz/ www.tenkate.nl https://www.collapro.com/ |



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| Wood biorefinery for production of lignosulphonate, cellulose, ethanol and vanilin | Norway | www.borregaard.com ; http://www.susvaluewaste.no/2017/09/07/one-of-the-worlds-most-advanced-biorefineries/ |
| Fermentation of sugars and other organic substances from agri-waste and unsold fruits and vegetables into gelatin-like cellulose material (Scoby) | Poland | https://www.makegrowlab.com/scobypackaging |
| Biodegradable disposable tableware based on bran | Poland | http://biotrem.pl/pl/ |
| Pastas, flour and cereals based on new varieties of cereals | Poland | https://biobabalscy.pl/ |
| Production of biodiesel and glycerine from rapeseed oil | Slovakia | https://www.meroco.sk/sk |
| Production of bioethanol from corn maize | Slovakia | https://www.enviral.sk/sk/ |
| Organic farming of plants, animals and food production | Slovakia | https://www.bio-centrum.sk/ |
| Plastic re-granulate and compost made from municipal waste | Slovakia | http://envigeos.sk/ |
| Wood pellets, briquettes, lump wood and dry wood chips from raw wood | Slovakia | http://www.biopel.sk/ |
| Combustion of biomass (wood chips and straw pellets) into heat | Slovakia, different locations | http://www.narodnaenergeticka.sk/ |



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| Biorefinery for production of bioactive compounds (polyphenols, triterpenic acids, etc) from olive oil industry by-products | Spain, Andalusia | https://www.natacgroup.com/ |
| Biogas and fertiliser generation from farming manure and slaughter house residues for a local supply | Spain, Andalusia | https://es.slideshare.net/agenciadelconocimiento/planta-de-biogs-agroindustrial-de-campillos-por-emilio-daz-y-david-piero-giesa-agroenergasi |
| Production of biofertilizers from by-products from olive oil industry | Spain, Andalusia | https://oleovaloriza.es/ |
| Biofertilisers, biofungicides, and bio soil remediation from seaweed, plants, seeds, bacteria, fungi and agro-food industry wastes | Spain, Andalusia | https://nbt.es/productos-para-la-agricultura/ |
| Cellulose and power production from forestry and agricultural biomass with heat recovery and use of fly ashes for fertiliser | Spain, Andalusia | https://ence.es |
| Conversion of glycerol and sugars into bio-based succinic acid (SUCCINITY) | Spain, Catalonia | http://www.succinity.com/biobased-succinic-acid/technology |
| Pelletization of agricultural residues into feed and fodder, and pellets | Spain, Puebla de Alfindén | http://agroinlog-h2020.eu/en/home/ |
| Hydrothermal processing (HTP) of biomass into 5-HMF | Switzerland | http://www.avalon-industries.com/web/pages/en/technology/hydrothermal-processing.php |
| Conversion of grass fibres into insulation materials (Gramitherm) | Switzerland, Lausanne | http://gramitherm.ch/?lang=de |



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| Biorefinery converting grass into insulation materials and composites | Switzerland, Odenwald | www.biowert.com |
| Making beer by replacing one-third of the malted barley with unsold bread | UK, Yorkshire | https://www.toastale.com |
| Combustion of wood chips & agro-pellets into heat for greenhouses | Ukraine | http://www.uabio.org/en/ ; https://camellia.ua/en/about |
| Wood chips from energy willow plantations | Ukraine | https://www.salix-energy.com/about |
| Briquettes for heat from beech sawdust | Ukraine | http://www.vgsm.com.ua/nasha-produkciya/briketi |
| Energy from wood and agricultural waste for municipalities | Ukraine | https://zhovkva-rada.gov.ua/dijalnist-radi/mizhnarodni-proekti/realizacija-pershogo-etapu-kotelni.html |
| Biogas and fertiliser from poultry manure (ImBio) | Ukraine | http://integro.co.ua/en/ |
| Insulation material in the form of mortar based on hemp and lime | Ukraine | http://hempire.com.ua/en/ |
| Mechanical 3D puzzles made from high quality plywood | Ukraine | https://ugears.ua/mechanical-3d-puzzles/ |
| Second generation bioethanol production from corn stover | USA | www.poet-dsm.com |