Best practice examples

Deliverable 3.4

MAIN AUTHORS: CIRCE, BZN, WR, DBFZ

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Main Authors	Javier Marcos Gonzalez (CIRCE), Martien van den Oever (WR), Nora Hatvani (BZN), Bomin Yuan (DBFZ).
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Table 1 Document Factsheet.

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Consolidated Implementation Plan Draft	25/11/2019	Draft description of approach, activities & results. Sent to BZN, WR & DBFZ for review.	CIRCE
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Table 2: Document History.

ABBREVIATIONS

CAPEX: Investment cost

CO_2: Carbon dioxide

DM: Dry matter content

DoA: Description of Action

EU: European Union

€: Euro

GHG: Greenhouse

GMO: Genetically modified organism

HDPE: High density polyethylene

HMF: Hydroxymethylfurfural

HUF: Hungarian Forint coins

GMP+: Good manufacturing practices

g: Gram

GWh: Gigawatt hours

kg: Kilogram

k€: 1000 euros

l: Liter

LCA: Life cycle analysis

MSD: Micro-scale digester

PP: Polypropylene

PLA: Polylactic Acid

PhD: Doctor of Philosophy

R&D: Research and Development

RTO: Research and Technology Organisation

ton: 1000 kg

TRL: Technology readiness level

WP: Work package

Wt.-%: Weight percentage

2G: Second generation

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: AGRARGAZDASAGI KUTATO INTEZET

NAK: MAGYAR AGRAR-, ELELMISZERGAZDASAGI ES VIDEKFEJLESZTESI KAMARA

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: 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.

PUBLISHABLE SUMMARY

The bioeconomy transition is routed in new opportunities with high potential of replication at EU level. To this end, it is important to identify which measures could potentially have a high impact on the bio-based economy. Theoretically, several measures have been agreed to support stable and appealing markets for biobased products, such as fossil carbon tax, a CO_2 tax, quotas, tax credits, removal of fossil subsidies and, mandates and bans. Nevertheless, there are also other actions, namely "soft measures" which could also be very fruitful in the development of sustainable activities towards long-term bioeconomy initiatives in the field of increasing public awareness. These "soft" measures are regarded as easy to implement in the current political climate. Among others, the adoption of bio-based products can answer the call from the public and politicians for concrete measures from the EU and its Member States for more climate-friendly products. An enhanced bio-based economy has an important role to play in meeting the ambition of the 2015 Paris Agreement and in delivering the European Green Deal.

The POWER4BIO project counts on learning from experiences. Examples and references might speed up the decision made at national and regional level, which will enable a stronger commitment towards solutions under the concept of bioeconomy. To this end, policy makers urge to gain access to reliable reference sources of information to use these sources in their internal procedures. Furthermore, the detailed description of existing cases is an instrumental key to learn and inspire new initiatives. The regions oversee the state of the art and point out the value of being informed of initiatives which are successful with new business model. As a matter of fact, the POWER4BIO regions have arisen the need of a catalogue of technologies in real production cases (Deliverable D3.3) but in some specific cases, more technical information is required to foster and boost regional bioeconomy actions. This is the aim of this deliverable D3.4, were a thorough analysis, selection and description of the best practices of biorefineries worldwide is included.

In the context of the POWER4BIO project, best practices are industrial production sites, which use specific biomass sources to produce biobased products. This deliverable pays special attention to two elements: rural application of the selected biorefineries and their competitivity. Furthermore, aligned with deliverables D3.3 and D4.1 of the project, the solutions are classified in 4 categories, in view to its application, such as, bioenergy, biochemicals, feed&food and biomaterials. This classification allows for an easy to understand and use of the cases detailed depicted in this document. In total, 12 EU best practices, 3 of each of the 4 categories are included in this report. The information per best practices include the minimum information to illustrate the cases. They provide the reader with information to consider its potential for replicability. Lastly, all the cases have been harmonised content-wise so as to facilitate the understanding and comparison of examples.

POWER4BIO (www.power4bio.eu) collaborates with the Horizon 2020 project BE-Rural, which also assesses technology options and business models for regional and local bio-based economies. A joint guidance document will summarise the relevant outputs of the two projects and provide concrete recommendations for policy-makers regarding the application of bio-based technology options and business models in specific regional contexts. The present report will contribute to this joint output. For further complementary information from the BE-Rural project, we encourage the reader to visit: https://be-rural.eu/results/.

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1 INTRODUCTION

Since the beginning of the project, even at the Kick-of-meeting of the Power4Bio project the need of learning from real experiences in the field of biorefineries and bioproduction sites was underlined. All the regions are interested on having access to information depicting biorefineries and all the elements which make them sustainable. In other words, to learn from existing competitive production sites.

To this end, three tasks, T3.3, 3.4 and 4.1 have common goals. The three activities address the collection of information to illustrate and explain how biorefineries and their key components can deliver the four biobased product groups the P4B project aims at: bioenergy, biomaterials, biochemicals and food & feed.

The T3.3 focused on key data of technological, market and environmental components of a wide range of cases of the mentioned 4 families of bioproducts resulting in an online catalogue of technologies which presented the information targeted by means of an easy-to-use tool in a repository of solutions format.

The T3.4 moves into a more detailed description of preselected bioproduct production sites. Thus T3.4 is based on a selection of cases included in the catalogue (T3.3). Nevertheless, in this task, specific criteria are used to dig into those cases with highest potential to be replicated in rural areas, with special emphasis on their competitive capacity. As part of the work accomplished, general criteria were used to align the information collected from all the cases. The exercise started based on the long list of best practices identified in most of the cases, in task 3.3. From them, a thorough analysis of the cases concluded with 12 cases, which included enough information to become "examples". In this process, some cases were disregarded due to the lack of information regarding the topics targeted. This situation also occurred in the twin task T4.1. The RTO´s of this task have faced the difficulties of having access to reliable information. In this case, an exhaustive literature analysis has been performed as well as an intense correspondence with owners of the production sites have been carried out additionally to complement and enrich the final factsheets.

In Annex C, additional activities performed in task 3.3 since the delivery of the catalogue webtool and submission of D3.3 report until the end of December 2019 have been described.

2 SELECTION OF BEST EXAMPLES

The process of selection of the best practices was conditioned by the difficulties when it comes to gather information from the companies. In order to optimize this process, the twelve solutions described in this task are part of the nineteen solutions analysed in deliverable D4.1. In this way, from the one and the same company, overall information gathered was increased, minimizing the effort and time expense and increasing the efficiency.

2.1 Approach

The starting point for the development of the task was the information gathered in the previous task 3.3 in which forty solutions were selected. Among them, initially, the set of four solutions per bio-application was chosen for the business model development in the task 4.1 and finally, three of these solutions were selected for the task 3.4.

The solutions described in this task include techniques already tested at high TRL, which are ready to be operated at commercial or precommercial state. In this context, the information of this deliverable is not focused on describing solutions from a technological point of view, but in order to complete its description in task 3.3 and 4.1 by considering aspects such as its potential replicability in rural areas therefore contributing to the rural development and its competitiveness at small scale. The analysis of the information was based on two criteria, a market-oriented criterion and a "rural" criterion. For each one, different factors were considered in order to describe the information in more detail. These are in line with the variables of analysis normally used in the rural development plans of the many European regions and many times underlined in documents regarding bioeconomy strategies at regional level.

The information gathered includes regional features, challenges detected, opportunities, social and economic impacts, identification of risk, success factors, support instruments and lessons learned useful for other regions.

The solutions have been selected as the most appropriate for the analysis considering they encompass a wide range of information regarding market and rurality according with the description of the task included in the DoA mentioning that "special attention will be paid to models that can be deployed at smaller scale in rural areas" is specifically mentioned.

This factor was used to analyse the consistency of the information and to decide whether to include it in the final factsheet. In the case of inconsistencies or lack of information, the selection of another solution (extracted from the long list elaborated in the task 3.3) was proposed. An outline of the approach is showed in the Figure 1.

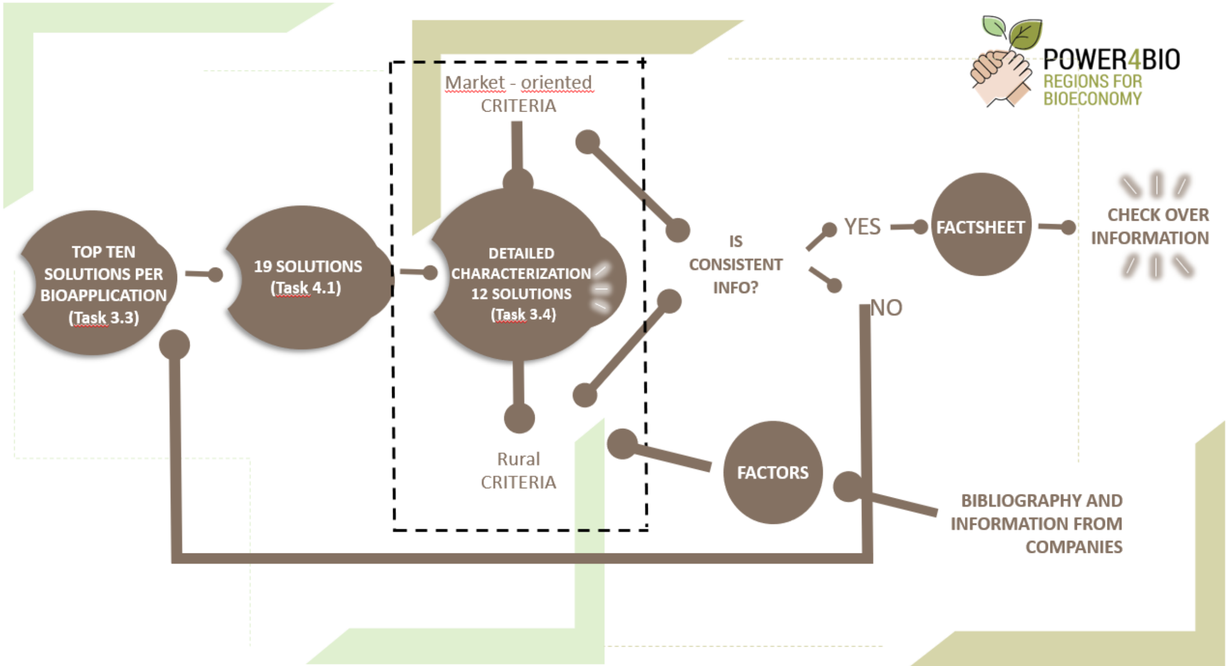

Figure 1. Approach and methodology of the task 3.4 including inputs from previous task and main output to feed into.

2.2 Template to collect solutions

In order to make it easier to gather information for each solution, a template was circulated between the partners involved. This template served to summarize the information and facilitate the dialogue between RTO´s. As mentioned in the section 2.1, two criteria were used for the screening of information and they were pointed out in the template. The first one is related to market aspects and it was used to evaluate the competitiveness of a solution. The second one comprises “rural” criterion and it is addressed to encompass information related to the adaptation of the solutions to rural environment at small scale. Furthermore, different factors were used to compile the market and rurality related information. One of these factors was “advantages for farmers”. It is important to note that this factor was described for every solution according to individual criterion of each RTO in charge of the solution. The rest of the factors used try to extract and present information using the same criteria in order to be able to analyse similarities and differences between them. An example of the template and the information requested is presented below (Figure 2). In this case the solution used for the example was the company HoSt, analysed by CIRCE within the bioenergy group.

