



INTEGRATED BIOMASS LOGISTICS CENTRES FOR THE AGRO-INDUSTRY

## Generic strategies for IBLC development

Deliverable D6.4

**Project AGROinLOG** “Demonstration of innovative integrated biomass logistics centres for the Agro-industry sector in Europe”

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Prepared by: Wageningen Food & Biobased Research (WFBR)


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	<b>Company</b>
<b>Author/s</b>	WFBR, CIRCE, ZLC, CERTH, RISE, ASAE, INASO-PASEGES, UCAB, UBFME, Lantmännen, SPANISH-COOPS
<b>Task Leader</b>	WFBR
<b>WP Leader</b>	WFBR
<b>Reviewer</b>	CIRCE

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## ABBREVIATIONS

DM	Dry matter
ECBF	European Circular Bioeconomy Fund (
ECP	Energy Conversion Park
EIB	European Investment Bank
FM	Fresh matter
F&F	Feed & Fodder
GIS	Geographic Information System
GR	Grain
ha	hectare
IBLC	Integrated Biomass Logistics Centre
kWh	kilowatt hour
LA	Lactic acid
MIP	Mixed Integer Programming
OOG	Olive Oil Greece
OOS	Olive Oil Spain
PBS	Polybutylene succinate
PLA	Polylactic acid
R&D	Research and Development
SA	Succinic acid
SU	Sugar
TPOMW	Two-phase olive mill waste
WI	Wine

## PARTNERS SHORT NAMES


**CIRCE:** Fundación CIRCE

**WFBR:** Wageningen Food & Biobased Research

**ZLC:** Fundación Zaragoza Logistics Centre

**CERTH:** Ethniko Kentro Erevnas Kai Technologikis Anaptyxis

**RISE:** RISE Research Institutes of Sweden AB

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**CREA:** Consiglio per la Ricerca in Agricoltura e L'analisi dell' Economia Agraria

**APS:** Agroindustrial Pascual Sanz S.L

**NUTRIA:** Anonymi Biomichaniki Etairia Typopiisis Kai Emporias Agrotikon

**LANTMÄNNEN:** Lantmännen Ekonomisk Förening

**Processum:** RISE Processum AB


**SPANISH CO-OPS:** Cooperativas Agro-Alimentarias de España. Sociedad Cooperativa

**INASO:** Institouto Agrotikis Kai Synetairistikis Oikonomias INASO PASEGES

**AESA:** Agriconsulting Europe S.A

**UCAB:** Association Ukrainian Agribusinessclub

**UBFME:** University of Belgrade. Faculty of Mechanical Engineer

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## EXECUTIVE SUMMARY

Among the goals of the AGROinLOG project one is to develop generic IBLC strategies based on case studies. The case studies in this context are elaborated descriptions of potential integrations of biomass processing in value chains for food and non-food markets. The purpose of these case studies is to, on the one hand gain insight in how the identified opportunities that are technically feasible can be developed into pathways for IBLCs in different sectors and markets, and on the other hand to develop a step-by-step approach to feed the description of generic strategies for development of IBLCs that will be applicable for different sectors and in different regions.

The detailed approach towards the design of such generic strategies for the targeted sectors consisted of the following activities:

- refining the work plan;
- performing case studies;
- performing an integrated analysis of the cases studies;
- determining a generic approach for strategy development;
- performing MIP case studies.

To perform the actual integral analysis of the various case studies the outcomes of the various case studies are carefully studied and compared on the technical aspects of an IBLC pathway, namely:


- feedstock supply;
- logistics;
- IBLC design;
- intermediate biobased products;
- final market.

Furthermore, also the non-technical aspects of establishing an IBLC were compared between the pathways of the various cases studies. Different sources of information were used and combined to develop a generic step-by-step approach. A mixed integer programming (MIP) model was developed to be used in the case studies for quantitative analysis. These MIP studies give relevant insight in the economic aspects of establishing a new and / or expanding an existing IBLC.

### Sector case studies

The cases studies were performed in five different sectors: feed & fodder, olive oil mills (chain), wine (cellars & distilleries), grain chain and sugar. The cases studies were thoroughly analyzed in a uniform way, using a common data template so that they could be compared more easily. The lessons learned from each case study are first of all applicable for the specific sector at hand. Some examples of sector specific lessons learned (regarding successes, difficulties and solutions) and recommendations are given below:

- Feed & fodder - A competitive advantage over other producers can be obtained by saving on average 5-10 % in terms of production cost in the IBLC. These lower production costs also open new markets which were not profitable before due to market prices.

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- Olive oil mills (chain) - There are opportunities for new alliances between farmers, local authorities and agro-services with the aim to optimize the IBLC business model. It should be ensured that all actors involved in the chain will benefit and therefore are inclined to participate. The wrong assumption that underutilized biomass can be obtained at no cost should be avoided.
- Wine (cellars & distilleries) - It is important to transfer scientific knowledge in collaboration with the customer to develop new products that can be supplied by the IBLC. Legislative problems and obstacles should be overcome together with government and policy makers, e.g. the issue that some by-products are considered waste by legislation.
- Grain chain - It is necessary to identify a secure market with added value when the IBLC is producing a new biobased intermediate such as biochar.
- Sugar - Actors in the value chain need to be willing and have the capacity to act and collaborate if the IBLC is going to be realised. Also, there is a need for policies, norms, and values in society that support the development of the IBLC.

More lessons learned can be found in Chapter 3. Although these lessons learned were sector specific, some of them can also be applied in other sectors, possibly with some adjustments. E.g. the new boiler technology that was developed for the feed & fodder IBLC to gain the competitive advantage, can probably also be exported to other sectors.

### Integral analysis of the case studies

The results of the individual case studies were compared and analyzed in an integral way regarding the technical and non-technical aspects of their IBLC pathway. The lessons learned were grouped per aspect of the pathway of an IBLC (feedstock supply, logistics, IBLC design, intermediate biobased products & final market and finally non-technical aspects of establishing an IBLC). This resulted in a clustered overview of successes (Table 4), difficulties (Table 5), solutions (Table 6) and recommendations (Table 7). The lessons learned, including the sector where they were mentioned, were labeled with a reference number of the related step in the generic step-by-step approach. Most of the lessons learned appear to be in the categories 'Intermediate biobased products & final market' and 'Non-technical aspects of establishing an IBLC'. Issues in these categories can probably also have a broader impact than for only the specific sector at hand. Hence, they are indeed worthwhile to compare. Logistics are often not mentioned at all in the cases studies and feedstock supply also only has a limited number of lessons learned. Lessons learned regarding the actual IBLC design itself are often related to company or sector specific issues, and therefore more difficult to generalize. Therefore, in these conclusions the focus is on the categories 'Intermediate biobased products & final market' and 'Non-technical aspects of establishing an IBLC'. A selection of the lessons learned and recommendations in these two categories that could apply to several sectors is described below and more detailed information can be found in Chapter 4.

*Successes* - Residues for power and heat production were an interesting business option. Achieving more competitiveness was seen as a success. This was achieved e.g. by cost savings, but also by collaboration. Factors that influenced the costs were energy savings, obtaining carbon credits, costs of feedstocks and production costs. An economic success was the increase in equipment investments in a region. Social successes were an increase of local employment opportunities, building alliances

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and knowledge transfer to customers. A sustainability success was the reduction of greenhouse gas and toxic gas emissions.

*Difficulties* - Difficulties occur due to competitions with alternative products, immature markets and unprofitable biobased products. Economic aspects are the significant investments that could be needed to set-up an IBLC, and the fear that it will take a long time for the IBLC to reach a mature stage. Although collaboration was mentioned as a success in some case studies it was also often mentioned as a difficulty, since the willingness and capacity to cooperate is not always there. Aligning all actors is perceived as being difficult. Rules & regulations are also given as barriers for achieving an IBLC, e.g. waste legislation. Furthermore, norms and values in society are critical for success. Public opposition can easily lead to failure.


*Solutions* - Specific handling systems were a solution to health problems. Furthermore, awareness of competing use for the feedstocks is an important point to consider and market development is necessary in some cases. An economic solution is to find (internal) customers for produced heat in the IBLC. Social acceptance can be improved by information campaigns and starting dialog with the stakeholders. Collaborative innovation and networks around the IBLC will strengthen the whole value chain and will shorten the time to market.

*Recommendations* - It is recommended to secure the market for the (intermediate) biobased product first, before investing in the IBLC. Production that is focused on both energy and material recycling of local biomass resources is considered a sustainable way forward. An economic recommendation is to promote newly developed innovative business lines in an IBLC as a business for other companies as well. Collaboration of the stakeholders in the value chain (farmers, cooperatives, agro-industry, etc.) is considered a very important social aspect of establishing an IBLC. Support from administration is needed through regulative or incentive aspects. And there is a need for policies, norms, and values in society that support the development of the IBLC. Finally, a sustainability implementation potential needs to be secured.

### Generic step-by-step approach

The insights gathered from the different case studies, their integral analysis, and the other information from previous work in AGROinLOG and literature, made it possible to develop a step-by-step approach. Its aim is to maximize the likelihood of acceptance and implementation of an IBLC and it is constructed in such a way that all relevant aspects are reviewed. Therefore, it is a guide to ensure companies that these relevant aspects are brought to the minimum attention during the process towards the possible development of an IBLC. However, the approach does not indicate a mandatory 'route' to follow. In other words, there is not necessarily a mandatory sequentially. The steps are grouped by the pathway of a value chain containing an IBLC:

- Feedstock;
- Logistics;
- IBLC;
- Intermediates / Biobased Product and Final Markets market;
- Non-technical aspects of establishing an IBLC.

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The steps within these aspects of the pathway are described in more detail in Table 9 and Table 10 and the complete generic step-by-step approach is visualized in Figure 8.

### MIP case studies

The two MIP case studies give relevant insights regarding the economic aspects of establishing an IBLC using the step-by-step approach for the different topics of the pathway. Although the conclusions in Chapter 6 are very case specific, some more general indications emerge for setting up an IBLC:


- Raw material costs and processing costs often dominate the total costs.
- Raw material transport costs have only a small contribution to the total costs in the case when the transport distance to the IBLC is relatively small. At larger distances the transport costs will of course increase.
- An efficient planning of the use of process lines, stockpile, and storage capacity in the IBLC is needed.
- Using the idle time of the existing processing equipment to produce biobased products, such as energy pellets, can increase the profit of the IBLC.
- To determine the economic feasibility of additional process lines, accurate estimates of all cost aspects, including investment costs for extra equipment, are required.
- The demand for the biobased product should be adequate, so market size should be checked in practice.

These indications can be taken into account when designing a new IBLC. However, they need to be verified of course for the circumstances of that specific case.


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# 1 INTRODUCTION

Among the goals of the AGROinLOG project one is to develop generic IBLC strategies based on case studies. The case studies in this context are elaborated descriptions of potential integrations of biomass processing in value chains for food and non-food markets. The purpose of these case studies is to, on the one hand gain insight in how the identified opportunities that are technically feasible can be developed into pathways for IBLCs in different sectors and markets, and on the other hand to develop a step-by-step approach to feed the description of generic strategies for development of IBLCs that will be applicable for different sectors and in different regions.

In this project, it was decided to develop a so called step-by-step approach to be able to maximize the likelihood of acceptance and implementation of an IBLC by constructing it in such a way that all relevant aspects related to an IBLC development are reviewed. Therefore, this approach is a guide to ensure individual companies that all these relevant aspects are brought to their minimum attention during the process towards the possible development of their IBLC. This will lead to an individual design and development path of such a future IBLC, however following a generic strategy, i.e. a process driven IBLC concept from a company's point of view.

The development of this step-by-step- generic approach is also based on previous outcomes within this AGROinLOG project: (1) the description of the characteristics of an IBLC 'Updated conceptual description of an Integrated Biomass Logistics Centre (IBLC)', (2) the detailed information about the sectors from 'Basic analysis of targeted agricultural sectors', (3) the opportunities that were specified in the report 'Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration', (4) the information in the business model descriptions of the three demos and (5) the sector case studies.

The present document was structured as follows. Chapter 2 describes the methodology used. In this research case studies of various agro-industrial sectors were the main way of obtaining results. Chapter 3 contains the summarized results per case study (which are described in more detail in Appendix B until Appendix H). Per case study a general description is given of the suggested IBLC and the chosen pathway. Furthermore lessons learned and recommendations for each specific sector are mentioned. In Chapter 4, the cases studies are analysed in an integrated way in order to obtain generic solutions and recommendations. A step-by-step- generic approach that follows from the analysis is given in Chapter 5. It is a guide to ensure companies that relevant aspects are brought to attention during the process towards the possible development of an IBLC. In Chapter 6, an example is mentioned of a further economic assessment of two cases studies with the Mixed Integer Programming (MIP) optimization. Final conclusions and recommendations are part of Chapter 0.

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## 2 METHODOLOGY


The goal of an integral analysis of the various case studies is to find common aspects that can be of use to determine generic strategies for establishing an IBLC (see Chapter 5). The detailed approach towards the design of such generic strategies for the targeted sectors consisted of the following activities:

- refining the work plan;
- performing case studies;
- performing an integrated analysis of the cases studies;
- determining a generic approach for strategy development;
- performing MIP case studies.

### 2.1 Refining the work plan

In the kick-off meeting WFBR presented a summary of the methodology that was designed at the proposal stage. The work to be performed included conducting *case studies* that are needed to i) see how the identified opportunities can be developed in reality into *pathways* for IBLC's in different sectors and markets and ii) to feed the description of *generic strategies* for the development of IBLCs that will be applicable for different sectors and in different regions. The initial methodology was further discussed and several concepts described (e.g. case study, pathway & generic strategy) were further refined. Based on a discussion in a second meeting the following definitions were adopted:

- A *case study* is preferably an existing situation to evaluate the current situation (lessons learned) and to describe the pathways to develop a new IBLC or improve the existing IBLC. It should cover all aspects of the IBLC: feedstock supply, logistics, technical & non-technical, economical, intermediate products, market and policy. Furthermore, a good balance is needed in a case study between quantitative and qualitative data.
- A *pathway* is a narrow / specific description of one possible way to utilize a certain raw biomass feedstock with defined (idle) resources of an IBLC to produce a certain type of intermediate/bio-commodity that can then be used by an industry to produce bioenergy, biofuels, biomaterials or biochemicals.
- A *generic strategy* is a theoretical and universal description of strategies for a stepwise implementation to establish an IBLC based on general aspects that apply in several pathways.

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## 2.2 Performing case studies

A brainstorm of the partners based on the analysis of the targeted agricultural sectors<sup>1</sup> and of the identified opportunities for new business in these sectors<sup>2</sup> led to a long list of potential case studies ideas. From this long list, initially six sectors were chosen, that will ideally present a variation in the sectors and markets in which IBLCs can be established. Due to a lack of interest showed by the actors involved in the vegetable oil sector, it was decided to cancel the vegetable oil extraction case. Consequently, five case studies remained. Dedicated case study teams were formed for each of these sectors. The composition of these case study teams (Table 1:) was based on the interest of the partners and the experience with certain sectors in the previous tasks. WFBR made a case study methodology document including the expected content of the case studies (see Annex A.) which was discussed with all partners involved. In principle one case study is done for each sector. The technical partners CIRCE, ZLC, CERTH, RISE and WFBR were made responsible for data analysis and writing of the sector specific template report.


*Table 1: Case study teams for the chosen sectors*

Team list			
Chosen sector	Lead partner	Technical partners	Association partners
Feed and fodder	CIRCE	RISE	SPANISH CO-OPS, AESA
Olive oil mills (chain)	CERTH	CIRCE & ZLC	INASO-PASEGES, SPANISH CO-OPS, AESA
Wine (cellars & distilleries)	CERTH	CIRCE & ZLC	INASO-PASEGES, UBFME, SPANISH CO-OPS
Grain chain	RISE	CERTH	INASO-PASEGES, UCAB, Lantmännen
Sugar	RISE	WFBR & ZLC	UCAB

The association partners (organizations representing specific agro-companies in their country) were responsible for collecting data to substantiate the technical feasibility and the optimal logistical chain design of the case studies. They also achieved stakeholders' involvement by putting their needs and expectations in the heart of the strategy for a local IBLC. Taking advantage of the workshops organized under another task the information compiled brought very valuable input to the strategy design in this task. A key-point in the discussion was the variability among the case studies and the need to homogenize the results as much as possible while keeping of course the objective of the work. However, the variability of the case studies cannot be avoided completely so this certainly imposes difficulties for the design of generic strategies development.

<sup>1</sup> AGROinLOG, 2018. Basic analysis of targeted agricultural sectors - Cover report and six Annex country reports. AGROinLOG project, Deliverable D6.2, 520 pp.

<sup>2</sup> AGROinLOG, 2019. Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration. AGROinLOG project, Deliverable D6.3, 115 pp.

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## Real versus hypothetical case study

The question addressed was if a *real* or a *hypothetical* case study should be used. Characteristics of these real and hypothetical case study types are given in Table 2. It was agreed that a study of a real existing IBLC does not necessarily have to be one existing IBLC, but it can also be done based on combined experiences of certain parts of the value chains from different cases. E.g. the data on feedstock sourcing can be from one example of a real situation and the experiences of using the idle time of certain machines can come from another example. An IBLC can be hypothetical, but by combining information and data from existing companies that have implemented the IBLC concept an IBLC case study can be defined.

A specific country was always chosen in relation to a case study if an existing real IBLC was documented, because that IBLC is of course located on a certain position, and therefore addressing specific circumstances associated to it. Based on this position, the conditions faced or main keys that could make the initiative successful are closely related to the site specific conditions (for instance reduced distance of the raw material supply will lead to reduced price of the input material comparing to other possible locations). A hypothetical IBLC case study could combine aspects from multiple countries. For the final market that uses the intermediates provided by the real or hypothetical IBLC always an existing market should be used and not hypothetical estimates of a market. This is because a hypothetical case study should be kept as realistic as possible to make the case study more meaningful.

Table 2: Real and hypothetical IBLC case study.

Real & hypothetical		
Issue	Real IBLC	Hypothetical IBLC
Description of type of study	Learn from an existing IBLC: what happened when they wanted to become an IBLC, what steps did they have to take, how did they solve problems, etc.	Design a hypothetical preferred IBLC for a company with realistic considerations and see if that could be technically, economically, and environmentally feasible
Final market that uses the intermediates	An existing market should be used and not hypothetical estimates	An existing market should be used and not hypothetical estimates
Constraints output case study	Outcome can be measured and depends on real data and real decisions that were made	Output is calculated and depends on estimated data and assumptions that can be made during the design
Character of study	More a descriptive study of an 'actual' situation	More a feasibility study of a business plan
Type of study bases	Evidence-based studies	Model and/or expert-opinion-based studies
Power for strategy generalization	High	Relatively low
Sector	Feed & fodder sector Olive oil sector (Natac Group)	Olive oil sector (ABEA) Wine sector Grain sector Sugar sector


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As mentioned before an existing real IBLC was preferred. However, since there were not many IBLCs operating yet, hypothetical case studies could not be avoided in some sectors. The feed & fodder case study was partially based on an existing IBLC. However, there were no IBLC cases found yet in the olive oil sector. Focus was therefore on pathways based on experience of existing industries. Also, no existing IBLC cases were known yet related to processing pruning residues in the wine sector, so a hypothetical case study was designed. In the grain sector case, there was a real site of an existing company that could be willing to switch to an IBLC to produce biochar. Finally, in the sugar sector a hypothetical IBLC case study was designed.

It should be kept in mind that analysing the case studies and the pathways must lead to insights (lessons learned) to be able to generate a generic strategy. Hence, case studies were chosen in such a way that they will provide the necessary information (qualitative and quantitative) that is relevant for generating this generic strategy. Furthermore, synchronizing the results of the different case studies is important for generating the detailed generic strategy. Disclosure of (commercial) data was considered carefully in IBLC case studies based partially or entirely in real cases. To be able to describe the case studies in a uniform way a *common data template* was devised (see Annex A. Common data template). This contained the following main categories, each including several detail questions:

1. General introduction of the case study for specific sector
2. Description of the six stages of the chosen pathway
  - a. Feedstock supply
  - b. Logistics
  - c. IBLC design
  - d. Intermediate biobased products
  - e. Final market
  - f. Non-technical issues
3. Lessons learned
4. Recommendations for this specific sector

A general introduction of each case study (1) is needed to set the context of the specific sector in which the IBLC is operating or in which it will be developed. The size of the sector is described, and its main economic activities. Furthermore, a general description is given of the suggested IBLC. Then the six stages of the chosen pathway are described in detail (2). These data are needed to assess the IBLC within the whole value chain. Both technical issues (2a.-2e.) and non-technical issues (2f) were given. These data were used in the integrated analysis of the case studies (see Section 2.3 and Chapter 4) and for performing two MIP case studies (see Section 2.3 and Chapter 6). Each case study template includes a section with lessons learned (3) and recommendations for the specific sector (4). These two sections were summarized in Chapter 3, and also formed the basis for the integrated analysis of the case studies (again see Section 2.3 and Chapter 4).

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## 2.3 Performing an integrated analysis of the case studies

To perform the actual integral analysis of the various case studies the outcomes of the various case studies are carefully studied and compared on the technical aspects of an IBLC pathway, namely:

- feedstock supply;
- logistics;
- IBLC design;
- intermediate biobased products;
- final market.

Furthermore, also the non-technical aspects of establishing an IBLC will be compared between the pathways of the various cases studies (see Figure 1).

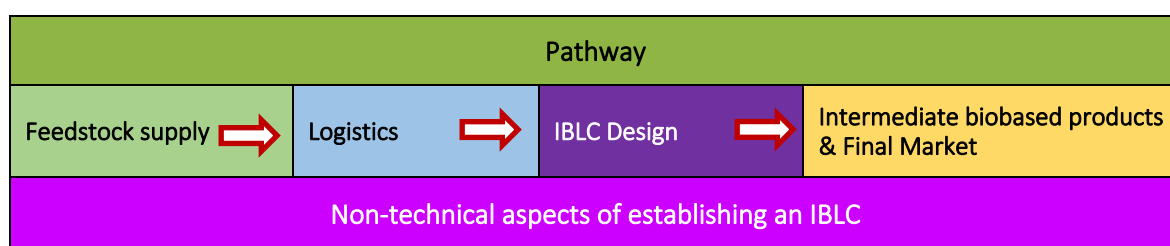


Figure 1: Generic pathway visualisation.

## 2.4 Determining a generic approach for strategy development


Different sources of information were used and combined to develop the generic strategy:

*Reports of WP6* - First of all, the description of the characteristics of an IBLC was used from 'Updated conceptual description of an Integrated Biomass Logistics Centre (IBLC)'<sup>3,4</sup>. Then, detailed information about the sectors from 'Basic analysis of targeted agricultural sectors'<sup>5</sup> was used. And finally, the generic strategies also depend on the opportunities that were specified in the report

<sup>3</sup> AGROinLOG, 2017. Updated conceptual description of an Integrated Biomass Logistics Centre (IBLC). AGROinLOG project, Deliverable D6.1, 59 pp.

<sup>4</sup> Annevelink, E., B. van Gogh, F. Sebastián Nogués, S. Espatolero, T. De la Cruz, D. Luzzini, M. Karampinis, M. Kougioumtzis & J. Olsson, 2017. Conceptual description of an integrated biomass logistics centre (IBLC). In: Proceedings of the 25th European Biomass Conference and Exhibition, 12-15 June 2016, Stockholm, Sweden, 200-203.

<sup>5</sup> AGROinLOG, 2018. Basic analysis of targeted agricultural sectors - Cover report and six Annex country reports. AGROinLOG project, Deliverable D6.2, 520 pp.

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‘Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration’<sup>6</sup>.

*Three IBLC demos* - The information in the business model descriptions of the three demos was also used as input to determine the generic approach were these demos have a different set-up.

*Sector case studies* - The structure of the common data template was designed to reflect the topics that are important in the generic strategy. The two different sections ‘recommendations’ and ‘lessons learned’ are important parts of the sector cases studies that were summarized in Chapter 3.

*Literature* - This can be e.g. on the Energy Conversion Park (ECP) project ([www.ecp-biomass.eu](http://www.ecp-biomass.eu)) where a stepwise approach was formulated to establish a so-called energy conversion park ([www.ecp-biomass.eu/node/176](http://www.ecp-biomass.eu/node/176)) but also on other literature that was already studied in previous tasks.


## 2.5 Performing MIP case studies

In the context of this work, WFBR developed a mixed integer programming (MIP) model to be used in the case studies for quantitative analysis. The MIP model (including a separate manual) is a decision support tool to help optimize the food and bio-based businesses for an IBLC. The optimization is subject to a specific set of realistic constraints including the availability of the raw food and biomass feedstock, the storage and machinery capacities, demands, etc. Different types of costs (e.g. transportation costs, storage costs and processing costs) are taken into account to generate the best investment and operation plans that will maximize the total profits of the IBLC. This model was designed in a flexible way that allows quick construction and analysis of new model scenarios (e.g. adding or deleting machines, raw materials, farms, storage facilities, etc.).

The MIP studies give relevant insight in the economic aspects of establishing a new and / or expanding an existing IBLC. These economic aspects are related to feedstock, logistics, the IBLC (resources and capacity) and intermediates and final markets.

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<sup>6</sup> AGROinLOG, 2019. Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration. AGROinLOG project, Deliverable D6.3, 115 pp.

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## 3 MAIN RESULTS PER SECTOR CASE STUDY

### 3.1 Introduction

The following topics from the Annexes B. until G., describing the case studies in more detail, were summarized in each case study section below:

- 1d - General description of the suggested IBLC within the sector
- 2.1a - Types of available feedstock
- 2.3a - Available pre-treatment & handling machinery, storage facilities, labour and other infrastructure types including average capacity per period (month)
- 2.3b - Idle period of available and suitable pre-treatment & handling machinery, storage facilities, labour and other infrastructure
- 2.4a - Types of intermediate biobased products made at IBLC
- 2.5a - Types of final biobased products (that are made by another industry from the feedstock 'intermediate biobased products' delivered by the IBLC)
- 3a, b, c & d (so all) - Recommendations for this specific sector
- 4a - Recommendations

More details and the rest of the information about the case studies can be found in the Annexes B. until G.

### 3.2 Feed and fodder sector - AGROPAL & additional information from other sources - Spain

#### General description of the suggested IBLC


This case study is focused on the use of the surplus fodder to produce pellets, which are further employed to produce thermal energy for the dehydration process. More detailed information can be found in Annex B.

The information collected in this deliverable is partially focused on AGROPAL Soc. Coop. case study, including a cheese factory (Quesos Cerrato Soc. Coop.) and a fodder dehydration factory (Villoldo) owned by AGROPAL. They use the fodder-derived pellets to achieve an energetic self-consumption. However, due to the lack of information related to certain aspects of energy consumption and costs, other inputs were received from other sources and companies of the sector.

#### Description of the chosen pathway

*Feedstock:* Herbal waste, particularly cereal straw.

*IBLC (equipment):* Two types of boilers were purchased. Firstly, a heating boiler for one of the fodder dehydration factories, and secondly a steam production boiler for the cheese factory. It involved an

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overall investment of € 970,000. The steam boiler for the cheese factory had a depreciation period of 6 years, considering a boiler service life of 25 years.

*Intermediate biobased products:* The type of intermediate biobased products made at IBLC is solid biofuels (straw pellets) and because of the ‘self-consumption’ at the IBLC no final biobased products are manufactured.

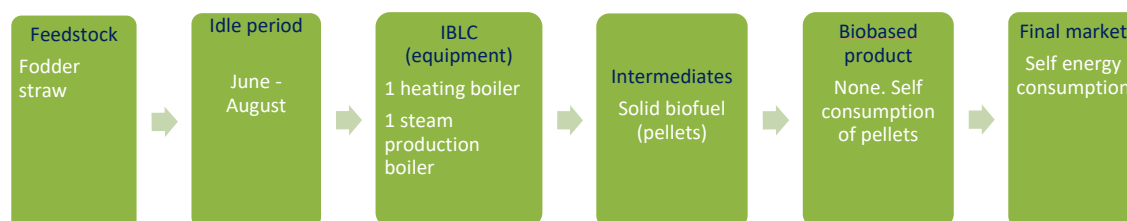



Figure 2: Pathway around the implemented IBLC in AGROPAL.

## Lessons learned

*Successes:* The main success of the case is the greater competitive advantage over other producers by saving on an average 5-10 % in terms of production cost (Spanish Co-ops, 2017). In general lower production costs also open new markets which were not profitable before due to market prices. However, for AGROPAL this was not relevant because of the self-consumption of the pellets. This case also shows that it increases local employment opportunities and increase of the equipment investment in the region in the agricultural sector. Besides that, it also shows that it is possible to develop a new line in other companies due to the sale of carbon credits. And last but not least, energetic savings and a decrease of the fossil fuels use, as well as an independence of fossil fuels market are shown by natural gas savings that vary between 20-70 %, depending on the straw price (Spanish Co-ops, 2017).

*Difficulties:* Some of the main barriers found during the project development were (1) raw material production variations due to weather circumstances, (2) technical difficulties and cost related to straw densification and the combustion process, (3) challenges related to prototyping the boiler, (4) finding the right biofuel additives which counteract the pernicious effects of the straw burning and finally (5) the needed use of starch and molasses as binding materials in the pellet manufacturing process.

*Solutions for problems* of the needed use of starch and molasses as binding materials was tackled by testing different matrixes, tested with the aim to find an optimal size to counteract the expansion trend of the raw material during this process. And for the combustion system, the boiler was specifically designed for this type of fuel due to the straw particular features, a temperature variation was studied and optimized in order to reach an equilibrium between the ashes fusion and the slag formation. Additionally, an air dilution is performed by adding fresh air to the combustion air.

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## Recommendations for this specific sector

Originally, the energetic valorisation of straw attended to a strategy focused on removing straw when having a production surplus, which created additional management and harvesting costs. This, in addition to the impossibility to burn this straw due to environmental concerns and need of management, were the main causes to start this new valorisation line. And once the biofuel fabrication process is implemented and optimized, promoting this business line is proposed as one of the major opportunities, by replicating the milling and granulating process in different cereal industries. And furthermore, the development of the specific boilers, the energetic costs could be improved by the installation of this ad-hoc boiler models, in other consumption points owned by the cooperative, such as: animal feeding production, second industry of fodder drying and cereal drying industry and even exporting the boiler model to different consumption points, i.e. different sectors, could be a great business opportunity.

## 3.3 Olive oil sector - ABEA - Greece


### General description of the suggested IBLC

The IBLC concept on the pomace mill (ABEA) owned by the Mills of Crete is studied. Crete and more specifically Chania region produces, in annual base, a huge potential of residual biomass (e.g. olive tree prunings and olive leaves) from the olive sector, quantities that ABEA could manage for its benefit, introducing new final bio-based products in the local market. Apart from this, ABEA has a long idle period time (from August to November) and thus it is considered suitable for the implementation of one or both of the selected pathways that will be studied in the olive oil sector. The first pathway will be focused on the exploitation of the residual olive tree prunings and the production of new bio-based products (pellets), while the second pathway is based on the exploitation of olive leaves and the extraction of olive phenols. More detailed information can be found in Annex C.

### Description of the chosen pathway

*Feedstock:* Considering the first pathway, the residual olive tree prunings that will be utilised is a source of “biomass” that is burned in open fires, and yet not exploited. As for the second pathway, the olive leaves that are separated in olive mills and/or burned along the olive tree prunings, were selected as raw materials.

*IBLC (equipment)* – Concerning the first pathway and the olive tree prunings a new investment in harvester/shredder machines like FACMA COMBY TR200 from the company seems necessary for the harvesting of the raw material before entering the IBLC. The existing equipment of the pomace mill, i.e. the belt dryer, the storage facilities, as well as the personnel that ABEA currently employs will be available for the new activities of the IBLC. As for the second pathway and the phenols extraction, again some of the existing facilities (dryer, storage facilities) can be also used. However, biobased products processes would require even higher investments than the ones needed for the exploitation of olive tree prunings pathway. The idle period for ABEA pomace mill ranges between July and October.

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*Intermediate biobased products* - None, since in this case study the produced olive pellets as well as the extracted polyphenols are the final biobased products delivered directly to the final consumers.

*Final biobased products*: The main types of final biobased products from the first olive oil pathway are: olive prunings in the form of pellets, and there is an option for briquettes or either use the prunings directly in hog fuel form. The final biobased products that can be derived from the second pathway can be various, for instance olive polyphenols, such as oleuropein and hydroxytyrosol as well as triterpenes (oleanolic and maslinic acids) with unique applications in pharmaceutical, chemical, animal feeding or nutraceutical markets.

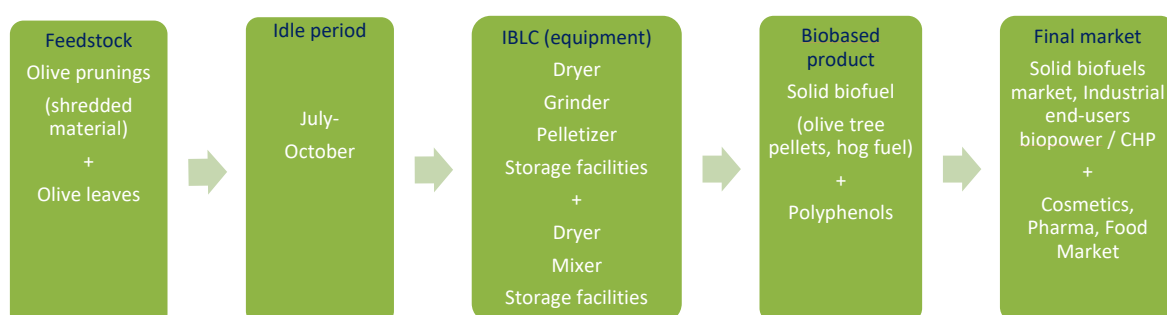



Figure 3: Pathway around the suggested IBLC.

## Lessons learned

As it was mentioned above both of the studied cases are hypothetical scenarios. For that reason, it was believed that it is better to present some lessons learned from an existing case (FIUSIS power plant), which produces electricity exclusively from olive tree prunings and was examined in previous project by CErTH<sup>7</sup>. FIUSIS power plant, follows the above mentioned logistics and this is the reason why it was chosen to present its lessons learned. All the harvesting techniques as well as the handling processes of the olive tree prunings can be an effective example to imitate for the future IBLC. Further to this, the plant owner and manager, is interested in expanding the business activities in two new areas. The first is the production of olive tree prunings pellets for the domestic / industrial sector and the second one is the use of the biomass ash as a fertilizer.

Based on FIUSIS experience the successes factors are related to (1) the high density of the olive groves which lead on the reduction of the transportation distances, (2) the high joining rate of farmers in the pruning supplement chain, (3) the high pruning surface amounts, (4) creating rural employment and agricultural services companies, (5) giving opportunities to new alliances between farmers, local authorities and agro-services with the aim to optimize the business model, (6) creating value from an already sorted out residue that is utilized for heat and power generation today and (7)

<sup>7</sup> uP\_running: "Take-off for sustainable supply of woody biomass from agrarian pruning and plantation removal", (<https://www.up-running.eu/>). This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 691748.

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establishing agreement with the neighbouring municipalities in order to involve farmers in stopping pruning burning and adhere to the collecting procedures.

On the other hand the biggest difficulties are (1) convincing farmers to establish ways of collaboration, (2) legislative problems/obstacles for by- products that so far are considered waste by legislation and used to burn in open fires, (3) escalating the process towards industrial size, and (4) the fear that other types of competitive fuels (sunflower pellets, exhausted olive cake, wood pellets) can attract the end users due to lower prices or higher fuel quality. However, in order to overcome the reluctance of farmers, the best solution according to FIUSIS would be an intense information campaign to promote the social acceptance far before the year of the investment.

### Recommendations for this specific sector

The implementation of an IBLC for the valorisation of olive tree pruning requires the active collaboration of farmers and cooperatives. It is necessary to develop alliances between the local authorities and the agricultural sector and try to overcome the common belief that burning prunings in open fire is the easy way to treat prunings. In this way new opportunities for the region, the environment and of course for the local market and its consumers will emerge.


## 3.4 Olive oil sector - Natac Group - Oleícola El Tejar - Spain

### General description of the suggested IBLC

Under the AGROinLOG project strategic alliances between agro-industries and biotech SMEs were assessed to evaluate the extraction of new high added value bio-products such as phenols (Figure 4). The proposal for this sector was inspired by the successful partnership that Natac Group has with the world leading olive pomace oil producer, Oleícola El Tejar (second degree cooperative), with whom they have created a joint venture called Innovaoleo. Natac Group is a Spanish Biotech SME dedicated to the research, development, manufacture and marketing of natural ingredients. Thanks to this strategic alliance with the cooperative, they have access to all the necessary raw materials for the production of olive-derived extracts. In addition, this working formula allows to share several costs related with storage, logistic and transport activities, leading to highly competitive products. While agro-industries supply the raw material and other assets such as infrastructure for storage, logistics and processing, Spanish Biotech SMEs provide knowledge and technology. More detailed information can be found in Annex D.

### Description of the chosen pathway

*Feedstock:* Two Phase Olive Mill Waste (TPOMW) and olive leaves are the main raw materials required for the phenols' extraction process.

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*IBLC (equipment):* Infrastructure, facilities and equipment related to auxiliary processes (fire extinction, security, steam boiler, etc.) and biomass management (washing, chipping, drying, mixing, storage, etc.) will be required during the process. Idle period in the olive pomace oil industries (when facilities, equipment and other compatible resources are available for alternative purposes) usually goes from August to November.

*Intermediate biobased products:* Olive pomace oil industries produce crude pomace oil, which is sent to refineries for the obtaining of olive pomace oil for human consumption.

*Final biobased products:* Olive extracts for pharmaceutical, nutraceutical, animal feed and cosmetics industries, which will be later incorporated into final products. In addition, olive pomace oil industries generate two solid biofuels at the end of their process that are also ready to market: olive stones and exhausted olive pomace.

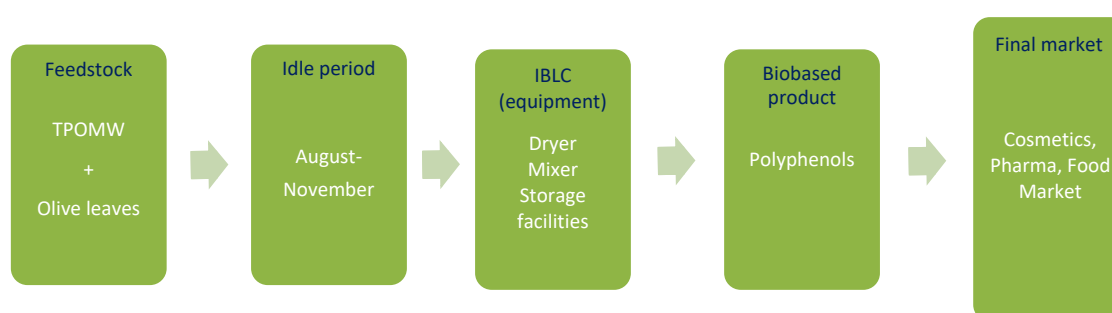


Figure 4: Pathway around the suggested IBLC.


## Lessons learned

*Successes* are related to (1) building alliances to allow the optimization of the business model, (2) existence of companies with long experience and top-quality technical equipment and (3) scientific knowledge transfer into new products in collaboration with the customer.

*Difficulties* are (1) convincing farmers, agro-industries and innovation centres to establish new ways of collaboration, especially when the actors belong to in different sectors, (2) escalating the process towards industrial size, (3) legislative problems / obstacles e.g. by-products that are considered waste by legislation and (4) development of an IBLC requires long maturation times with significant investments in Research, Development & Innovation.

The main *solution* should be to ensure that all actors involved in the chain will benefit and therefore are inclined to participate. Another way towards success is the implementation of models such as collaborative innovation, ensuring success and shortening time to market access.

*Things to avoid* are assuming that under-exploited biomass will be obtained at no cost. Because all the stakeholders involved should benefit this also means that under-exploited biomass should be made available at a certain price / cost.

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## Recommendations for this specific sector

It is necessary to (1) search for formulas to bring together agents from very different sectors, (2) seek innovative business models so that all agents can generate profits and (3) overcome conservative thinking. It is important to be able to combine technological development, access to raw materials, manufacturing capacity and, of course, international trade.

## 3.5 Wine sector - Distilleries Alliance with Logistic and Biotech Companies - Spain

### General description of the suggested IBLC

Suggested case study in the wine sector depicts a hypothetical alliance between distilleries, logistic companies and technological centers that would allow both the vineyards pruning valorisation and the extraction of phenols within these agro-industries, running as IBLCs. For this purpose, several interviews were carried out to distilleries, to a logistic company (Athisa Biogeneración) and to a Spanish Biotech SME (Natac Group). Therefore, the case study for the wine sector includes two different pathways: vineyards pruning and phenols. More detailed information can be found in Annex E.


### Description of the chosen pathway

*Feedstock:* Raw materials for the proposed pathways are vineyards pruning, grape pomace (which contains grape seeds, grape skins and grape stalks), lees and filter pastes.

*IBLC (equipment):* Concerning the first pathway most vineyard farmers already have tractors and pulling systems to collect the vineyards pruning from the soil. Sometimes cooperatives and wineries in general also have trailers which they can use to transport the pruning from farmers parcels to the gathering points. As for the second pathway (phenols' extraction), biotech SMEs such as Natac Group take advantage of the assets and facilities that agro-industries have. In this line, through their association with the distilleries, both the logistics and biotech companies would ensure the supply of raw materials and access to machinery for drying (trommel), storage facilities, etc., necessary both for the valorisation of the pruning and the extraction of the polyphenols. The idle period in the distilleries, when facilities, equipment or other resources compatible with the processing of biomass would be available, extends from June to September, with the start and end months of this period varying according to the region.

*Intermediate biobased products:* All the distilleries generate ashes by burning the exhausted grape pomace that they self-consume to meet their thermal needs. These ashes can be considered an intermediate bio-product for the manufacture of fertilizers. The same would occur in the hypothetical case of self-consumption of the chips and pellets produced from pruning for energy purposes. Distilleries generate several intermediate biobased products such as grape seeds, tartrate and alcohol.

*Final biobased products:* Main final products from vineyards pruning pathway are pellets, chips in bulk and chips in bales. Regarding the phenol's pathway those would be proanthocyanidins,

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anthocyanins, flavonoids, resveratrol, enocyanine, etc. However, it should be noted that bigger distilleries currently produce some of these and other final bio-products such as tartaric acid, grape seed oil, bioethanol, grape seed flour and colouring agents. All distilleries produce exhausted grape pomace. Most of these products are destined to biofuel, pharmaceutical, chemical, animal feeding, nutraceutical and food markets.

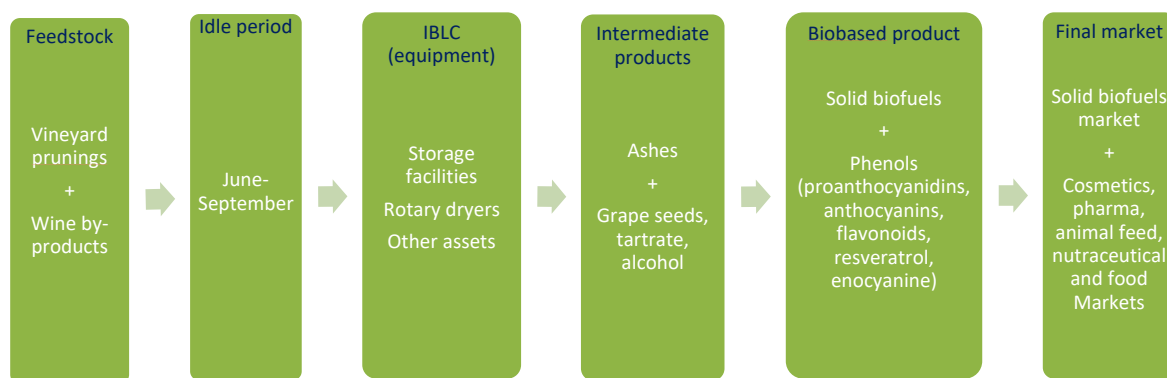


Figure 5: Pathway around the suggested IBLC.

## Lessons learned

*Successes* are related to (1) overcoming the high content of stones, sand and other remnants that vineyards pruning usually present (cleaning equipment patented by Athisa Biogeneración or new pre-pruning machinery developed within the operational group VidBiomasa), (2) creating rural (and young) employment, (3) building alliances to allow optimization of rural business models, (4) transferring scientific knowledge in collaboration with the customer to develop new products and (5) the reduction of greenhouse gas emissions by promoting the substitution of fossil fuels.


*Difficulties* are (1) convincing farmers to establish ways of collaboration, especially when the actors are in different sectors, (2) scaling up the process towards industrial size, (3) legislative problems / obstacles e.g. by-products that are considered waste by legislation and (4) development of an IBLC requires long maturation times with significant investments in Research, Development & Innovation.

The main *solution* should be to ensure that all actors involved in the chain will benefit and therefore are inclined to participate. Another way towards success is the implementation of models such as collaborative innovation, shortening times to market access.

*Things to avoid* are the common assumptions that underutilized biomass will be obtained at no cost. All operators should benefit.

## Recommendations for this specific sector

It is necessary to (1) search for formulas to bring together agents from very different sectors, (2) seek innovative business models so that all agents generate profits and (3) overcome conservative thinking. It is important to be able to combine technological development, access to raw materials, manufacturing capacity and, of course, international trade.

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## 3.6 Grain chain sector - Lantmännen - Sweden

### General description of the suggested IBLC

One of the residues from the cereal production chain today is chaff. Chaff is the dry, scaly protective casings of the seeds of cereal grain. It also consists of dust and damaged seeds. Nowadays, the chaff is utilized in energy recovery. One possible new utilization for the chaff is the production of biochar. Production of biochar can refine the management of several waste streams, such as chaff, that are difficult to utilize for anything more useful than energy recovery. At one of Lantmännen's cereal handling site, they receive many different types of cereals and seeds. One facility is cleansing seeds and one facility is drying and cleansing different types of material such as cereal grains and fodder peas.

Biochar is a solid material obtained from the carbonisation of biomass and is produced from intentionally heating a biomass feedstock via pyrolysis (without oxygen) or gasification (limited oxygen). Biochar can be used as a product itself or as an ingredient within a blended product. One possible further processing of the biochar is pelletizing. There are several possible markets for biochar, such as soil improvement, carbon capture, filtration material, animal feed additive and bioenergy. More detailed information can be found in Annex F.


### Description of the chosen pathway

*Feedstock* - The type of available feedstock is chaff, a side-stream from cereal production.

*IBLC (equipment)* - Possible IBLC equipment that can be utilized in the suggested IBLC is found in an old feed factory on the site that was shut down many years ago. The pyrolysis equipment does not exist on the site today, a new investment is needed for this. It would also be optimal if the chaff can arrive in containers to the site and that the material is just tipped down into the pit with conveyors so that there will be as little handling. The material should also be stored in containers. There is an existing equipment for pelletising on the site today, this could be utilized for pelletizing the chaff which is another way to simplify the handling of the chaff. At the feed industry on the site there is a pelletizing machine, balers and mixers amongst others that could be utilized in the IBLC. The chaff could be tipped indoor in a bunker silo. The biochar can be stored in bulk on concrete with a roof above.

*Intermediate biobased products* - The type of intermediate biobased product made at the IBLC is biochar.

*Final biobased products* - The types of final biobased products are primary soil improver and bioenergy. Alternative markets are carbon capture, filtration material and animal feed additive.

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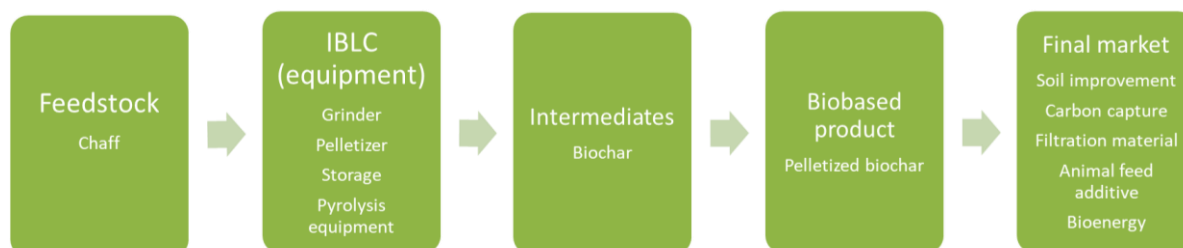


Figure 6: Pathway around the suggested IBLC.

## Lessons learned

Successes are (1) relative low investments compared to other possible investments in biorefineries in the pyrolysis plant and (2) creating value from an already sorted out residue that is utilized for heat and power generation nowadays.

*Difficulties* are (1) to produce biochar with a profit, (2) the biochar market is immature, (3) difficulty to handle the biochar due to risks in the working environment amongst others and (4) current biochar technology is new (although pyrolysis technology is already at TRL 9) and it is not sure if technology will work at specific efficiency levels. There are no examples that the technology has worked on larger scale.

*Solutions for problems* are (1) the necessity to create a market with added value for the biochar and (2) minimizing the difficulties with the chaff by handling it in containers. Moreover, avoid investing in a plant without having an available heat sink.


## Recommendations for this specific sector

Before the investments can be done in the IBLC/Pyrolysis equipment a secure market for the biochar has to be identified, preferable with an increased market need. A biochar production that is not only focused on energy production but on both energy and material recycling of local biomass resources is a sustainable way forward. This is the way to create added value for both the customers, the region and the environment.

## 3.7 Sugar sector - Nordic sugar - Sweden

### General description of the suggested IBLC

Nordic sugar is producing sugar in campaigns that usually last from late September to January. Outside of the campaign on-site production capacity would potentially be available. In the production of sugar from sugar beets several co-products, are generated. Beet pulp is the co-product generated in largest quantities. Globally there is a huge demand for bio-based materials to be used in, for example, packaging. In the suggested IBLC, the beet pulp is utilized as feedstock for production of succinic acid (SA). SA is a water-soluble crystal, traditionally made from fossil resources, that is used as a chemical intermediate in a high number of chemicals and products. This production could

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be conducted during the time of the year when there is no production in the sugar factory. More detailed information can be found in Annex G.

### Description of the chosen pathway

*Feedstock* - The type of available feedstock is beet pulp, a co-product from the sugar industry.

*IBLC (equipment)* - Evaporators and centrifuges are examples of existing equipment that can be utilized in the IBLC, but the existing equipment must be adapted to be integrated with the IBLC. Existing cleaning equipment, the infrastructure for steam, electricity, water, computer systems, laboratories etc. could also be utilized. The equipment on the site is not utilized during March to August (six months). But it might be necessary to run the process also during the sugar campaign since there is no storage area on the site for the pressed beet pulp.

*Intermediate biobased products* - The types of intermediate biobased are SA, biomass, other organic acids, residuals and water. Biomass and residuals could be used for production of biogas (equipment that could also be shared with the sugar factory).

*Final biobased products* - The final product is polybutylene succinate (PBS). PBS is a polyester made from SA and 1,4-butanediol (1,4-BDO).

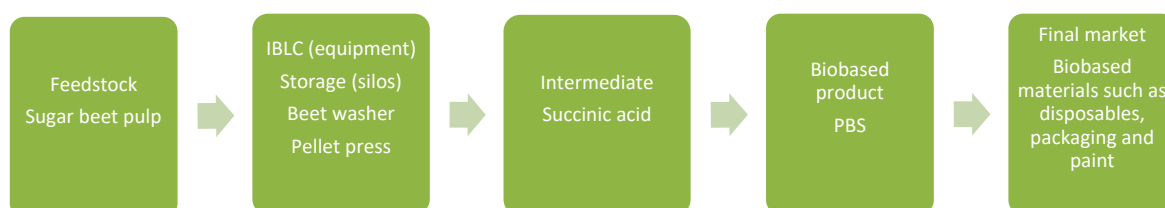



Figure 7: Pathway around the suggested IBLC.

### Lessons learned

*Successes* are (1) collaborations between Nordic Sugar and GAIA Biomaterials in producing SA and PBS on a more regional scale, (2) although a techno-economic assessment is lacking and given the fact that a production process often requires a certain size for economies of scale it is believed that it could be economically feasible (3) by creating an IBLC profit will most likely increase and an 'improved value chain' could convince farmers to continue to grow sugar beets even if the sugar price would fluctuate.


*Difficulties* are (1) significant investment will be necessary, (2) actors' willingness and capacity to act and collaborate as well as policies, norms, and values in society are critical for the success or failure, (3) possibly the lack of institutional support and actor commitment and alignment for this development in Sweden, (4) alignment of all actors along the whole value chain in a network that strives towards a common goal of advancing the technology is necessary to bring about novel technology development and market implementation.

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*Solutions for problems* are (1) technical research including experiments on different scales to prove the concept and systems studies for assessment will be necessary to be able to conduct a techno economic assessment and a more realistic business case and (2) starting a dialog about the production of SA in Örtöfta and PBS in the Skåne county as a steppingstone for a potential future SA network. Nevertheless, it is worth pointing out that the beet pulp is mainly utilized as feed today and this needs to be considered in the business case both for economic reasons and to avoid negative publicity due to environmental effects i.e. fuel vs. food.

### Recommendations for this specific sector

Establishing an IBLC in Örtöfta is potentially promising but more research and development is necessary before any recommendations can be given. Starting from producing biobased SA through the biotechnological fermentation of refined sugars or starch from cultivated crops (e.g. corn) could be the way to start the production of SA for Nordic Sugar and then move forward towards utilizing both C5 and C6 sugar as in the case with beet fibres. However, emissions caused by land use change (iLUC) should be added in this case to mirror long-term sustainability issues caused by increased production of agricultural crops. And actors in the value chain need to be willing and have the capacity to act and collaborate if the case study is going to be realised. Also, there is a need for policies, norms, and values in society that support the development of the IBLC.

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## 4 INTEGRAL ANALYSIS OF THE CASE STUDIES

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### 4.1 Introduction

The goal of the integral analysis of the various case studies summarized in Chapter 3 is to show common aspects that can be of use to determine a generic strategy for establishing an IBLC (in Chapter 5). This was done by taking the main results of the various cases studies and comparing them regarding the technical and non-technical aspects of the IBLC pathways.

First of all, an overview of the main characteristics of all the descriptions of the chosen pathways in the various case studies is given in Table 3. Then the lessons learned from the case studies were grouped per aspect of the pathway of an IBLC (feedstock supply, logistics, IBLC design, intermediate biobased products & final market and finally non-technical aspects of establishing an IBLC). Based on these aforementioned aspects, the integral analysis is grouped in four overarching topics in order to enable logical structuring:

- successes;
- difficulties;
- solutions (and things to avoid);
- recommendations.




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Table 3: Overview of the main characteristics of the chosen pathways in the various case studies.

Case study characteristics						
Sector	Feed & fodder	Olive oil mills	Olive oil pomace industries & biotech companies	Wine	Grain	Sugar
Name	AGROPAL & additional information from other sources	ABEA	Natac Group – Oleícola El Tejar	Distilleries Alliance with Logistic and biotech companies	Lantmännen	Nordic Sugar
Status IBLC	Real	Hypothetical	Real	Hypothetical	Hypothetical	Hypothetical
Feedstocks	Cereal straw	Olive tree prunings; Olive leaves	Two Phase Olive Mill Waste (TPOMW); Olive leaves	Wine production by-products; Vineyards pruning; Vine strains that are uprooted	Chaff (a side-stream from cereal production)	Beet pulp (a co-product from the sugar industry)
Logistics	Average distance 15 km from field to intermediate storage; 70 km from intermediate storage to IBLC; Trucks	Average distance 5-10 km from field to IBLC; Trucks	Average distance 0-1 km from industry to IBLC; Internal transport	Average distance 3.3 km and maximum 5 km from field to IBLC; Trailers	Average distance 80-90 km from field to IBLC; Container truck	Average distance 200 km from industry to IBLC; Tank trucks

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Sector	Feed & fodder	Olive oil mills	Olive oil pomace industries & biotech companies	Wine	Grain	Sugar
IBLC machinery	Two boiler types	Integrated harvester/shredder for harvesting prunings. Existing belt dryer and storage facilities; Grinder, cooler, a pellet press and a mixer	Machinery for washing, chipping, drying, mixing and storage facilities	Rotary dryers, storage platforms, forklifts and tractors, trommel dryer	Equipment for pelletising, balers and mixers, bunker silo	Evaporators, centrifuges, cleaning equipment, infrastructure for steam, electricity, water, computer systems, laboratories etc
Intermediates	Solid biofuels (straw pellets)	None	None	Ash; Grape seeds, tartrate, food alcohol, neutral alcohol, crude alcohol	Biochar	Succinic acid (SA), biomass, other organic acids, residuals and water, biogas
Final market	Self-consumption IBLC	Solid biofuels: mainly pellets and optionally briquettes; Various olive polyphenols for pharmaceutical, nutraceutical, animal feed and cosmetics industries	Olive extracts for pharmaceutical, nutraceutical, animal feed and cosmetics industries	Proanthocyanidins, anthocyanins, flavonoids, resveratrol, enocyanine; Tartaric acid, grape seed oil, bioethanol, grape seed flour, colouring agents; Solid biofuels: pellets, chips in bulk and chips in bales	Soil improver; Bioenergy	Polybutylene succinate (PBS) a polyester made from succinic acid (SA) and 1,4-butanediol (1,4-BDO).

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## 4.2 Integral comparison of sector case studies

In Table 4 to Table 7 the findings of the various case studies are sorted per item of the pathway, and presented under the heading 'Results'. The origin of each finding is labelled with a code of the case study where it was mentioned in Chapter 3: F&F = Feed & Fodder; OOG = Olive Oil Greece; OOS = Olive Oil Spain; WI = Wine; GR = Grain; SU = Sugar. The step numbers in the last column of the Tables refer to the step numbers in the generic step-by-step approach that will be described in Chapter 5.

The main **successes** of the case studies are described in Table 4. Regarding the feedstock supply it was important to find enough farmers that can supply sufficient biomass of a required quality. For the logistics, a supply at relatively short distances needs to be achieved. A long experience with top-quality equipment was seen as a success factor for the IBLC design. Many successes were related to intermediate biobased products and the final market. Residues for power and heat production were an interesting business option. Achieving more competitiveness was seen as a success. This was achieved e.g. by cost savings, but also by collaboration. Factors that influenced the costs were energy savings, obtaining carbon credits, costs of feedstocks and production costs. Finally, many successes were mentioned regarding non-technical aspects of establishing an IBLC. An economic success was the increase in equipment investments in a region. Social successes were an increase of local employment opportunities, building alliances and knowledge transfer to customers. A sustainability success was the reduction of greenhouse gas and toxic gas emissions.

The main **difficulties** of the case studies are described in Table 5. Raw material production variations are a difficulty for the feedstock supply. No specific difficulties were mentioned in the case studies regarding logistics. Technical difficulties regarding processes and technologies in the IBLC design are mentioned in several cases. Regarding the intermediate biobased products and the final market difficulties occur due to competitions with alternative products, immature markets and unprofitable biobased products. Finally, many difficulties are related to non-technical aspects of establishing an IBLC. Economic aspects are the significant investments that could be needed to set-up an IBLC, and the fear that it will take a long time for the IBLC to reach a mature stage. Although collaboration was mentioned as a success in some case studies it was also often mentioned as a difficulty, since the capacity and or willingness to cooperate is not always there. Aligning all actors is perceived as being difficult. Rules & regulations are also given as barriers for achieving an IBLC, e.g. waste legislation. Furthermore, norms and values in society are critical for success. Public opposition can easily lead to failure.


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Table 4: The successes of the case studies (step numbers refer to the generic step-by-step approach in Chapter 5).

Case study successes		
Topic	Results	Step number
Feedstock supply	• High joining rate of farmers in the pruning supply chain (OOG).	3
	• High pruning surface amounts (OOG).	34
	• Overcoming the high content of stones, sand and other remnants that is usually present in prunings (WI).	
Logistics	• High density of olive groves leads to the reduction of the transportation distances (OOG).	13
IBLC design	• Long experience and top-quality technical equipment (OOS).	23
Intermediate biobased products & final market	• Creating value from an already sorted out residue that is utilized for heat and power generation today (GR).	31
	• Creating value from a residue that is currently burned on the field (prunings) (OOG, OOS, WI)	31
	• Greater competitive advantage by saving on an average 5-10 % in terms of production cost (F&F).	33
	• Transferring scientific knowledge in collaboration with the customer into new products (WI).	33
	• Collaborations in producing succinic acid (SA) and polybutylene succinate (PBS) on a more regional scale (SU).	33
	• Although a techno-economic assessment is lacking and given the fact that a production process often requires a certain size for economies of scale it is believed that it could be economical feasible (SU).	33
	• By creating an IBLC profit will most likely increase and an 'improved value chain' could convince farmers to continue to grow sugar beets even if the sugar price would fluctuate (SU).	33
	• Energetic savings and a decrease of the fossil fuels use, as well as an independence of fossil fuels market are shown by natural gas savings that vary between 20-70 %, depending on the straw price (F&F).	35
	• Possibility to develop a new production line due to the sale of carbon credits (F&F).	35
	• Lower production costs open new markets which were not profitable before due to market prices (F&F).	35
Non-technical aspects of establishing an IBLC	• An increase of equipment investments in the region in the agricultural sector (F&F).	41
	• Relative low investments compared to other possible investments in biorefineries in the pyrolysis plant (GR).	41
	• An increase of local employment opportunities (F&F)	42
	• Transferring scientific knowledge in collaboration with the customer into new products (OOS).	42
	• Creating rural (and young) employment and agricultural services companies (WI & OOG).	42
	• Building alliances to allow optimization of the business model (OOS, OOG & WI).	42
	• Establishing agreement with the neighbouring municipalities in order to involve farmers in stopping pruning burning and adhere to the collecting procedures (OOG).	42
	• The reduction of greenhouse gas and toxic gas emissions by promoting the substitution of fossil fuels (WI).	45

F&F = Feed & Fodder; OOG = Olive Oil Greece; OOS = Olive Oil Spain; WI = Wine; GR = Grain; SU = Sugar



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Table 5: The difficulties of the case studies (step numbers refer to the generic step-by-step approach in Chapter 5)

Case study difficulties		
Topic	Results	Step number
Feedstock supply	<ul style="list-style-type: none"> <li>Raw material production variations due to weather circumstances (F&amp;F).</li> </ul>	3
Logistics	<ul style="list-style-type: none"> <li><i>Nothing mentioned about this in case studies.</i></li> </ul>	-
IBLC design	<ul style="list-style-type: none"> <li>Technical difficulties and cost related to straw densification and the combustion process (F&amp;F).</li> </ul>	23
	<ul style="list-style-type: none"> <li>Challenges related to prototyping the boiler (F&amp;F).</li> </ul>	23
	<ul style="list-style-type: none"> <li>Finding the right biofuel additives which counteract the pernicious effects of the straw burning (F&amp;F).</li> </ul>	23
	<ul style="list-style-type: none"> <li>Needed use of starch and molasses a binding materials in the pellet manufacturing process (F&amp;F).</li> </ul>	23
	<ul style="list-style-type: none"> <li>Escalating the process towards industrial size (OOS, OOG &amp; WI).</li> </ul>	23
	<ul style="list-style-type: none"> <li>Current biochar technology is new, and it is not sure if technology will work at specific efficiency levels (GR).</li> </ul>	23
Intermediate biobased products & final market	<ul style="list-style-type: none"> <li>Competitive market of biofuels. Fear that other types of competitive fuels (sunflower pellets, exhausted olive cake, wood pellets) can attract the end users due to lower prices or higher fuel quality (OOG).</li> </ul>	33
	<ul style="list-style-type: none"> <li>Difficulty to handle the biochar due to risks in the working environment amongst others (GR).</li> </ul>	33
	<ul style="list-style-type: none"> <li>The biochar market is immature (GR).</li> </ul>	34
	<ul style="list-style-type: none"> <li>Difficult to produce biochar with a profit (GR).</li> </ul>	35
Non-technical aspects of establishing an IBLC	<ul style="list-style-type: none"> <li>Significant investment will be necessary (SU).</li> </ul>	41
	<ul style="list-style-type: none"> <li>Development of an IBLC requires long maturation times with significant investments in R&amp;D (OOS &amp; WI).</li> </ul>	41
	<ul style="list-style-type: none"> <li>Convincing farmers to establish ways of collaboration, especially when the actors are in different sectors (OOG, OOS &amp; WI).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Actors' willingness and capacity to act and collaborate (SU).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Alignment of all actors along the whole value chain in a network that strives towards a common goal of advancing the technology is necessary to bring about novel technology development and market implementation (SU).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Legislative problems / obstacles e.g. by-products that are considered waste by legislation (OOS, OOG &amp; WI).</li> </ul>	43
	<ul style="list-style-type: none"> <li>Policies, norms, and values in society are critical for the success or failure (SU).</li> </ul>	43
	<ul style="list-style-type: none"> <li>Possibly the lack of institutional support and actor commitment and alignment for this development in Sweden (SU).</li> </ul>	43

F&F = Feed & Fodder; OOG = Olive Oil Greece; OOS = Olive Oil Spain; WI = Wine; GR = Grain; SU = Sugar

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The **solutions** of the case studies are described in Table 6. No specific solutions were mentioned for the feedstock supply and the logistics. For the IBLC design, technical research was recommended to prove the concept combined with thorough testing of the technologies. Also, systems studies for assessment will be necessary for a more realistic business case. Regarding the intermediate biobased products & final market specific handling systems were a solution to health problems. Furthermore, awareness of competing use for the feedstocks is an important point to consider and market development is necessary in some cases. Finally, as already mentioned many solutions are related to non-technical aspects of establishing an IBLC, often in response to the difficulties mentioned before. An economic solution is to find (internal) customers for produced heat in the IBLC. Social acceptance can be improved by information campaigns and starting dialog with the stakeholders. Collaborative innovation and networks around the IBLC will strengthen the whole value chain and will shorten the time to market.

The only **thing to avoid** from the lessons learned of the case studies was mentioned in the category Non-technical aspects of establishing an IBLC: do not assume that underutilized biomass will be obtained at "0" cost. All the stakeholders involved should benefit.

The **recommendations** of the case studies are described in Table 7. No specific recommendations were mentioned for the feedstock supply and the logistics. Concerning the IBLC one recommendation was made to implement the IBLC step-by-step, first using easier feedstocks and then more challenging ones. Regarding the intermediate biobased products & final market it is recommended to secure the market for the (intermediate) biobased product first, before investing in the IBLC. Production that is focused on both energy and material recycling of local biomass resources is considered a sustainable way forward. Once again, most of the recommendations focus on non-technical aspects of establishing an IBLC. An economic recommendation is to promote newly developed innovative business lines in an IBLC as a business for other companies as well. Collaboration of the stakeholders in the value chain (farmers, cooperatives, agro-industry, etc.) is considered a very important social aspect of establishing an IBLC. Support from administration is needed through regulative or incentive aspects. And there is a need for policies, norms, and values in society that support the development of the IBLC. Finally, a sustainability implementation potential needs to be secured.