Best Practice Title	*"Production of biogas from cattle manure anaerobic digestion. 'Green gas Kampen (Dairy farmer de Groot)".*
Contact Person (Company)	HoSt
Market-oriented criteria	
Competitiveness of the solution	
Widespread availability of alternative energy produced from manure can increase the competitiveness of the power generation market in Europe, therefore contributing to the reduction of the production costs. Energy will become less expensive if information about micro-scale digestion are spreading, and appropriate support is provided. The other important aspect of local energy sources is the enhanced security of power supply. In rural areas of some countries, electricity grid is often of poor quality and susceptible to breakdowns. Many activities in farming business strongly require a continuous power supply, thus having one's own stable energy source should be found as a noticeable competitive advantage	
Rural criteria	
Employment in rural areas	
Micro-scale digesters (MSD) do not require many man-hours for operation. Farmers can operate and maintain them themselves. This means more work for farmers, but according to those who operate such plants, it is manageable. On the other hand, new workplaces can be created in other areas, i.e. technology providers, plant developers, and technical support.	
Capital formation in the region	
In case of MSD local resources are used and local companies perform maintenance of installations. Therefore, the capital remains in the region. This contributes to improving quality of life of the residents.	
Social responsibility	
MSD are usually built on farms, near houses. The proximity is much closer than in the case of large-scale installations. When planning an investment in a MSD, it is good to talk to the neighbours about it. The distance from other buildings should be enough to make the noise level acceptable. A well-operated plant will not have a negative impact on living conditions. Farmers who have neighbours with animal farms can launch a biogas project together or make an agreement to utilize also their manure. This type of cooperation can tighten social cohesion.	
De-centralized bioproducts production	
Decentralized energy production in plants with MSD improves the security of energy supply for households through reducing grid loads. When farms are more energy-independent, the grid load is	

reduced and the whole power network is less susceptible to failures. Furthermore, the significant costs for the grid losses and for the grid stabilization can be avoided.

Advantages for farmers

More stable and cheaper energy: Many activities related to farming require different forms of energy. As it happens, biogas can be transformed on site into electricity, heat or even fuel for machinery and transport. Having one's own secure source of energy on the farm should, among other advantages, be as important as an insurance policy. Moreover, producing energy for the farm may be profitable mostly due to the avoided cost of energy purchase. The income from surplus energy sales may be an additional advantage and shorten the payback time of the investment. This aspect, however, strongly depends on national or local policy and relation between network operator and producer of renewable energy. As it is observed in most of EU countries, the network operators tend to favour large energy producers over small ones. Therefore, there is some room for policy improvements to ensure proper balance between all parties.

Unnecessary disposal of manure: Manure is utilized on the farm, so the farm owner does not pay for its disposal and avoids costs of manure transport. However, in animal breeding regions like Denmark, Brittany in France or north-west Germany, where there is an excess of nutrients for the soil produced locally, if manure is digested on the farm, the digestate might need to be exported from the region.

Less chemical fertilizers: Digestate is a better fertilizer than untreated manure. Its costs are negligible, because it is produced from the farm's own residue. With better manure management due to the application of digestate instead of manure, fewer chemical fertilizers are needed on the farm, with the same crop yields. Also, the production of chemical fertilizers costs a lot of energy and fossil resources.

Organic Products: Avoiding chemical fertilizers and safe utilization of manure on the farm (digestion treatment results in low levels of pathogenic germs in digested manure can help obtain Eco-Labels or organic farming certificates for farm products, which raises their market value.

References

[1] www.bio-up.nl

[2] https://www.host.nl/en/biogas-plants/agricultural-biogas-plants/

[3] Cornelissen Consulting Services B.V. www.cocos.nl

[4] DCA Multimedia B.V. www.boerenbusiness.nl

Figure 2. Example of the template used to present the information collected

3 DESCRIPTION OF FACTORS CONSIDERED UNDER THE RURAL AND MARKET-ORIENTED CRITERION.

In this section, the factors used to describe the solutions according to rural and market-oriented criteria are explained. An agreement in the selection of these factors was carried out with the aim of identifying those that better define the "competitiveness" and "rurality" of a solution. Detailed information regarding the identification of keys that facilitate the deployment of these solutions in rural areas at small scale was obtained. The reasons to use these factors and the type of information needed for each one is summarised within this section and a list of these factors is presented in Table 3 and Table 4.

As a previous activity in the definition and description of the factors used in the analysis of information in the task 3.4, a revision of the factors obtained from task 2.2 regarding the characterization of the bio-economies in the POWER4BIO regions was carried out. Thus, the information included in the task 2.2 was used as information source/framework for this section.

3.1 Competitiveness

Market-oriented information can be summed up in the competitiveness factor of a solution. In order to define it in more detail, three aspects were considered:

1. Availability of solutions
2. Technical information
3. Appropiate support

The existence of similar plants different to the examples proposed for each bio-application in the regions and the number of initiatives currently implemented with similar characteristics was used as an indicator of the replicability and competitiveness of a solution (see factor 2 in the Table 6, in Annex B). Many references mentioned that the measurement of innovation referred to the degree to which new technologies are adopted, together with investment in research and development is essential in order to face challenges in regions with very different features [**1**]. Thus, the existence and number of patents (degree of innovation) were considered as key information to collect (See factor 3, in Table 6, in Annex B).

In addition, information concerning to the advantages and disadvantages of the conversion processes regarding production parameters and feedstock was included in this section. Special attention was stressed in the information regarding the use of by-products. This content gives a measure of the "technical competitiveness" of the solution (See factor 1, in Table 6, in Annex B).

Other relevant aspect such as the identification of the main support instruments was evaluated. On the basis of rural regions traditionally have relied on central governments interventions and subsidies for their development, more recently, emphasis has been placed on local development actions, which require supportive governance arrangements for local activities, including the creation and operation of local level partnerships by a wide range of stakeholders, between which the boundaries may become blurred [**1**].

At present, the feasible implementation of solutions with high degree of innovation in rural areas in many cases depends on external financial support, so it is important to compile information related to support instruments and types of funding schemes which are essential to minimize the risk of deployment of a solution in the rural environment and at small scale. Public and private initiatives were considered in each case, reporting different information based on the different features between regions (See factors 6 and 7 in Table 6, in Annex B). Specific and more detailed information regarding financial support is presented in deliverable 4.1 ("Examples of regional bio-based business models") for the same solutions. A summary of factors used to describe the market-oriented criterion is presented in Table 3 below.

Table 3. Summary of factors analysed under market-oriented criteria

Criterion	Factors	Description of factors
❖ Competitiveness	❖ Availability	✓ Number of solutions implemented in each region.
		✓ Innovativeness (patents).
	❖ Technical information	✓ Production capacity.
		✓ Treatment capacity
		✓ Cummulative energy demand.
		✓ Feedstock price.
		✓ Information about advantages and disadvantages of the technology.
		✓ Alternative options for purpose/application.

	❖ Appropiate support	✓ Support instruments.
		✓ Funding schemes and support possibilities.

3.2 Rurality

The degree of rurality of a solution was analised with the help of these five factors.

1. Capital formation in the region
2. Social responsibility
3. Employment in rural areas
4. Advantages for farmers
5. De-centralized bioproducts production.

Capital formation in the region contains information regarding human and environmental capital. The information that comprise human capital includes education, skills and entrepreneurship among others [1]. In this context, for the solutions analysed, both level of entrepreneurship as well as skills are the basis over which collaborations between local companies and rural biorefineries can be articulated. In the process of selecting and assessing the information of the best practices, other elements were considered. In particular, regulatory environment in each case was studied. This would ease the analysis and the understanding of the specific circumstances and how the owners of the best practice have faced and overcome those potential hurdles. Thus, it is also a very valuable information for the readers of each described best practice. (See factor 6, in the Table 6, Annex B). Environmental capital includes information regarding the level and quality of local resources and its 'exploitation' to bring economic benefit [**1**]. Thus, the analysis of the availability and access to raw materials, trends in demand, evolution, information and statistics on available types of feedstock, as well as their existing and potential competitors for its use were key aspects to consider (it was already mentioned in the factor named "Availability and use of resources" within the task 2.2. (See factor 1 in the Table 6, Annex B) highlighting the strong possible interconnections between rural and industrial environment.

For the solutions analysed in this report, these facets are translated into an analysis of the location of the production, the distance from the supply to rural biorefinery and the origin of the resources.

Regarding the definition of social responsibility, it is a concept that aims to ensure secure healthcare for the people living in rural areas and eliminate all barriers like distance, financial condition, etc [**2**]. In order to apply the definition of "social responsibility" to the analysis of the solutions, the concept of social capital, was used. There are a number of factors and facets associated with social capital, some of which relate to population density and others more to processes, as level of emissions (in the production of biomass and in the biorefinery processes) and its impact on living conditions or on the distribution and market uptake. These impacts are in general specific for each region and can change over short periods of time which makes it challenging to evaluate these aspects (See factor 8 in the Table 6, Annex B). Other aspects such as the degree of co-operation and the role of partnerships in relationship-building between sectors have been considered as the degree of social responsibility of the solutions in the evaluation.

Regarding employment in rural areas, this factor comprises information related to the type of employment, participation rate, the nature of employment and the unemployment rate. For many rural areas, employment in the agriculture and agri-food sectors together with the market and economic aspects (See factor 4 in the Table 6, Annex B) may be critical in explaining local economic performance. The European Commission, in 2006 used the term 'Rural Jobs Gap' to describe the lower rates of employment and economic activity, higher rates of unemployment, and lower levels of qualitative human capital (training and skills). The Commission links the rural jobs gap to demographic trends (ageing, selective migration and gender issues) and structural differences, such as the slower development of secondary and tertiary activities in rural areas, blocking in many cases its capacity to create high quality jobs

Indeed the Agriculture Council of July 2003 identified several challenges for the future of rural employment such as the ageing of the farming population, the participation of young people and women in the rural economy, the enlargement of the European Union and the switch from product to producer support under the revised CAP (common agricultural policy). [**1**]. All these features have been considered in the analysis of the solutions.

The factor "Advantages for farmers" describes different competitive advantages obtained as result of the implementation of specific technological solutions. Most of them have to do with incomes derived from the sale of raw material and energy self-consumption. Moreover, other incomes related to the sale of certificated farm products and savings in the waste disposal have been considered. All of them are general or specific for the bio-applications analysed.

Finally, the information regarding de-centralized bioproducts production was focused on the analysis of the flexibility of the production processes, specifically in its adaptation to small scale production and its lower level of investment and operation cost. All the factors considered in the evaluation of the "rurality" of a solution are presented below, in the Table 4.

Table 4. Summary of factors to be studied under rurality criteria in the chosen best practices.

Factors	Description of factors
❖ Capital formation in the region	✓ Resources origin (local).
	✓ Activities from local companies (eg. maintenance).
	✓ Feedstock obtained close to the rural biorefinery.
	✓ Location of production.
❖ Social responsibility	✓ Impacts on living conditions.
	✓ Cooperation.
	✓ Density of the location where is the biorefinery.
	✓ GHG emissions.
❖ Employment in rural areas	✓ Easy-to-operate and easy-to-mantain systems.
	✓ Creation of new work places in other areas (higher specialization).
	✓ Rural women and young job creation.
❖ Advantages for farmers	✓ Incomes derived from sales of products and savings in the waste disposal.
	✓ Certificates for farm products.
	✓ Possible energy and feedstock self-supply.
	✓ Distribution of biorefinery.
	✓ Cummulative energy demand.
	✓ Alternative options for purpose/application.
❖ De-centralized bioproducts production	✓ Level of security (less dependency on large plant supply, avoiding uncertainties.
	✓ GHG emissions
	✓ Investment and operation cost.