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Table 6: The solutions of the case studies (step numbers refer to the generic step-by-step approach in Chapter 5).

Case study solutions		
Topic	Results	Step number
Feedstock supply	<ul style="list-style-type: none"> <li>Nothing mentioned about this in case studies.</li> </ul>	-
Logistics	<ul style="list-style-type: none"> <li>Nothing mentioned about this in case studies.</li> </ul>	-
IBLC design	<ul style="list-style-type: none"> <li>Technical research to prove the concept and systems studies for assessment will be necessary for a more realistic business case (SU).</li> </ul>	22
	<ul style="list-style-type: none"> <li>The problems of binding materials were tackled by testing different matrixes (F&amp;F).</li> </ul>	23
	<ul style="list-style-type: none"> <li>For the combustion system, a temperature variation was studied and optimized in order to reach an equilibrium between the ashes fusion and the slag formation (F&amp;F).</li> </ul>	23
	<ul style="list-style-type: none"> <li>Air dilution was performed by adding fresh air to the combustion air (F&amp;F).</li> </ul>	23
Intermediate biobased products & final market	<ul style="list-style-type: none"> <li>Be aware of the fact that the beet pulp is mainly utilized as feed today for economic reasons and to avoid negative publicity (SU).</li> </ul>	33
	<ul style="list-style-type: none"> <li>Minimizing the difficulties with the chaff by handling it in containers (GR).</li> </ul>	33
	<ul style="list-style-type: none"> <li>The necessity to create a market with added value for the biochar (GR).</li> </ul>	34
Non-technical aspects of establishing an IBLC	<ul style="list-style-type: none"> <li>Avoid investing in a plant without having an available heat sink (GR).</li> </ul>	41
	<ul style="list-style-type: none"> <li>In order to overcome the reluctance of farmers, a really good solution would be an intense information campaign to promote social acceptance before the year of the investment (OOG).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Ensure that all actors involved in the chain would benefit and therefore are inclined to participate (OOS).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Implement models such as collaborative innovation ensuring success and shorten time to market access (OOS).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Ensure that all actors involved in the chain would benefit and therefore are inclined to participate (WI).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Implement models such as collaborative innovation ensuring success and shorten time to market access (WI).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Starting a dialog about the production of succinic acid (SA) and polybutylene succinate (PBS) as a steppingstone for a potential future SA network (SU).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Develop alliances between the local authorities and the agricultural sector and try to overcome the common belief that considers biomass burning in open fires on field the easy way to treat prunings (OOG)</li> </ul>	42

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Table 7: The recommendations of the case studies (step numbers refer to the generic step-by-step approach in Chapter 5).

Case study recommendations		
Topic	Results	Step number
Feedstock supply	<ul style="list-style-type: none"> <li>Nothing mentioned about this in case studies.</li> </ul>	-
Logistics	<ul style="list-style-type: none"> <li>Nothing mentioned about this in case studies.</li> </ul>	-
IBLC design	<ul style="list-style-type: none"> <li>Starting from producing biobased succinic acid (SA) through the biotechnological fermentation of refined sugars or starch from cultivated crops (e.g. corn) could be the way to start the production and then move forward towards utilizing both C5 and C6 sugar as in the case with beet fibres (SU).</li> </ul>	24
Intermediate biobased products & final market	<ul style="list-style-type: none"> <li>Before the investments can be done in the IBLC/Pyrolysis equipment a secure (increasing) market for the biochar has to be identified (GR).</li> </ul>	34
	<ul style="list-style-type: none"> <li>A biochar production that is focused on both energy and material recycling of local biomass resources is a sustainable way forward, for both the customers, the region and the environment (GR).</li> </ul>	34
Non-technical aspects of establishing an IBLC	<ul style="list-style-type: none"> <li>Once the biofuel fabrication process is implemented and optimized, promoting this business line is proposed as one of the major opportunities (F&amp;F).</li> </ul>	41
	<ul style="list-style-type: none"> <li>The developed boiler model could be implemented at different companies owned by the cooperative (F&amp;F).</li> </ul>	41
	<ul style="list-style-type: none"> <li>Seek innovative business models so that all agents generate profits (OOS &amp; WI).</li> </ul>	41
	<ul style="list-style-type: none"> <li>Obtain active collaboration of farmers and cooperatives (OOG).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Search for formulas to bring together agents from very different sectors (OOS &amp; WI).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Overcome conservative thinking (OOS &amp; WI).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Actors' in the value chain need to be willing and have the capacity to act and collaborate if the case study is going to be realised (SU).</li> </ul>	42
	<ul style="list-style-type: none"> <li>Support from administration is needed through regulative or incentive aspects so farmers will not burn the prunings (OOG).</li> </ul>	43
	<ul style="list-style-type: none"> <li>There is a need for policies, norms, and values in society that support the development of the IBLC (SU).</li> </ul>	43
	<ul style="list-style-type: none"> <li>Establishing an IBLC is potentially promising but more research and development is necessary (SU).</li> </ul>	44
	<ul style="list-style-type: none"> <li>It is important to be able to combine technological development, access to raw materials, manufacturing capacity and, of course, international trade (OOS &amp; WI).</li> </ul>	45
	<ul style="list-style-type: none"> <li>Emissions caused by indirect Land Use Change (iLUC) should be added to mirror long-term sustainability issues caused by increased production of agricultural crops (SU).</li> </ul>	45

F&F = Feed & Fodder; OOG = Olive Oil Greece; OOS = Olive Oil Spain; WI = Wine; GR = Grain; SU = Sugar

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## 5 A GENERIC APPROACH FOR IBLC STRATEGY DEVELOPMENT

### 5.1 Introduction

Establishing an IBLC can be approached from several points of view: i) farmers: how can an extra income be obtained by improving the residues/non-food biomass management, ii) policy makers: what measures are needed to reach several goals such as CO<sub>2</sub>-targets, regional development, etc. and iii) companies: how can resources and idle periods be optimized to increase the profitability of the agro-industry?

In this report the third point of view (without ignoring the other two) was adopted. The starting-point are existing companies that see a possible business strategy for synergies in terms of unexploited facilities, equipment and staff capabilities. They want to achieve this by diversifying their regular activities both on the input (food and biomass feedstock) and output (food, biocommodities & intermediate biobased feedstocks) side. Consequently, they want to investigate a possible transformation towards an IBLC.

In the AGROinLOG report '*Updated conceptual description of an Integrated Biomass Logistics Centre (IBLC)*'<sup>8</sup>, it was stated that different subtypes within the IBLC concept may develop, depending on which factor will serve as a catalyst in a specific setting (or market) environment. Therefore, four IBLC subtypes were identified:


- Input driven concepts: availability of biomass residues / materials is leading
- Process driven concepts: availability of (idle) processing, storage and personnel capacity is leading
- Output driven concepts: market demand for biocommodities / new products is leading
- Combined concepts: multiple drivers are leading

Combining the point of view on how to approach an IBLC is combined and the different subtypes an IBLC concept may develop leads to Table 8.

Table 8: Point of view related to IBLC subtypes.

Point of view related to IBLC subtypes		
	Point of view	IBLC Subtype
Farmer	How to obtain extra income by improving the residues/non-food biomass management	Input drive concept
Company	How can resources and idle periods be optimized to increase the profitability of the agro-industry	Process driven concept
Policy maker	What measures are needed to reach several goals such as CO <sub>2</sub> -targets, regional development, etc.	Output driven concept

<sup>8</sup> AGROinLOG, 2017. Updated conceptual description of an Integrated Biomass Logistics Centre (IBLC). AGROinLOG project, Deliverable D6.1, 59 pp.

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Focus in this Chapter will be on the implementation of an IBLC subtype ‘Process driven concepts’ from a company’s point of view.

## 5.2 The generic step-by-step approach

As mentioned before, focus in this report will be on the implementation of an IBLC subtype ‘Process driven concepts’. The future IBLC is taken at the center of the design. The implementation process of an IBLC can be long and does not always go optimally. With each step, a technically and economically feasible project can be delayed or even rejected. Therefore, in the AGROinLOG project we propose a step-by-step approach to maximize the likelihood of acceptance and implementation of an IBLC.

A previous report<sup>9</sup> of the AGROinLOG project contains a ‘*Schematic position of an IBLC in the value chain*’. In Table 9 the generic strategies (aimed at ‘types’ of issues when designing an IBLC) are ‘mapped’ according to this original scheme (shown at the top of Table 9). For example, the amount of available biomass, the quality of the biomass and the ‘distance’ of the sourcing area are related to the first ‘column’ (left side) of Table 9. This scheme places the IBLC in a ‘central position’, and therefore it visualizes that this step-by-step approach selects the point of view of the companies who want to use their idle time. Furthermore, specific pathways can be attached to the scheme. This guides the developer in a logical way to approach the different ‘issues to address’.

Based on different sources of information the step-by-step- generic approach was developed:


- *Reports of WP6* - First of all, the description of the characteristics of an IBLC was used from ‘Updated conceptual description of an Integrated Biomass Logistics Centre (IBLC)’<sup>10</sup>. Then, detailed information about the sectors from ‘Basic analysis of targeted agricultural sectors’<sup>11</sup> was used. And finally, the generic strategies also depend on the opportunities that were specified in the report ‘Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration’<sup>12</sup>.
- *Three IBLC demos* - The information in the business model descriptions of the three demos (WP2) are also used as input to determine the generic approach were these demos have a different set-up;

<sup>9</sup> AGROinLOG, 2017. Updated conceptual description of an Integrated Biomass Logistics Centre (IBLC). AGROinLOG project, Deliverable D6.1, 59 pp.

<sup>10</sup> Annevelink, E., B. van Gogh, F. Sebastián Nogués, S. Espatolero, T. De la Cruz, D. Luzzini, M. Karampinis, M. Kougioumtzis & J. Olsson, 2017. Conceptual description of an integrated biomass logistics centre (IBLC). In: Proceedings of the 25th European Biomass Conference and Exhibition, 12-15 June 2016, Stockholm, Sweden, 200-203.

<sup>11</sup> AGROinLOG, 2018. Basic analysis of targeted agricultural sectors - Cover report and six Annex country reports. AGROinLOG project, Deliverable D6.2, 520 pp.

<sup>12</sup> AGROinLOG, 2019. Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration. AGROinLOG project, Deliverable D6.3, 115 pp.

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- *Sector case studies* - The structure of the common data template is designed to reflect the topics that are important in the generic strategy. The two different sections 'recommendations' and 'lessons learned' are important parts of the sector case studies that were summarized in Chapter 3;
- *Literature* – This can be e.g. on the ECP project ([www.ecp-biomass.eu](http://www.ecp-biomass.eu)) where a stepwise approach was formulated to establish a so-called energy conversion park ([www.ecp-biomass.eu/node/176](http://www.ecp-biomass.eu/node/176)) but also on other literature that was already studied in previous tasks.

## 5.3 From a generic step-by-step approach to generic strategies

This step-by-step approach to maximize the likelihood of acceptance and implementation of an IBLC is thus constructed in such a way that all relevant aspects are reviewed. Therefore, it is a guide to ensure companies that these relevant aspects are brought to the minimum attention during the process towards the possible development of an IBLC. However, the approach does not indicate a mandatory 'route' to follow. In other words, there is not necessarily a mandatory sequentially. To stipulate the latter, the approach described in the following section was visualized.

An important question is how to visualize the steps in a way that shows their logic connections and interactions without a mandatory sequentially. Figure 8 is a schematic representation of the step-by-step approach. It is meant to give inspiration to a developer of an IBLC. There is not a predefined sequence of the topics that need to be dealt with when implementing an IBLC. Steps need to be taken on different topics:

- Feedstock;
- Logistics;
- IBLC;
- Intermediates / Biobased Product and Final Markets market;
- Non-technical aspects of establishing an IBLC.

These different aspects are represented by the varying colours of the steps in both Table 9 and Table 10 and Figure 8.

The IBLC plays a central role and probably acts like the 'starting point' of the approach because of the premises of the process driven concepts from a company's point of view. However, this is certainly not the starting point or condition for the generic step-by-step approach. When developing towards an IBLC, a company must consider from every technical and non-technical aspect which critical components deserve attention. This is indicated in the figure by placing these aspects 'centrally' and showing what these crucial components are. For example, a company can start with the non-technical aspects and from there 'treat' the relevant parts. In short, the 'white areas' are the starting points from which, for instance a company, starts asking the right questions. The method is intended to help avoiding missing the parts that are important for the success of the transition into an IBLC.


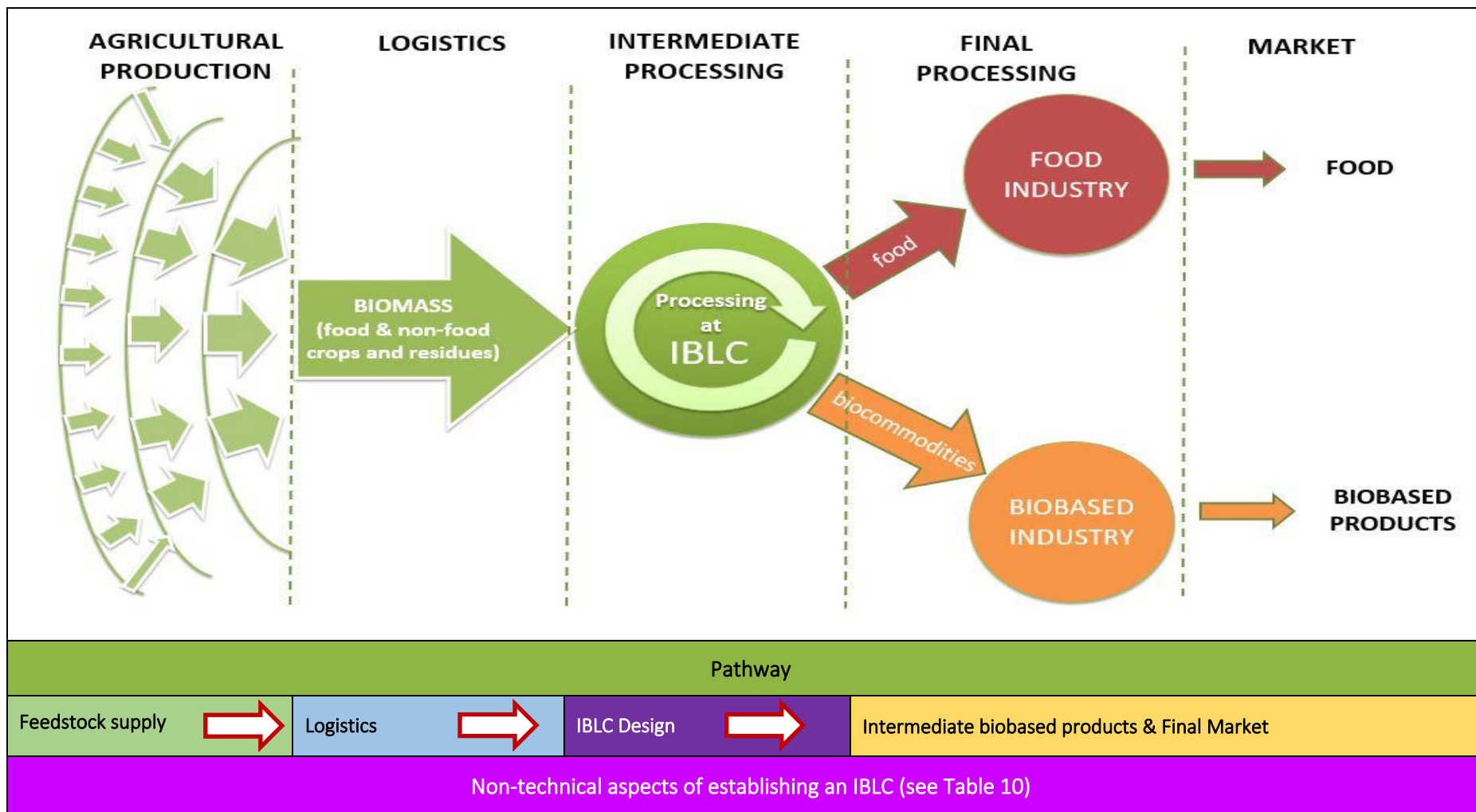





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Table 9: Generic strategies mapped according to the position of the IBLC in the value chain.







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Feedstock supply 	Logistics 	IBLC Design 	Intermediate biobased products & Final Market
<p>1. <b>Assess and estimate the theoretical potential of the biomass:</b> overall maximum amount of terrestrial biomass which can be considered theoretically available</p> <p>a) Map seasonality of availability of biomass resources</p> <p>b) Review location of available biomass resources</p>	<p>11. <b>Consider the whole logistics chain:</b> the whole logistic chain has to be planned, thought through and, assessed from the field to the IBLC and from the IBLC to the final agro-industrial processing plant and / or final market</p>	<p>21. <b>Assess the available resources and the idle time:</b> determine the unexploited facilities (including storage), equipment and staff and taking seasonality into account ("How much idle time is theoretically available?")</p>	<p>31. <b>Determine the most interesting product-process-market-combination:</b> based on a techno-economic assessment; the result is which combination is most promising towards implementation based on market potential</p>
<p>2. <b>Assess and estimate the technical potential of the biomass:</b> fraction of the theoretical potential which is available with the current technological possibilities. Such as:</p> <p>a) harvesting techniques, infrastructure and accessibility, processing techniques</p>	<p>12. <b>Diversify suppliers of an IBLC</b> to guarantee the supply with competitive prices and to ensure the continuous working mode of the logistics chain</p>	<p>22. <b>Conduct a technical assessment of the facility and equipment:</b> determine what are the technical possibilities for processing the available biomass</p>	<p>32. <b>Base the business concept on the real tested properties of the biomass used:</b> properties and quality of the raw material will define the market of the final product and its price</p>

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Feedstock supply 	Logistics 	IBLC Design 	Intermediate biobased products & Final Market
<p>3. <b>Assess and estimate the economic potential of the biomass:</b> share of the technical potential which meets criteria of economic profitability:</p> <ul style="list-style-type: none"> <li>a) Look for opportunities to reduce biomass harvesting and collection costs</li> <li>b) Look for biomass that can be used for large scale supplies to reduce cost of raw material <ul style="list-style-type: none"> <li>i) Look for residues without competitive uses</li> </ul> </li> </ul>	<p>13. <b>Optimize the transportation chain:</b> make as much use of existing transportation capacity that is already used by the different stakeholders in the new value chain</p>	<p>23. <b>Determine the maturity of the existing technology:</b> for processing a new feedstock use mainly proven technology in order to be able to start on the short term and lower risk. Difficulties linked to processing technology include:</p> <ul style="list-style-type: none"> <li>- lack of knowledge on processing new types of feedstocks;</li> <li>- investments in additional equipment for processing (or for harvesting or transport);</li> <li>- compatibility issues when processing food and non-food feedstocks or</li> <li>- the difficulties to meet biomass end-product compatibility /quality requirements.</li> </ul>	<p>33. <b>Competitiveness:</b> be assured that agricultural biomass is competitive and can be mobilized on a large scale. Consider:</p> <ul style="list-style-type: none"> <li>a) Markets / customers' needs</li> <li>b) Quality requirements</li> <li>c) Competitors</li> </ul>

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Feedstock supply 	Logistics 	IBLC Design 	Intermediates biobased products & Final Market
4. <b>Assess the biomass quality:</b> analyze the quality of the raw materials and make an estimate of the necessary and requested quality by the final market; in order to define required pre-treatments and most efficient technologies to obtain it	14. <b>Storage at field:</b> look for storage options at the field to lower cost and to flatten supply	24. <b>Use existing capacity:</b> use existing processing equipment and storage facilities (“What can be used when transforming into an IBLC?”)	34. <b>Thoroughly assess the market potential:</b> <ul style="list-style-type: none"> <li>a) get good insight in the competitiveness in the local / regional / national / international market and possible volumes <ul style="list-style-type: none"> <li>i. a strong regional demand for specific biobased products is, obviously, an advantage for an IBLC. Bioenergy and biofuels will be more competitive with a local distribution. Biocommodities with a higher added value, may even have a market at national or international level</li> </ul> </li> <li>b) Gain insight in potential volumes and focus on possibilities to mobilize at large scale</li> </ul>
	15. <b>Align harvesting and logistics planning:</b> plan and optimize the harvesting and logistics e.g. the dependence and influence of the weather during harvesting period		35. <b>Conduct a cost analysis and determine the minimum selling price:</b> raw material cost + pre-treatment & operations cost + personnel cost + investment (depreciation) + minimum profit desired by the cooperative



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Table 10: Non-technical aspects of establishing an IBLC.

Non-technical aspects of establishing an IBLC	
41. <b>Economic:</b>	<ul style="list-style-type: none"> <li>a. Also gain insight in the contribution to the local economy and <b>policy incentives</b>.</li> <li>b. An <b>investor</b> will <b>need</b> a clear picture of the financial commitment required and the payback time.</li> </ul>
42. <b>Social acceptance:</b>	Increasing sustainability awareness improves the overall social acceptance of alternative products produced in an IBLCs. Unfortunately, IBLC development may also face rooted farming practices that prevent the use of residues or the reluctance of farmers to change “business as usual”. It will be convenient to give insight in environmental preservation via soil preservation and air pollution.
43. <b>Regulations:</b>	Current regulation sometimes hinders the use of agricultural by-products and residues. Changes are expected as the EU gears towards a stronger Circular Economy, however, presently this causes uncertainty.
44. <b>Local Stakeholder involvement:</b>	<p>Local communities can be affected by the operation of an IBLC. Even a small on-farm scheme can affect the neighbors. Hence, consultation of local stakeholders in advance, even if very informal, is recommended. Look for synergies with public sector and respond to societal challenges.</p> <ul style="list-style-type: none"> <li>a. Creating <b>local support</b>: local stakeholders are consulted to obtain more support. For example, local authorities and industry are contacted to inform them of the ideas on the one hand and, on the other hand, to consider their interest and possible collaboration schemes.</li> <li>b. Further consideration needs to be given to the <b>communication</b> plan to involve the local stakeholders</li> </ul>
45. <b>Sustainable implementation potential:</b>	<p>The sustainable implementation potential is not a potential on its own, but rather the result of integrating environmental, economic and social sustainability criteria in biomass resource assessments. Focus on the fraction of the economic potential that can be implemented within a certain time frame and under concrete socio-political framework conditions, including:</p> <ul style="list-style-type: none"> <li>a. <b>Policy interventions</b>, and</li> <li>b. <b>Economic, institutional and social constraints</b>.</li> </ul>

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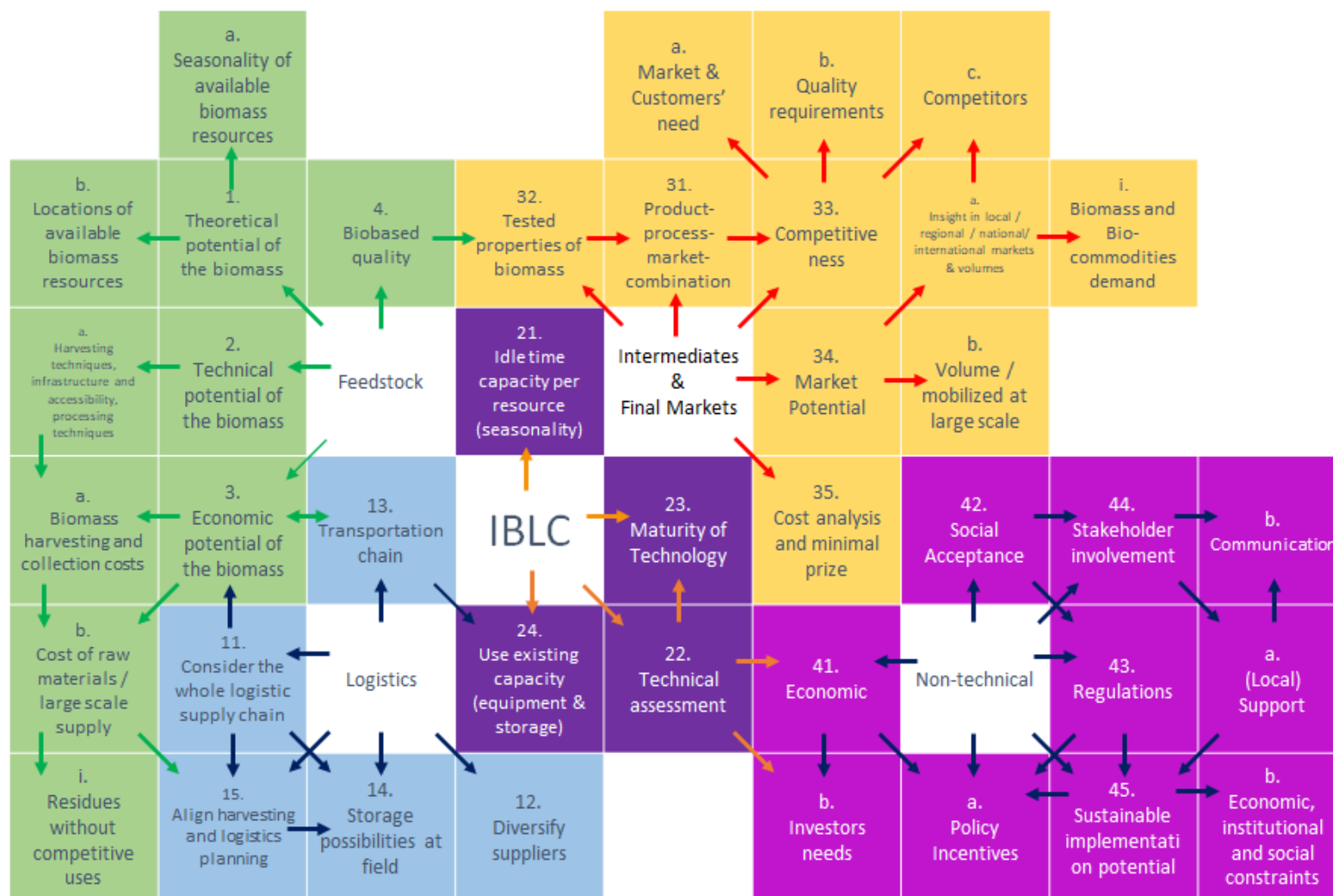



Figure 8: Scheme step-by-step approach.

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## 6 THE MIP CASE STUDIES

### 6.1 Introduction


A mixed integer programming (MIP) model was built by WFBR to derive relevant insights in the economic aspects of establishing a new IBLC and / or expanding an existing IBLC. These economic aspects are related to the technical aspects of an IBLC pathway, namely feedstocks, logistics, the IBLC design (resources and capacity), intermediate biobased products and final market. Two hypothetical case studies were chosen to be further evaluated using this MIP model: a case related to the feed & fodder sector and a case related to the olive oil sector. Both cases were defined with the information from the related demo cases of the AGROinLOG project as a starting point. However, for modelling and demonstration purposes, the cases were made more generic. The parameters with the largest influence on the results were varied in a scenario analysis. The results and conclusions of the scenario analysis give insight in the economic aspects of establishing an IBLC.

### 6.2 Description of the MIP model

The IBLC optimization model is built with the Mixed Integer Programming (MIP) technique which deals simultaneously with both continuous and integer decision variables. It is a decision support tool that can jointly optimize the profit of food and biomass supply chains with an IBLC subject to a set of realistic constraints such as the availability of raw food and raw biomass products, the storage and machinery capacities, market demands, etc. It also takes into account both the logistics of the value chain and the inner-plant process aspects within an IBLC to derive the optimal logistic and processing plans. A schematic overview of the MIP model is presented in Figure 9.

Starting with **feedstock sourcing**, multiple farms can be modelled with multiple feedstocks which are categorized as raw food and raw biomass products. Those feedstocks are available within different harvesting periods. In each harvesting period, for each farm, the model decides the quantities of feedstocks in both types that are stored on the farm or moved to the IBLC. The total availability of the feedstocks is different from one to another within certain sourcing radiuses in kilometers of the IBLC. The farm gate price of each feedstock (i.e. the raw material price) is defined as the price of the feedstock excluding the on-farm storage costs and excluding the transportation costs from the farm to the IBLC. Those two types of cost are defined separately. The weight decay of the feedstocks on farms due to degradation is also considered by the model.

The **transportation costs of the feedstock** (i.e. costs for raw material transport from the farm to the IBLC) depend on the volume of the feedstock, the transport distances from the farm to the IBLC and the unit transport costs per cubic meter per kilometer. The bulk density of the feedstock is used to convert the mass of the feedstock to the equivalent volume.

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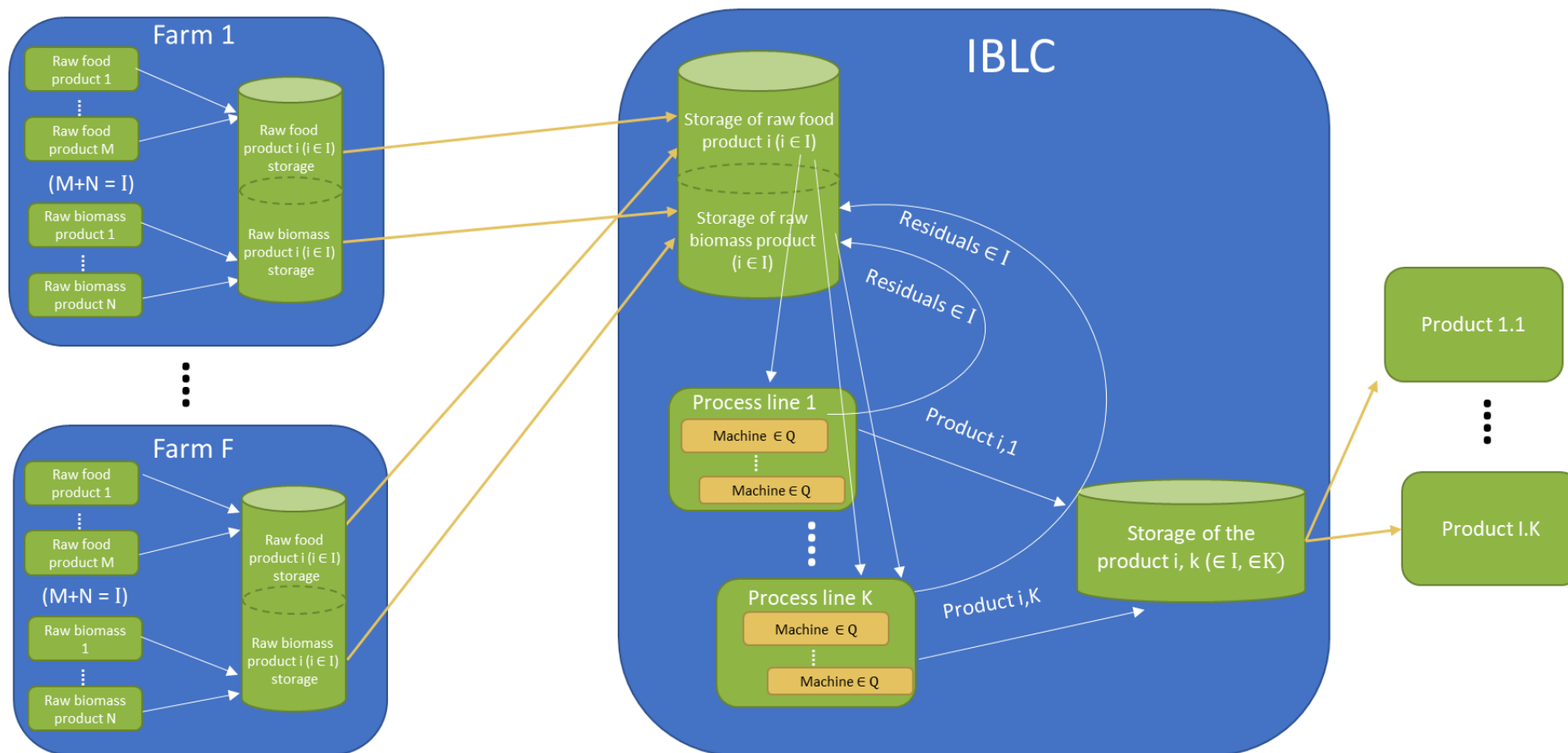



Figure 9: The schematic overview of the MIP model for IBLC optimization.

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After transporting the feedstocks to the IBLC, the model can decide either to **process** them fully in the same period when they arrive, or to move them fully into the **storage** of the IBLC, or a combination of the both. To process a feedstock, a certain processing line with multiple types of machineries is used. Each of the machines has a fixed processing capacity per period. When the capacity of the machine is a limiting factor for processing the feedstocks, the model allows the IBLC to purchase an extra machine (= an investment). The required investment costs are annualized considering a depreciation period of 10 years and no interest.

Another type of cost that is associated with the processing line is the variable processing costs. These costs depend on the throughput of the feedstocks in that specific processing line. The MIP model allows co-processing multiple feedstocks in one machine at the same time. If this is the case, the current version of the MIP model is not able to include switching costs and cleaning costs. This restriction was accepted, because in the two cases studies at hand, these costs turned out to be marginal compared to other costs<sup>13</sup>. Finally, a conversion factor is applied for each processed feedstock in each machine line to account for the processing losses of the raw food or the raw biobased product. With respect to the storage costs in the IBLC, the fixed storage costs per period are incurred based on the cubic meters that are used for storing the feedstocks and the processed products. When the storage capacity is a limiting factor, it is possible for the IBLC to obtain extra new fixed storage capacity (cubic meters) at defined annual costs. Both for the feedstocks and the processed products in the storage of the IBLC, a decay factor per time period can be defined.

The selling price of the products are assumed to include the outbound transportation costs (from the IBLC to the buyer). These product transport costs depend similarly to the inbound transportation costs (from the farm to the IBLC) on the volume, transport distance, and transport costs per cubic meter per kilometer.

The MIP model takes into consideration all the aforementioned aspects and calculates the optimal solution (i.e. the highest profit) for the combined food and biobased supply chains subject to the following constraints:


- demand constraints for the processed products;
- feedstock availability constraints;
- machine capacity constraints;
- storage capacity constraints.

The outputs of the model based on the optimal solution provide the insights in terms of:

- total costs of different types (e.g. transportation costs, processing costs);
- storage plans for the feedstocks and processed products on farms and in the IBLC;
- processing schedule of the IBLC;
- utilization rate of the machines in IBLC;
- utilization rate of the storage capacity of IBLC;
- investment plans for extra machinery and storage capacity in the IBLC.

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<sup>13</sup> However, another version of the MIP model is available for future cases studies, in which switching costs and cleaning costs can be handled if they are relevant.

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## 6.3 Results feed & fodder sector MIP case study

### 6.3.1 Model Parameters

The MIP case study of the feed & fodder sector was based on data provided by CIRCE from the APS demo case. However for modelling and demonstration purposes, the evaluated MIP case was made more generic by adding data from other sources and by estimating certain values that were not available. The goal of this MIP case study was not to exactly model the APS demo, but to design a more general example of an IBLC in the feed & fodder sector, that can be implemented in an imaginary new situation. A description of the used input data is given in Annex H. Based on this data simplified process lines are defined in Table 11.


*Table 11: Three simplified process lines feed & fodder MIP cases study.*

Simplified process lines				
Process line	Description process line	Process line equipment	Distance of feedstock to IBLC (km)	Feedstock availability
1	Lucerne bulk is processed into lucerne feed bales	dryer – cooler 1 – baler	10 - 30	April to November
2	Lucerne bales are processed into lucerne feed pellets	grinder – mill – pelletizer – cooler 2.	10 - 100	April to November
3	Wheat straw (60 %) and wood chips (40 %) are processed into energy pellets	wood grinder – dryer – hopper – grinder – mill – pelletizer – cooler 2	100	July and August

Remark: the data below in the text is what we assumed in the MIP case study:

- Process line 2. The lucerne bales usually have a lower quality compared to lucerne bulk.
- Process line 3. The composition of wheat straw and wood chips is chosen based on the ash content and related to the quality of the energy pellets. The wood chips are processed in a wood grinder, dryer, and hopper before they are mixed with grinded wheat straw and enter the pelletizing process. The wheat straw is available close (within 30 km) to the IBLC in July and August. The wood chips are assumed to be available the whole year, but the transport distance is further than 100 km. Both raw materials are assumed to be available in abundance. Therefore, the mixture is assumed to be available from July to August at a distance of 100 km from the IBLC.

The selling prices of the products (per tonne wet weight, including product transport to the buyer) are assumed to be 225 €/tonne for the lucerne feed bales, 180 €/tonne for the lucerne feed pellets, and 143 €/tonne for the energy pellets. The production costs are allocated to raw material costs (excluding transport), raw material (RM) transport, processing costs, costs for obtaining extra equipment, and product transport to the buyer. An overview of the various costs and the potential profit are given in Figure 10. The costs are expressed in euro per tonne product, which means that the processing yield (loss of raw material) is incorporated in the costs. Note that this overview is based on the input parameters of the MIP model, which means an average

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raw material transport distance is used and the costs for extra equipment are excluded. These aspects are taken into account in the scenario analysis of the MIP model (Section 6.3.3).

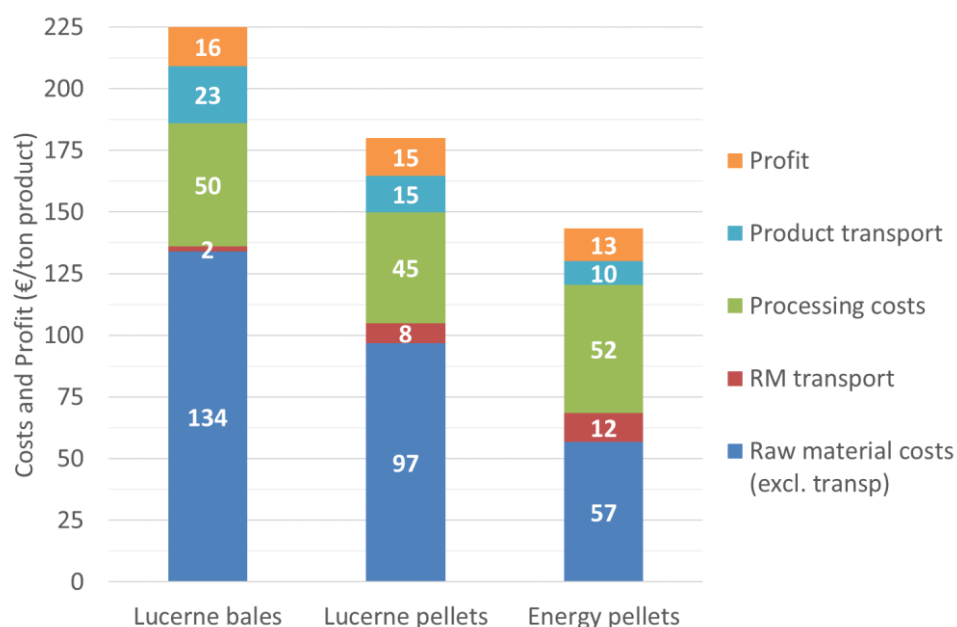


Figure 10: Various costs and potential profit for each of the three products (using the average raw material transport distance, excluding costs for extra equipment).


It is shown that for all three products the raw material costs and processing costs dominate the production costs. Because of the small raw material transport distances, the raw material transport has only a small contribution to the production costs. The raw material transport costs are highest for the energy pellets, because of larger distances. Based on the general assumptions, slightly less profit can be made on the energy pellets (13 €/tonne) compared to the lucerne feed pellets (15 €/tonne) and lucerne feed bales (16 €/tonne).

## 6.3.2 Scenarios

For the analysis, different scenarios were defined. For all scenarios the MIP model calculates the situation in which the profit is optimized. The analyzed scenarios are given in Table 12. A simplified overview of the current scenario and the baseline scenario is given in Figure 11. Table 12

Table 12: Scenarios in the feed & fodder MIP cases study.

Scenarios	
Scenario	Description
Current situation	Only lucerne is processed into feed bales or feed pellets
Baseline	Compared to the 'Current situation Scenario' also wheat straw and wood chips can be processed into energy pellets
Variations on baseline	Compared to the 'Baseline Scenario': <ul style="list-style-type: none"> <li>○ Lucerne availability +/- 50 %</li> <li>○ Raw material costs of wheat straw and wood chips +/- 25 %</li> <li>○ Processing costs of all products +/- 25 %</li> <li>○ Energy pellet selling price +/- 25 %</li> </ul>

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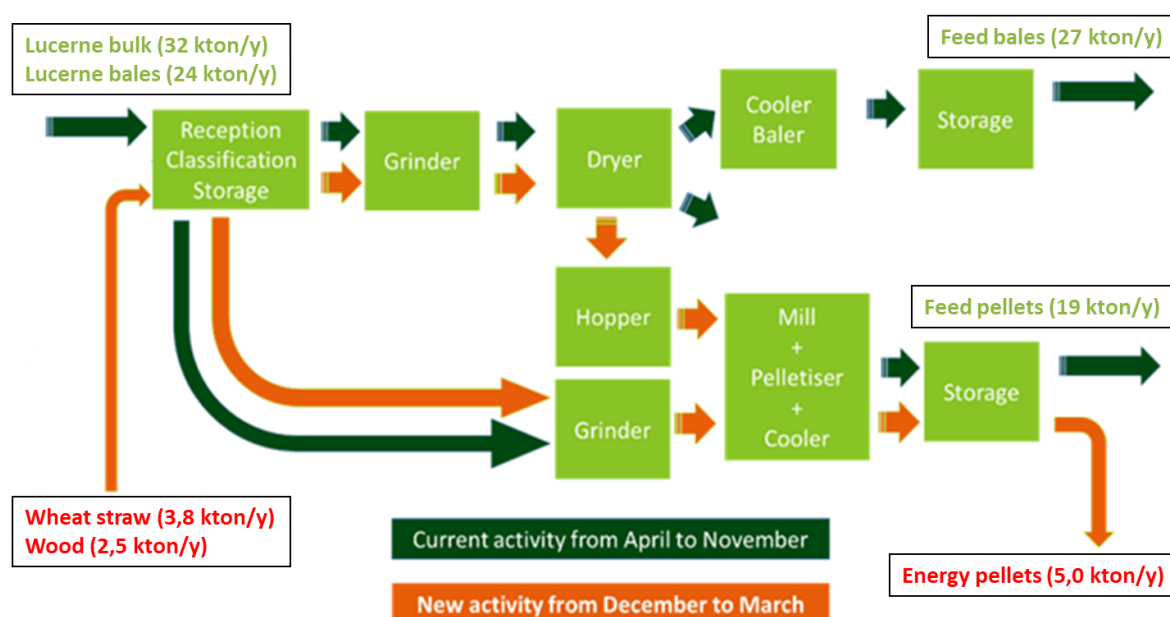


Figure 11: Equipment usage and production of the current and baseline scenario.


For the current scenario, the equipment is set to full capacity for the production of the lucerne feed products. In the MIP model, the option is given to double the capacity of the equipment by making extra investments. The investment costs are annualized by distributing the investment costs over 10 years. Costs related to maintenance, labor, and overhead for extra equipment are assumed to be already included in the processing costs.

Storage capacity at the IBLC, for raw materials and products combined, can be extended to a maximum of 17 ktonne per month. The decay during the storage of raw material is set to 1 % per month. In all scenarios, the costs related to cleaning, product changeover, and storage capacity are negligible, because in this specific case study these costs turned out to be marginal compared to other costs.

### 6.3.3 Scenario analysis

The annually produced products with the highest profit for the different scenarios are shown in Figure 12. The monthly produced products of the first six scenarios are shown in Figure 13. The scenarios with a +/- 25 % variation on raw material costs, processing costs, and energy pellet selling price compared to the baseline have the same monthly production, and therefore only the results of the +/- 25 % variation on raw material costs are shown. The annual costs and profit of the different scenarios are shown in Figure 14. The total costs, revenues, profit and margin are shown in Table 13.

The figures and table on produced products and costs and profit of the different scenarios are discussed after Table 13. A detailed comparison of the current and baseline scenario is given in Annex I.

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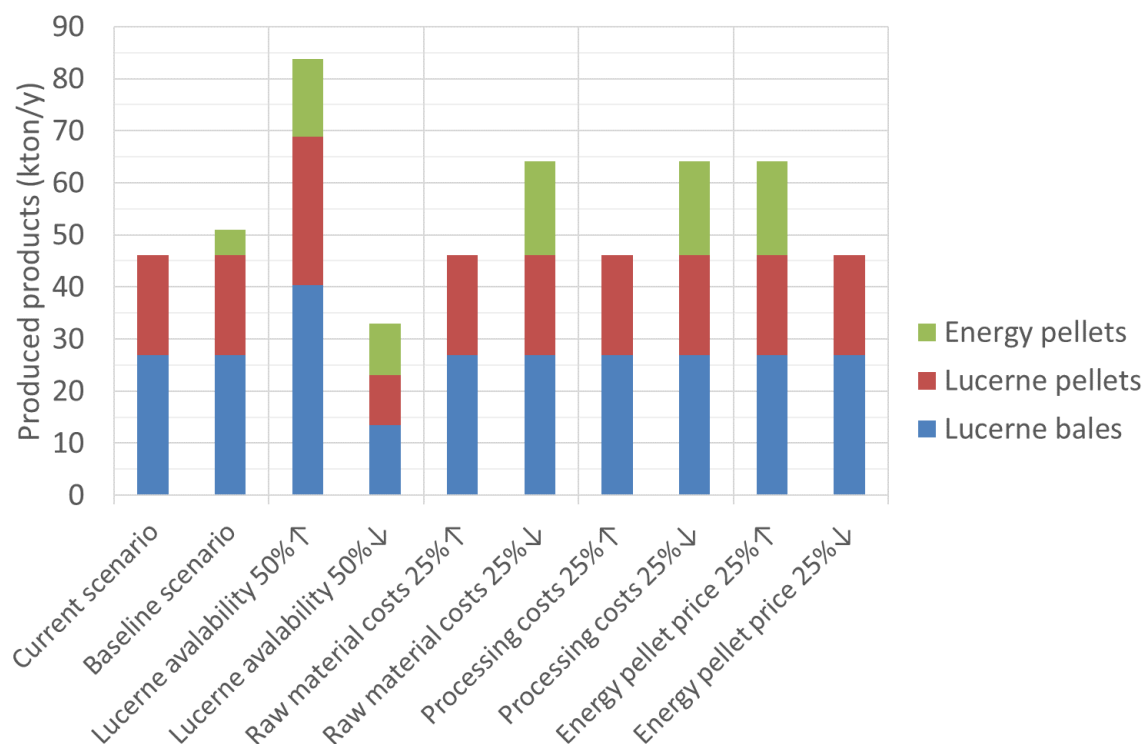


Figure 12: Annually produced products for the different scenarios.

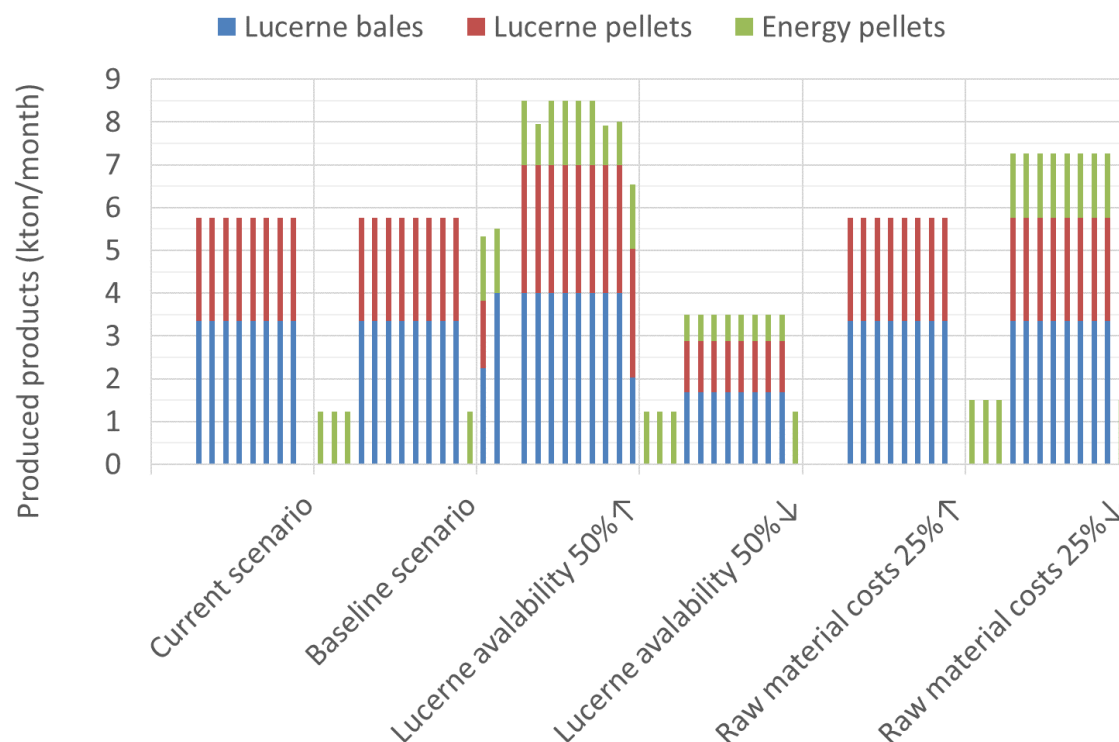


Figure 13: Produced products per month for the different scenarios

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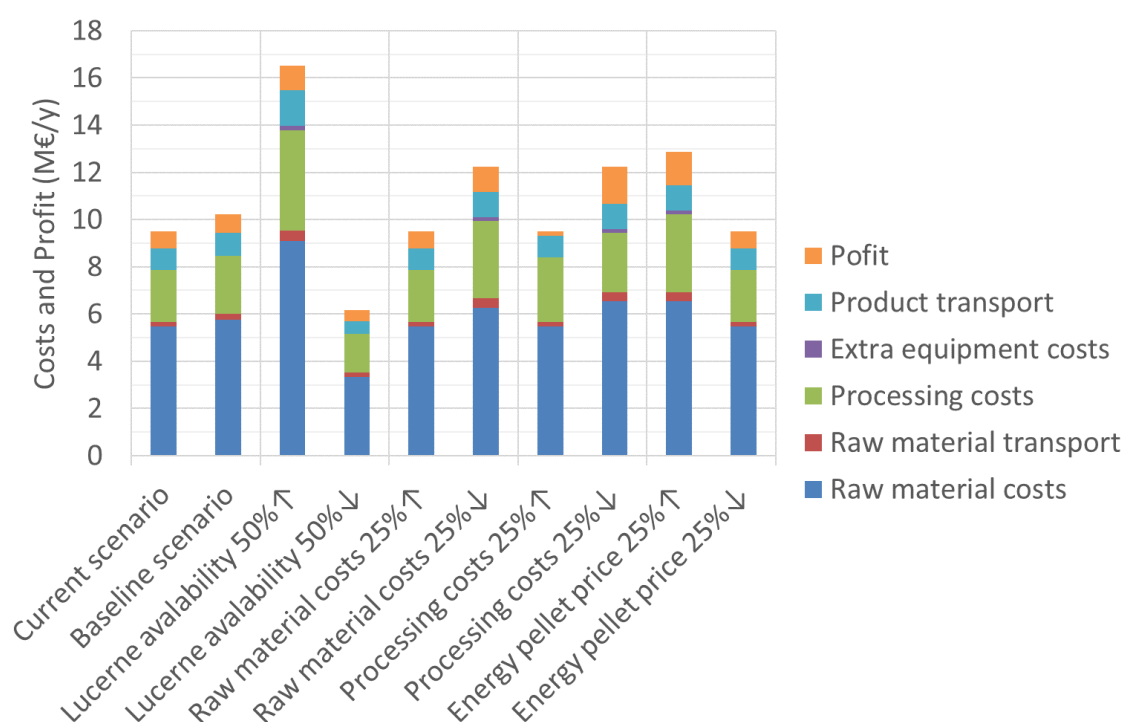


Figure 14: Annual costs and profit for different scenarios.


Table 13: Costs, revenue, profit, and margin.

Costs, revenue, profit, and margin										
	Current scenario	Base-line	Lucerne availability		Raw material costs		Processing costs		Energy pellet price	
			50%↑	50%↓	25%↑	25%↓	25%↑	25%↓	25%↑	25%↓
Extra equip.?	no	no	yes	no	no	yes	no	yes	yes	no
Costs	8.8	9.4	15.3	5.7	8.8	11.0	9.3	10.5	11.3	8.8
Revenue	9.5	10.2	16.3	6.2	9.5	12.1	9.5	12.1	12.7	9.5
Profit	0.7	0.8	1.1	0.5	0.7	1.0	0.2	1.6	1.4	0.7
Margin	7.8 %	7.7 %	6.4 %	7.7 %	7.8 %	8.7 %	2.0 %	12.9 %	11.2 %	7.8 %

In the **current scenario**, the lucerne bulk and lucerne bales are processed in the months in which they are available. All lucerne that is available is processed. During these months, the equipment is running at full capacity. The calculated profit is 0.7 M€/year which results in a margin of 7.8 %.

In the **baseline scenario**, the idle time of the processing of the lucerne products is used to produce energy pellets. In this scenario it is not profitable to invest in extra equipment. The calculated profit increases only 0.1 M€/y and the margin decreases slightly to 7.7 %.

When **lucerne availability increases** with 50 %, it is profitable to invest in extra equipment. Not only more lucerne but also more energy pellets can be produced in the (extra) idle time of the lucerne

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processing equipment. In this scenario, the raw materials are stockpiled and processed in the months that they are not available. In the optimized scenario the storage reaches its maximum and therefore there is no production in March. The calculated profit increases significantly with 0.4 M€/y to a total of 1.1 M€/year. The margin decreases to 6.4 %, because the margin on energy pellets is smaller compared to the lucerne products. When the **lucerne availability decreases** with 50 %, more energy pellets can be produced, also in the months in which lucerne is available. In this scenario, the profit decreases 0.2 M€/y to a total of 0.5 M€/year, but the margin decreases slightly to only 7.7 %.

When the **raw material costs** of wheat straw and wood chips **increase** with 25 %, it is not profitable to produce energy pellets, even not in the idle time of the production of lucerne products. This change does not affect the production of lucerne products. For the scenario of **decreasing energy pellet price** by 25 %, the same pattern is observed.

When **increasing the processing costs** for all feedstocks by 25 %, no energy pellets are produced and the profit decreases to 0.2 M€/y with a margin of just 2.0 % because the profitability for producing lucerne products also decreases.

When **raw material costs decrease** of wheat straw and wood chips or **energy pellet prices increase** with 25 %, or **processing costs decrease** 25 %, it is profitable to produce energy pellets. In these scenarios it is also profitable to invest in extra equipment. Especially in the scenarios with decreased processing costs and increased selling prices of energy pellets, the profit and margin increase significantly.


### 6.3.4 Conclusions

This MIP case study gives relevant insights in the economic aspects of establishing a new IBLC using the step-by-step approach for the different topics of the pathway. Raw material costs and processing costs dominate total costs in the suggested setup of an IBLC in the feed and fodder sector.

Feedstock supply & Logistics: Raw material transport costs have only a small contribution to the total costs in the case when the transport distance to the IBLC is smaller than 100 km. This means that the feedstock can be sourced in a relatively close distance to the IBLC (step number 1b. and 13. of the step-by-step approach in Chapter 5).

Feedstock supply & IBLC design: Being able to process different raw materials into different products, makes the IBLC less vulnerable for fluctuations in raw material availability and / or raw material prices. This will require efficient planning of the use of process lines, stockpile, and storage capacity (step number 2., 3., 21. and 24.).

IBLC design: Using the idle time of the existing lucerne processing equipment to produce energy pellets can increase the profit of the IBLC. However, because of the relatively small margin on the energy pellets, in only a few scenarios it is worthwhile investing in extra processing equipment. If raw material costs or processing costs increase, or selling prices of energy pellets decrease, then it is not profitable to produce energy pellets at all in this case study. In general it can be concluded, that taking into account the production of other products in the design of new plants or new process lines, could make the IBLC even more cost effective (step number 21. and 24.).

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IBLC design & Final markets: Designing new process lines within an existing IBLC, to take into account the production of more than one type of product in an IBLC, can make the IBLC more cost effective. However, to determine the economic feasibility of additional process lines, accurate estimates of all cost aspects, including investment costs for extra equipment, are required (step number 22., 23. and 41.).

Intermediates & Final markets: If raw material costs or processing costs increase, or selling prices of energy pellets decrease, it is not profitable to produce (low margin) energy pellets (step number 31., 34. and 35.).

## 6.4 Results olive oil sector MIP case study

### 6.4.1 Model Parameters

The MIP case study of the olive oil sector is largely based on data provided by ABEA. However, it should be emphasized that the model does not exactly represent the ABEA situation. For modelling and demonstration purposes, the case was made more generic. Processes are simplified and missing or unknown parameters are estimated based on expert knowledge. Most important parameters are varied by +/-50 % or +/-25 % in the scenario analysis. A detailed description of the used data is given in Annex J. An overview of the processes is shown in Figure 15. The processing of pomace into pomace oil and exhausted pomace (shown at the top of the Figure) is not considered in the MIP case study. To be able to utilize the idle time of the dryer, processing the exhausted pomace to solid fuel is included in the MIP case study. In contrast to the ABEA situation, in the MIP case also costs related to the prunings (i.e. collecting and burning costs for farmers or harvesting costs for the IBLC) are taken into account. In this way the MIP model calculates the most profitable situation for the farmers and IBLC combined.

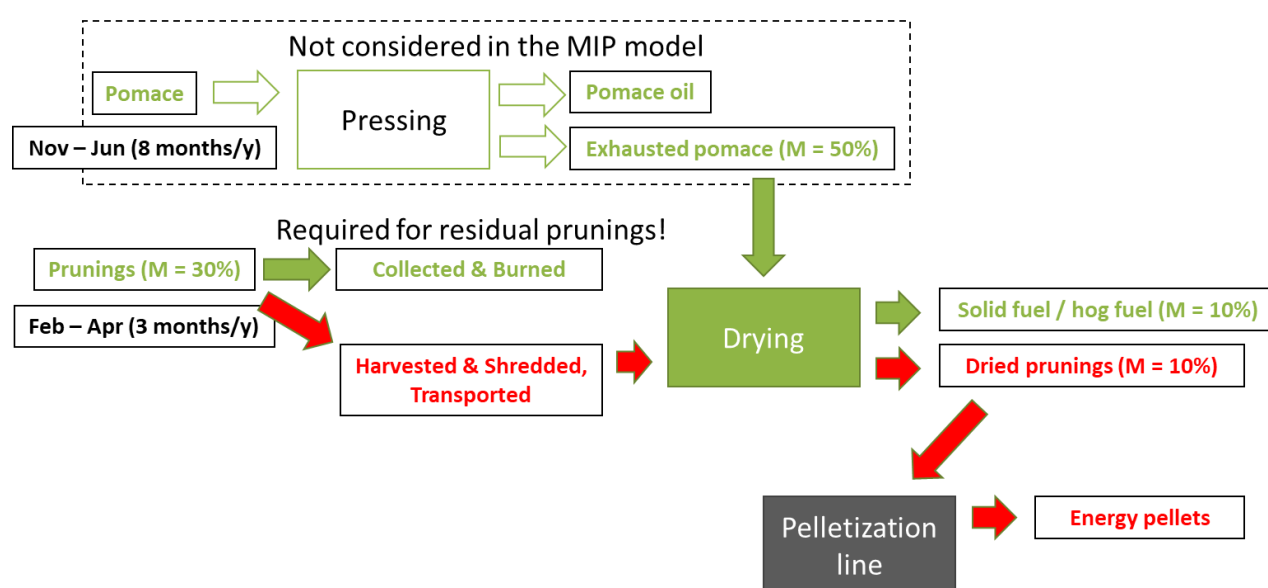



Figure 15: Processes of the olive oil MIP case study.

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The following processes are defined in the olive oil MIP case:

- Olive pomace is processed to pomace oil with exhausted pomace (exhausted olive cake) as residue. The exhausted pomace is dried and sold in the market as solid fuel. Olive pomace is available from November to June (current activity);
- Prunings are harvested from February to April, dried in the field, and burned (current activity);
- Alternatively, prunings are harvested from February to April, shredded, transported to the IBLC, stored at the IBLC, and dried in the idle time of the drying of the exhausted pomace (new IBLC activity);
- Dried prunings are pelletized to energy pellets (new IBLC activity).

The dried prunings can be stored without degradation after the drying process and therefore, it is not required to perform the drying and pelletization in the same period. Which means that the pelletization line can be running the whole year round with a relatively small capacity.

The selling prices (including transport costs of 10 €/tonne product) are assumed to be 100 €/tonne for the solid fuel (hog fuel), and 160 €/tonne for the energy pellets. An overview of the costs and profits/losses based on a raw material transport distance of maximum 10 kilometers for the prunings and without costs for extra equipment are given in Figure 16.

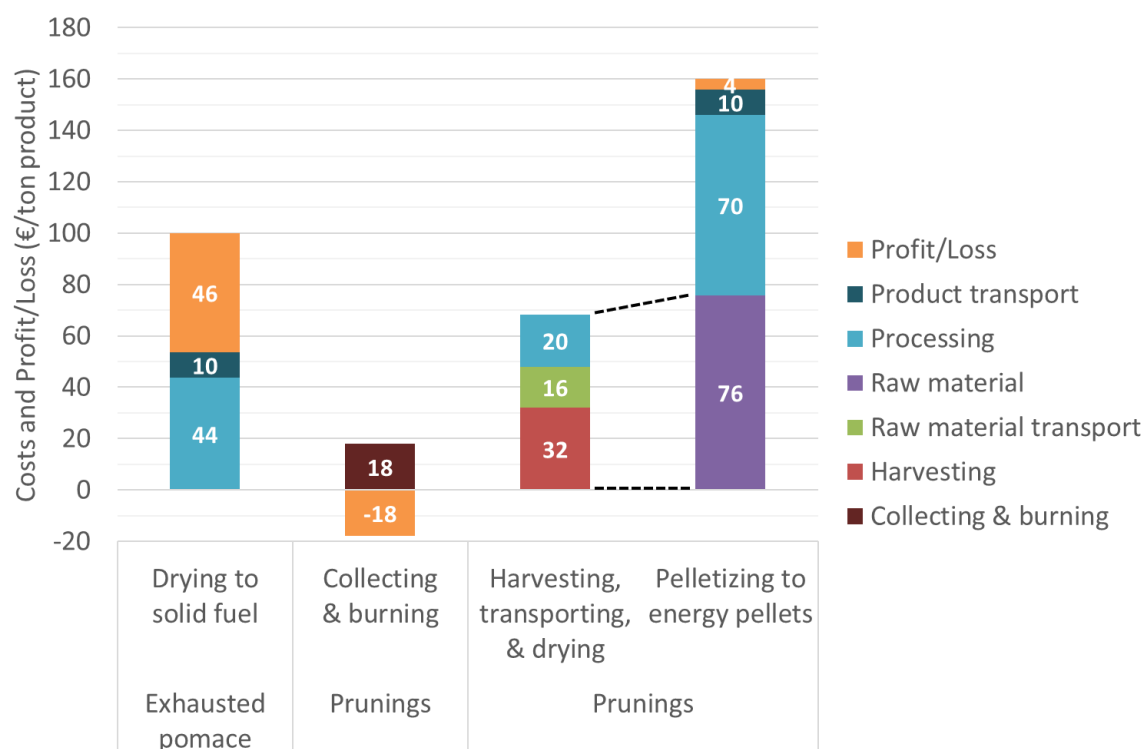



Figure 16: Costs and profit/loss for each product (using a raw material transport distance of 10 km, excluding costs for extra equipment)

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It is assumed that exhausted pomace is freely available at the pomace mill. Because the lack of raw material costs and raw material transport costs, a relatively large profit is made on the solid fuel.

As collecting and burning prunings does not result in a product with revenue, the loss is equal to the collecting and burning costs of 18 €/tonne.

The costs are expressed in euro per-tonne product, which means that the processing yields (losses of raw materials) are incorporated in the costs. This is demonstrated by the dotted lines: the harvesting, transport, and processing of the prunings costs 68 €/tonne dried prunings. The dried prunings are processed into energy pellets with a yield of 90 %. Therefore, the raw material costs (i.e. dried prunings) for the pelletizing are 76 €/tonne energy pellet.

Only a small profit is made in the processing of the prunings into energy pellets. However, processing prunings prevents the collecting and burning costs, which are currently a loss of 18 €/tonne raw materials as mentioned before.

## 6.4.2 Scenarios


For the analysis, different scenarios were defined. For all scenarios the MIP model calculates the situation in which the profit is optimized. The analyzed scenarios are described in Table 14.

*Table 14: Scenarios in the olive oil MIP case study.*

Scenarios	
Scenario	Description
Current situation	No production of energy pellets
1	Pelletization line of 1 tonne/h installed
	<ul style="list-style-type: none"> <li>○ No option to double the capacity</li> <li>○ Option to double the capacity</li> </ul>
2	Variations on scenario 1 with the option to double the capacity of the pelletization line:
	○ Pruning collection and burning costs +/-50%
	○ Harvesting costs +/-25 %
	○ Pelletization costs +/-25 %
	○ Pellet prices +/-25 %

In the MIP model the option is given to double the capacity of the pelletization line by making an extra investment. The investment costs to double the capacity to 2 tonne/hour are estimated on 300,000 €. The investment costs are annualized by distributing the investment costs over 10 years. Costs related to maintenance, labor, and overhead for extra equipment are assumed to be already included in the processing costs.

Storage capacity for raw materials, intermediate products, and products is assumed to be sufficient at the IBLC. Therefore, storage costs are negligible. The decay during the storage of the prunings in the field and at the IBLC is set to 1 % per month. In all scenarios the costs related to cleaning, product changeover are negligible.

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### 6.4.3 Scenario analysis

The annually produced products with the highest profit for the different scenarios are shown in **¡Error! No se encuentra el origen de la referencia..** The processing of the exhausted pomace to solid fuel is the same amount in all scenarios. In all scenarios the prunings are processed into energy pellets, except the scenario with a 25 % decrease in energy pellet prices. However, the amounts processed vary between the scenarios.

In a number of scenarios the amount of energy pellets is doubled, because the capacity of the pelletization line is doubled. Already with the default parameters, it is profitable to double the capacity of the pelletization line. The monthly harvested prunings for the production of energy pellets for the scenario with a pelletization line with 1 tonne/hour and 2 tonne/hour are shown in Figure 18. Prunings are only harvested from zone 1 (0-5 km) and zone 2 (5-10 km), because the capacity of the pelletization line is limiting. It should be noted that the costs to transport the prunings to the IBLC significantly increase if the transport distance is above 10 km.