4 DESCRIPTION OF THE BEST EXAMPLES

4.1 Gathering of information

The information was gathered from the companies via questionnaire and/or interviews. The interviews were carried out face to face with representatives of the companies or via teleconferences. Other public information sources such as activity reports, web pages, presentations and dissemination documents were used to gather information. In order to present the information, a factsheet including the factors mentioned in the section 3 was elaborated by CIRCE and it was sent to the rest of RTO´s for its revision. As mentioned before, previously to complete the factsheet, large discussions about its content and structure regarding level of detail and format, were held with the rest of RTO´s. Finally, all partners involved came to an agreement in the type of factsheet to use. Thus, it was further used to present the analysis of information of the solutions. Each RTO in charge of specific bio-based product group (bioenergy, biochemical, biomaterials and feed&food led by CIRCE, DBFZ, BZN and WR respectively) reported information of three best practices related to their respective fields (biomaterials, biochemicals, food and bioenergy).

4.1.1 Information gathered from public sources

European and international information reports as well as scientific publications were reviewed, focusing on those documents regarding the bioeconomy strategies development in the European countries and Rural Development Plans. Also, reports including specific information of the activity from the companies were consulted.

4.1.2 Information from companies

The gathering of information from the companies was carried out with the help of the POWER4BIO regions. As a first step and in order to establish the dialogue with the chosen plants more easily, the regional representatives helped each RTO to contact with the companies. Once the first contact was established, a questionnaire was sent to the companies. In addition to this, interviews were held with the operators when possible, preferably in situ at the facilities, otherwise by phone. During the process of gathering of information many challenges had to be overcome, mainly related to establishing contact with the companies, scheduling the telco or phone call and due to the lack of information regarding the impact of the solutions on the rural environment.

4.2 Information report

One factsheet per solution was elaborated. In order to design and develop the factsheet, different quality requirements of quality were considered according to the descriptions of market-oriented and rural criterion (See sections 3.1 and 3.2). The uniformity regarding the type of information included in each factor was checked and compared among solutions. The factor "advantages for farmers" was supposed to be an exception due to its heterogeneity. During the process of analysis and presentation of information, each RTO´s had to face some challenges, mainly related to the screening of useful information. Finally, twelve factsheets were completed, three per bio-application as result of the task. One example developed for Pilze-Nagy Ltd company is presented below (Figure 3). The rest of factsheets are listed in the 4.4 section and included in the Annex A.

Best Practice Title	*"Production of oyster mushroom and oyster mushroom substrate based on straw, combined with the valorization of the by-products of mushroom production and other agricultural and food industrial processes by producing electrical energy in a biogas plant".*
Contact Person (Company)	Pilze-Nagy Ltd
Market-oriented criteria	
Competitiveness of the solution	
The main products of the company are oyster mushroom and oyster mushroom substrate. It means an advantage from the point of view of competition that these oyster mushrooms are chemical free and the oyster mushroom substrate contains no harmful (competitor) microorganisms. Adaptation of the technology to different environmental conditions is possible but time consuming and knowledge-intensive. The waste of the growing process is spent mushroom substrate (SMS). To valorize this material, Pilze-Nagy Ltd invested in a biogas plant which can use SMS as main feedstock for electrical energy production. Beside SMS the biogas plant is able to utilize residues of other agricultural and food industrial processes (poultry manure, marc and other by-products of distillery process, expired food, sludge from slaughterhouse with high moisture content, oil based sludge, other food industrial wastes, etc.). By producing electrical energy, the company reduces the production costs of oyster mushrooms and substrate and the risk of high energy prices. In the same time sells the surplus energy and the biogas plant offers an opportunity to the nearby farmers and food industry companies to make revenue from their so far unused by-products, or at least to spend less money on waste management. One of the by-products of the electrical energy producing process is biogas digestate. After separating its solid phase, this material, being rich in nitrogen, can be used as biofertilizer by local farmers.	

Oyster mushroom and substrate producing plants have been built using the support of the Ministry of Agriculture and Regional Development, as well as the County Council of Regional Development. Several developments related to the mushroom growing have been supported by co-funds received from the State of Hungary and the EU. 70% of the 340 million HUF (1 million EUR) investment value of biogas plant was provided by the company (a part of it as bank loan), while further 110 million HUF (0,34 million EUR) has arrived as support by the Environment Protection and Infrastructure Operative Program.

Rural criteria

Employment in rural areas

Oyster mushrooms and oyster mushroom substrate production requires qualified human resources as well, which could help to raise the number of qualified employees in rural areas. The biogas plant requires only a few people to operate.

Capital formation in the region

The main feedstock of oyster mushroom growing is cereal crop straw and the mushroom spawn (mushroom mycelia used to inoculate the prepared substrate). Besides wheat straw they use other crop stalk and alfalfa and other green fodder residues. Pilze-Nagy Ltd purchases half of the straw from nearby farmers (from the east side of Southern Great Plain) and half of the straw from dealers. This way the company can continuously monitor and control the price and quality differences on the market. Agricultural and food industrial residues are also bought from local farmers and food industry companies resulting revenues from their so far unused by-products.

Social responsibility

There is a close cooperation with other mushroom growers, who are using Pilze-Nagy Ltd's oyster mushroom substrate and in the end Pilze-Nagy Ltd repurchases the final oyster mushroom from them. The biogas plant helps to the local or national electricity transmission system operator company to provide the required amount of electrical energy to the area. It can support rural development and mitigate the negative effects of general economic fluctuations on local energy and fertilizer production.

De-centralized bioproducts production

Although the investment costs are relatively high, the technology can be downscaled which can create great socio-economic potential to promote long-term sustainable growth, create jobs and thus decrease poverty in poorer regions. The most important expenses are feedstock, energy and labour

costs. The expenditure incurred related to the operation of the biogas plant is 80% of the revenue from electricity produced.
Advantages for farmers
Local farmers have an opportunity to sell their straw, other crop stalk, alfalfa and other green fodder residues to the company, which can raise their financial and production stability. It could also result savings in waste disposal costs. Separated biogas digestate and the liquid digestate of the biogas plant can be purchased by local farmers and applied to their fields as a nitrogen-rich fertilizer. This could reduce the use for chemical fertilizers. Local mushroom growers can cooperate with the company resulting a higher chance for them for quality production and financial success.
References
[1] http://pleurotus.hu/

Figure 3. Pilze-Nagy Ltd.

In general, it can be said that the information presented in the competitiveness factor is related to the flexibility of the production processes, including routes for further valorization of by-products, uses of alternatives raw materials and types of instruments of support needed to set-up the bio-solutions. The information assessed considering the rurality factor gives an idea of the potential collaborations between local farmers and the biorefinery companies and of its advantages, for example the incomes obtained from the supply of raw material, creation of new qualified jobs and reduction of impacts on living conditions.

4.3 Quality check

The aim of this work was to analyze the information presented in the factors for each solution in terms of quantity and level of detail.

Although a comparison was not feasible to the wide diversity among the solutions but also the type of information gathered in each case it was possible to assess and check the way the information has been report. In this context, this review process assumed the heterogeneity of information between solutions. Different drafts of factsheets were discussed with all RTO´s, with the aim to assure that the quantity of information included all the inputs available and related to the topic targeted with the same level of detail (minimum level of information contained in the Table 3 and Table 4).

In some cases, difficulties when it comes to establish contact with the companies caused a lack of information reported.

4.4 List of solutions

Each RTO selected three solutions for the analysis. These solutions were also assessed in task 4.1. This approach was used aiming to complete the description of the best example plants with information regarding the adaptation and implementation in rural areas and its competitiveness in this environment. Thus, the solutions included in this list constitute suitable industrial examples (biorefineries) in the field of bioeconomy for the potential application of process based on biological feedstocks in rural areas and at small scale.

The information included in these examples encompass a large variety of feedstocks, products and conversion technologies as well as social facets. The consideration of all these aspects constitute a very valuable feature of the set of solutions listed so it reflects that many different business cases can be appropriate and adaptable to the rural environment. This was the objective behind the selection of these solutions in order to increase and broaden the knowledge of new processes and the adaptability of industrial traditional operations.

A list of the best practices analysed is presented in the *Table **5*** below.

Table 5. List of the best practices for each bio-application.

RTO and Bio-application	Name of Companies	Good Practices
Bio-energy *(CIRCE).*	HOST	*"Production of biogas from cattle manure anaerobic digestion. 'Green gas Kampen (Dairy farmer de Groot)".*
	TERRANOVA	*"Hydrothermal Carbonization (HTC) of Sewage Sludge".*
	HAFFNER ENERGY	*"Production of renewable hydrogen via thermolysis of biomass".*
Food and Bioenergy *(BZN).*	PILZE-NAGY	*"Production of oyster mushroom and oyster mushroom substrate based on straw, combined with the valorisation of the by-products of mushroom production and other agricultural and food industrial processes by producing electrical energy in a biogas plant".*

Bio-materials (*BZN).*	HEMPIRE	*"Sustainable insulation and construction material made by using hemp hurds"*
	BIOWERT	*"Meadow grass silage biorefinery producing grass fibre enhanced plastic granulates and natural insulation material combined with biogas plant producing electrical energy from used grass juice and food".*
Bio-chemicals (*DBFZ*)	AVA-BIOCHEM	*"Production of 5-HMF from 1st generation sugars such as sugar beet and corn"*
	GREEN SUGAR	*"Production of fermentable sugars from waste resources"*
	MATER-BIOTECH	*"Production of 1,4-butanediol (BDO) directly through fermentation of sugars derived from the hydrolysis of starch"*
Food and Feed *(WR).*	BESTICO	*"Bioconversion of organic side streams by black soldier fly - producing insects, lipid & protein for feed".*
	ROTTERZWAM	*"Growing mushrooms on coffee grounds".*
	INNOVAOLEO	*"Extraction of food additives from olive oil by-products".*

In order to analyze in depth the feasibility of the industrial examples presented at small scale in areas less industrialized, the relation between its commercial exploitation potential and its social responsibility is essential. With the solutions selected different exemplary industrial behaviors, which maintains an equilibrium between business, technological advance, and social progress were achieved.

5 CONCLUSIONS

The information obtained in the task 3.4 is complementary to the exercise undertaken in the twin task 4.1, each of the tasks providing information from two different points of view. In this task the best practices are described paying special attention to facets that can boost their deployment at small scale in rural areas focusing the analysis on social and marketability features. This approach is already considered in the regional development plans for each region included in the POWER4BIO project and it is equally an important aspect to consider in the future bioeconomy strategies development.

The methodology used to gather and compile information, specially the criteria and factors used were selected accordingly to the reference methods currently used to analyze the feasibility of biorefinery solutions. However, some of these indicators were adapted in order to be applied to these specific bio-applications. Each RTO, as experts in each one of the bio-applications carried out this activity. The set of factors obtained as a result of the task 2.2 together with information from task 3.3 and 4.1 and other reference information were the basis for the selection and description of the criteria used in the analysis of information in this task. Furthermore, the factors used to analyze the adaptation of the solutions to the rural environment and at small scale were in line with the type of indicators already reported in regional development plans, bio-economies strategies documents and biorefinery technological solutions reports.