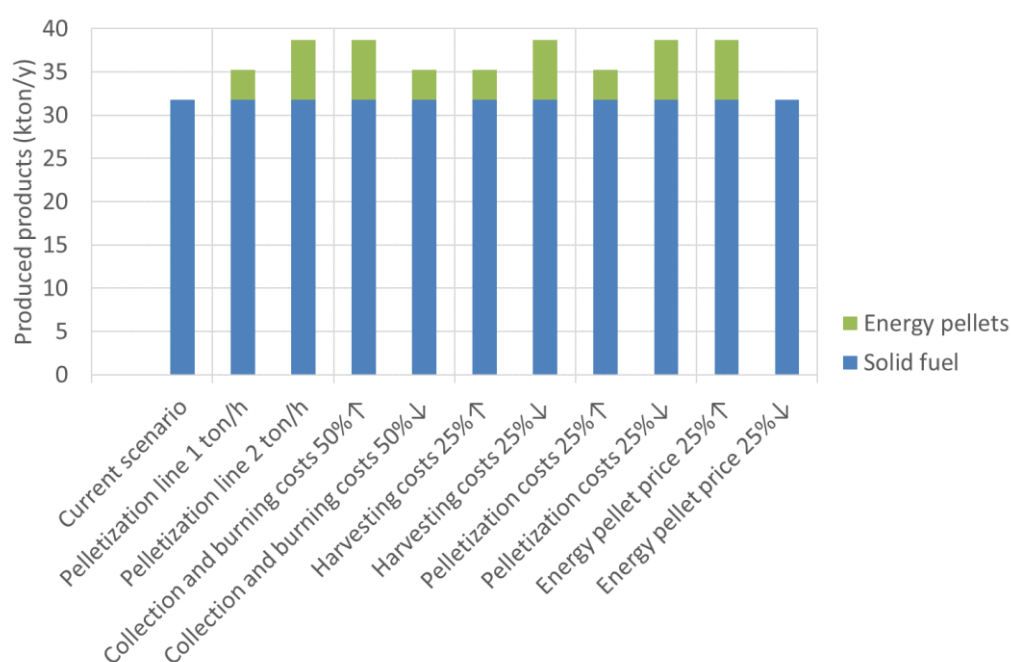



Figure 17: Annually produced products for the different scenarios.

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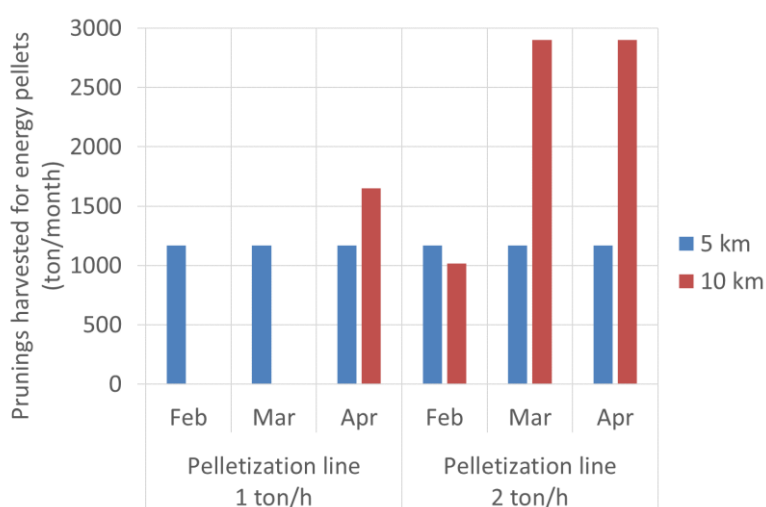


Figure 18: Monthly harvested prunings for the production of energy pellets for the scenario with a pelletization line with 1 tonne/h (left) and 2 tonne/h (right).

The annual costs and profit of the different scenarios are shown in Figure 19.

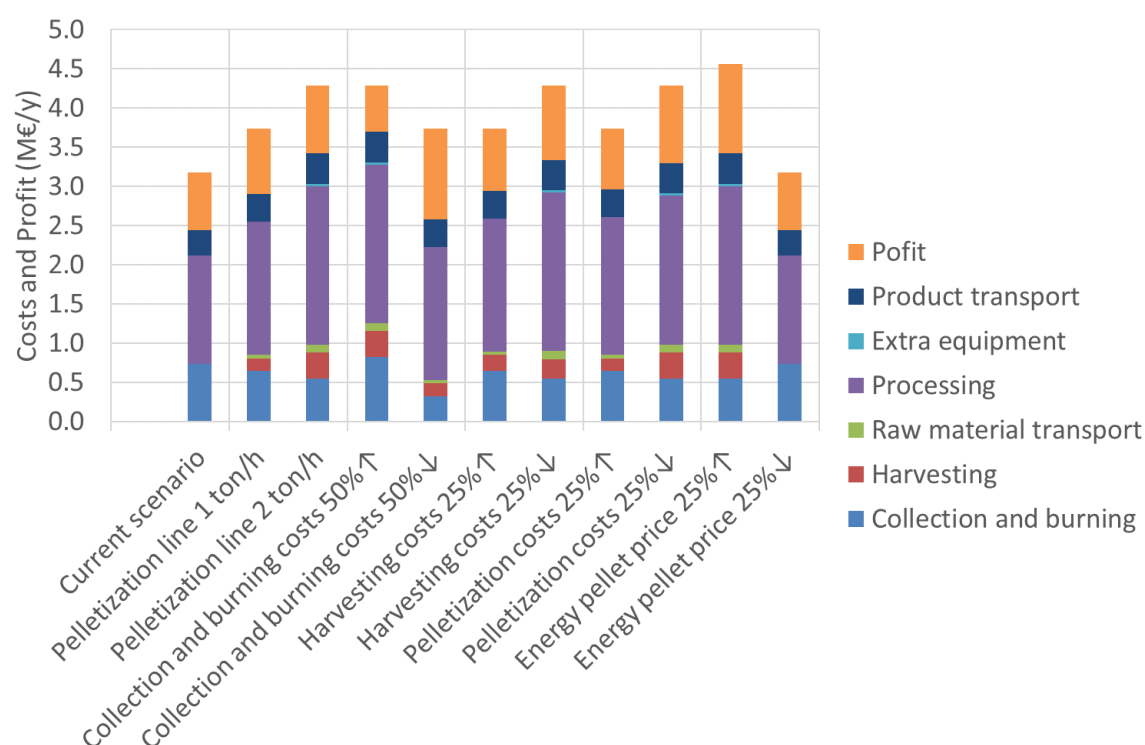


Figure 19: Annual costs and profit for different scenarios.

The total costs, revenues, profit and margin are shown in


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Table 15.


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Table 15: Costs, revenue, profit, and margin.

Costs, revenue, profit, and margin						
	Current scenario	Pelletization line		Collection and burning costs		
		1 tonne/hour	2 tonne/hour	50 %↑	50 %↓	
Extra equip.?	no	no	yes	yes	no	
Costs	2.4	2.9	3.4	3.7	2.6	
Revenue	3.2	3.7	4.3	4.3	3.7	
Profit	0.7	0.8	0.9	0.6	1.2	
Margin	23 %	22 %	20 %	14 %	31 %	
	Harvesting costs		Pelletization costs		Energy pellet price	
	25 %↑	25 %↓	25 %↑	25 %↓	25 %↑	25 %↓
Extra equip.?	no	yes	no	yes	yes	no
Costs	2.9	3.3	3.0	3.3	3.4	2.4
Revenue	3.7	4.3	3.7	4.3	4.6	3.2
Profit	0.8	0.9	0.8	1.0	1.1	0.7
Margin	21 %	22 %	21 %	23 %	25 %	23 %

In the **current scenario** exhausted pomace is processed to solid fuel. This scenario has an annual profit of 0.7 M€ and a margin of 23 %. The collection and burning costs of the prunings have a significant contribution to the total costs.

In the scenario with the **pelletization line fixed at 1 tonne/h** the profit increases to 0.8 M€. When the option to double the **pelletization line to 2 tonne/h** is taken, the profit increases to 0.9 M€.

When **collection and burning costs increase** it is more profitable to produce energy pellets. Although the capacity of the pelletization line is doubled, not all prunings can be processed. Because the collection and burning costs increase, the profit decreases to 0.6 M€. When **collection and burning costs decrease**, it is still profitable to produce energy pellets from nearby prunings. In this scenario however, it is not profitable to double the capacity of the pelletization line. Because of the large reduction of the collection and burning costs, the profit increases to 1.2 M€.


Variation in both the **harvesting costs** and **pelletization costs** result in the same production of energy pellets. If the costs decrease in both scenario's then it is profitable to double the capacity of the pelletization line. If the costs increase with 25 %, it is not profitable to double the capacity of the pelletization line, but it is still profitable to process nearby prunings.

In the scenario in which the **energy pellet price decreases** it is not profitable to process prunings. In this scenario all prunings are collected and burned.

## 6.4.4 Conclusions

This MIP case study gives relevant insights in the economic aspects of establishing an IBLC using the step-by-step approach for the different topics of the pathway.


Feedstock supply & Logistics: Savings on collection and burning of prunings makes the production of energy pellets economically attractive. Note that the collection and burning costs are for the farmer

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and the harvesting costs are for the IBLC. In the ABEA situation (Annex C.), it is suggested that the farmer should pay the IBLC 5 €/tonne to harvest the prunings. In this way, the farmers have a costs reduction 13 €/tonne prunings and the IBLC saves 5 € on harvesting costs. As the transport costs of the prunings have a significant contribution, the distance of farm to the IBLC is likely to have an influence on the compensation price of harvesting the prunings (step number 3b. and 13. of the step-by-step approach in Chapter 5).

Feedstock supply & IBLC design: In a number of scenarios the capacity of the pelletization line, although it was doubled, was still limiting. This suggests an opportunity for even further increasing the capacity of the pelletization line. This could be studied in more detail in the future (step number 3. and 24.).

Intermediates & Final markets: As the processing of prunings to energy pellets reduces the collection and burning costs, it is a profitable alternative. However, the demand for the energy pellets should be adequate, which should be checked in practice. In the ABEA situation (Annex C.) it is estimated that the maximum demand for energy pellets in the region is about 5 tonnes per year. The options to export the energy pellets outside the region and the related costs should also be investigated (step number 34a. and 35.).

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## 7 CONCLUSIONS & RECOMMENDATIONS

### 7.1 Conclusions

#### Sector case studies


The cases studies were performed in five different sectors: feed & fodder, olive oil mills (chain), wine (cellars & distilleries), grain chain and sugar. The cases studies were thoroughly analyzed in a uniform way, using a common data template so that they could be compared more easily. The lessons learned from each case study are first of all applicable for the specific sector at hand. Some examples of sector specific lessons learned (regarding successes, difficulties and solutions) and recommendations are given below:

- Feed & fodder - A competitive advantage over other producers can be obtained by saving on average 5-10 % in terms of production cost in the IBLC. These lower production costs also open new markets which were not profitable before due to market prices.
- Olive oil mills (chain) - There are opportunities for new alliances between farmers, local authorities and agro-services with the aim to optimize the IBLC business model. It should be ensured that all actors involved in the chain will benefit and therefore are inclined to participate. The wrong assumption that underutilized biomass can be obtained at no cost should be avoided.
- Wine (cellars & distilleries) - It is important to transfer scientific knowledge in collaboration with the customer to develop new products that can be supplied by the IBLC. Legislative problems and obstacles should be overcome together with government and policy makers, e.g. the issue that some by-products are considered waste by legislation.
- Grain chain - It is necessary to identify a secure market with added value when the IBLC is producing a new biobased intermediate such as biochar.
- Sugar - Actors in the value chain need to be willing and have the capacity to act and collaborate if the IBLC is going to be implemented. Also, there is a need for policies, norms, and values in society that support the development of the IBLC.

More lessons learned can be found in Chapter 3. Although these lessons learned were sector specific and defined based on a regional case input data, some of them can also be applied in other sectors, possibly with some adjustments. E.g. the new boiler technology that was developed for the feed & fodder IBLC to gain the competitive advantage, can probably also be exported to other sectors.

#### Integral analysis of the case studies

The results of the individual case studies were compared and analyzed in an integral way regarding the technical and non-technical aspects of their IBLC pathway. The lessons learned were grouped per aspect of the pathway of an IBLC (feedstock supply, logistics, IBLC design, intermediate biobased products & final market and finally non-technical aspects of establishing an IBLC). This resulted in a clustered overview of successes (Table 4), difficulties (Table 5), solutions (Table 6) and recommendations (Table 7). The lessons learned, including the sector where they were mentioned,

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were labeled with a step number of the related step in the generic step-by step approach. Most of the lessons learned appear to be in the categories ‘Intermediate biobased products & final market’ and ‘Non-technical aspects of establishing an IBLC’. Issues in these categories can probably also have a broader impact than for only the specific sector at hand. So they are indeed worthwhile to compare. Logistics are often not mentioned at all in the cases studies and feedstock supply also only has a limited number of lessons learned. Lessons learned regarding the actual IBLC design itself are often related to company or sector/region specific issues, and consequently more difficult to generalize. Therefore, in these conclusions the focus is on the categories ‘Intermediate biobased products & final market’ and ‘Non-technical aspects of establishing an IBLC’. A selection of the lessons learned and recommendations in these two categories that could apply to several sectors is described below and more detailed information can be found in Chapter 4.

*Successes* - Residues for power and heat production were an interesting business option. Achieving more competitiveness was seen as a success. This was achieved e.g. by cost savings, but also by collaboration. Factors that influenced the costs were energy savings, obtaining carbon credits, costs of feedstocks and production costs. An economic success was the increase in equipment investments in a region. Social successes were an increase of local employment opportunities, building alliances and knowledge transfer to customers. A sustainability success was the reduction of greenhouse gas and toxic gas emissions.

*Difficulties* - Difficulties occur due to competitions with alternative products, immature markets and unprofitable biobased products. Economic aspects are the significant investments that could be needed to set-up an IBLC, and the fear that it will take a long time for the IBLC to reach a mature stage. Although collaboration was mentioned as a success in some case studies it was also often mentioned as a difficulty, since the willingness and capacity to cooperate is not always there. Aligning all actors is perceived as being difficult. Rules & regulations are also given as barriers for achieving an IBLC, e.g. waste legislation. Furthermore, norms and values in society are critical for success. Public opposition can easily lead to failure.

*Solutions* - Specific handling systems were a solution to health problems. Furthermore, awareness of competing use for the feedstocks is an important point to consider and market development is necessary in some cases. An economic solution is to find (internal) customers for produced heat in the IBLC. Social acceptance can be improved by information campaigns and starting dialog with the stakeholders. Collaborative innovation and networks around the IBLC will strengthen the whole value chain and will shorten the time to market.

*Recommendations* - It is recommended to secure the market for the (intermediate) biobased product first, before investing in the IBLC. Production that is focused on both energy and material recycling of local biomass resources is considered a sustainable way forward. An economic recommendation is to promote newly developed innovative business lines in an IBLC as a business for other companies as well. Collaboration of the stakeholders in the value chain (farmers, cooperatives, agro-industry, etc.) is considered a very important social aspect of establishing an IBLC. Support from administration is needed through regulative or incentive aspects. And there is a need for policies, norms, and values in society that support the development of the IBLC. Finally, a sustainability implementation potential needs to be secured.

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## Generic step-by-step approach

The insights gathered from the different case studies, their integral analysis, and the other information from previous work in AGROinLOG and literature, made it possible to develop a step-by-step approach. Its aim is to maximize the likelihood of acceptance and implementation of an IBLC and it is constructed in such a way that all relevant aspects are reviewed. Therefore, it is a guide to ensure companies that these relevant aspects are brought to the minimum attention during the process towards the possible development of an IBLC. However, the approach does not indicate a mandatory 'route' to follow. In other words, there is not necessarily a mandatory sequentially. The steps are grouped by the pathway of a value chain containing an IBLC:

- Feedstock;
- Logistics;
- IBLC;
- Intermediates / Biobased Product and Final Markets market;
- Non-technical aspects of establishing an IBLC.


The steps within these aspects of the pathway are described in more detail in Table 9 and Table 10 and the complete generic step-by-step approach is visualized in Figure 8.

## MIP case studies

The two MIP case studies give relevant insights in the economic aspects of establishing an IBLC using the step-by-step approach for the different topics of the pathway. Although the conclusions in Chapter 6 are very case specific, some more general indications emerge for setting up an IBLC:

- Raw material costs and processing costs often dominate the total costs.
- Raw material transport costs have only a small contribution to the total costs in the case when the transport distance to the IBLC is relatively small. At larger distances the transport costs will of course increase.
- An efficient planning of the use of process lines, stockpile, and storage capacity in the IBLC is needed.
- Using the idle time of the existing processing equipment to produce biobased products, such as energy pellets, can increase the profit of the IBLC.
- To determine the economic feasibility of additional process lines, accurate estimates of all cost aspects, including investment costs for extra equipment, are required.
- The demand for the biobased product should be adequate, so market size should be checked in practice.

These indications can be taken into account when designing a new IBLC. However, they need to be verified of course for the circumstances of that specific case.

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## 7.2 Recommendations

### Generic step-by-step approach

The developed step-by-step approach has a company's point of view and is therefore process driven. This leaves the other possible points of view, i.e. that of the farmer, the buying industry and the policy makers unaddressed. For future research it could also be possible, desirable or even relevant to develop such a step-by-step approach from these aforementioned points of view. That will also shift the focus of the approach from process driven to input and / or output driven. The design, structure and purpose of this task were not pre-sorted to also address these points of view. In other words, the choice for case studies, etc. will have to be determined differently, but the chosen method makes it also possible to generate the same approach (including the visualization) based on the point of view of the farmer or the policy maker.


### MIP case studies

The general indications for setting up an IBLC always need to be verified for the specific IBLC design at hand. For this purpose the MIP model can play an important support tool.


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## ANNEX A. COMMON DATA TEMPLATE


Content	Category	Type	Level of detail	Qualitative/ Quantitative
1. General introduction case study for specific sector	Basic information	a) Size of the sector in the country/region b) Main economic activities of the sector c) Existing and newly planned production plants of the sector in the country/region d) General description of the suggested IBLC within the sector	Country, Region	Both
2. Description of the six stages of the chosen pathway	2.1 Feedstock supply	a) Types of available feedstock (e.g. agriculture, forestry, livestock, side-streams, residues, waste, etc.) b) Yearly amount of the total production per feedstock in the region (and sometimes neighbouring regions) that is not currently being used for existing industries, and that is thus available for IBLCs [tonne dry matter or tonne fresh matter combined with moisture content] c) Seasonality pattern per feedstock (in what periods will it become available e.g. harvested in September-October) d) Distribution per feedstock (specify actual locations of areas where it is produced in the region/neighbouring regions) e) Quality feedstock before it enters the IBLC (e.g. density, form, size, moisture content, ash content, etc.)	Region	Qualitative: a, c, d  Quantitative: b, e, f, g

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		<ul style="list-style-type: none"> <li>f) Unit on-farm storage costs when storage happens on the farm [€/tonne dry matter or €/m<sup>3</sup>]</li> <li>g) Price of feedstock at roadside (before transport, when sold by farmer to IBLC) [€/tonne dry matter or €/tonne fresh matter combined with moisture content]</li> </ul>		
	2.2 Logistics	<ul style="list-style-type: none"> <li>• <u>Transportation</u> <ul style="list-style-type: none"> <li>a) Transportation types used including average capacity</li> <li>b) Transportation distances (average/related to distribution of feedstock) [km]</li> <li>c) Transportation losses [%]</li> <li>d) Transportation energy/fuel consumption [MJ/km or l/km]</li> <li>e) Transportation costs [€/km]</li> </ul> </li> </ul>	Company	Qualitative: a  Quantitative: b, c, d, e
	2.3 IBLC design	<ul style="list-style-type: none"> <li>• <u>Synergy with existing machinery, storage, labour &amp; infrastructure</u> <ul style="list-style-type: none"> <li>a) Available pre-treatment &amp; handling machinery, storage facilities, labour and other infrastructure types including average capacity per period (month)</li> <li>b) Idle period of available and suitable pre-treatment &amp; handling machinery, storage facilities, labour and other infrastructure</li> <li>c) Efficiency: losses during production, storage and pre-treatments [%]</li> <li>d) Machinery energy consumption [MJ/tonne dry matter] &amp; operation rate</li> <li>e) Costs of used pre-treatment &amp; handling machinery, storage facilities, labour and other infrastructure</li> <li>f) Intermediate biobased products obtained (see 2.4)</li> </ul> </li> <li>• <u>New machinery, storage &amp; infrastructure</u></li> </ul>	Company	Qualitative: a, b, f, i, k  Quantitative: a(part), c, d, e, g, h, j

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		<ul style="list-style-type: none"> <li>g) Additional required investments for new machinery/infrastructure (CAPEX)</li> <li>h) Additional amount of (part time) personnel required</li> <li>i) Additional maintenance requirements (e.g. cleaning costs, machine resetting costs for switching between feed stocks) [€/tonne dry matter]</li> <li>j) Additional operational costs for personnel, maintenance, management [€/tonne dry matter]</li> <li>k) Current state of IBLC design (TRL, technology maturity) and future improvements foreseen (coming 5 years)</li> </ul>		
	2.4 Intermediate biobased products	<ul style="list-style-type: none"> <li>• <u>Intermediate biobased products</u> <ul style="list-style-type: none"> <li>a) Types of intermediate biobased products made at IBLC</li> <li>b) Quantities produced at IBLC per year/month [tonnes/year and tonnes/month]</li> <li>c) Quality intermediate biobased product when leaving IBLC (e.g. density, form, size, moisture content, ash content, etc.)</li> <li>d) Price of intermediate biobased products sold by IBLC to final industry [€/tonne]</li> <li>e) Industries that buy the intermediate products from the IBLC</li> </ul> </li> <li>• <u>Competing intermediate (biobased) products</u> <ul style="list-style-type: none"> <li>f) Competing alternative intermediate (biobased) product types</li> <li>g) Quality of competing alternative intermediate (biobased) products compared to intermediate biobased products from IBLC</li> <li>h) Price and market share of competing alternative intermediate (biobased) products [€/tonne]</li> </ul> </li> </ul>	Company	<p>Qualitative: a, e, f, g</p> <p>Quantitative: b, c, d, h</p>

	<b>Document:</b>	D6.4. Generic strategies for IBLC development		
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	2.5 Final market	<ul style="list-style-type: none"> <li>• <u>Final biobased products</u> <ol style="list-style-type: none"> <li>a) Types of final biobased products (that are made by another industry from the feedstock 'intermediate biobased products' delivered by the IBLC)</li> <li>b) Quality requirements needed to satisfy consumers' preferences</li> <li>c) Price of final biobased product(s) paid by consumer</li> <li>d) Stakeholders involved in the final market</li> </ol> </li> </ul>	Region, Country	Qualitative: a, b, d  Quantitative: c
	2.6 Non-technical issues	<ul style="list-style-type: none"> <li>• <u>IBLC</u> <ol style="list-style-type: none"> <li>a) Measures, incentives &amp; subsidies that could stimulate starting &amp; setting up an IBLC</li> <li>b) Environmental regulations that apply to the IBLC</li> <li>c) Social acceptance new activity at the IBLC (e.g. more trucks can cause problem due to noise)</li> </ol> </li> <li>• <u>Final biobased products</u> <ol style="list-style-type: none"> <li>d) Measures, incentives &amp; subsidies fostering the uptake of biobased products, the creation of new markets, etc.</li> <li>e) Social acceptance of the (new) final biobased products</li> </ol> </li> </ul>	Region, Country	Qualitative: all
3. Lessons learned		<ol style="list-style-type: none"> <li>a) Successes</li> <li>b) Difficulties (e.g. technical &amp; economical bottlenecks, conflicts, etc.)</li> <li>c) Solutions for problems</li> <li>d) Things to avoid</li> </ol>	Company, Region, Country	Qualitative: all
4. Recommendations for this specific sector		<ol style="list-style-type: none"> <li>a) Recommendations</li> </ol>	Sector	Qualitative: all

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## ANNEX B. DATA CASE STUDY 1. FEED & FODDER SECTOR - AGROPAL & ADDITIONAL INFORMATION FROM OTHER SOURCES - SPAIN

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### 1. General introduction case study for specific sector

#### *a) Size of the sector in the country/region*

Feed and fodder can consist of mixes of different crops such as: barley, wheat and oats, whole crop silages, peas and broad beans, maize for forage, clover and alfalfa (lucerne), among others. More specifically, in Spain, 85 % of the raw materials for dehydrated fodder industries corresponds to lucerne.

Production of animal compound feedstuff requires several raw materials in order to prepare specific formulas. In addition, animal feedstuff can also use residues and by-products from other agricultural processes.


In this context, the feedstuff production in the EU 28 (Figure 20) slightly increased by 0.4 % in 2016 to 155 million tonnes. Particularly, the average value of the industrial production of compound feedstuff in Spain reached €6,820 million and €300 million in the case of fodder plants production.

Currently, there are 70 fodder dehydrator industries and almost 1,500 feed industrial manufacturers in Spain. The total cultivated area in Spain of forage crops covered almost 1.1 million ha in 2014, presenting a feedstuff production of 23.3 million tonnes (2015) and a 1.61 million tonnes fodder production between 2016-2017.

According to the AEFA (Spanish association of dehydrated lucerne manufacturers), Spain beat historic numbers in terms of lucerne and fodder exportation throughout the financial year 2017-2018, which supposed 72 % of the total season production. Spain exports 1,127,147 tonnes of dehydrated fodder, the dehydrated lucerne being the main exported product. More than 50 % of Spain's exportations are destined to United Arab Emirates, being also Jordan, China or other European Union countries considered as important destinations.

In Spain, most animal feeding products industries are micro enterprises with 1-9 employees (around 48 %), followed by small companies with 1-49 employees (31 %) and companies with no employees (15 %). Only few of them had more than 50 employees (6 %) and none more than 500. Generally, these industries own compatible equipment with the processing of biomass (pelletizers, silos for storage, screening or chipping machinery), so as high degree of staff professionalization and many other valuable assets which are useful for the biomass processing activities (workforce, means of transport, etc.).

Unfortunately, around 94 % of feed and fodder sector Spanish industries are not expected to have economic strength and resources to implement an IBLC within their facilities. Despite this, the

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remaining 6 % seems to reunite required conditions to start new biomass related business lines. The fodder dehydrator industries have a greater size than the feed industries and thus, have better chances of becoming an IBLC.

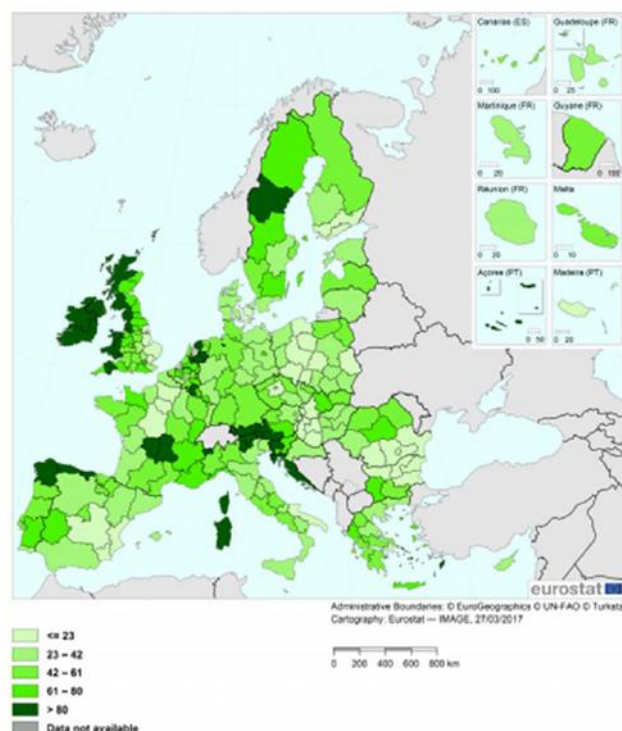


Figure 20: Feed & fodder sector map. Share of fodder area in Utilized Agricultural Area (UAA) by NUTS 2 regions for the EU-28 (Eurostat, 2017)


Food industry by-products are potential raw materials for animal feeding which inclusion could help to reduce the carbon footprint of the animal feedstuff. Feed and fodder sector industries are used to handle both raw materials and final products such as bales, pellet or other granulated format and thus, they have wide experience in the management of biomass.

The EU debate on food waste in the context of circular economy has delivered a clear recognition that the feed industry is part of the solution. The small amounts of residues from feed industries in Spain are not available for IBLC purposes since legislation obliges to remove them (CESFAC, 2017).

Fodder dehydration industries in Spain do not produce any important biomass residue, either in the agrarian or processing phase. Instead, those industries could have a relatively easy access to agrarian residues, which can be used as raw material to produce solid biomass.

Whereas feedstuff manufacturer industries in Spain keep their production ongoing during all the year (no idle period), fodder dehydrator industries in Spain have an idle period that can last from November to March/April in general. Consequently, the start-up of IBLCs in Spain would bring up employment in the region as a social benefit, also environmental benefits.

Despite the huge variations in feed material prices over the last years, the proportion of feed materials per category remained relatively stable (50 % for cereals, 27 % for oilseed meals) (FEFAC,

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2017). In the case of animal feed industries in Spain, the lack of idle period joined to the small size that features them constitute significant barriers that must be overcome for implementing an IBLC.

#### *b) Main economic activities of the sector*

Main economic activities of the sector concern the use of fodders destined to animal feeding, highlighting the following:

- Dehydrated lucerne in the form of bales;
- Dehydrated common vetch in the form of bales;
- Pure lucerne in the form of loose material.

Other activities such as animal feeding blending, sunflower and corn drying, seed selection and certified seed processing are relevant in the sector.

#### *c) Existing and newly planned production plants of the sector in the country/region*

Existing production plants of the sector in Spain are shown in Figure 21. Fodder dehydrator industries are mostly agglomerated in the north-west of Spain (Aragón, Navarra, Cataluña, etc.), the 85 % of the dehydrated fodder being manufactured in the Valle del Ebro area. It should be noted that, according to Eurostat agency (March 2018), the Spanish region Castilla y León harvested more barley than any other region in the EU and had the second highest level of harvested production for common wheat and spelt (Eurostat, 2017).

Meanwhile, feedstuff industries have a wider spread distribution all over the country, with a higher concentration of animal feed manufacturers in Catalonia (16 %), followed by Andalucía (15.3 %), Castilla y León (15 %) and Castilla-La Mancha (near 11 %).

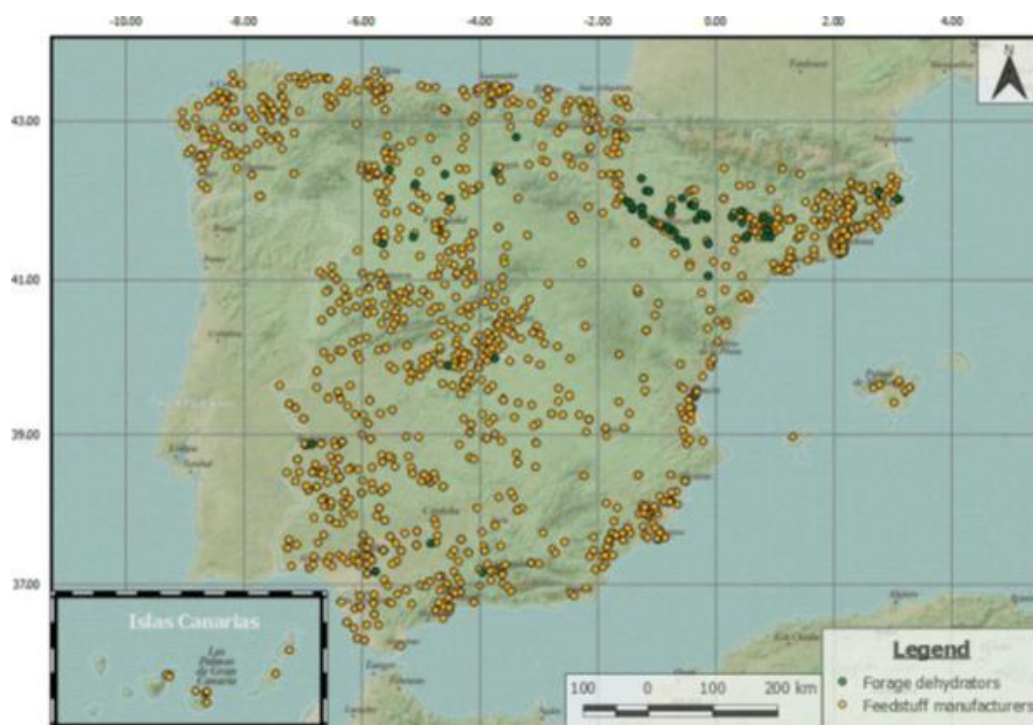



Figure 21: Location of Spanish feed and fodder sector industries. Source: (Spanish Coops (elaborated from SILUM and AEFA with 2017 data), 2017)

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As for the newly planned production plants, no related information is known to this effect.

*d) General description of the suggested IBLC within the sector*

Use of the surplus fodder to produce pellets, which are further employed in a cheese factory (Quesos Cerrato Soc. Coop.; Figure 22) and a dehydration industry owned by AGROPAL S.C., in order to produce thermal energy for the dehydration process, achieving thus an energetic self-consumption.