In order to get a better understanding between solutions and offer to the user useful descriptions, a similar minimum information criterion was considered. Regarding the analysis of information, some relevant conclusions were extracted and are summarized below:

- Lower quantity of information reported regarding “rurality” of the solutions and it was more qualitative than in the case of “competitiveness” criterion.
- Many of these solutions include innovations that facilitate its adaptation to the rural environment at small scale including in some cases “tailor-made” conversion processes.

Some specific conclusions for each bio-application are presented hereunder:

- Biomaterials: The operation of the plants requires engineers and experts as well which could increase the number of people with higher education in the rural area. The key aspect of these solutions is the ability to connect to existing food and feed and/or biomass-based energy value chains thereby strengthening their economic sustainability and making them ecologically more sustainable. The main advantages for farmers were the sale of raw material and the potential use and application of products/by-products generated by the biorefinery. Some challenges regarding adaptation of the conversion systems to different raw materials were reported. Although in general, the existence of similar cases (industrial plants with similar conversion system) were not found which can be an indicator of a moderate replicability. In the two biomaterials cases, the solutions include patented technologies which could help the replication of these solutions.

- Biochemicals: The best practice examples of biochemicals have high technology and knowledge level. All of them hold several patents. The products have very wide application areas. The feedstocks are derived from Europe, this guarantees a high quality. In the meanwhile, the local farmers can benefit from the high demand for the feedstock from the biochemical production plants. The importance of starting to use the 2nd instead of the 1st generation feedstock is gaining more and more attention. The common goal of these companies is to scale up the process while using 2G feedstock. Beyond that, the environmental aspects and sustainability are of great importance. These practice examples show their efforts in trying to keep the process environmentally friendly and lowering the GHG emissions. All of the three companies are receiving funding from EU projects and national supports. It can be seen that usually the largest amount of investments is aimed at construction of new factories or for new equipment. Establishing factories in the regions has boosted the local employment. However, the companies are not only looking for employees in the local area. For those that focus on scientific research and development, the qualification of employees is most important.
- Food and Feed: The primary production solutions are very adaptable to the desired (small) scale and labour intensive and relatively investment capital extensive. These plants are currently working with low production capacities, but it is adaptable to a large production. The extraction solution is relatively investment capital intensive and flexible in scale at the design phase; such solutions may be set up as a cooperation of farmers and once the solution is established, changing the scale requires significant additional investment. All 3 solutions are suitable in rural areas due to the high availability of the feedstock and their flexibility to handle different kinds of feedstock, where it should be noted that to produce feed grade products, GMP+ grade feedstock needs to be used. The solutions allow to keep employment in the rural areas, with complexity of work ranging from routine work to highly qualified jobs. The solutions deliver products which are in a way new to the market, so relations with potential customers need to be established during the process of establishing the solution.
- Bioenergy: The solutions for this group present a high degree of adaptability at small scale. The described technologies to produce energy include different conversion processes with a wide range of production capacities and a large variety of products. A competitive advantage of these solutions is the reduction of the energy cost and the generation of a stable energy source in rural areas. More information and promotion between rural community regarding the

technologies suitable to produce energy would facilitate its implementation and it would help to increase the competitiveness degree of these solutions. Moreover, the processes to produce energy are easy to implement and can be integrate in farms and/or plants currently in operation. The use of by-products or low cost agricultural raw material as well as the utilization of secondary products as nutrients as fertilizers or biochar as soil amendment in the farm, can contribute to the feasibility and sustainability of the solutions. The main advantage for farmers is the possibility to make the farm an energy self-consumer selling its surplus of energy. The main challenges are related to the cost of infrastructure and equipment.

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7 ANNEXES

Annex A. Best Practices examples

Best Practice Title	*"Meadow grass silage biorefinery producing grass fibre enhanced plastic granulates and natural insulation material combined with biogas plant producing electrical energy from used grass juice and food".*
Contact Person (Company)	Biowert
Market-oriented criterion	
Competitiveness of the solution	
The main products based on grass from permanent pastureland and arable land for crop production are grass fibre insulation (AgriCellBW), natural fibre reinforced plastic (AgriPlastBW) and fertiliser made from digestate (AgriFerBW). The integrated biogas plant produces biogas which is used in combined heat and power facilities. The whole system shows high signs of innovation. The combination of a biogas plant with the biorefinery is a textbook example of circular economy, where output of one may serve as input for the other (Figure). The grass juice remaining from mechanical pretreatment of grass silage is used as substrate in the biogas plant (together with local co-substrates such as food waste and slurry). The heat and electricity derived from the biogas facility is used to satisfy the energy in the biorefinery and excess electricity is exported to the electricity grid. Wastewater arising from the process is reused for pretreatment (slurrying) of grass silage. Digestate from the biogas plant is further processed to a concentrated and a liquid biofertilizer (AgriFerBW) used by local farmers. This closes the nutrient cycle in the circular economy [1]. Outside input is mostly food waste or other organic feedstock waste materials as well as renewable materials (meadow grass). Waste materials are recycled within the circular economy. The facility has an annual throughput of about 2,000 tonnes dry matter (equivalent to 8,000 tonnes grass per year at 25%–30% DM). The integrated biogas plant produces 1,340,000 m^3 of biogas annually which is used in combined heat and power facilities, which in 2012 produced 5.2 GWh of electricity. The production of AgriPlast uses recycled additive materials (recycled HDPE, PP, etc), further increasing environmental impact. Products made of AgriPlast are also recyclable several times without losses. Quality is also an important value in bioeconomy. AgriPlast must meet the technical requirements of customer applications. In case of changing market expectations (100 % biobased and/or biodegradability) it must be further developed. Organic fertiliser AgriFer is RAL (National Board for	

Delivery Conditions in Germany) certified, while the insulation material AgriCell has a DIBt (Deutsches Institut für Bautechnik) approval.

Rural criterion

Employment in rural areas

The feedstock production and the operation of the biorefinery and the biogas plant require several types of employees, thereby beside agricultural jobs industrial jobs (production manager, engineers, etc.) are created as well.

Capital formation in the region

The plant is located in Brensbach, Germany. Local feedstock providers are important partners, meadow grass for Biowert is provided by the local farmers and their association, while food leftovers and fat provided by waste material handling companies.

Social responsibility

The production process is ecologically, regionally and socially responsible. It is regional because meadow grass processed is a raw material from the Odenwald region where livestock farming is declining and new ways of exploiting grassland are being sought. The company offers employees and business partners a sustainable outlook for the future. Public perception and political attractiveness of the technology lies in the establishment of a circular economy with its low environmental impact and the reduction of the consumption of fossil raw materials. Biogas systems can support rural development and mitigate the negative effects of general economic fluctuations by local energy and fertilizer production. Biogas drastically reduces the dependence of local communities on imported fuels and increases the local energy supply.

Des-centralized bioproducts production

This production system could operate properly even in structurally weak but agriculturally heavy regions. Thanks to the biogas plant the system itself can provide enough heat and power. Furthermore it can sell the surplus electric energy to the regional or national electricity transmission system operator company thereby helping the regional electricity supply system. Investment costs for the biorefinery greatly depend on land availability, construction permits, costs for the biogas plant and compliance of existing laws and regulations. Costs also depend on grass fibre production capacities and thus the machinery needed. Operating costs for the biorefinery depend on availability of electricity and heat, whether this is provided by the biogas plant or it needs to be supplied from outside. Other production costs include wastewater treatment requirements (grass juice). Operating costs for the biogas plant are typical as per market standards. There are no real investment costs synergies between the segments, but combining the biorefinery and biogas plant allows for headcount synergies. The main challenge is market development for fibre-reinforced materials. Injection moulding and extrusion processes need to be adapted to the specificities of the grass fibre enhanced granulates. It takes 18-24 months to install and optimize the technology.

Advantages for farmers

Local farmers have an opportunity to sell their meadow grass to the company, which can raise their financial and production stability. Although it requires additional researches and optimization, the production system could work with other feedstock as well, which could make the system functional in regions with different environmental, climatic and geographical characteristics. The liquid biofertilizer (AgriFerBW) from the biogas plant can be purchased by local farmers and applied to their fields as a nitrogen-rich fertiliser. This could reduce the use for chemical fertilizers. In the long run farmers can get a new social function as energy producers or waste managers thanks to the nearby biogas plant.

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[1] https://www.ieabioenergy.com/wp-content/uploads/2019/07/IEA_grass-refinery_end.pdf

Figure 4. Biowert.

Best Practice Title	*"Sustainable insulation and construction material made by using hemp hurds"*
Contact Person (Company)	Hempire
Market-oriented criterion	
Competitiveness of the solution	
Hempire produces insulation material from hemp hurds and own produced lime based binder with a production capacity of 3,000 tonnes/year of binder. This insulation material is used for new buildings and for existing buildings as well, as additional insulation layer. The production technology of the material is currently under patenting process. The benefits of this insulation material are very diverse : There is no need to use ventilation system because of the vapor permeable walls. Insulation acting as humidity and temperature regulator in the building. The high thermal mass and thermal inertia help avoid temperature fluctuations. Hygroscopic hemp hurds can absorb excessive moisture inside a house and release it. Significant savings can be achived on heating and cooling all year round due to excellent thermal insulation properties. "Hempire Mix" contains only natural, non-toxic components (no cement). The material is non-flammable, repels rodents, locks up CO_2 (negative carbon footprint), does not rot and protects walls from fungus due to the regulation of humidity. It has also excellent acoustic absorption due to high porosity. Lime used in "Hempire Mix" raises PH levels, creating alkaline environment inside a house. It is possible to use this insulation material for houses with light foundation. This means that hemp based insulation material is a competitive product on the market and its natural origin and negative carbon footprint could mean a huge advantage in environment-friendly society.	
Rural criterion	
Employment in rural areas	
The feedstock production requires hemp growers, which could result additional jobs in the agricultural industry. To revive hemp sector, there is a need for agricultural experts as well for seed-related researchers. Thereby it could raise the number of qualified employees in rural areas. The insulation material production technology is easy-to-learn and easy-to-operate, thereby it creates jobs for the unqualified people as well, which can encourage young people to stay in a rural area. Thanks to the growing global demand for various products produced from hemp, including construction materials, there is a huge potential for thousands of jobs in the short term from hemp in various areas whether that is on the fibre side or the seed side [1].	
Capital formation in the region	

Hemp growers can sell their products to the company. As it has been mentioned before, to revive the hemp sector, there is a need for agricultural experts and seed-related researchers, which could result revenue for research organisations. To use this insulation material in the construction industry in higher quantities and more frequently there is a need for architects with adequate knowledge, which could result revenue for architect businesses.
Social responsibility
There has to be a good cooperation between the company and hemp growers. Since currently this sector is really small and vulnerable, the members of the sector have to help each other and thereby strengthen the stability of their own businesses. Since hemp-based insulation material has a negative carbon footprint, it has a really positive impact on living conditions not just for the owners of the building, but for the neighborhood and the region as well. By its excellent characteristics and natural origin, hemp based insulation material could help to use more biomass-based construction materials and to (re)invent their potential in the construction industry.
De-centralized bioproducts production
The capital and operation costs of an insulation material production facility are relatively low, because it does not require expensive and complex machinery and high qualified human resources. The main challenge is to find good quality feedstock. Other issues are the lack of knowledge and education related to bio-based materials and the very conservative construction industrial approach. These factors could increase the level of uncertainty of the solution.
Advantages for farmers
Local farmers have an opportunity to sell their hemp to the company in the frame of a long-term cooperation, which can raise their financial and production stability on the long term with the increase of the research in the hemp corps area it could result a more complex hemp based value chain.
References
[1] https://www.agriland.ie/farming-news/hemp-harvesting-there-is-potential-for-80000-rural-jobs.

Figure 5.Hempire.

Best Practice Title	*“Production of 5-HMF from 1st generation sugars such as sugar beet and corn”*
Contact Person (Company)	AVA-Biochem
Market-oriented criterion	
Competitiveness of the solution	
AVA Biochem has developed an HTP technology that is very precise in process control for 5-HMF molecules. The separation and purification processes are also very efficient [1]. AVA Biochem produces 5-10 tonnes 5-HMF with different purities from around 20 tonnes fructose per year now. The company is planning to scale up the technology and built a new industrial plant with a production capacity of 6,500 tonnes/year 5-HMF. This will use around 13,000 tonnes/year fructose. Several patents have been registered for this technology, such as EP2697341A1, EP3424915A1. At the moment, this technology processes with 1st generation sugars such as sugar beet and corn. The suppliers of the feedstocks are located in different areas in Europe. After scale-up of the process, quite a big amount of sugar is required, to increase feedstock flexibility, AVA Biochem is also trying to apply 2nd generation sugars. The product 5-HMF is used as a platform chemical for various innovative applications in the green chemical industry. Recently, formaldehyde was reclassified as a carcinogenic and mutagenic substance, the resin manufacturing industry is actively searching for viable alternatives. Non-toxic 5-HMF with its aldehyde functional group represents an ideal candidate to replace formaldehyde in many applications. Beside this, Furan-based monomers made from 5-HMF are key components in new high-performance biopolymers such as polyesters, polyurethanes and polyamides. Highly pure 5-HMF (purity > 99%) in crystalline form is a promising substance for use in food and feed additives as well as different health applications, due to its antioxidative, anti-allergic and anti-hyperuricemic effects [2]. There is no harmful or toxic solvents involved, so this process can be regarded as safe. It is important for the sustainability of the chemical production process. On the other side, a lot of water is needed in the process, and accordingly, the required amount of energy to transport water is large. However, process water can be partly recycled through wastewater treatment. AVA Biochem is financed through shareholders, EU projects, and joint development agreements with partners, who pay it for its engineering and development work. If a new factory is built in rural areas, and it has an offtake agreement with partners, who will buy the products and are willing to build the factory together, then it is also possible to get bank loan.	
Rural criterion	
Employment in rural areas	

At present, there are 20 people working at AVA Biochem at a full demonstration plant in Muttenz/Basel. Among them, around 20-40% are women. As mentioned above, enough automation of the process is one of the crucial factors to achieve an economical large-scale production. Goal of AVA Biochem is to have only around 6 people at the new industrial plant, but at the same time, to have a better product quality. The company is not limited to recruit employees in the region but focuses on attracting talents from all over the world to join its team. These educated employees can stay here in the region, which, in turn, will increase the education level and future development of the region.

Capital formation in the region

AVA Biochem guaranteed that the raw materials come exclusively from Europe, and the production plant is located in Switzerland. Muttenz is well accessible with the proximity to the airport, train and the Rhine. Moreover, it lies in the chemical region of Switzerland with many specialized and qualified employees. When choosing a suitable location for a biorefinery site, one should consider different criterion, such as closeness to raw material, product markets, heat sinks and sources [3]. Besides, existing experiences and expertise is of high importance as well. There should be a demonstration plant providing practical proof of concept at first. The industrial site on a larger scale needs to be proven that it is commercial and economical. Furthermore, each process step needs to be proven scalable, not only to facilitate an eventual scale-up of the whole process chain in the future, but also to be adapted to the availability of feedstocks. AVA Biochem recommends that the acquisition of raw material and further processing of products should be collocated in an industrial plant. Since the product 5-HMF is unstable, it has to be processed on site to its stable derivative before it is transported.

Social responsibility

There are no environmentally hazardous solvents or toxic catalysts involved in the process, unlike the other companies in the field. Only in the production of 5-HMF crystals for special and fine chemical market there are solvents used, but the solvents can be recovered and reused. The plant is quite secure to operate. There is no GHG emissions data for the process at present, but the company will calculate it in the future.

De-centralized bioproducts production

To build the demonstration plant and make it run can be challenging. In addition, the system needs to be continuously improved during the operation. Last but not least, the production process should be sufficiently automated, at least at the industrial and commercial scale, to reduce manpower consumption. Currently, planning and building the new industrial plant occupies the most investment of AVA Biochem. The company is continuously improving its technology, so it spends much on intellectual property protection as well.

The operation costs are mostly spent on raw materials (50%). The feedstock should be Europe-based with 95% fructose content, and it should be GMO-free. The second important operating expense is personnel costs. To reduce these two expenses, the next goals of the company is to apply 2nd generation sugars and to reduce workers on production site by increasing its automation level.

Advantages for farmers

The company AVA Biochem should stay in the region and it plans to build a large-scale plant soon, which is in vicinity of biomass sources, this can reduce the costs on raw materials.

As mentioned before, this new industrial plant, which is planned to have a 5-HMF production capacity of 6,500 tonnes/a, will have a highly increased need for the feedstock fructose. On the one hand, this strengthen the motivation to convert 1st to 2nd generation feedstock, on the other hand this offers the local farmers for sugar cultivation an opportunity to boost their production and sales. It is also worth considering to find suppliers in the local region to reduce the transport expenses, or even to conclude cooperation agreements with the local farmers. This can bring development to local agriculture.

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Figure 6. AVA-Biochem.

Best Practice Title	*“Sugar production from lignocellulosic biomass through hydrolysis”.*
Contact Person (Company)	Green Sugar

Market-oriented criterion

Competitiveness of the solution

Green Sugar is a German engineering company founded in Dresden in 2007. Based on the work of the German Nobel laureate Friedrich Bergius, the company has developed a proprietary process for the production of fermentable sugars from waste resources, such as fruit bunches, straw and wood pellets. This has two main advantages: firstly, there is no competition with the food industry and the prices are low. Secondly, the solution can also be implemented in rural areas, where agricultural land is needed for food production. Currently, the company operates a pilot plant at its Meißen site, on which the technology has been validated in recent years by several well-known market participants. It receives support from the Federal Ministry of Research and Development as well as the Saxon Development Bank (SAB). Furthermore it is part of the BioEconomy Cluster (Halle/Germany) [1].

The “LC2GreenSugar®” process, which is used to extract glucose from wood, enables the utilization of all components of any vegetable biomass. Main difference of the solution compared to established process is the creation of a second acid-cycle. Lignin does not need to be completely released from hydrochloric acid (HCl) in the hydrolysis reactor, it is left with about 6 Wt.-% HCl. This has following advantages: 1. Reduction of water consumption by 80%. 2. Significantly lower retention time, thus increase of space-time-yield. 3. Minimal amount of washing-water. The lignin is then burned and the acid is recovered through flue gas scrubbing. This results in a second acid-cycle, which connects the process steps hydrolysis, lignin processing, flue gas scrubbing and acid recovery [2].

The main product is sugar, which can be processed for PLA production or a plethora of bio-based platform chemicals (5-HMF, Levulinic acid, Furfural, etc.), biosurfactants, bioethanol and amino acids [1]. Compared to the conventional plastics, the bio-based PLA can help to reduce GHG emissions (especially when sourced from waste biomass) and the dependency on fossil resources. Beside sugars, lignin is also extracted. Combustion of lignin can generate energy, which makes the process energy-neutral and decrease the production costs. The main drawback is the use of large amounts of hydrochloric acid, which requires hydrogen to be produced. Hydrogen is still mainly sourced from crude oil. The development of a recyclable, sustainable and non-toxic catalyst would be favorable.

The company is currently planning a production site in Malaysia to process the waste biomass of palm oil production [3]. This includes a cooperation with ThyssenKrupp to produce PLA on site (GreenSugar Platon) and a unit for cogeneration of heat and power. The technology for hydrolysis received a patent "Method for the hydrolysis of pelletizable biomasses using hydrohalic acids" with the number "DE102012020166A1", "US10006098B2", "CA2887258C", "EP2906727A1", "KR20150070223A".

Rural criterion
Employment in rural areas
A plant on technical scale requires maintenance personnel with higher education, providing opportunities for the young people in the region. There are 10-19 people working at Green Sugar at the moment [4]. Besides the direct creation of jobs, the mobilization of waste biomass would be a new economic asset for the region provided it is locally sourced. Furthermore, the construction of a factory creates new jobs in other areas, i.e. plant design, engineering and technical support.
Capital formation in the region
The Green Sugar solution can use local resources, meaning the capital remains in the region, strengthening the situation of farmers. When choosing a location, regions that provide large amounts of suitable biomass should be favored to keep the supply routes short. Acid supply needs to be considered as well. Aside from the main product, energy and heat can be produced. The sugars and biochemicals will be sold internationally, but heat and power can stay in the region and provide improvement of life standards.
Social responsibility
Diligence and due care are paramount in planning and operating the plant. Lignin and (concentrated) acid pose a threat of pollution in the direct vicinity. Other possible emissions consist of noise and smell. Thus, the inhabitants of the area need to be considered and included in the planning process. Once the operation is running, the creation of jobs and capital in the region is bound to have a positive impact on the social situation. On the other hand, Green Sugar products enable the customer to increase its social responsibility by valorising the residual biomass and contributing to the development of the rural communities. Linde Dresden supports Green Sugar in Engineering-Procurement-Construction. The acid recovery is being developed in cooperation with SGL Carbon. Together with its partner Platon Solutions, Green Sugar is working on the initiation of the first integrated biorefinery for the production of biodegradable plastics [1].
De-centralized bioproducts production
The solution presents the opportunity to locally produce sugars/biochemicals and lignin from waste biomass, reducing GHG emissions compared to conventional production. This has yet to be proven in operational environment. The plan for an industrial-scale plant in Malaysia includes a unit for co-generation of heat and power. This enables a decentralized production of power thus reducing the dependency on large plants and enhancing grid security.
Advantages for farmers

The mobilization of waste biomass which was previously used mostly for fertilization provides an additional source of income for the farmers. Many work related activites on farms require electrical power, thus a more stable energy supply means security. Job creation in other fields, such as maintenance, engineering, technical support broadens the employment perspective in the region.

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Figure 7.Green Sugar.