Figure 22: Quesos Cerrato Soc. Coop. Source: (Spanish Co-ops, 2017)

## 2. Description of the six stages of the chosen pathway

### 2.1 Feedstock supply

*a) Types of available feedstock (e.g. agriculture, forestry, livestock, side-streams, residues, waste, etc.)*


The agricultural cooperative AGROPAL S.C. (Figure 23) has access to significant amounts of herbal waste, particularly cereal straw, but also corn stalk and sunflower, which are originated in the cooperative members' parcels.


*b) Yearly amount of the total production per feedstock in the region (and sometimes neighbouring regions) that is not currently being used for existing industries, and that is thus available for IBLCs [tonne dry matter or tonne fresh matter combined with moisture content]*

AGROPAL S.C. collects around 300,000 tonnes/year of straw. The cooperative members have the right to collect a percentage of this amount. This way, around 100,000 tonnes/year are available for the cooperative and, from it, only 4,000 tonnes/year are intended to solid biofuel production, the rest of it being intended to animal care and feeding (Sancho, 2018). This low amount is related to the special requirements for straw pellets boilers, which make necessary the development of specific boilers.



Figure 23: AGROPAL S.C. Source: (Spanish Co-ops, 2017)

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## 2.2 Logistics

### Transportation

#### *a) Transportation types used, including average capacity*

Transport system varies depending on the factory type. In the case of the agricultural factories of Villoldo and Astudillo, the internal transport is performed by diesel pallet truck (type A diesel) between the production area and the warehouse. Different types of specific transportation are also used, such as buckets, worm screws and conveyor belts. In addition, articulated lorries equipped with open or closed platform are employed to perform the transport of the straw to the warehouse and the pelleting plant.

As for the cheese factory (Quesos Cerrato Soc. Coop.) in Baltanás, which accounts with a storage capacity of 40 tonnes, the internal transport of the raw material is performed by conveyor belts and wheelbarrows, around 50 vehicles per year. Diesel pallet trucks (type B diesel) are also employed to transport the final product to the cold stores and expedition room. However, this transport cost is residual.

#### *b) Transportation distances (average/related to distribution of feedstock) [km]*

The average distance between the crop field and the intermediate warehouse is around 15 km. This distance increases up to 70 km between the warehouses and the pelleting plant, being a very variable value.

#### *c) Transportation losses [%]*


No significant transportation losses are reported. However, there are storage losses, around 3 % of the material due to the break of packages. This can be increased in winter, if the material is stocked outside, up to 15 % because of the rain (AGRONEWS CASTILLA Y LEÓN).

#### *d) Transportation energy/fuel consumption [MJ/km or l/km]*

No data available.

#### *e) Transportation costs [€/km]*

According to an interview performed to experts from the sector contacted, the transportation costs are usually calculated considering an average value of distance (150-200 km) and a cost of 1 €/km. The costs can be distributed as shown in the following picture (Figure 25), considering an average selling price of 42 €/tonne, including transport to the IBLC in a radius of 20 km.

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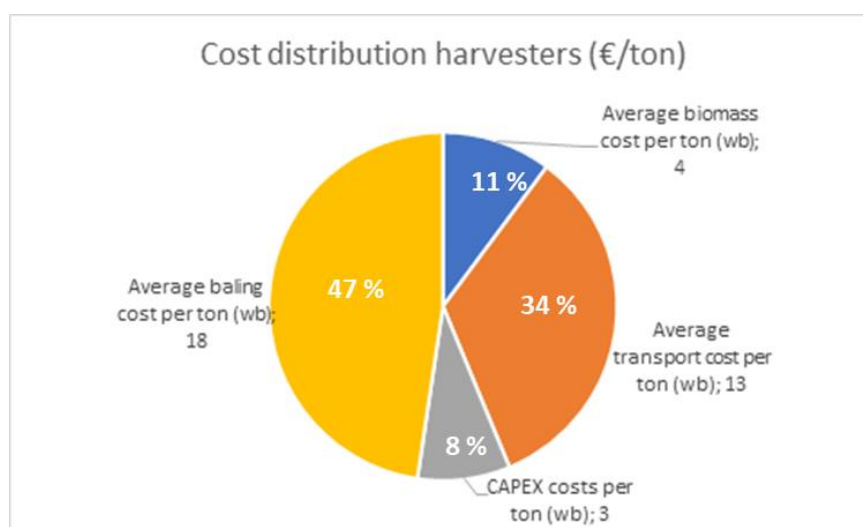


Figure 25: Cost distribution for straw harvesting according to the harvesters' interviews in Spain.

## 2.3 IBLC design

### Synergy with existing machinery, storage, labour & infrastructure


#### d) Machinery energy consumption [MJ/tonne dry matter] & operation rate

Due to GNPD, it is not possible to detail AGROPAL specific values of energy consumption. However, they were involved in a H2020 European Project (SCOoPE project), Grant Agreement N° 695985), in which general energy consumptions of this sector were included in a public report (Table 16 and

Table 17).

Table 16: Average energy consumptions distribution of the stages in a fodder dehydration line 20,000 tons of wet raw material processed. Source: (SCOoPE project), Grant Agreement N° 695985)

Average energy consumptions of the stages in a fodder dehydration line	
Stages of fodder dehydration	Energy consumption ratio (%)
<b>Electricity</b>	
Reception and handling	8.60
Dehydration, electric power	2.90
Grinding	0.40
Fodder mixing	0.20
Granulation-pelletizing	3.60
Pellet cooling	0.20
Baling	1.00
Lighting	0.20
Compressed air	1.30
<b>Total electric power</b>	<b>18.40</b>
<b>Gas</b>	
Dehydration, thermal power	81.6

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**Total thermal power**

**81.60**

Table 17: Average energy consumptions distribution of the stages in a cheese factory (Source: SCOOpe project (H2020, Grant Agreement N° 695985).


Average energy consumptions distribution of the stages in a cheese factory. Source: (SCOOPE project)	
Stages of cheese line	Energy consumption ratio (%)
<b>Electricity</b>	
Milk reception	0.10
Sanitation	0.04
Previous thermal treatment	0.20
Isothermal storage	0.04
Thermal treatment, pasteurizer	0.20
Curding vat	0.38
Total pressing and molding	1.40
Whey and ingredients storage	4.04
Salting treatment	5.49
Airing	2.41
Maduration	11.72
Washing – brushing - painting	0.04
Cutting	0.02
Packaging and labelling	0.11
Final product storage	6.73
Cleaning and disinfection	0.08
Lighting	5.98
Air conditioning	17.58
<b>Total electric power</b>	<b>56.56</b>
<b>Gas (thermal energy)</b>	
Previous thermal treatment	11.97
Thermal treatment, pasteurizer	14.27
Curding	2.06
Cleaning and disinfection	14.46
Mold washing	0.68
<b>Total thermal power</b>	<b>43.44</b>

f) Intermediate biobased products obtained (see 2.4)

Solid biofuels (straw pellets).

New machinery, storage & infrastructure

g) Additional required investments for new machinery/infrastructure (CAPEX)

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Two objectives were set for the infrastructure (Figure 26): firstly, the development of a heating boiler for one of the fodder dehydration factories, owned by the cooperative. Secondly, the development of a steam production boiler for the cheese factory in Baltanás. Both installations are currently operating successfully.



Figure 26: AGROPAL boiler from SUGIMAT Efficient Energy Solutions. Source: (Ripoll, 2018)

The innovations were applied in two well differentiated areas and, therefore, two different investments (Sancho, 2018) (Curiel, 2015):

- Fodder dehydration line. This process requires hot air to remove the moisture surplus from the collected fodder, in order to process them in granule form or in high density and pressure bales form. This would allow a suitable transport without increasing the transportation costs and its consequences on the price. The investment reached € 500,000.
- Steam line in the cheese factory. Steam at 8-10 bar of pressure is required for the pasteurisation processes of milk, cheese curd and cheese whey, as well as the equipment and machinery cleaning. The investment reached € 470,000 and, according to the manufacturer, the depreciation period of the equipment would be 6 years, considering a boiler service life of 25 years.

Both installations funding is included in the CLIMA projects programme (Sancho, 2018) a national funding call which promotes the development of projects with the aim to reduce de greenhouse gases production, fostered by the Spanish Ministry of Ecologic Transition and Demographic Challenge from the Spanish Government.

#### *h) Additional amount of (part time) personnel required*

The regular maintenance service is also in charge of the boilers' maintenance, which implies a total of 2 hours of work per each work shift, so no additional personnel is required in this case.

## **2.4 Intermediate biobased products**

### Intermediate biobased products

#### *a) Types of intermediate biobased products made at IBLC*

Solid biofuels (straw pellets) (Figure 27).


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Figure 27: AGROPAL straw pellets. Source: (Spanish Co-ops, 2017).

*b) Quantities produced at IBLC per year/month [tonnes/year and tonnes/month]*

Around 700 tonnes/year of straw pellets are produced currently, which allow the supply up to 60 % of the required thermal energy for the cheese factory. Further steps are focused on achieving values around 75-80 % (Sancho, 2018).

*c) Quality intermediate biobased product when leaving IBLC (e.g. density, form, size, moisture content, ash content, etc.)*

No product leaves the IBLC due to self-consumption.

*d) Price of intermediate biobased products sold by IBLC to final industry [€/tonne]*

All the product is self-consumed by the manufacture industry. For the moment, there are not secondary industries which buy it.

*e) Industries that buy the intermediate products from the IBLC*

All the product is self-consumed by the manufacture industry. For the moment, there are not secondary industries which buy it.

## 2.5 Final market

### Final biobased products


None. Self-consumption IBLC.

## 2.6 Non-technical issues

### IBLC

*a) Measures, incentives & subsidies that could stimulate starting & setting up an IBLC*

In Spain, it is impossible to leave the straw surplus on the field, because of the dry and cold weather, which hinders the material decomposition during the autumn and winter season. Years ago, this surplus was removed by a controlled burning of the straw, but nowadays there are legal restrictions related to this aspect due to environmental concerns (Royal Decree-Law 11/2005 from Spanish Government). In addition, the derived cost related to the alternative management of the straw, make necessary the development of different processes to remove the production waste when a

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surplus is produced. In this context, the energetic valorisation of straw is presented as an interesting strategy to approach this objective.

Own and public funding have made possible this project. Public funding support from different Spanish institutions: on the one hand, the CDTI (acronym of Centre for Industrial Technological Development, from the Spanish Ministry of Economy, Industry and Competitiveness), through the project “Development of new biofuels of densified biomass”; on the other hand, the Regional Community of Castilla y León supported the investment related to the cheese factory “Quesos Cerrato” through the rural development programme 2014-2020, co-funded by FEADER-CEE funds. In addition, as mentioned before, the fodder dehydration line and the steam line in the cheese factory were funded by the CLIMA projects programme.

#### *b) Environmental regulations that apply to the IBLC*

The main environmental regulations which apply to the IBLC project are:

- (European Directive (UE) 2015/1513 of the European Parliament and Council), where Directive 98/70/CE is modified, related to the gasoline and gasoil quality, and the Directive 2009/28/CE, related to the promotion of the use of energy, arising from renewable energies.
- (Royal Decree-Law 11/2005 from Spanish Government), concerning the stubble and pruning burning where urgent actions are approved in terms of forest fires.
- (Royal Decree 56/2016), related to energetic efficiency in terms of energetic audit, service providers certification and energetic auditors, and the promotion of energy supply efficiency.

#### Final biobased products


None. Self-consumption IBLC.

### **3. Lessons learned**

#### *a) Successes*

Several goals were achieved concerning this innovation:

- Greater competitive advantage over other producers. Fuels’ energetic costs, employed for the products transformation were reduced around 45-55 %, mainly related to fodders and animal feeding produced from dehydrated fodders and cheese (Spanish Co-ops, 2017). This would imply an average savings around 5-10 % in terms of production costs, which include raw materials, increasing thus the profitability of the process (Spanish Co-ops, 2017). Additionally, new market lines were opened, which were not profitable before due to market prices.
- Development of a new line due to the sale of carbon credits. The previously mentioned CLIMA projects program allowed the substitution of old equipment by the new ones in Villoldo and Baltanás’ factories. AGROPAL signed a purchase-sale contract of verified emissions reductions of greenhouse gases with the previous Spanish Ministry of Agriculture, Food and Environment (MAGRAMA), currently called Spanish Ministry of Ecologic from the

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Spanish Government. The Spanish MAGRAMA bought from AGROPAL through FES-CO<sub>2</sub> fund (Spanish carbon fund for a sustainable economy) 6,239 tonnes of CO<sub>2</sub> verified reductions (AGRONEWS CASTILLA Y LEÓN), (AGROPAL S.C., 2015).

- The valorisation of agricultural by-product (cereal straw surplus, mainly wheat and barley), which usually implies an additional cost for the producers (AGROPAL members). Considering the great limitations in terms of stubble and pruning burning, even prohibition, the development of alternatives to its transformation towards an environmental-friendly and cheap fuel is a need, more than a challenge.
- An increase of the local qualified employment opportunities, so as in all the supply chain and biofuel consumption.
- An increase of the equipment investment in the region in the agricultural sector. The purchase of the new combustion equipment by AGROPAL had a “call effect”, consequently other fodder dehydration and production industries dared to invest in biomass equipment, using the same fuel or ligneous fuel (wood pellets, wood chips, almond shells, pine cones of pine trees, grape waste, olive stones, among others).
- Energetic savings and a decrease of the fossil fuels use, as well as an independence of fossil fuels market, according to the goals of Horizon 2020 program. Natural gas savings varies between 20-70 %, depending on the straw price (Spanish Co-ops, 2017).

*b) Difficulties (e.g. technical & economical bottlenecks, conflicts, etc.)*

Some of the main barriers found during the project development were:

- Production irregularity, due to weather circumstances. Drought periods are common in the region and, then, the cereal straw can be scarce. Consequently, the prices could limit the project profitability.
- Technical difficulties and costs related to straw densification. Its high fibre composition (cellulose, hemicellulose and lignin) and the high mineral amount, silica and other alkaline oxides, make this a very abrasive material, which requires specific settings for the milling and granulating process. In these processes, the energetic consumption and the wearing parts are greater than expected, reaching much higher values compared to the green fodder pelleting process, where AGROPAL has already previous experience.
- Technical difficulties related to the combustion process. The chemical composition of the cereal straw is different to other biomass, presenting a high level of chlorine, sulphur, volatile matter and minerals. For this reason, the combustion of this biomass has special features:
  - High flammability capability.
  - Sintering: volatile matter is placed on the thermal exchange surfaces and boiler pipes.
  - Scorification: formation of solid material by alkaline oxides fusion at temperatures higher than 780 °C.
  - Ashes formation.
  - Installation corrosion related to chloride species presence.
- Technological challenge: prototype boiler manufacture for this biofuel, which could solve the mentioned difficulties through controlling the following combustion parameters:

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- Flows and location of primary and secondary combustion air.
- Thickness of biofuel layer exposed to ignition.
- Residence time of biofuel.
- Type of materials and wall thickness building of the boiler.
- Ashes extraction system.
- Finding biofuel additives which counteract the pernicious effects of the straw burning in the essay setups and, finally, in the commercial equipment. Calcium oxide (CaO) derived compounds were mainly used to avoid the formation of slag. Furthermore, the corrosion can be avoided by increasing the metal thickness of the combustion equipment elements.
- Binding materials were used in the pellet manufacture, highlighting the use of starch and molasses.

#### *c) Solutions for problems*

Originally, the energetic valorisation of straw attended to a strategy focused on removing straw when having a production surplus, which created additional management and harvesting costs. This, in addition to the impossibility to burn this straw due to environmental concerns and need of management, were the main causes to start this new valorisation line.

Moreover, contrary to wood biomass, straw is a difficult material to pelletize due to its lack of natural binder. Different matrixes were tested with the aim to find an optimal size to counteract the expansion trend of the raw material during this process, choosing finally the 6 mm matrix as the most suitable one.


As for the combustion system, due to the straw special features, a temperature alternance was studied and optimized in order to reach an equilibrium between the ashes fusion and the slag formation. Additionally, in order to keep the combustion temperature at 750 °C, an air dilution is performed by adding fresh air to the combustion air.

## **4. Recommendations for this specific sector**

### *a) Recommendations*

The following recommendations are proposed, to achieve the main long-term opportunities for this sector:

- Once the biofuel fabrication process is implemented and optimized, promoting this business line is proposed as one of the major opportunities, by replicating the milling and granulating process in different cereal industries in the region where AGROPAL members have presence.
- Concerning the development of the specify boilers, the energetic costs could be improved by the installation of this ad-hoc boiler models, in other consumption points owned by the cooperative, such as:
  - Animal feeding production.
  - Second industry of fodder drying.
  - Cereal drying industry.

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- Similarly, exporting the boiler model to different consumption points, i.e. different sectors, could be a great business opportunity. This way, the new final users would become new AGROPAL clients for the biofuel supply, such as:
  - Other industries in the region.
  - Great livestock farms.
  - District heating.
  - Great buildings or public centres.

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## 6. Special Note

The information collected in this deliverable is partially focused on AGROPAL Soc. Coop. case study, including a cheese factory (Quesos Cerrato Soc. Coop.) and a fodder dehydration factory (Villoldo) owned by AGROPAL. They use the fodder-derived pellets to achieve an energetic self-consumption. However, due to the lack of information related to certain aspects of energy consumption and costs, other inputs were received from other sources and companies of the sector.

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## ANNEX C. DATA CASE STUDY 2. OLIVE OIL SECTOR - ABEA - GREECE

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### 1. General introduction case study for specific sector

#### *a) Size of the sector in the country/region*

Greece is the third olive oil producer in the world, after Spain and Italy with a typical annual production ranging from around 300 to over 400 ktonnes (in a very productive year, e.g. 2012-2014) of olive oil depending on the olive oil year. With a total cultivated area of 792,642 ha of olive trees according to ELSTAT (2017), olive oil sector represents one of the most, if not the most important sector of Greece. Regarding the volume of the sector, Greece has around 2,500 olive mills and 35 pomace mills, while according to stakeholder's feedback in Greece there are 7 large scale refineries and another 3-4 small companies that refine olive and pomace oil.

The region of Crete consists one of the biggest olive oil producer in the Greek territory, with a total cultivated area that reaches the 173,609 ha according to MyGIS platform (GIS tool that calculates olive pruning biomass in the olive areas of Greece, developed in the framework of AGROinLOG project by CERTH), and an olive oil production that goes beyond the 60 ktonnes of olive oil. In general, the majority of olive mills (36.5 %) are located in Peloponnese, however significant amount of the total national olive mills (around 550 olive oil mills) are concentrated in Crete. From these one around 100 olive mills are placed in Chania, the region where the suggested IBLC is located.


#### *b) Main economic activities of the sector*

Olive oil sector represents one of the most significant economic sectors in Greece. Regarding its economic strength, it is worth to mention that only the 27 % of the Greek olive oil is distributed for domestic consumption or exported as branded product while most of it, is sold in bulk form. Domestic consumption absorbs about two thirds of the olive oil production in Greece while the rest is exported in large quantities (e.g. about 70 % to Italy where they are mixed with different origin olive oil and re-exported as an Italian brand olive oil). The value of the domestic olive oil production is estimated at around € 800 million contributing to 0.4 % of Greece's GDP per year (average during 2010-2015). However, the economic information of the recent years shows a decline of the olive oil production within the 2020.

Regarding the economic activities of the sector, the Greek economy is primarily based in the production of olive and pomace oil. Olive pomace (waste from olive mills) is usually used as a raw material for the extraction of pomace oil and therefore for the production of solid biofuels originated from the stone, flesh and skin of the olive fruit.

#### *c) Existing and newly planned production plants of the sector in the country/region*

In general, and based on ABEA's information, there are no plans to create any new production plant concerning the olive oil sector in the wide area. However, it is worth to mention that according to

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ABEA there are around 100 olive mills and only 1 pomace mill in the current time in the region of Chania.

#### *d) General description of the suggested IBLC within the sector*

Concerning the size of the olive oil sector in Greece and after some contacts with the Mills of Crete, it was decided to study the IBLC concept on the pomace mill (ABEA) owned by the Mills of Crete. Mills of Crete have already developed sustainable and innovative solutions in the olive oil sector since they are producing “olive biomass” (the woody part, separated from the flesh, of the olive pomace after extracting pomace oil).

One of the main reasons that lead CERTH to select ABEA for this case study is the huge potential of residual biomass that Crete and more specifically Chania region produce annually. ABEA is a pomace mill which extracts pomace oil from olive pomace in large quantities (only for the 2018 they managed to extract around 2,813 t/y of pomace oil from around 60,517 tonnes/y of exhausted olive cake). Moreover ABEA works in a percentage of 65-70 % with two-phase olive pomace in which the moisture content of the input material (two- phase pomace) ranges between 50-70 %, and the rest percentage (30- 35 %) with three-phase olive pomace with a moisture content that ranges at 45-60 %. In addition ABEA, along with the extracted pomace oil, separates and use/sell as biofuel, the solid fraction of the pomace, the exhausted olive cake. Apart from this, ABEA was selected, since it is one of the biggest agro-industry in the wide area of Chania (with total income for the economic year of 2018: 9,815,475 €), with a long idle period time and for that reason it was considered suitable for the implementation of both of the selected pathways that will be studied in the olive oil sector. The first pathway will be focused on the exploitation of the residual olive tree prunings and the production of biofuels (pellets), while the second one is based on the exploitation of olive leaves and the extraction of phenols.


The main idea for both of the suggested IBLC scenarios lies on the next steps: Olive prunings will be harvested via mechanized means and transported to ABEA’s storage area. There pelletization will take place following the first pathway and the produced pellets will be sold in regional and national markets. Concerning the second pathway, the raw material produced by the olive mills will be transferred directly at ABEA’s storage facilities where under a certain procedure (drying, mixing, filtration, freeze drying) olive phenols such as oleuropein and hydroxytyrosol as well as triterpenes (oleanolic and maslinic acids) will be extracted and will be used in further production of biobased products.

## **2. Description of the six stages of the chosen pathway**

### **2.1 Feedstock supply**

#### *a) Types of available feedstock (e.g. agriculture, forestry, livestock, side-streams, residues, waste, etc.)*

Chania has a large available potential of residual olive tree prunings, a source of “biomass” that is burned in open fires, and yet not exploited. Another agricultural residue that is not exploited is that of olive leaves that are separated in olive mills or burned along the prunings. Both olive prunings and

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olive leaves can be used for both of the above-mentioned pathways as the primarily feedstock for the suggested IBLC case study.

*b) Yearly amount of the total production per feedstock in the region (and sometimes neighbouring regions) that is not currently being used for existing industries, and that is thus available for IBLCs [tonne dry matter or tonne fresh matter combined with moisture content]*

Regarding the feedstock supply of the proposed IBLC case studies, different raw materials were selected for the two hypothetical pathways. As it was mentioned above the olive tree pruning pathway is based on the exploitation of the annual residual olive tree prunings in the wide area of Chania, a large potential which according to MyGIS platform reaches the 92,307 dry tonnes (while Crete concentrates in total around 473,925 dry tonnes of olive tree pruning biomass). The above estimations are valorized in an area of 173,610 ha considering the total cultivated area of Crete and 32,287 ha considering the total cultivated area of Chania.


Considering the second pathway and the phenols extraction the information relied on the experience of Natac Group company collected on the Spanish Olive oil sector Case Study - Natac Group – Oleícola. El Tejar. Natac Group is a Spanish biotech SME dedicated to researching and developing natural ingredients for various biobased markets (pharmaceuticals, nutraceuticals, animal feed and cosmetics). In order to design the entire proposed system for the second pathway literature surveys was used for the estimation of the final quantity of olive leaves produced from the olive mills. According to Mr. Galanakis [1], three- phase olive mills produce significant quantities of solid wastes with outputs of 0.05 tonnes of leaves per tonne of olives. Based on that scenario and on the assumption that from an annual olive fruit production of 77,775 tonnes can be produced around 15,555 tonnes of olive oil in the region of Chania (ELSTAT, 2017), then it can be estimated that the quantity of olive leaves that can be used for the second pathway is around 3,889 tonnes of leaves.

*c) Seasonality pattern per feedstock (in what periods will it become available e.g. harvested in September-October)*

Pruning is usually carried out from January to March. Considering that prunings have to remain at least 1 month on the soil in order to decrease the moisture content, it is expected that the feedstock will be available at the right conditions between February and April.

*d) Distribution per feedstock (specify actual locations of areas where it is produced in the region/neighbouring regions)*

In general, Crete consists one of the regions with the highest potential of olive trees in the Greek territory, which automatically leads to one of the highest potential of residual biomass (olive tree prunings). As it is presented in the following pictures (screenshots from the MyGIS platform), the highest residual potential is concentrated at Heraklion region, while Chania follows. However, this distribution of the raw material (olive tree prunings) differs according to the distance. This can be seen from the second picture as well as from Table 18 in which the available amounts of olive tree prunings are presented in accordance with the distances from ABEA. Here it should be noted that all the amounts have as starting point the ABEA plant and they do not sum up.

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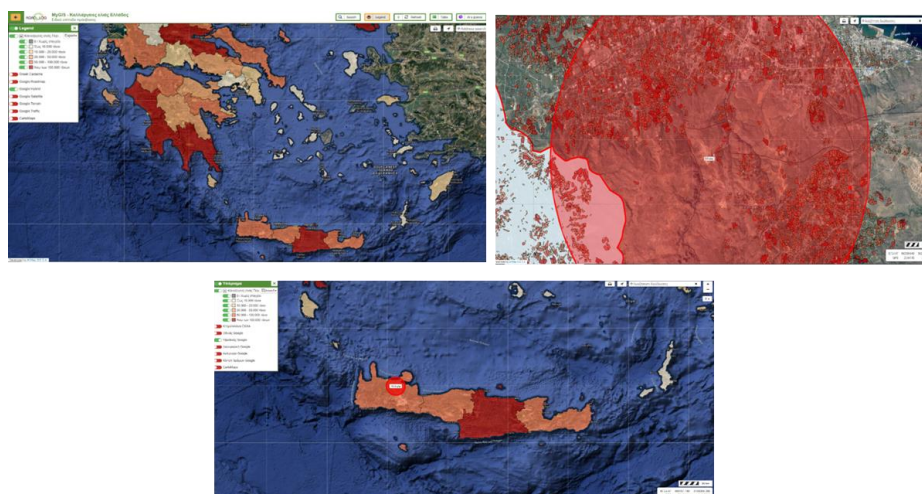


Figure 28: Screenshots from the MyGIS platform.

Table 18: Distribution of olive tree prunings in accordance with distance from ABEA unit.

Olive tree prunings	
Distance (km)	Dry biomass (ktonnes)
5	3.5
10	12.2
15	26.2
20	40.8

e) *Quality feedstock before it enters the IBLC (e.g. density, form, size, moisture content, ash content, etc.)*

Concerning the quality of the feedstock and taking into consideration that prunings have to remain at least 1 month on the soil in order to decrease their moisture content, it was thought that an intergraded shredder like the FACMA COMBY TR 200 shredder or a static chipper could be very helpful in the managing of them. Based on previous demonstrations taken place in different Greek regions, it was observed that the on-field pre-treatment of the olive tree prunings can offer various advantages in the whole operation of the value chain and as a consequence on the future IBLC. One of the most important advantage that is gained is the quality of the produced raw material. From all the demonstrations that have already implemented in the Greek territory, it was concluded that both chips (resulted fuel from static chipper) and “hog fuel” (resulted material from the integrated shredder) can actually fit on the IBLC concept of this case study. Concerning the quality characteristics of the produced fuels (olive tree prunings as well as olive leaves) these are summarized in the tables below. In Table 19 results from 49 different samples that were harvested with an integrated shredder during the AGROinLOG demonstration activities in the Greek IBLC area (Agios Konstantinos, Central Greece) are presented. Moreover, the results from different olive leaves samples are also presented in Table 20.


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Table 19: OTP fuel characterization results from 49 samples.

OTP fuel characterization results (from 49 samples)			
Property	Min	Max	Average
Moisture content (w-% ar)	19.2	40.5	29.85
Ash (w-% db)	2.9	8.2	5.55
Volatile Matter (w-% db)	74.8	79.7	77.25
Carbon, C (w-% db)	47.66	52.12	49.89
Hydrogen, H (w-% db)	5.54	8.38	6.96
Nitrogen, N (w-% db)	0.55	2.19	1.37
Sulphur, S (w-% db)	0.06	0.6	0.33
Chlorine, Cl (w-% db)	0.03	0.14	0.09
High Heating Value (MJ/kg db)	18.83	20.38	19.61
Bulk density (kg/m <sup>3</sup> ar)	180	300	240

Ar: as received; db: dry basis

Table 20: Olive leaves fuel characterization results.

Olive leaves fuel characterization results			
Property	Min	Max	Average
Moisture content (w-% ar)	18.2	23.8	21
Ash (w-% db)	2.7	5.7	4.2
Volatile Matter (w-% db)	78.6	80.3	79.45
Carbon, C (w-% db)	48.6	52.44	50.52
Hydrogen, H (w-% db)	6.08	7.27	6.67
Nitrogen, N (w-% db)	0.11	1.10	0.61
Sulphur, S (w-% db)	0.04	0.10	0.07
Chlorine, Cl (w-% db)	0.06	0.08	0.07
High Heating Value (MJ/kg db)	18.96	21.61	20.28

Ar: as received; db: dry basis


Regarding the phenol's pathway, the manufacture of certain biobased products is only feasible from the exploitation of specific raw materials. Unfortunately, there was not any further information concerning the physical composition of the pruning olive leaves needed during the phenol extraction process.

*f) Unit on-farm storage costs when storage happens on the farm [€/tonne dry matter or €/m<sup>3</sup>]*

In most of the cases, farmers do not select the on-farm storage since they are afraid of soil contamination from various pathogenic microorganisms. Thus, there is no cost for on-farm storage.

*g) Price of feedstock at roadside (before transport, when sold by farmer to IBLC) [€/tonne dry matter or €/tonne fresh matter combined with moisture content]*

So far farmers in their majority follow the technique of the open burning of their prunings, for which they have to pay an extra wage in order to collect prunings and burn them. By implementing the IBLC concept, farmers avoid the burning of the prunings and its cost. Thus, it is an avoidance cost for them

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and thus, it can be considered as savings for them. In this sense, the IBLC can get the prunings for free from the olive groves or get paid for 5 €/tonne to harvest the prunings from the farmer. In this way both sides are satisfied.

## 2.2 Logistics

### Transportation

#### *a) Transportation types used including average capacity*

As noted below, for both of the selected pathways a radius of 5-10 km around ABEA was considered satisfy in order to implement our study. Based on previous demonstration activities the most common transportation types that were used, are trucks with an average capacity of 3-5 t/route.




Figure 29: Transportation types.

#### *b) Transportation distances (average/related to distribution of feedstock) [km]*

Taking into consideration that the proposed case study will be focused on the region of Chania we assume an average transportation distance of 5-10 km maximum (from the field to the IBLC). However, as it was mentioned above the transportation distance that is selected depends on the total amount of olive tree prunings (and as a consequence the olive leaves) that the proposed IBLC can finally mobilize during its idle time. Nevertheless, according to CERTH's previous experience from various demo activities in the framework of AGROinLOG project, the transportation distance that is selected for ABEA to mobilize the necessary quantities of olive tree prunings is the 7 km. This distance was decided according to the amount of prunings that ABEA can handle during the idle time period of the belt dryer, which are around 5,000 tonnes of dry biomass.

#### *c) Transportation losses [%]*

These transportation losses are referred on the olive tree pruning pathway and can be estimated at 2 % of the raw material that is transported. In the same line, we cannot estimate any transportation losses for the phenols extraction pathway due to the fact that the olive leaves are included in the olive tree prunings.

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*d) Transportation energy/fuel consumption [MJ/km or l/km]*

An average transportation fuel consumption for the olive tree prunings collection was estimated around 0.4 L/Km.

*e) Transportation costs [€/km]*

Similar than in the previous section, and based on feedback from various local farmers the transportation cost for the olive tree prunings was estimated at 10-20 €/t.

## 2.3 IBLC design

### Synergy with existing machinery, storage, labour & infrastructure

*a) Available pre-treatment & handling machinery, storage facilities, labour and other infrastructure types including average capacity per period (month)*

In general, the main philosophy that both of the proposed IBLC's concepts are based on is the efficient synergy of the existing machinery and equipment. The whole IBLC design is going to fit in ABEA's needs, which means that any existing equipment (the dryer, the storage facilities) as well as the personnel that ABEA currently uses will be available for the future IBLC. Taking into consideration that the first pathway is focused on the pellet production, it is assumed that the existing dryer (of 30 tonne/h capacity) as well as the storage facilities that ABEA has in its own property can be used for the needs of the pellet production. As for the second pathway and the phenols extraction, existing machineries like the dryer and storage facilities can again be used for the needs of this case study. However, for more specific operations, and new machineries for washing, chipping, drying (trommel), mixing, etc. new investments could be useful for the development of new activities.

*b) Idle period of available and suitable pre-treatment & handling machinery, storage facilities, labour and other infrastructure*


The working period for ABEA pomace mill ranges between November and June. After this period all the available and necessary machineries, facilities as well as labour force can be used for the needs of the proposed IBLC.

*c) Efficiency: losses during production, storage and pre-treatments [%]*

Concerning the harvesting part of the olive tree prunings, losses can reach at 20 % of the harvested raw material, while losses during the storage and pelletization process can reach the 2 % and 10 % equal.

*d) Machinery energy consumption [MJ/tonne dry matter] & operation rate*

In the case of the first pathway and based on data collected during the demonstration of pellet production from olive tree prunings, the energy consumption are the following ones: a) the heat consumption for the pellet production was 1,044.5 kWh (primary energy)/ dry ton of produced pellet, while b) the electricity consumption for the entire pellet production was 295.5 kWh (primary

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energy)/ dry ton of produced pellet. Indicatively, the electricity consumption of the entire process can be analysed in Figure 30.