Best Practice Title	*"Production of 1,4-butanediol (1,4-BDO) from sugar by fermentation". BDO)".*
Contact Person (Compa	Mater-Biotech (Novamont)

Market-oriented criterion
Competitiveness of the solution
1,4 BDO is a chemical building block for a wide range of applications in sectors such as textiles, electronics, automotive and the production of consumer goods, as well as the biopolymer sector. Nowadays, 42% of the global production of BDO is ran by Reppe process, as well as in different ways from maleic anhydride, propylene oxide and butadiene. Some companies are now developing and up-scaling bio-based BDO production via hydrogenation of succinic acid or fermentation of sugars [1]. Mater-Biotech is the world's first special industrial plant (TRL 9) that can produce 1,4-butanediol (BDO) directly through fermentation of sugars with a capacity of 30,000 t/a. Mater-Biotech is 100% owned by Novamont S.P.A., a company experienced in the development and production of bioplastics and biochemicals. Mater-Biotech is a result of the industrial conversion of an abandoned location, which avoids greenfield investment by integrating biorefineries in the local areas [3]. The process of Mater-Biotech is using Europe based sugar derived from the hydrolysis of starch. It uses a genetically modified Escherichia coli microorganism developed by Genomatica (Patent US9175297B2). The feedstock typically consists of a mixture of Glucose and Saccharose in varying ratios (10-90 %) and concentration between 10-100 g/l in aqueous solution. At an agitation rate of 800-900 rpm, air flow of 0,4-1 kg/s, pH 6-7, temperature 30-37 °C, the microorganism is able to convert the sugars to 1,4-BDO in a single step process, more efficient and environmentally friendly than the pathway from fossil resources [2]. Purification is a 2-step-process: first the separation of the solid fraction (consists of microorganism, cell residues, salts, etc.) by, for example, settling, centrifugation, filtration, osmosis or similar [4]. Then the purification of the remaining liquid phase through treatment chosen from evaporation, distillation, or similar. The final product 1,4-BDO is condensed. Main problem regarding the sustainability of the process is that the current feedstock (first generation sugars) is in direct competition with the food industry. The future goal is to use second generation sugars, which is already studied by the Novamont researchers at laboratory and industrial level. Currently Novamont is using 1,4-BDO for Mater-Bi bioplastics production [5]. The 1,4-BDO makes it possible to produce the fourth generation Mater-Bi bioplastics, significantly increasing its content of renewable raw materials (from 36 to 61%). This decreases GHG emissions of the bioplastic with a 10-15% lower carbon footprint. Moreover, the plant is conceived to reuse by-products for its own energy purpose within a circular economy perspective. For instance, the

retentate of the filtration is degraded in a digester to produce biogas, which is then utilized to produce energy. The plant is composed of six interconnected sites and four proprietary technologies, integrating the chemical processes already consolidated for the production of biochemicals with industrial biotechnology, thereby opening the way for the production of other chemical intermediates from renewable sources [3].

Rural criterion
Employment in rural areas
At present 77 people are working at Mater-Biotech plant, 80 % come from less than 50 km of the plant [6]. By reactivating a shutdown industrial site, the company (re-)mobilizes the highly skilled workforce in the region and offers the young folk in the region opportunities for education and training. In 2018 the indirect employment was around 50 jobs. During the conversion of the plant there were as many as 300 people working on site, in addition to around 50 people from the Novamont group. These workers come from around 100 companies, including contractors and subcontractors, which are involved in the construction and renovation of the plant.
Capital formation in the region
Mater-Biotech reconverted the deactivated industrial site in the local region of Rovigo (Italy) to avoid greenfield investments, at the same time, it transformed the local problems into development opportunities. Mater-Biotech represents a good example of industrial development through territorial regeneration and enhancement of preexisting infrastructures, skills and human resources, with positive returns on the downstream industry and its connected activities. Feedstock sugars originate from Europe, which ensures the quality of the feedstock. The high production capacity with 30000 tonnes/a can increase the income of the farmers, since a big amount of feedstock is needed.
Social responsibility
The bioeconomy model of Mater-Biotech is based on the in-house technologies, connecting with the plants and partnerships in the region. Mater-Biotech uses a microorganism developed by Genomatica, a company in bioengineering in California for its butanediol fermentation processes directly from sugar. Bio-butanediol produced from sugars has the same characteristics as fossil butanediol, but with at least 60% lower carbon footprint (according to LCA studies from Mater-Biotech). The process itself can be considered relatively safe, there’s no directly harmful substances involved.
De-centralized bioproducts production
Mater-Biotech receives funding from Europe (i. e. Horizon, BBI-JU), nation and region. A total investment of over 100 million € was necessary to convert the existing abandoned plant, 70 % of

which were equipment costs. Around 40% of the plant is completely new, the remaining 60% have undergone major maintenance and restructuring. Local production of biochemical dampens the dependency on large plant supply, especially when the production from 2G biomass is up and running.

Advantages for farmers

Feedstock (1G sugar) is sourced in whole EU, hence this solution does not (yet) pose any noteworthy advantages for local farmers. The company is currently developing the process to use 2G biomass as feedstock, which has the potential to benefit farmers in the region. It is unclear however when they will be able to implement this on industrial scale.

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Figure 8. Mater-Biotech (Novamont).

Best Practice Title	"Bioconversionof organic side streams by black soldier fly-producing insects, lipid & protein for feed".
Contact Person (Compa	Bestico

Market-oriented criterion

Competitiveness of the solution

An increasing population demands higher quality food, at the same time creating more unused biomass. Several biorefineries such as potato industry and beer & bioethanol industry produce wet perishable residue streams which can be used as feed. The beer brewing process results in about 20 kg of brewers spent grains (BSG) per hectoliter of beer. The large breweries in the Netherlands and Germany produce about 25,000 – 150,000 tonnes/a of BSG [1]. Bioethanol plants produce even more distiller grains and solubles (DGS). Potato processing companies in the Netherlands produce about 25,000 tonnes/a of potato steam peels. The shelf life of such wet streams, however, is short. By using such GMP + quality residue streams to feed e.g. Black Soldier Fly (BSF, Hermetia illucens) larvae, it can be converted into nutritious feed having a much longer shelf life. The solution produces high quality protein rich pet food and feed that contains essential amino acids which are low in feeds produced from plants [2]. Also, oil can be extracted for bio-diesel production. The substrate residue (skins of worms) remaining after pressing of the worms can be used as fertilizer. The larvae are produced in crates on rack cupboards, making the solution simply scalable to the amounts of vegetable residue streams available, whether smaller or larger quantities. The solution, which is not covered by patents, can be implemented near locations where the vegetable residue streams are released in order to avoid transportation of the wet streams. At present over 30 solutions are implemented worldwide. The solution in the Netherlands at present processes about 400 tonnes/a of vegetable residues into 135 tonnes/a of insects, small part of which is sold as such, while the largest part is processed into protein (about 90 tonnes/a) and lipids. The company is a subsidiary of a multinational.

Rural criterion

Employment in rural areas

The solution can be operated in rural areas where wet starch/protein residue streams become available. Farmers may operate the solution because producing larvae may be regarded as a farming expertise. The protein rich product is very suitable for aquaculture, poultry and pet food, which means that aquaculture activities may be established as well. In case of pet food products, these would not need to be imported from elsewhere anymore. If the oils are used for production of biodiesel, new workplaces for biodiesel production are likely created in other areas, as biodiesel production is performed at very large scale. The infrastructure may be provided by local or regional enterprises, establishing buildings, storage capacity for feedstock and products, crates/boxes for producing larvae, pressing equipment for extraction of proteins and oils, etc.

Capital formation in the region

Large part of the required infrastructure can be sourced locally or regionally, which keeps the capital in the region. For extraction of proteins and oils, the farmers may use expertise of the (industrial) feedstock suppliers which are often familiar with different kinds of technologies. Or, eventually the larvae production is implemented decentral near small scale biorefineries, and extraction of proteins and oils is performed centrally, e.g. in a biomass yard.

Social responsibility

Farmers operating the solution will (need to) work in close collaboration with suppliers of vegetable residue streams (their feedstock), as well as with the farmers buying their larvae products as feed for e.g. aquaculture and chicken farming (their customers). The solution may be of interest in rural areas where high quality feed would need to be sourced from specialized feed producers and transported via poor infrastructure (e.g. areas with low population density). The production facility applies an absorption tower, a so called air washer, which reduces smell around the buildings to basically zero.

Advantages for farmers

Employment for educated people: As growing of the larvae requires considerable knowledge, specialized (highly educated) people can find employ and have reasons to stay in the rural areas.

Scalable nature of the solution: Scale can be adapted to the volume of residue feedstock streams that become available locally. Depending on the scale, extraction of proteins and oils may need to be performed centralized.

Conservation of perishable biomass streams: Wet biomass streams have a limited shelf life, while that of dry larvae products is much longer.

Short production cycle: The larvae grow in about 10 days [2]. This means that, although larvae best grow on feedstock having uniform physical and nutritional properties, each new batch of growing larvae can start with another kind of feedstock.

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Figure 9.Bestico.

Best Practice Title	*"Growing mushrooms on coffe grounds".*
Contact Person (Compa	Rotterzwam
Market-oriented criterion	
Competitiveness of the solution	
Many products are transported from ports and rural areas into cities and a large amount of residues is transported out from the cities again. With the tendency of growing cities, transportation increases. Transforming residue streams into new products in the city itself, or in its direct proximity, may reduce traffic in metropolitan areas, while also reducing transportation costs and emissions like GHG and fine particles. However, such innovative waste management systems may also be applied in rural areas to valorize residue streams locally and keep employment and capital in the region. Fresh Oyster mushrooms are cultivated on locally collected coffee grounds and sold to supermarkets and restaurants in the area. In 8 old containers about 80 tonnes of coffee grounds are converted into 16 tonnes of mushrooms per annum [1]. The growing area/volume can be scaled with available substrate or required production. The use of containers even allows moving the production units to places where substrate material becomes available. Capital required for establishing the facilities was largely collected via crowdfunding [1]; the idea of growing healthy food on local residues may have contributed to the popularity of the initiative. Mushrooms may grow on various other substrates, including sawdust, seed hulls, leaves, straw, etc. In particular when disposal of organic streams can be converted from landfilling, even when it is a temporary storage of the organic stream before a farmer may spread it over the land as a fertilizer, to other usage such as mushroom production, formation of bio-methane, a strong greenhouse gas, can be reduced. When incineration of (wet) coffee grounds can be avoided, their use for mushroom production saves energy to evaporate the water in the coffee grounds, thus saving CO_2 emissions. Mushrooms offer a nutritious food containing in particular proteins, carbohydrates, minerals, fibres and vitamins [2]. The spent coffee ground substrate is still classified as waste, although it contains a lot of ingredients which make it potentially useful as a fertilizer. Rotterzwam and partner WUR are conducting scientific research on the influence of the coffee grounds and the spent substrate on the quality of the soil, soil organisms and soil biodiversity [3]. The technology is not covered by patents, but specific know-how is required, which can be provided by Rotterzwam. They have already trained over 40 entrepreneurs to start growing mushrooms on coffee grounds themselves.	
Rural criterion	

Employment in rural areas
The solution can be operated in rural areas where wet organic streams become available. Operators of the solution may be farmers but also other persons having room to place the production facilities. The operators require specific know-how, which can be learned by many persons, however, including young people. The mushrooms can be used fresh but can also be used in snacks and even in products like beer. Further, soap can be produced based on the coffee grounds. So potentially other bioeconomy activities can be established next to this solution. The infrastructure may be provided by local or regional enterprises.
Capital formation in the region
Facilities of example case include 8 containers including climate system and installation, area for preparing substrate, mixer, packaging machine, cold room and office. All of this can be sourced locally. Also, the nursery roof is covered with solar panels which fully cover the energy requirement on an annual basis. Solar panels are produced elsewhere, but can be installed by local companies. Capital spent for facilities and solar panels is 260 k€ [4].
Social responsibility
The solution may be of particular interest for (small) rural communities having their own organic residues. To overcome the issue of insufficient amounts of organic residues and insufficient means to invest individually, farmers could collaborate in a cooperative to jointly invest in an adapted scale mushroom production facility as well as to jointly operate the solution and benefit from it. Mushroom production may be accompanied by smell. Mushroom production on coffee grounds are causing less smell issues compared to mushroom growing on conventional straw and horse and chicken manure-based substrates.
Advantages for farmers
Scalable nature of the solution: Production scale is very much adaptable to the volume of available substrate material, going from a few tonnes per annum up to ktonnes. *Mobile production:* The use of containers allows moving the production units to places where substrate material becomes available. *Various feedstock for substrate*: Mushrooms may grow on various other substrates, including sawdust, seed hulls, leaves, straw, etc. *Short production cycle*: The actual growing cycle of Oyster mushrooms on one batch of substrate is about 2 months, allowing for 3 harvests [5]. After each production cycle the production cells need to be entirely cleaned. This means that each new batch of growing mushrooms in principle can start with another kind of substrate.