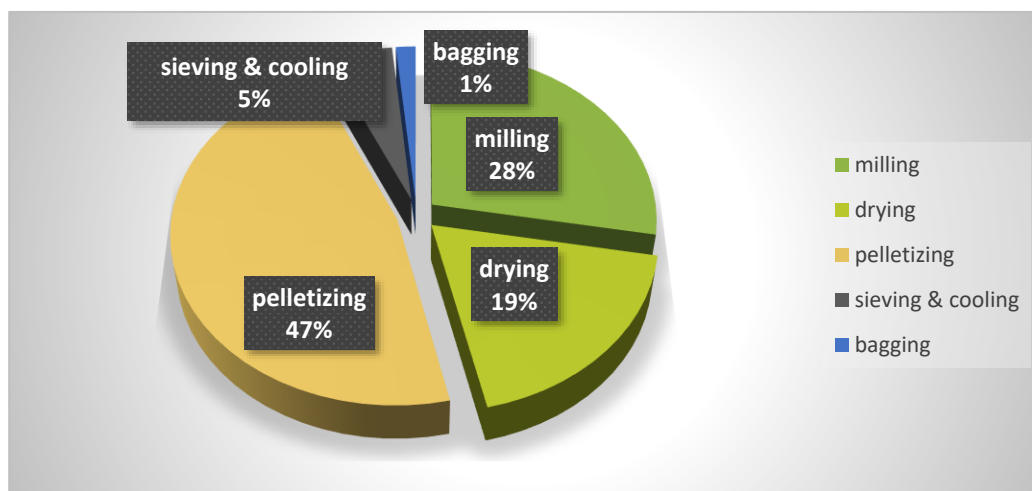


Figure 30: Analysed machinery electricity consumption.


Unfortunately, this information is not available for the phenols production.

*e) Costs of used pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

The total harvesting cost of prunings, as calculated through the harvesting demonstrations performed in the Greek IBLC area in Agios Konstantinos, with an integrated harvester (FACMA), was around 45 €/dry ton of harvested pruning. Indicatively the workers' cost was estimated at 60 €/day for both workers based on quotes of local actors, while the cost for renting the harvester's tractor and driver was considered at 200 €/day. In Figure 31 the total cost breakdown is presented.

Moreover, the pelletization cost was estimated around to 80 €/tonne of pellet produced with the following cost break down: 25 €/tonne for electricity, 20 €/tonne personnel cost, 25 €/tonne maintenance, packaging, marketing costs and 10 €/tonne costs to banks, liabilities, etc. All the values are expressed per tonne of pellet produced at their moisture content, around 10 % over a wet basis.

No data was retrieved for the phenols pathway.

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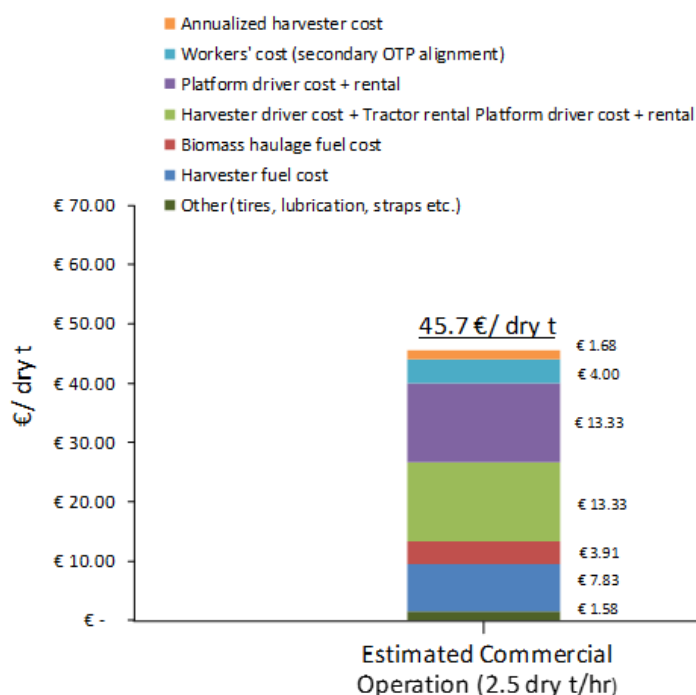


Figure 31: Cost breakdown of the total harvesting costs of olive tree prunings.

#### f) Intermediate biobased products obtained (see 2.4)


In this sector, there is no intermediate biobased products. The olive tree pellets as well as the olive polyphenols that are produced from both of the proposed pathways are considered as final biobased products.

#### New machinery, storage & infrastructure

#### g) Additional required investments for new machinery/infrastructure (CAPEX)

Starting from the harvesting part of the olive tree prunings and based on previous experience from numerous demonstration activities, the investment of two new shredders like the FACMA COMBY TR 200 from the company is considered really necessary. It should be mentioned that this investment is depended on the amount of olive prunings that is targeted to be harvested. For the case of ABEA, an amount of 5,000 tons of pellets is considered as an adequate amount. In order to harvest this amount of pruning in around 3 months, the IBLC will need to harvest around 5,000 tonnes of dry prunings (or around 7,000 wet tons of prunings, considering a 27.5 % moisture content). This amount of prunings corresponds to around 7 km distance from the IBLC (ABEA). This decision was taken based on the harvesting efficiency of the FAMCA COMBY TR 200 which according to CERTH's calculations from the last demo activities in the region of Agios Konstantinos (Greek IBLC area) is 2.5 dry ton/hr and for a period of 3 months in which the dryer can work maximum for around 1000 hours. This decision also improves the logistic costs, since an increase in the transportation distance increases dramatically the logistics costs. Nevertheless, the CAPEX for one of this machinery is around 20,000 €.

Following to the next step and the pelletization line that ABEA will need to build for the IBLC needs, the new investments are:

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- Press Pellet → (100 k€ purchasing cost for the production of 1 tonne/h of pellets. Data retrieved from BIOALTEN pellet plant);
- Wood Chipper → (65 k€ purchasing cost for the production of 1 tonne/h of pellets. Data retrieved from BIOALTEN pellet plant);
- Grinding Mill → (60 k€ purchasing cost for the production of 1 tonne/h of pellets. Data retrieved from BIOALTEN pellet plant);
- Cooler → (20 k€ purchasing cost for the production of 1 tonne/h of pellets. Data retrieved from BIOALTEN pellet plant);
- Packaging → (45 k€ purchasing cost for the production of 1 tonne/h of pellets. Data retrieved from BIOALTEN pellet plant).

From all the above-mentioned necessary equipment the investment of a dryer is not included since ABEA has already one belt dryer which uses in her production processes and can be used in the future IBLC, along with the briquette machine that ABEA also has in her property and produces around 500 kg/h. All the above information is retrieved both from ABEA pomace mill and from the BIOALTEN company. The total investment cost needed for the pelletization line of 1 ton of pellet per hour is estimated around 300 k€

Closing with the second pathway and the phenols extraction, biobased products processes would usually require even higher investments than the ones needed for the olive tree prunings, though this information was not provided during the interviews.

#### *h) Additional amount of (part time) personnel required*


As it was mentioned above, the purchase of two intergraded shredders (e.g. FACMA COMBY TR200) was though as an extremely useful solution. For this procedure, 2 seasonal teams of 5 people each (1 FACMA driver, 2 drivers for the platforms, 2 workers on field), working for 3 months will be needed.

Concerning the employment at the IBLC and based on information retrieved by ABEA's interview, it is proposed that for a pellet production line, three full time workers would be needed per shift, 6 in total (for 2 shifts). An additional specialised operator would be doing maintenance and production supporting activities like filling up the feeders, truck loading. The total full-time equivalent jobs are 7 employees on the production floor.

However, when implementing new activities for biobased products manufacture, like the phenols' extraction, perhaps new more expertise labour will also be needed for this pathway since the existing labour could not be able to cope with the extraction processes. Unfortunately, there is no data concerning the amount of the personnel needed for this process.

#### *k) Current state of IBLC design (TRL, technology maturity) and future improvements foreseen (coming 5 years)*

Since the proposed IBLC design is based on existing cases and technologies, the TRL ranges between 7 and 8.

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## 2.5 Final market

### Final biobased products

a) *Types of final biobased products (that are made by another industry from the feedstock 'intermediate biobased products' delivered by the IBLC)*

The main types of final biobased products from the first olive oil pathway are: pellets and there is an option for briquettes, or hog fuel (all based on olive tree prunings), as we can see in the following Figure 32. As it was mentioned above the final quantities of the olive tree pellets that ABEA is going to produce is 5,000 dry tonnes.



Figure 32: Pellets from olive tree prunings produced by CERTH .

Concerning the phenols extraction pathway, the produced phenols (like the oleuropein and the hydroxytyrosol as well as triterpenes (oleanolic and maslinic acids) will be further used in the final production of variable biobased products in order to cover the needs of different pharmaceutical animal nutrition and cosmetics sectors.

b) *Quality requirements needed to satisfy consumers' preferences*

According to the fuel analysis that was implemented in the produced pellets during the demonstrations in the AGROinLOG project, the main fuel characteristics of the pellets are given in Table 21.


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Table 21: Fuel characteristics of OTP pellets (6 samples).

Fuel characterization of OTP pellets (6 samples)			
Property	Min	Max	Average
Ash (w-% db)	5.4	5.6	5.5
Volatile Matter (w-% db)	77.1	77.9	77.5
Carbon, C (w-% db)	49.83	50.46	50.13
Hydrogen, H (w-% db)	5.85	6.38	6.17
Nitrogen, N (w-% db)	0.93	2.35	1.65
Sulphur, S (w-% db)	0.10	0.11	0.10
Chlorine, Cl (w-% db)	0.07	0.09	0.08
High Heating Value (MJ/kg db)	19.58	19.95	19.76
Bulk density (kg/m <sup>3</sup> ar)	640	700	670

Ar: as received; db: dry basis

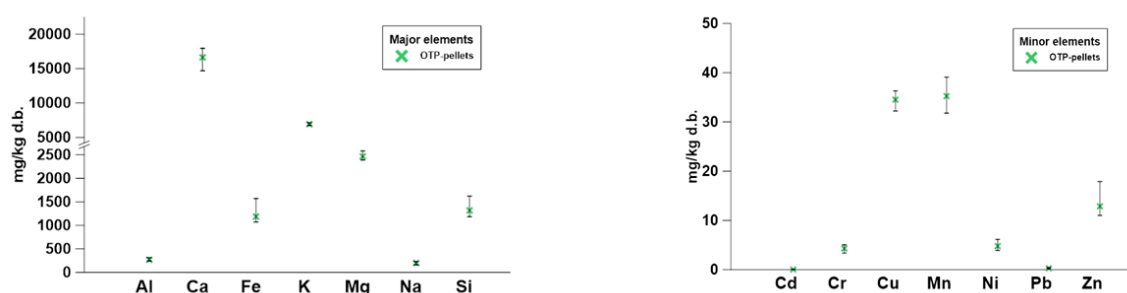



Figure 33: Elements in OTP pellets.

On the other hand, the quality requirements for the biobased products from the olive phenols are not standard since the specifications are marked either by the customer or by official regulations such as the European Pharmacopoeia (which marks moisture content, ashes, pesticide residues, heavy materials, etc.), or the content of impurities marked by pharmaceutical, food, nutraceutical and/or cosmetic regulations. For example, in the case of olive leaf there are already standardized products, as is the case of olive leaf extract with 20 % oleuropein.

#### c) Price of final biobased product(s) paid by consumer

Pellet from olive prunings: around 150 €/tonne

The average price range for the biobased products is very wide, although the average price is between 20-30 €/kg, according to Natac Group's information (as referred on the Spanish Case Study). In general, the price for these products is determined from the added value that offer in the market (market demand, geographical proximity, etc.).

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#### *d) Stakeholders involved in the final market*

Within the nature of the final biobased products various stakeholders are involved in the final market. In the case of the pellets' domestic users or public or private companies for heating purposes as well as industrial units can be attractive potential end users. As for the biobased products produced from the olive phenols pharmaceutical as well as cosmetics industries can incorporate them into their final products.

## 2.6 Non-technical issues

### IBLC

#### *a) Measures, incentives & subsidies that could stimulate starting & setting up an IBLC*

Based on our experience the most important measure to be adopted is the institutional prohibition on the burning of the prunings. This is the first step for the stimulation of future IBLCs in the olive sector.

#### *b) Environmental regulations that apply to the IBLC*

According to ABEA there is a control in gas emissions in order to maintain the operating license.

#### *c) Social acceptance new activity at the IBLC (e.g. more trucks can cause problem due to noise)*

Since both of the case studies are hypothetical scenarios, we assume that the social acceptance of these concepts will be encouraging, as it will provide benefits in the local community (employment, environmental benefits, no smoke/ smell from burning prunings etc.).


### Final biobased products

#### *d) Measures, incentives & subsidies fostering the uptake of biobased products, the creation of new markets, etc.*

The local region is mature already on the use of biobased products and eager for new ones. Even more if these products are coming from the region and support the local community and have a positive environmental impact.

#### *e) Social acceptance of the (new) final biobased products*

Concerning the social acceptance of the new final biobased products of the first pathway, it is believed that the new olive tree pruning pellets, will find a good acceptance from the farmers as well as from the local market. As a "local" and environmentally friendly product (since the burning of them will finally stop), olive tree pruning pellets will cover the needs of the local market of solid biofuels since there is a great demand for solid biofuels in Crete (the currently produced quantities of the exhausted olive cake cannot cover their needs and they import more exhausted olive cake from the mainland of Greece and abroad, such as Tunisia). However, as it was already mentioned above, ABEA is a pomace mill which extracts pomace oil from olive pomace in large quantities. Along with the extracted pomace oil, the solid fraction of the pomace, exhausted olive cake, is separated and used/sold as biofuel. This exhausted olive cake is currently sold by ABEA in various end-users in

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Chania, such as cheese producers, bakeries, pools, hotels, laundries which consume more than 5,000 tonnes of exhausted olive cake per year. ABEA also sells separated pomace wood (exhausted olive cake without the skin part, that contains mainly the woody part and is a better fuel than the normal/non separated exhausted olive cake) of 1500 t to households for domestic use.

### 3. Lessons learned

As it was mentioned above both of the studied cases are hypothetical scenarios. For that reason, it is believed that it was better to present some lessons learned from an existing case (FIUSIS power plant), which produces electricity exclusively from olive tree prunings and was examined in previous project by CERTH<sup>14</sup>. FIUSIS power plant, follows the above mentioned logistics and this is the reason why it was chosen to present its lessons learned. All the harvesting techniques as well as the handling processes of the olive tree prunings can be an effective example to imitate for the future IBLC. Further to this, the plant owner and manager, is interested in expanding the business activities in two new areas. The first is the production of olive tree prunings pellets for the domestic / industrial sector and the second one is the use of the biomass ash as a fertilizer.

#### a) Successes

The main success factors that made possible FIUSIS initiative are summarised as follows:


- The high density of olive groves in the area reduces the transport distances and the total area of the supply basin. This is also the case for ABEA, the high density of olive groves in the area.
- A high joining rate of farmers in supplying prunings due to a good dissemination by FIUSIS and the relevant advantages of the new kind of pruning management as solid biofuel.
- The pruning surface amounts (t/ha) are significantly high. Also the case for the vigorous olive trees of the region of Chania.
- The creation of rural employment and agricultural services companies.
- The creation of value from an already sorted out residue that is utilized for heat and power generation today.
- The given opportunities to new alliances between farmers, local authorities and agro-services with the aim to optimize the business model.
- The establishment of new agreements with the neighbouring municipalities in order to involve farmers in stopping pruning burning and adhere to the collecting procedures.

#### b) Difficulties (e.g. technical & economical bottlenecks, conflicts, etc.)

The biggest difficulty, according to FIUSIS, lies in convincing farmers to establish ways of collaboration. Moreover, the existing legislative problems/obstacles for the by-products that so far

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<sup>14</sup> uP\_running: "Take-off for sustainable supply of woody biomass from agrarian pruning and plantation removal", (<https://www.up-running.eu/>). This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 691748.

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are considered waste by legislation and used in open fires, as well as the escalation of the whole process to industrial size make the whole effort even more difficult. Finally, the fear that other types of competitive fuels (sunflower pellets, exhausted olive cake, wood pellets) can attract the end users due to lower prices or higher fuel quality make it really difficult for the local market of biofuels.

#### *c) Solutions for problems*

In order to overcome the reluctance of farmers, an intense information campaign to promote social acceptance was displayed and agrarian residues utilization for energy was subject of debate by local policy makers and social groups in the year before the investment was done.


### **4. Recommendations for this specific sector**

#### *a) Recommendations*

The implementation of an IBLC for the valorisation of olive tree pruning requires the active collaboration of farmers and cooperatives. It is necessary to develop alliances between the local authorities and the agricultural sector and try to overcome the common belief that considers biomass burning in open fires on farms as an easy way to treat prunings. In this way new opportunities for the region, the environment and of course for the local market and its consumers will emerge.

### **5. References**

Galanakis, C.M., Olive Mill Waste: Recent Advances for Sustainable Management. 2017.

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## ANNEX D. DATA CASE STUDY 3. OLIVE OIL SECTOR - NATAC GROUP - OLEÍCOLA EL TEJAR - SPAIN

### 1. General introduction case study for specific sector

#### a) Size of the sector in the country/region

Spanish olive grove represents 23 % from world olive crop area and produces about 44 % of total production. These facts remark the worldwide leadership that the olive oil industry of Spain has in this sector.

As shown in the next figure (Figure 34), olive oil sector accounted, during the 2016-2017 campaign, 1,813 oil mills, 67 olive pomace oil industries and 26 refineries, which represents around 7 % of total food industries in Spain. In addition, there are around 10 companies where the olive oil residues are valorised with bioenergy purposes. Concerning olive pomace oil industries, Oleícola El Tejar Nuestra Señora de Araceli S.C.A. process around 30 % of national olive pomace production.

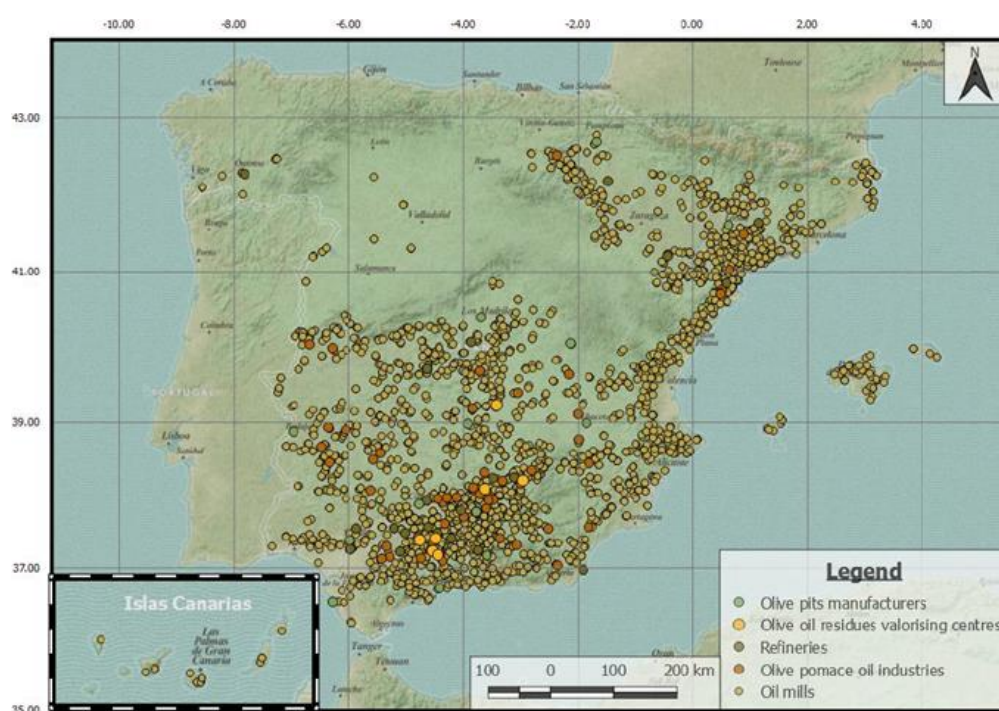



Figure 34: Olive oil sector in Spain.

Most of the industries of the olive oil sector are concentrated in the southern (Andalusia) and eastern (Catalonia and Valencia) regions of the country. Olive derived products are known and appreciated for its numerous and healthy properties, especially in cardiovascular health and improvement of the immune system.

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#### *b) Main economic activities of the sector*

Olive oil sector is composed by several industries with specific roles through all the olive oil production process stages. Oil mills, oil refineries, oil packagers and olive pomace oil industries could be considered as the most relevant ones.

The average market value of Spanish olive oil (determined by the price at source) in recent marketing years (2010-2017) was around 3 billion Euros. The olive-pomace oil sub-sector accounted (on average) around 150 million euros in the marketing years between 2010 and 2016. Recent economic information shows a clear pattern of growth in product sales, intensified in the last years. This reflects the strength and stability that the olive oil industries have shown during the crisis years.

Despite the main economic activity within the olive grove sector is the extraction and marketing of olive oil and olive pomace oil extraction, there are other activities linked to this sector that are destined to increase the added value of several by-products. For instance, though the wet olive pomace by-product generated during the olive oil extraction is usually destined to olive pomace oil extraction, it can also be used as feedstock for the manufacture of bio-fertilisers, the extraction of high value-added biobased compounds or as an ingredient in animal feed. Although these activities are less relevant in economic terms, they also represent an interesting alternative for the valorisation of olive oil by-products.

These alternative activities are only profitable if they are carried out in close proximity to the main activity (extraction of olive oil or extraction of olive-pomace oil).


#### *c) Existing and newly planned production plants of the sector in the country/region*

Spanish olive oil sector is a dynamic sector in which every year new oil mills begin or cease their activity, despite this, there is no known plan to build new olive pomace oil industries or related companies in Spain.

At present, Natac Group (a Spanish Biotech SME dedicated to the research, development, manufacture and marketing of natural ingredients) is running four extraction plants that use different kind of agro-food biomasses as raw materials. One of them, Innovaoleo, is a joint venture created with Oleícola El Tejar olive pomace oil industry (a second-degree cooperative that processes around 30 % of total olive oil by-products) for the production of olive-derived extracts. In addition, Natac Group is building a new plant in the Extremadura Region to obtain natural biobased products from alternative raw materials. They also plan to multiply the current capacity of Innovaoleo by four within the following years.

#### *d) General description of the suggested IBLC within the sector*

This case study proposes strategic alliances between olive oil pomace industries and biotech SMEs for the extraction of new high added value bio-products such as phenols. The proposal for this sector was inspired by the successful partnership (through Innovaoleo) that Natac Group holds with the world leading olive pomace oil producer, Oleícola El Tejar.

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Natac Group works on the foundation of a sustainable business model based on strategic alliances with the most important local producers – farmers, co-ops, large food companies, etc.– so that they can offer natural, plant-derived ingredients from different regions, specialising in Mediterranean plants, especially in olive- and grapevine-derived extracts.

In this sense, Innovaoleo facilities were integrated within one of the production plants owned by Oleícola El Tejar (Figure 35), since this integration is especially suitable for olive pomace oil industries.



Figure 35: Innovaoleo location.

This type of strategic alliances makes vertical integration possible. Because their allies follow Natac Group's criteria regarding the cultivation, harvesting, and processing of raw materials, they purposely enhance the beneficial properties in the ingredients Natac Group develops.

The integration of different processes (Figure 36), technologies, and equipment into a unique synergy, result in a complete portfolio of products that enable Natac Group to:

- Specialise in Mediterranean raw materials;
- Control the cycle from the farmer all the way to your product;
- Develop ingredients based on a sustainable model;
- Have access to available and large quantities of different types of raw material;
- Be able to offer natural extracts that stand out in a highly competitive market;
- Bring innovation and scientific advancements;
- Offer products with different applications in international markets.


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Figure 36: Integration of processes.

Through this working formula Natac Group shares or even avoids raw material, logistic and by-product costs, which allows them to obtain highly competitive products. While agro-industries supply their by-products and provide infrastructure for logistics and processing, Natac Group provides the required technology and knowledge. So, the mission of Natac Group is to transfer scientific knowledge to industrially viable projects that create value and improve people's lives.

Due to the strategic locations of olive pomace oil industries (surrounded by oil mills and olive groves) and the availability of compatible equipment for biomass exploitation, they are proposed as the ideal agro-industries where integrating biomass logistics centres for the extraction of phenols.


## 2. Description of the six stages of the chosen pathway

### 2.1 Feedstock supply

a) *Types of available feedstock (e.g. agriculture, forestry, livestock, side-streams, residues, waste, etc.)*

For the extraction of olive-derived extracts such as phenols two main feedstocks are needed: Two Phase Olive Mil Waste (TPOMW) and olive leaves. Though TPOMW is used for the extraction of olive pomace oil, the phenols' extraction process has a minimum impact on the physical-chemical features of the feedstock, so most of it can be returned afterwards into the agro-industry process. In addition, since there is not yet a big market for these products, very little amounts of feedstock are used during the phenols' extraction (compared with the whole amount that an agro-industry can process). Therefore, feedstock availability is always ensured.

b) *Yearly amount of the total production per feedstock in the region (and sometimes neighbouring regions) that is not currently being used for existing industries, and that is thus available for IBLCs [tonne dry matter or tonne fresh matter combined with moisture content]*

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As already mentioned, phenols' extraction process has a minimum impact on the physical-chemical features of the feedstock, so most of it can be returned afterwards into the agro-industry process. In addition, since there is not yet a big market for these products, very little amounts of feedstock are used during the phenols' extraction (compared with the whole amount that an agro-industry can process). Therefore, in practice, almost 100 % is returned and Oleícola El Tejar overall process is not affected. This is an innovative aspect of the model.

In any case, it should be noted that Oleícola El Tejar has a significant amount (Figure 37) of raw material available (TPOMW, leaves and olive pits) to be valued and that, in general, was increasing over the last years.

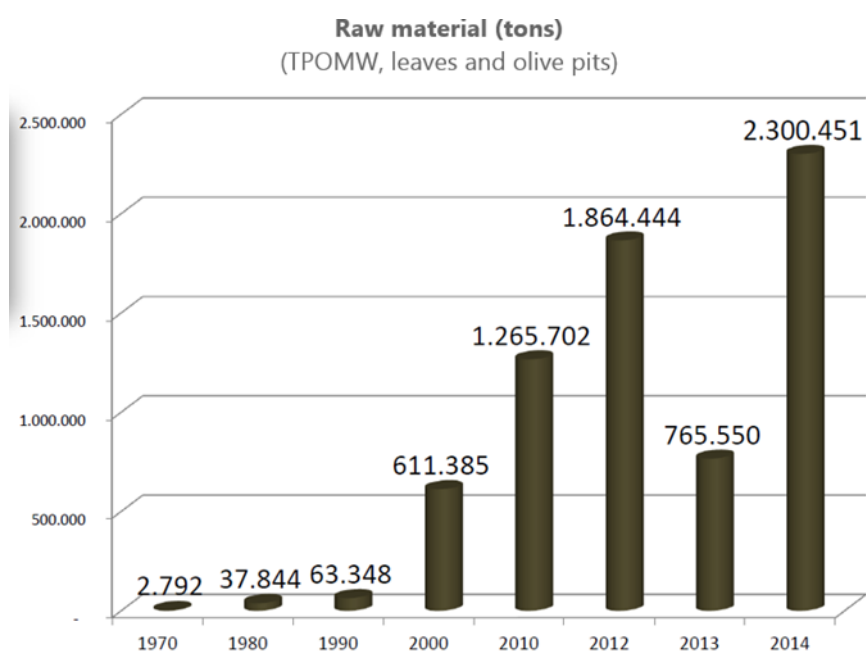



Figure 37: Increasing quantities of raw materials of Oleícola El Tejar.

c) *Seasonality pattern per feedstock (in what periods will it become available e.g. harvested in September-October)*

Oil mills by-products (processed in grape pomace oil industries such as Oleícola El Tejar) are usually available from September to January, varying the months of beginning and end of this period depending on the regions.

d) *Distribution per feedstock (specify actual locations of areas where it is produced in the region/neighbouring regions)*

Oleícola El Tejar processes olive oil by-products coming from almost every region in Spain where olive groves are cultivated. However, since most olive oil sector industries are concentrated on Andalucía Region, most olive oil by-products are generated in the South area of the country.

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e) *Quality feedstock before it enters the IBLC (e.g. density, form, size, moisture content, ash content, etc.)*

Feedstock features are highly relevant for the manufacture of biobased products. For instance, in the case of olive leaves, depending on which biobased products are targeted, these will be collected at different stages due to differences in the chemical composition. Leaves can be obtained during the oil mill processes (in this case they are separated and dried in the floor) or when managing the pruning of olive groves.

TPOMW physical-chemical composition shows the following average values:

- Moisture content: 50-60 %;
- Ash content: 2-3 %;
- pH≈5;
- C/N≈50 %.

f) *Unit on-farm storage costs when storage happens on the farm [€/tonne dry matter or €/m<sup>3</sup>]*

In line with what has already been said, raw material storage costs would be usually borne by the agro-industry that supplies the feedstock in the proposed business model (alliance between olive pomace oil industries and biotech SMEs). However, no figures on this regard could be retrieved during the interviews.

g) *Price of feedstock at roadside (before transport, when sold by farmer to IBLC) [€/tonne dry matter or €/tonne fresh matter combined with moisture content]*

Due to the formula of alliances proposed, the raw material would be contributed by the olive pomace oil industry at no cost. As already mentioned, most of the feedstock is returned to the process after the phenols' extraction, so there is no significant impact for the agro-industry.

## 2.2 Logistics

### Transportation


Since in the proposed business model phenols' extraction plants would be integrated within the own agro-industries with which they establish collaborative alliances (such as the one established between Natac Group and Oleícola El Tejar), costs associated with the raw material transport are not expected to be relevant and are usually assumed by agro-industries. In the same line, losses during transportation are not significant.

## 2.3 IBLC design

### Synergy with existing machinery, storage, labour & infrastructure

a) *Available pre-treatment & handling machinery, storage facilities, labour and other infrastructure types including average capacity per period (month)*

Olive pomace oil industries own horizontal dryers and storage facilities that can be used for the phenols' extraction process. Natac Group, in the development of its activity, usually takes advantage

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of the machinery and facilities from agro-industries that supply raw materials. In general, it makes use of the infrastructure related to auxiliary processes (fire extinction, security, steam boiler, etc.) but also, for more specific operations, it uses machinery for washing, chipping, drying (trommel), mixing, etc. as well as storage facilities.

*b) Idle period of available and suitable pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

The idle period in the olive pomace oil industries where facilities, equipment or other compatible resources are available comes from August to November, varying the months of beginning and end of this period depending on the regions.

*c) Efficiency: losses during production, storage and pre-treatments [%]*

This information is not available.

*d) Machinery energy consumption [MJ/tonne dry matter] & operation rate*

This information is not available.

*e) Costs of used pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

This information is not available.

*f) Intermediate biobased products obtained (see 2.4)*

In this case phenols are considered as final biobased products due to the proposed business model (integration of the biotech SME within the agro-industry facilities). These final biobased products are later sold to pharmaceutical, nutraceutical, animal feed and cosmetics industries for their incorporation into new final products. It is a B2B (business to business) business model.

#### New machinery, storage & infrastructure

*g) Additional required investments for new machinery/infrastructure (CAPEX)*

This information is not available.

*h) Additional amount of (part time) personnel required*


This information is not available.

*i) Additional maintenance requirements (e.g. cleaning costs, machine resetting costs for switching between feed stocks) [€/tonne dry matter]*

No additional requirements or maintenance costs beyond those already incurred by agribusinesses and the new machinery are required.

*j) Additional operational costs for personnel, maintenance, management [€/tonne dry matter]*

The additional costs related to the process are more significant at first, with all that is involved in starting up the processing plant and, in this case, adapting or coupling to an existing process. Once

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the plant runs into the usual regime the costs are similar to those of any agro-industrial activity. In fact, the designed business model makes possible to absorb many pre-invested costs by agro-industries, especially at the beginning of the activity, during the start-up.

*k) Current state of IBLC design (TRL, technology maturity) and future improvements foreseen (coming 5 years)*

At present, Innovaoleo phenols' extraction plant is fully operational with real market activity. In the short term (next five years) new investments are expected. These will allow to multiply the production scale by four. In addition, Natac Group is developing new products in TRL 4-5-6 such as biobased products (from olive oil by-products) destined to feed aquaculture salmon.

## 2.4 Intermediate biobased products

### Intermediate biobased products

Innovaoleo only produces final biobased products that are sold to the pharmaceutical, nutraceutical, animal feed and cosmetics industries for incorporation into final products. It is a B2B (business to business) business model.

## 2.5 Final market

### Final biobased products

*a) Types of final biobased products (that are made by another industry from the feedstock 'intermediate biobased products' delivered by the IBLC)*

Natac Group offers ingredients (extracted at Innovaoleo phenols' extraction plant) containing high concentrations of polyphenols (oleuropein, hydroxytyrosol) and triterpenes (oleanolic and maslinic acids), as well as a wide variety of innovative, olive-derived formulas with unique applications in the food industry (both nutraceutical, as well as functional foods), and in the pharmaceutical, animal nutrition, and cosmetics sectors. It is a B2B (business to business) business model.