Health: Eventually the mushrooms may be sold on the market. However, edible mushrooms contain proteins and fibres, but also vitamins B and eventually D, as well as antioxidants which may help to support the immune system and prevent damage to cells and tissues. Own production of mushrooms may stimulate rural communities to strengthen their healthy diet while making the use of expensive dietary supplements superfluous at the same time.

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Figure 10. Rotterzwam

Best Practice Title	*"Extraction of food additives from olive oil by-products".*
Contact Person (Compa	Innovaoleo

Market-oriented criterion

Competitiveness of the solution

Over 7 million tonnes of wastes and by-products are produced during the olive oil production processes in the Mediterranean area each year [1]. Residues include olive pomace, olive stones and olive leaves, which have found limited outlets till recently. Trials to use de-stoned pomace for feed have shown issues with digestability and palatability; also the current waste management practices in the olive oil sector result in environmental problems such as soil contamination and water-bodies pollution as well as unpleasant odor emissions [2]. Although the development on producing useful feed out of olive oil industry residues continues, alternative usage options of these residues are of interest. Olive pomace, olive stones and olive leaves contain high value compounds like polyphenols (Oleuropein), hydroxytirosol and triterpenes which can be extracted for application in food, pharma and nutraceuticals. The solution is based on conventional extraction technology not covered by patents, Innovaoleo has built up considerable know-how though.

The solution allows extraction of a Polyphenols fraction (containing 4-40% Oleuropein) and a Triterpenes fraction (containing 30-98% Oleanolic acid) from olive leaves. And extraction of Hydroxtyrosol (up to 20% in the extract) and a Triterpenes extract (containing 6-40% Maslinic acid) from olive pomace [3]. Overall, from 1000 tonnes of olive biomass may result in 100 tonnes of extracts [4]. The residual biomass after extraction is combusted for the generation of power by a partner company, leading to reduced CO_2 emissions. The company is a joint venture of an olive processing company and a vegetable extracts company.

Rural criterion

Employment in rural areas

The solution can be operated in areas where olives are grown and processed. Farmers could set up a cooperation to establish such a plant and achieve higher value for their olive production, while reducing environmental impact. Operating the extraction plant requires educated and specialized personnel, so this solution offers opportunities for young people to stay in or return to rural areas. The solution in Palencia, Cordoba (Spain), offers about 10 full time jobs [5] and converts 1,000 tonnes of by-products per annum. Manufacturing equipment for extraction purposes requires specialized know how, so that may need to be sourced from elsewhere and create workplaces in other areas. Also, installation/assembly of the unit operation machines requires specialized personnel. Further infrastructure may be provided by local or regional enterprises: establishing buildings, storage capacity for feedstock and products, supplies for water, power and gas, etc. The high value products find outlet in food, pharma and nutraceuticals industry, so appropriate logistics to such processing sites creates further jobs.

Capital formation in the region

The extraction plant – equipment, installation, buildings and other facilities – was mainly built by regional companies from Andalusia, except for some individual equipment.

Social responsibility

The solution valorises underexploited side streams which may offer additional income for local farmers. By creating jobs for both factory workers as well as qualified bachelors and PhDs for R&D and innovation, the plant contributes to the socioeconomic dynamics of the rural community. The olive pomace leaves an unpleasant smell for the neighborhood. Active use of the pomace and its proper storage until processing could take into account measures to reduce the smell. The solution contributes to environmental impact reduction by the valorization of residues. To establish such an innovative solution, it is key to align the several actors from different sectors, farmers, industrial technology providers, R&D, innovators, entrepreneurs. All of them from different backgrounds and economical areas makes it challenging.

Advantages for farmers

Employment for educated people: As running an extraction plant requires considerable knowledge, specialized (highly educated) people can find employ and have reasons to stay in the rural areas.

Reduction of environmental impact: Current waste management practices in the olive oil sector result in environmental problems such as soil contamination and water-bodies pollution. Conversion of residues into high value-added products reduces leakage of polluting compounds to the environment. Continued pollution of the environment, at some point in time, would involve (serious) costs for cleaning the environment in order to retain productivity of the land.

Alternative use of extraction plant: Innovaoleo is investigating the feasibility of valorizing grape residues in a similar way. Similar technology may be used for extraction of specific compounds from several other crops: Lupin, Crambe and Camelina for oil, Cardoon for chemicals; Camomile for aroma's and medicinal compounds; Rosemary for essential oils. An extraction plant flexible in its feedstock would offer farmers more rotation options to select crops for cultivation.

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Figure 11. Innovaoleo

Best Practice Title	*"Production of renewable hydrogen via thermolysis of biomass".*
Contact Person (Company)	Haffner Energy

Market-oriented criterion
Competitiveness of the solution
The solution has as main product the renewable hydrogen produced from biomass (500 tonne/a of wood-based biomass). The use of agricultural residues is also foreseen. Average price of the biomass is around 90 €/tonne with a production capacity between 112-650 kg/day. The secondary products are hypergas and biochar. The main advantages of the process are the production of hydrogen with high quality (degree of purity of 99.97 %) and ultra-competitive prices (lower by 20 to 60 % than those of other renewable H_2) achieving hydrogen selling price lower than 4 € / kg respect to the 10 €/kg of the current prices. Other important advantage is an energy efficiency rate exceeding 70 %. Many aspects regarding competitiveness of the solution are related to the production flexibility of the solution since these processes are practical for an extensive range of current and prospective applications being able to adapt to the consumers demands (100%H_2 ;10% H_2/90%Hypergas ; 50%H_2/50%Hypergas) or being effective to a different scales in the rural environment. Many partners as Communauté de communes Vitry Champagne et Der, Vitry energies S.E.M and Centrale Supélec have contributed to the development and implementation of the solution together with other investment funds EUREFI proposed by CAISSE DES DEPOTS and PRI (Partenariat Régionaux d'Innovation) from BPI France et la région Grand-Est. All of that lead to the launch of the solution. The innovation of the solution has been recognized with awards as "Labellisé pôl IAR Axe "Bionergie", Lauréat "Territoires Hydrogène" and Lauréat Ademe.
Rural criterion
Employment in rural areas
This solution needs specific skilled workforce in order to be transferred to the rural environment. People living in rural areas, specifically young and women people, who normally suffer more unemployment in these areas can acquire the know how needed to operate the plant. In addition, new jobs opportunities in regards to infrastructure, logistics and supply should be created.
Capital formation in the region
Even though Haffner Energy is able to operate the plants, maintenance operations could be transfer to local people contributing in this way to maintain industrial activity in rural communities. Local and renewable raw materials are used in the process as wood, agro-waste and recycled biomass. This

location of the feedstock allows for the on-site production avoiding expensive logistics and boosting the industrial network in the region.

Social responsibility

Thanks to the easy adaptation of this solution to the rural environment, diverse ways of cooperation can be established with farms and the agricultural sector. The utilization of buildings and machinery needed in the process or the use of hypergas excess as an energy source for steam and heat production in farms and in auxiliary facilities can be taken into consideration. The implementation of this solution can lead to maintain and increase the population density of the rural location where is the biorefinery. Furthermore, this solution can avoid the GHG emissions produced by the fact of avoiding the burn of a large variety of agricultural residues, using it as feedstock to the process obtaining an extra income from its selling. In terms of impacts on living conditions, the use of renewable energy to mobility can help to reduce the pollutants in the air avoiding health problems.

De-centralized bioproducts production

The plant can be built up and operated at almost any location, its size can be adjusted to the local needs, achieving less dependency on large plant supply. Different challenges have to be overcome regarding to the operation cost and flexibility of the production.

Advantages for farmers

Due to the fact that the production of hydrogen can be sized to the consumption and locate where needed, a centralized plant is no needed and local distribution of the product is improved. Flexible production to meet the demand (flexible % of H_2) facilitate alternative options for diverse applications as mobility and/or heat and power production covering part of the energy demand in the rural community. Others relevant advantages for the rural community would be the possible use of the secondary products generated as the biochar as soil amendment in the fields and the indirect incomes derived from the implementation of new ways of waste management.

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Figure 12. Haffner Energy.

Best Practice Title	*"Bio-coal production via Hydrothermal Carbonization (HTC) of sewage sludge".*
Contact Person (Company)	Terranova-Energy

Market-oriented criterion
Competitiveness of the solution
TerraNova® Ultra process can be a solution to the energy demand from farms and to the limits of organic disposal on the agricultural lands becoming more and more restricted due to increasing environmental requirements. The main product is a bio-coal aimed to use in energy generation facilities and the secondary product is phosphorous to be used for the farmers as a rich organic fertilizer. The raw material is sewage sludge from wastewater treatment plants. A quantity of sewage sludge around of 8,000 t/year with 5-30% DM would be produced for a population of 100,000 P.E. (population equivalent). With this, the production capacity is around of 2,215 tonnes with 65% DM of bio-coal. One of the competitive advantages of this technology is its flexibility. TerraNova® Ultra process is able to treat with a large variety of sewage sludge/organic residues with high moisture content. This process is suitable to combine with sludge digestion technology at wastewater treatment plants. Furthermore, the products generated can be used in cogeneration plants and for fertilizer production. The flexibility of the TerraNova® Ultra process, together with its simplicity and low cost give as result a smarter utilization of sludges instead of its expensive disposal, reducing the volume of disposal by 75 % and the energy demand by 80 % respect to drying conventional. Furthermore, an increase of 15 % in the biogas yield and a recovery of nutrients (Phosphorous) together with the production of non-toxic and sterilized products can be achieved. With the reduction of volume respect to the thermal disposal (agricultural or landfill), a relevant reduction of the operation cost can be achieved. Also, the personnel cost, mainly maintenance, can be reduce by means the collaboration of farmers working near to the facility. Related to the CAPEX, the integration of the equipment in wastewater treatment plants already working can be reduce the total amount. TerraNova® Ultra process is also highly reliable and energy optimized process allowing an economic operation.
Rural criterion
Employment in rural areas
Due to the fact this solution is easily implemented in rural areas to small scale, new jobs can be created by means the cooperation of the farmers in the activities developed by other industrial partners. Local people can developed activities along the whole value chain, from acting as customer to use energy carriers and/or fertilizers, subcontracting working in the wastewater plants in the maintenance operations and higher specialization people involved in the operation and design of the systems.
Capital formation in the region

This solution can use local residues (agricultural wastes) contributing to the cooperation with other industrial partners near to the farm. Solution can produce locally products useful to farmers with a high added value as fertilizers for lands or energy carriers for energy supply in the farm. The activities carried out by farmers can also be developed in the rural wastewater treatment plants in which the solution is implemented.

Social responsibility

The implementation of this solution in the rural environment can lead an improvement on living conditions of the rural communities, avoiding problems generated from the traditional disposal of sewage sludges and helping to generate a close valorization value chain. Furthermore, GHG emissions derived from the transport of sewage sludges and other generated with its management are avoid. Thus, implementing an integral solution for the management of diverse agricultural and industrial waste, the reduction of cost and the impact of each one of them can be produced.

De-centralized bioproducts production

The adoption of this sewage sludges conversion technology in rural communities, in particular for the wastewater treatment plants working on these environments, can help to guarantee the supply of low cost raw materials for primary production (less dependency). The operation cost in the farm (mainly the cost regarding the energy production) would be reduced with the use of the bio-coal and maybe with fertilizers formulated from nutrients recovered. The GHG emissions would be reduced in the same way. The main challenge is the cost of the large number of equipment (CAPEX) and infrastructure needed to set-up the system.

Advantages for farmers

The implementation of an industrial collaborations between wastewater treatment plants, waste management companies and energy and fertilizer producers in order to apply the products and by-products from the HTC process would generate incomes for the farmers derived from the reduction of cost for the acquisition of raw materials, mainly fertilizers formulated from the recovery of nutrients (P and N), bio-coal for energy self-consume and HTC filtrate for co-digestion with other agricultural residues.

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Figure 13. Terranova-Energy.

Annex B. Key performance indicators.

Table 6. Summary of key performance indicators to characterize the regional bio-economies (Extract from task 2.2).

Key factors, main features characterizing regional bioeconomies	
1. **Availability and use of resources:** this criterion relates to the availability and access to raw materials, trends in demand, evolution, information and statistics on available types of feedstock, as well as their existing and potential competitors for its use.	
• Production efficiency of agricultural/forestry/fishery/aquaculture/other production in the region (average production yield/year)	○ Currently ○ Potential scenario by 2030
• Current exploitation of waste and residues streams in the region	
• Region existent resources' characteristics (physical and chemical)	
• Constraints leading to low production yields (for example low water availability in the region)	
• Raw material supply and demand balance at regional, national and international scale	○ Imported biomass and/or residues ○ Exported biomass and/or residues
• Long-term competitive and consistent availability of the resources at regional level	○ Currently ○ Potential scenario by 2030
• Existence of multiple consumers for the feedstock (competition over the resource)	
• Potential for higher valorisation of resources	
2. **Infrastructure/Industrial factors**: intends to draw a picture of the set of infrastructures and installations that enable the link between feedstock production sites, collection nodes, production and consumption, to meet the requirements of the supply chains, considering that these aspects are key decision factors for investors. Infrastructure and technologies for the treatment and utilization of the feedstock are considered.	
• Existence and level of development of agro-food, fishery, livestock, aquaculture, wood/paper value chains or waste recovery infrastructure with a strong technological specialisation in the region (logistic for the existent feedstocks in the region)	

• Existence of necessary infrastructure to host bio-based solutions in the region	○ Availability of logistic services (significant number of logistic operator) ○ Homogeneous distribution within the region/ surrounding regions of these logistical services ○ Existence of areas with concentration of services and industry (industrial parks)
• Type and size of the existing industries, farm exploitations, etc. in the region adequate for the implementation of bio-based value chain	
• Active presence of actors required along the value chain in the region or on the contrary lack of any of the actors required along the bio-based value chain	
3. **Research and innovation:** is related to the supporting institutions such as universities, testing and certification bodies, research institutions, and other organizations that could build and transfer know-how and offer technical and technological assistance to the entrepreneurship willing to be or already being part of the Regional Bioeconomy Strategy.	
• Establishment of scientific network with researchers and industry stakeholders to increase the capacity of the region/country on fields related to bioeconomy	
• Existence of technological expertise in technology transfer process	
• Development of pilot scale plants producing of bio-based products (for instance as part of research projects)	
• Knowledge on bioeconomy related topics available for the public (existence of information compiled that would allow to solve doubts regarding the value chain, cost, funding available, sustainability, etc.)	
• Existence of operational industrial and research clusters (size, management and governance) or entities communicating coherent and reliable data	
• Number of patents related to bioeconomy field registered in the region and country	
• Development of training programmes and performance of learning activities, mostly related to the emerging technology, but also related to markets, networks, users etc.	
• Correlation between industrial needs and research activities (research activities provide support regarding emerging technology to industrial actors)	
• Existence of coaching programs to identify opportunities and assist companies interested (coaching services)	

4. **Market/Economic aspects**: focus on the framework conditions for establishing regional markets, including: production conditions of biobased products, potential clients of regional production, innovative producers, institutions facilitating networking, investment framework, etc.	
• Active local and global markets and easy access for bio-based products	○ Difficulties for companies to access local and global market ○ Difficulties to launch a new bio-based product ○ Actions carried out to create a demand for the emerging technology/product
• Production costs of bio-based products comparing to alternative non bio-based products	
• Competitive advantages of the bio-based product/processes (different from cost)	
• Avoidance of waste management costs and/or environmental damages costs (related to disposal of feedstock now used as raw materials for biobased products for instance)	
• Possibility of additional profit generation for the raw material producers in bio-based value chains	
• Demand of biobased product (volume of biobased products purchased in the region)	
• Commercialisation of innovative technologies at national level	
• Existence of investors (public investors, private investors, banks, venture capital, business angels, crowdfunding) active in the bioeconomy sector	
• Existent opportunities: Under-used resources that remain unexploited (the aim is to identify, for instance, if an end user in a region demands a biobased product which could be produced in the region instead of imported since the regions accounts with the raw materials to produce it but maybe the technology required is not available, etc.)	
• Number of employees (for each bioeconomy subindustry, for all bioeconomy, for all regional economy)	
• Turnover (for each bioeconomy subindustry, for all bioeconomy, for all regional economy)	
• Share of the bioeconomy in number of employees and turnover terms (share from all regional economy)	
5. **Transition towards bioeconomy.** Using an interdisciplinary approach is key to define and assess the dimensions of the bioeconomy as a means of achieving sustainability from the indutrial point of view. To this end, to move from fossil fuel industries to biobased industries is at the heart of the overall bioeconomy-related concepts in public, scientific, and political	

discourse. In regional policies, the evaluation of existing facilities and the adaptation to a new bioeconomy paradigm appears to be critical.	
• Chemical, agro-food or other industrial companies that look for a shift from fossil resources to biological resources and bio-based products in the region or neighbouring regions	
• Technology maturity of the industrial sector in the region (chemical industry, bioenergy, etc.)	
• Feedstock flexibility of conversion technologies in the region or neighbouring regions	
• Number of consolidated industrial players, but also small and innovative young companies or entrepreneurs with the potential to stimulate innovation in the region or neighbouring regions	
• \`Close to zero´ waste production initiatives/examples and/or number of bio-based initiatives in the region	
• Existence and/or development of demonstration flagship technologies/biorefineries projects in the region	
• Existence of non-operative/dismissed plants in the region looking for conversion into modified (bioeconomy) plant	
• Active and dynamic business/entrepreneurial community/ cross-sectorial trend for operation in the region (for example number of start-ups, existent companies’ expansion process, etc.)	
• Innovation culture among companies: willingness and capacity (since they are often small, do they focus on their core business or innovation is one of their strategic objectives)	
6. **Public and institutional support/Governance/Policy framework:** This is a prerequisite for investor confidence. Information regarding the existence of policies and programs for the development and channeling of entrepreneurial talent for increasing the effectiveness of entrepreneurs and demand for entrepreneurship is needed. Furthermore, the existing regulatory framework for facilitating the establishment of new entrepreneurship is of paramount importance.	
• Existent supportive bioeconomy policy framework	
• Policy correlation/coherence at regional and national level (Bioeconomy, rural development, etc. priorities/targets aligned at regional and national level)	
• Cross-border and cross-regional collaboration/alliances (supporting regional and inter-regional projects of strategic importance for development of the bioeconomy sector)	

• Supporting strategic partnerships between industries and enterprises in the region or among neighbouring regions	
• Legislation/Regulations/Permitting process to facilitate implementation of initiatives (including for instance the reduction of the level of bureaucracy leading to lengthy administrative and approval procedures)	
• Existent measures differentiating among regulations (imposed by law), financial support measures and soft measures (guidelines):	○ fostering innovation ○ to promote industrial symbiosis ○ to support valorisation schemes ○ to support local value chains implementation ○ to facilitate the cooperation between government, research institutions and industry (including agriculture/forestry, harvesting, logistics, biomaterials, bioenergy, etc.) (for example collaboration agreements between industry-research institutions) ○ to optimise the innovation and knowledge transfer system (funding programmes targeting innovation and dissemination)
• Existent policies:	○ Energy and climate policies ○ Circular economy support policies ○ To strengthen interactions and greater involvement of stakeholders ○ Policies supporting innovation in technology (focus on conversion process) ○ Policies focusing on the biomass supply such as forest, environmental and nature conservation/sustainability policies, production close to zero waste policies, policy aiming the implementation of sustainable rural and water management systems, waste management policy, etc.
• Existence of national bioeconomy strategy (including the corresponding Action Plan)	
• Relevance of regional development planning	
• Stability of the policies and policies duration supporting bioeconomy initiatives (to avoid uncertainty caused by changes in government	

which often results on the cancellation of plans and programmes established by the previous government without a broad political consensus)	
• R&D budget (when it is reduced it is difficult for companies to access)	
7. **Funding**: It defines the current situation of the region in accessing both private and public funds and other kind of investment mechanisms, if existing. For example, private institutions interested to finance sustainable industrial projects or public budget to be invested in this kind of projects. In addition, it assesses the framework conditions to create an environment in which innovations can be developed, reach the market and become widely used.	
• Existence/availability of funding programmes targeting bioeconomy at national and regional level (specially for the commercialisation of bio-based technologies and products) supported for instance by European Investment Bank/Fund	
• Establishment of mechanisms that enable feasible synergies and combination of difference sources of funding	
• Internal coordination among programmes	
8. Social and environmental aspects: Bio-based products and processes may produce impacts on society and environment. These impacts may occur along the entire value chain of bio-based products and can be linked to the production of biomass, to biorefinery processes, distribution or market uptake. Moreover, these impacts are in general specific for each region and can change over short periods of time which makes challenging to evaluate these aspects.	
• Available skilled workforce (along the value chain: raw material collection and management, logistic, processing, distribution)	
• Communications to society regarding bio-based activities (regular flow of information)	
• Actions carried out to promote the change toward sustainable consumption	
• Environmental awareness:	○ Information disseminated regarding GHG emissions decrease achieved with bioeconomy initiatives/technologies ○ Resource depletion concerns ○ Others
• Actions implemented in the primary sector in the region or neighbouring regions (already in place or expected in the coming 5 years):	○ Contributing to the reduction of greenhouse gasses and other pollution ○ Strategy aiming for a \`zero waste´ circular bio-economy implemented ○ To decrease the use of non-renewable fossil raw materials
• Willingness to pay for bio-based products or/and consumer preferences towards bioproducts	

• Feeling of the society regarding the participation and transparency of the regional/national administration	