At present they produce around 20-30 tonnes/year of the following products (


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Table 22 and Figure 38).


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Table 22: Natac Group's polyphenols products.

Natac Group's polyphenols products		
	Part of the plant used	Extract standardised to:
Hydroxytyrosol	Olive fruit	1.5 – 20 % Hydroxytyrosol
Oleuropein	Olive	4 – 40 % Oleuropein
Triterpenes	Olive	30 – 98 % Oleanolic acid
	Olive fruit	6 – 40 % Maslinic acid
Full plant profile (Allolive)	Olive leaves and fruit	20 % Oleuropein 13 % Pentacyclic triterpenes 3 % Hydroxytyrosol 3 % $\alpha$ -Tocopherol

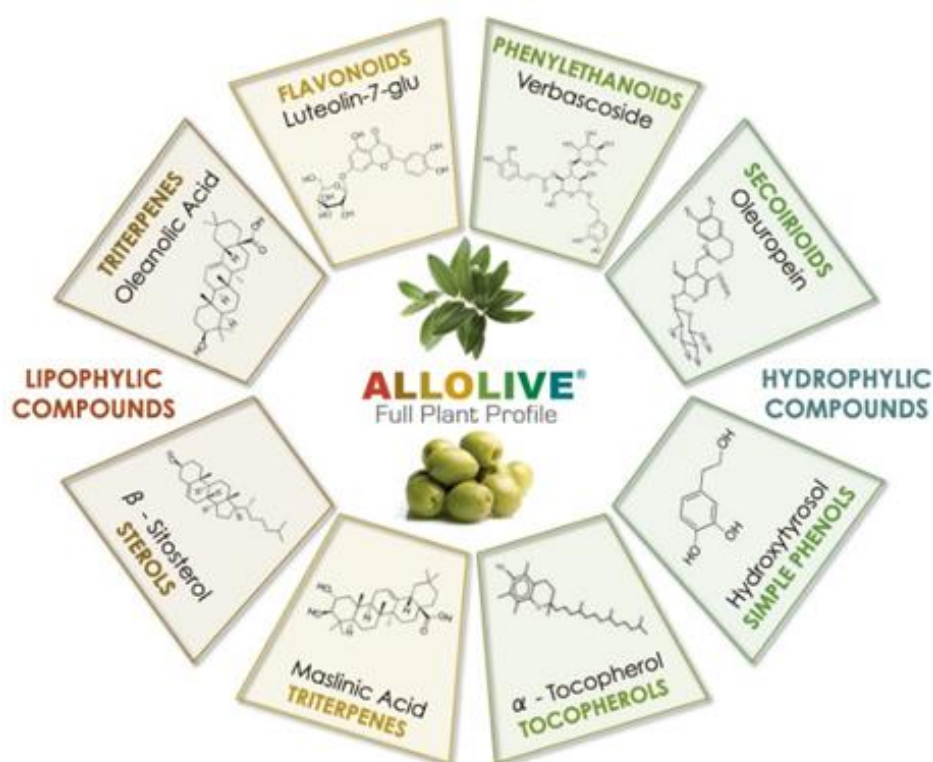



Figure 38: Schematic display of the final biobased Natac Group's products.

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#### *b) Quality requirements needed to satisfy consumers' preferences*

These products are offered according to the quality required in the market, tailored to the customer. In the case of innovative products, the specifications are marked either by the customer or by official regulations such as the European Pharmacopoeia (which marks moisture content, ashes, pesticide residues, heavy materials, etc.), or the content of impurities marked by pharmaceutical, food, nutraceutical and/or cosmetic regulations. For example, in the case of olive leaves there are already standardized products, as is the case of olive leaf extract with 20 % oleuropein content.

Olive extracts help to:

- Boost the immune system;
- Prevent cardiovascular risk;
- Control glucose levels;
- Regulate blood pressure;
- Reduce endothelial dysfunction;
- Act as antioxidants and anti-aging elements.

#### *c) Price of final biobased product(s) paid by consumer*


The price range of biobased products is very wide, although the average price is between 20-30 €/kg. In general, less richness of the active product is usually linked to products sold at lower cost and large volume and vice versa.

Products with lower added value are marketed in areas of geographical proximity while those with high added value are destined for more distant markets with greater purchasing power, such as Japan, where the costs associated with transport in relation to the selling price are not very relevant.

#### *d) Stakeholders involved in the final market*

Industries that buy biobased products such as the ones marketed by Natac Group have different requirements according to their own realities. In the case of pharmaceutical and nutraceutical industries only a few hundred kilos are usually required as the biobased products they buy usually have higher contents of the active ingredient (therefore these are handled in smaller volumes). However, the opposite is true in animal feed industries. Sales of biobased products for these industries are counted in tonnes. Much more exclusive is the cosmetic industry, which only acquires a few kilos of biobased products for their incorporation into final products. There are many companies in the market that are competitors offering the same products.

Other companies offer alternative biobased products obtained from other agri-food biomasses (green tea extracts, pomegranate, citrus, etc). On the other hand, the market for synthetic antioxidants is also been identified as competing. As for the price of their biobased products, Natac Group pointed out that, given their particular business model in which they establish alliances with agro-industries, the prices they offer are quite competitive in relation to those of alternative biobased products.

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## 2.6 Non-technical issues

### IBLC

#### *a) Measures, incentives & subsidies that could stimulate starting & setting up an IBLC*

There is a growing interest in the development of bioeconomy on the part of the administration at regional, national and European level from which agro-industries such as olive pomace oil industries could take advantage. In addition, the participation in Research, Development & Innovation projects enhances the development of new products and processing centres. In the case of Natac Group's biotech SME they successfully participated in both national (Ministry of Economy (MINECO), Centre for Industrial Technological Development (CDTI), Junta de Andalucía, Operational Groups, etc.) and European (FP7, H2020) Research, Development & Innovation projects, fact that has allowed them to advance in the development of their processing centres.

Despite the above, there is a significant need for both regulatory and economic measures.

#### *b) Environmental regulations that apply to the IBLC*

Biotech SMEs such as Natac Group are subjected to the same environmental regulations as those applicable to any agro-industrial activity in relation to dumping, waste, noise, emissions, etc.

#### *c) Social acceptance new activity at the IBLC (e.g. more trucks can cause problem due to noise)*

So far social acceptance of phenols' extraction plants seems to be good, no problems or complaints about their activities were reported by Natac Group.

### Final biobased products


#### *d) Measures, incentives & subsidies fostering the uptake of biobased products, the creation of new markets, etc.*

At present, there are not many measures or incentives in Spain to encourage the adoption of biobased products. As in other sectors, market entry is price driven.

However, the participation in national or European projects has allowed Natac Group to develop new biobased products. Regional and supra-autonomous Operational Groups are eligible for support from the European Agricultural Fund for Rural Development (EAFRD), both in terms of setting up the group and preparing its innovation project, and in terms of implementing that project. In this sense, both Natac Group and Oleícola El Tejar have participated through Innovaoleo at an operational group called Innoleaf, which aimed to make full use of the olive leaf.

#### *e) Social acceptance of the (new) final biobased products*

Extraction of final biobased products generally has a good acceptance because it implies the obtaining of products that already existed, but with a natural base and in a much more sustainable way. In the case of innovative products, market entry is guaranteed by efficiency and because the consumer is interested in "clean labels" on the products, that is, that they include natural components rather than synthetic ones in their formulation.

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### 3. Lessons learned

#### a) *Successes*

The partnership between Natac Group Biotech SME and the cooperative Oleícola El Tejar is an example of a successful business model, allowing them to offer high quality products in markets such as pharmaceuticals, cosmetics, etc. Success is measured by the fact that they were in business for over 10 years and have broad prospects for the future.

#### b) *Difficulties (e.g. technical & economical bottlenecks, conflicts, etc.)*

The biggest difficulty, according to Natac Group, lies in convincing farmers and agro-industries to establish new ways of collaboration. It is also difficult to bring together actors from different sectors (innovation, farmers, industry, etc.) and have them all benefit in some way. Scaling up processes to achieve industrial production and the development of an integral multi-product biorefinery requires long maturation times with significant investments in Research, Development & Innovation.

In addition, legal consideration of by-products as wastes, provokes administrative burdens that very often discourage agro-industries to implement new business lines such as the one proposed for the olive oil sector.

#### c) *Solutions for problems*

The main solution should be to ensure that all actors involved in the chain would benefit. In order to overcome the reluctance of farmers, agreements must be reached through compensation, indicating that it is essential to ensure that all actors are benefited and, thus, are inclined to participate.

The implementation of models such as collaborative innovation seems to be key to ensuring success and shorten time to market access.

#### d) *Things to avoid*

Business models in which it is considered that the under-exploited biomass will be obtained at no cost should be avoided. All operators should benefit, as noted above.


### 4. Recommendations for this specific sector

#### a) *Recommendations*

It is necessary to:

- Search formulas that can bring together agents from very different sectors;
- Seek innovative business models that allow all agents to generate profits;
- Overcome the conservative thinking.

It is important to be able to combine technological development, access to raw materials, manufacturing capacity and, of course, international trade.

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## ANNEX E. DATA CASE STUDY 4. WINE SECTOR - DISTILLERIES ALLIANCE WITH LOGISTIC & BIOTECH COMPANIES - SPAIN

### 1. General introduction case study for specific sector

#### a) Size of the sector in the country/region

Spanish vineyard occupies the widest wine area cropped all over the world (936,000 ha in 2017), positioning Spain among the three main wine producers. Thus, wine sector companies represent one of the most relevant industries of the country. Regarding sector volume, Spain has around 4,000 wine cellars and 20 distilleries.

Castilla-La Mancha is the first wine producer region of Spain, manufacturing more than half of the wine national production (50.6 %). In this region there are located around 600 wineries, almost 11 % of Spanish wineries. In addition, from the existing distilleries in Spain, 9 of them are placed in Castilla-La Mancha (Figure 39).

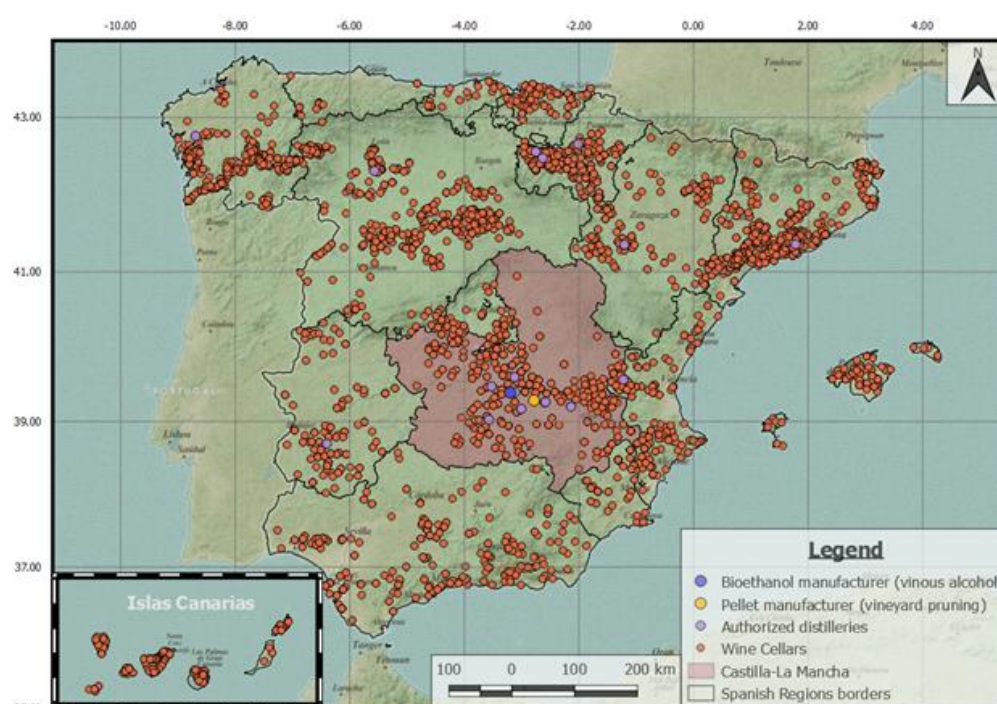



Figure 39: Wine sector in Spain.

#### b) Main economic activities of the sector

Spanish average annual production of wine and must is between 40 and 42 million hectolitres (44.4 million in 2018)<sup>15</sup>. While wine sector exports have multiplied by five over the past 25 years, national

<sup>15</sup> <http://www.fev.es/sector-cifras/>

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consumption was reduced to half during the last 20 years, standing current consumption lower than 20 litres per person per year.

Though there are two main economic activities in this sector, the production of red and white wine in the wineries and the obtaining of alcohol in the distilleries, there are several by-products that are susceptible of getting a better valorisation.

*c) Existing and newly planned production plants of the sector in the country/region*

Spanish wine sector is a dynamic sector in which every year new wineries begin or cease their activity, despite this there is no known plan to build new distilleries or related industries in Spain. However, Athisa Biogeneración, one of the few companies that collect the vineyards pruning for its valorisation as solid biofuel, is trying to scale-up its activity. The aim is to build-up a new power plant that would produce both electric and thermal energy (cogeneration) from the exclusive combustion of vineyards pruning. Moreover, Natac Group, a company which has among its objectives the extraction and elaboration of natural ingredients from the grape, is currently building new plants for the extraction of biobased products from different types of agro-food biomasses.

Alvinesa Natural Ingredients (main distillery in Spain) has recently approved (January 2020) the construction of a new plant for the production of high added value ingredients derived from grapes, such as polyphenols and anthocyanins. This construction implies an investment of 5 million Euros. The new plant, of around 4,000 square metres, with a capacity to produce more than 500,000 kilos of antioxidants and grape colourings, will have a laboratory with a clean room, a refrigerated warehouse for dry products and its own atomiser<sup>16</sup>.


*d) General description of the suggested IBLC within the sector*

Suggested case study in the wine sector depicts a hypothetical alliance between distilleries, logistic companies and technological centers that would allow both the vineyards pruning valorisation and the extraction of phenols within these agro-industries, running as IBLCs. For this purpose, several interviews were carried out to distilleries, to a logistic company (Athisa Biogeneración) and to a biotech SME (Natac Group). Therefore, the case study for the wine sector includes two different pathways: vineyards pruning and phenols.

Distilleries are industries that process grape pomace, lees and filter pastes generated by wineries. During the process distilleries extract some bio-products such as alcohol, tartaric salts, grape seed oil, exhausted grape pomace, etc., which are later marketed into the chemical, biomass, food and pharmaceutical sectors. These agro-industries usually self-consume part or all the by-products generated in their own process (mainly exhausted grape pomace, composed by dried grape skin, seeds and the cluster stalks) to cover their thermal energy needs in rotary dryers.

Despite there is one cooperative distillery (Destilerías San Valero) working in an Operational Group for the development of specific machinery aimed at the collection of pre-pruning of vines (so this can be valorised as biomass for energy purposes), no distilleries were identified in Spain with a

<sup>16</sup> <https://www.alvinesa.com/news/articulo/alvinesa-culmina-su-plan-de-inversiones-por-encima-de-60meur-con-la-construccion-de-una-nueva-planta-de/>

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developed logistic for its valorisation in their own facilities. This is the reason why an alliance with logistic companies such as Athisa Biogeneración is proposed.

Athisa Biogeneración, a company aimed at the energy valorisation of vineyards pruning, follows a specific procedure which includes collection, chipping, cleaning, and drying of vines pruning, in order to manufacture solid biofuels (pellets, chips, bales). These solid biofuels are currently sold both at national and international markets. They also uproot the vines when the plantation is renewed, although at a much more sporadic rate. At present these by-products are usually burnt without being valorised. Occasionally, and after a previous chipping, they are left in the fields.

Due to the strategic locations of distilleries (surrounded by wineries and vineyards) and the availability of compatible equipment for biomass exploitation, they are proposed as the ideal Agro-industries where integrating the biomass logistic centre that holds this hypothetical case study.

## 2. Description of the six stages of the chosen pathway

### 2.1 Feedstock supply

a) *Types of available feedstock (e.g. agriculture, forestry, livestock, side-streams, residues, waste, etc.)*

Wine sector farmers and industries produce different by-products during the different stages of the process (pruning, harvest, wine making and alcohol production). By-products generated in wineries are usually sent to distilleries, where they are processed for the production of several intermediate bio-products such as alcohol, tartrate, grape seeds, etc. However, distilleries are very interested in new opportunities that could allow them to increase the value of their products, thus, the final use of wineries by-products is highly based on the economic performance.


By-products currently generated during vine cultivation and wine production are:

- Vine cultivation (farmers): Pruning, vine strains and leaves. Usually unexploited, pruning is usually burnt by the farmers.
- Wine making (wineries): Grape pomace (seeds, skins and stalks), lees and filter pastes.

b) *Yearly amount of the total production per feedstock in the region (and sometimes neighbouring regions) that is not currently being used for existing industries, and that is thus available for IBLCs [tonne dry matter or tonne fresh matter combined with moisture content]*

Regarding the pruning pathway, Athisa's Bioegeneración estimation is that every year around 320,000 tonnes (moisture content: 30 %, after 60-90 days left on the field) of vineyards pruning are generated in an area of about 190,000 ha (corresponding yield of 1.7 tonne/ha) inside the Castilla-La Mancha Region. Considering the same yield of 1.7 tonne/ha Spanish Co-ops estimates that around 1,600,000 tonnes of vineyards pruning would be available at national level (moisture content: 30 %, after 60-90 days left on the field). In addition, vine strains are also uprooted at an average yield of 10-15 tonnes/ha, though these are collected in a much more sporadic cadence.

On the other hand, depending on their size, Spanish distilleries process significantly different amounts of wineries by-products, which is why this information is provided below by means of wide

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ranges<sup>17,18,19</sup>. In addition, as data was not available for all cases, some of the following figures were roughly estimated through extrapolations:

- 5,000 – 50,000 tonnes of lees;
- 15,000 – 175,000 tonnes of grape pomace;
- 1,000 – 11,000 tonnes of pastes.

As already mentioned, the availability of these by-products usually depends on which market/activity provides the distilleries with the best economic performance. Despite of this all of them are being valorised at present by the distilleries in several ways.

These by-products are the raw material for the phenols' extraction plants (wine sector). However, in the case of high added value biobased products, the quantities of raw materials required are usually small and, therefore, do not alter the overall process carried out by the distilleries. In addition, after the extraction of these high added value compounds most of the raw material used can be returned to distilleries process.

*c) Seasonality pattern per feedstock (in what periods will it become available e.g. harvested in September-October)*

Pruning is usually carried out from November to March. Considering that it has to remain between 2 and 3 months on the soil to lose enough moisture content, it is expected that this feedstock will be available at the right conditions between February and June.

By-products generated by wineries are available between the end of August and the end of January (working period), though some of them can be stored during several months (such as the grape pomace).

*d) Distribution per feedstock (specify actual locations of areas where it is produced in the region/neighbouring regions)*

Athisa Biogeneración has estimated the following availability (Table 23) for vineyards pruning in different municipalities of the Castilla-La Mancha Region (Spain).

As it has already been mentioned, Castilla-La Mancha is the first wine producer Region in Spain. This fact makes this region the most promising one to develop the hypothetical case study in Spain, since there is plenty available raw material coming both from vineyards and wineries.

<sup>17</sup> <http://www.agralco.es/quienes-somos/>

<sup>18</sup> <https://bioenergyinternational.es/alvinesa-coloca-una-tercera-unidad-de-generacion-de-vapor-con-biomasa/>

<sup>19</sup> <https://www.expansion.com/2011/10/25/valencia/1319567425.html>


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Table 23: Vineyards pruning availability in the Castilla – La Mancha Region

Vineyards pruning availability in the Castilla – La Mancha Region		
Zone	Municipality	Potential tonnes
1	Socuéllamos	34,980
	Villarrobledo	34,190
	Las Mesas	9,478
2	San Clemente	14,906
	El Provencio	6,992
3	Las Pedroneras	10,931
	Mota del Cuervo	12,737
4	Campo de Criptana	24,702
	Alcazar de S. Juan	20,154
5	El Tomelloso	21,715
	Agramasilla de Alba	11,000
6	Corral de Almaguer	24,980
	Quintanar de la Orden	9,732
	Miguel Esteban	11,838
	Villanueva del Alcardete	15,847
	El Toboso	13,784
7	Alhambra	15,139
	La Solana	8,653
	Manzanares	9,732
	Membrilla	6,635
Total	20 Municipalities	318,121 tonnes

e) *Quality feedstock before it enters the IBLC (e.g. density, form, size, moisture content, ash content etc.)*


The quality of the vineyards pruning in the field is usually low due to the high content (15-20 %) of inorganic contaminants (stones, sand, metals, etc.) that are incorporated during the dragging to the margins of the plots. For this reason, Athisa Biogeneración has patented a cleaning system that has made it possible to solve this technical barrier, reducing the ash content to below 3 % (after combustion). The moisture content of the pruning is between 40-60 % when the cut is made, with a density of about 100 kg/m<sup>3</sup>. This moisture content drops to 30 % after 30-60 days in the field.

Regarding the phenols' pathway, the manufacture of certain biobased products is only feasible from the exploitation of specific raw materials. Depending on the origin, several bio-products can be generated and destined for different uses.

In particular, the grape pomace received by the distilleries usually contains 55 % of grape pulp and skins, 25 % of stems and 20 % of seeds<sup>20</sup>. Its physicochemical composition shows the following average values:

- Moisture: 30-60 %;

<sup>20</sup> <https://bioenergyinternational.es/alvinesa-coloca-una-tercera-unidad-de-generacion-de-vapor-con-biomasa/>

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- Ashes: 3-6 %;
- pH≈4;
- C/N≈30 %;
- Alcoholic content: 3-7%.

*f) Unit on-farm storage costs when storage happens on the farm [€/tonne dry matter or €/m<sup>3</sup>]*

According to Athisa Biogeneración estimation, when vineyards pruning storage happens on the farm itself costs rises to 15-17 €/tonne. This figure considers the renting cost of the gathering area, the cost of collection and transport, and the cost of management of the pruning.

There is no available information related to the unit on-farm storage costs in the case of distilleries. With regard to the extraction of biobased products, due to the formula of alliances proposed by this case study, the storage costs of raw materials would be borne by the agro-industry that supplies the biotech company.

*g) Price of feedstock at roadside (before transport, when sold by farmer to IBLC) [€/tonne dry matter or €/tonne fresh matter combined with moisture content]*

Concerning the pruning pathway, the bonus that the farmer receives for the vineyards pruning collection and transport to the gathering sites amounts 10 €/tonne (30 % moisture content approx.) in the business model established by Athisa Biogeneración. In farmers decided to leave the logistics activities in hands of an external company they would only get non-tangible remuneration. It is a service of vineyard pruning pick up and removal that the farmer gets for free, and this is a value itself.

Several types of contracts can be set between distilleries and their customers. Cooperative distilleries, for instance, provide a service to other cooperative wineries by removing their by-products. In this sense, instead of paying for the purchase of these by-products, at the end of the year the profits generated by their activity are divided and distributed to the member cooperatives.

## 2.2 Logistics

### Transportation

*a) Transportation types used including average capacity*

In the case of vineyards pruning, trailers as the ones of the following pictures (Figure 40) can be used for their collection and their final transportation in the storage areas.

Some distilleries subcontract the transport of wineries by-products, making use of big trailers to transport the grape pomace.

For the extraction of biobased products, being the extraction plants integrated (as proposed in this case study) inside the agro-industries facilities with which they establish collaborative alliances, associated costs with transport of raw material are not relevant and are usually assumed by the agro-industry.


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Figure 40: Transportation system.

*b) Transportation distances (average/related to distribution of feedstock) [km]*


Average transport distance of vineyards pruning from the fields to the gathering points was estimated in 3.3 km, according to the logistics that Athisa Biogeneración has already established for their current activity. However, it should never exceed a maximum of 5 km to ensure a profitable and feasible activity. No data are available regarding the transport distances between the collection platforms and the central processing plant.

In the case of wine cellars by-products, average transport distance to distilleries was estimated in 60 km by one of the interviewed distilleries. However, this distance can vary significantly from one distillery to another.

Transport distances from agro-industries to biobased products extraction plants are not expected to be relevant, as this case study proposes to integrate the extraction plants within the facilities owned by the agro-industries (in this case, the distilleries).

*c) Transportation losses [%]*

According to Athisa Biogeneración experience, minimal transportation losses occur (<1 %) when transporting vineyards pruning. The same situation can be extrapolated for the transport of wine cellars by-products to distilleries.

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In the same line, losses in the transport within phenols' extraction plants are not expected to be significant due to the proximity of the agro-industries which supply the raw material.

*d) Transportation energy/fuel consumption [MJ/km or l/km]*

Due to the fact that transportation is very often outsourced by agro-industries, the only available information in this regard refers to the collection of the vineyards pruning. An average fuel consumption is estimated around 1 l/km concerning the use of all the machinery involved in the collection process (Telescope Manipulator (Manitou) + tractor).

*e) Transportation costs [€/km]*

Similar than in the previous section, there is a lack of data for transportation costs in distilleries and phenols' extraction plants since transport is very often outsourced. Although collection and transport of vineyards pruning from the field to the gathering points is also usually subcontracted, the remuneration for doing this work was valued by Athisa Biogeneración in around 10 €/tonne. No data are available regarding the transport costs between the collection platforms and the central processing plant.

## 2.3 IBLC design

### Synergy with existing machinery, storage, labour & infrastructure

*a) Available pre-treatment & handling machinery, storage facilities, labour and other infrastructure types including average capacity per period (month)*


Vineyard farmers usually have tractors and pulling systems to collect the pruning from the soil that could be used in the new logistic.

Distilleries owns machinery and facilities suitable for biomass processing such as rotary dryers, storage platforms, forklifts, tractors with shovels, etc. Labour force in distilleries ranges from 20 to 60 permanent employees (biggest ones hire up to 60 additional seasonal workers during some months and the smallest ones around 10), these employees have wide experience in the management of biomass by-products, an important aspect for the establishment of the new IBLC.

Regarding the phenols' pathway, biotech companies could take advantage of the machinery and facilities from agro-industries that supply raw materials. In this way, the alliance between biotech companies and agro-industries would significantly decrease investment costs. There are plenty assets that can be shared such as the infrastructure related to auxiliary processes (fire extinction, security, steam boiler, etc.) and storage facilities but also, for more specific operations, machinery for drying (trommel), mixing, etc. could be useful for the development of new activities.

*b) Idle period of available and suitable pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

Idle period in distilleries usually happens from June to September. Is precisely during these months when most of the facilities, equipment and other compatible resources would be available for the valorisation of vineyards pruning and the extraction of alternative biobased products, such as

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phenols. This would enable distilleries to prolong their activity and increase the added value of those by-products that are currently unused or underused. It would also provide a new source of additional income to their regular activity. However, this idle period could undergo significant variations if grape production were to increase in subsequent years.

*c) Efficiency: losses during production, storage and pre-treatments [%]*

Losses during the valorisation process of vineyards pruning were estimated by Athisa Biogeneración as follows:

- Processing (shredding and cleaning): loss of 15 %. Most of the losses are due to cleaning process, shredding has a minor impact in this loss of material. Cleaning process eliminate all the inorganic contaminants (sand, stones, metals, etc.).
- Drying: loss of 10-20 %. After the cleaning process Athisa Biogeneración performs a natural drying on covered structures, reducing moisture content to 12-25 %.

No data on this aspect was available for distilleries or phenols' extraction plants.

*d) Machinery energy consumption [MJ/tonne dry matter] & operation rate*

The only available data regarding machinery energy consumption concerns the telescopic equipment (2.18 l/tonne) and the joint performance of the trailer and tractor (4 l/tonne), used on the pruning collection.

*e) Costs of used pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

Concerning the vineyards pruning pathway, total production costs of chips is around 30 €/t, including storage costs, chipping, cleaning, equipment amortisation and royalties (17 years).


In small distilleries labour costs are estimated somewhere between 600,000-900,000 €/year. No data was retrieved for the phenols' pathway.

*f) Intermediate biobased products obtained (see 2.4)*

All the distilleries generate ashes by burning the exhausted grape pomace that they self-consume to meet their thermal needs. These ashes can be considered an intermediate bio-product for the manufacture of fertilizers. The same would occur in the hypothetical case of self-consumption of the chips and pellets produced from pruning for energy production.

Distilleries generate several intermediate biobased products such as grape seeds, tartrate as well as food, neutral and crude alcohol.

No intermediate products are produced during the phenols' extraction. However, after the extraction the remnant raw material can be re-introduced in the distilleries process and therefore, it could be considered as an intermediate biobased product.

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### New machinery, storage & infrastructure

#### *g) Additional required investments for new machinery/infrastructure (CAPEX)*

For the needs of the suggested IBLC new machinery investments will be required in most distilleries (despite the synergies with some of the existing equipment). For instance, the purchase of hammer mills is an investment that distilleries in general could perform to obtain a much more homogeneous texture in their final biomass products. Concerning the management of vineyards pruning, distilleries would probably have to invest in the purchase or renting of mobile industrial chippers, high capacity trailers, telescopic handlers, pellet press, cleaning systems, etc. Based on Athisa Biogeneración estimation, a tractor with trailers of 40 m<sup>3</sup> would be required to carry a minimum of 3,000 kg of vineyards pruning in every journey (so the logistics can be profitable). In this sense, if a trailer makes 8 trips a day, it can pick up 24 tonnes/day.


Sometimes, due to the lack of knowledge on these activities, some agro-industries make wrong investments in their new equipment, which highly compromise their chances to implement feasible IBLCs. The association with logistic companies such as Athisa Biogeneración would provide access to technical advice, lowering the risk of mistaken investments and obtaining better economic performances due to their wide experience with this type of equipment. In addition, depending on the terms of the agreement some of them could be probably rented or shared by the logistic company.

Biobased products processes such as the phenols' extraction would usually require even higher investments than the ones needed for the vineyards pruning valorisation, though this information was not provided during the interviews. However, the association with biotech companies is essential for a proper technical advice and the sharing of some investments.

#### *h) Additional amount of (part time) personnel required*

In the case of those distilleries that are partially self-consuming their own by-products for the production of bio-energy it is foreseen that no extra labour would be needed if they decide to have a full consume of their own biomass (mainly exhausted grape pomace), since they already have labour attached to this task. However, when starting new activities such as the vineyards pruning valorisation, it is expected that at least training sessions would be required for chipping, storage and other management operations. This new activity would be a chance for distilleries to extent the length of their employee's contracts (during the idle period), so more stable jobs and better efficiency of the workforce would be achieved.

When implementing new activities for biobased products manufacture in agro-industries, some of the existing labour could be attached to related operations with the management of the biomass.

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*i) Additional maintenance requirements (e.g. cleaning costs, machine resetting costs for switching between feed stocks) [€/tonne dry matter]*

It is important to consider maintenance requirements in the case of vineyards pruning, especially for chippers and cleaning equipment. The main cost is related to the maintenance of the shredders (hammers). The total cost of additional maintenance is about 2 €/tonne.

In the case of phenols' extraction, no additional maintenance costs are required besides those already incurred by agro-industries and the new machinery required for this activity (no data available).

*j) Additional operational costs for personnel, maintenance, management [€/tonne dry matter]*

Operational costs (personal, fuel and management) amounts around 9-12 €/tonne for chipping and cleaning processes in the case of the pruning valorisation.

For the phenols' extraction, the additional costs related to the process are more significant at first, with all that is involved in starting up the processing plant and, in this case, adapting or coupling to an existing process. Once the new activity flows into the usual regime, operational costs are similar than those of any agro-industrial activity.


*k) Current state of IBLC design (TRL, technology maturity) and future improvements foreseen (coming 5 years)*

Despite there are no distilleries in Spain that have already arranged a logistic for the valorisation of vineyards pruning in their own facilities, they are placed at strategic locations for doing so as they are usually surrounded by wineries and vineyards. In addition, they are very used to deal with the valorisation of by-products and residues of the wine sector. These factors, together with the aforementioned synergies in terms of machinery and facilities, idle period, etc., led to the inclusion of pruning as part of this case study.

Likewise, some companies have solved relevant barriers to the valorisation of vineyard pruning through the development of new equipment. Examples of this are the washing system patented by Athisa Biogeneración or the new pre-pruning machinery developed within the framework of the VidBiomasa operational group<sup>21</sup>. However, there are still many issues that could be improved concerning the collection and transport of the pruning (logistic), since this is the main bottleneck that hinders the profitability of its valorisation nowadays.

On the other hand, most distilleries self-consume all or part of their own biomass to cover their thermal needs. Those who are not yet exploiting all the potential in this regard (due to different reasons) are completely aware of this opportunity and plan to make the necessary investments in a near future, as these will ensure them to get relevant energy cost savings. Distilleries size is very linked in Spain with the degree of diversification (regarding the catalogue of final biobased products that are produced) and the TRL implemented in their processes.

<sup>21</sup> <https://www.heraldo.es/noticias/aragon/2020/03/19/de-la-vid-hasta-los-sarmientos-1364076.html>

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High sized distilleries such as Alvinesa Natural Ingredients are already running complex processes (phenols' extraction among others) in their facilities since they have access to huge amounts of wineries by-products. In addition, they are developing new products in TRL 4-5-6, as is the case of obtaining biobased products from other by-products/wastes.

## 2.4 Intermediate biobased products

### Intermediate biobased products

#### a) Types of intermediate biobased products made at IBLC

All the distilleries generate ashes by burning the exhausted grape pomace that they self-consume to meet their thermal needs. These ashes can be considered an intermediate bio-product for the manufacture of fertilizers. The same would occur in the hypothetical case of self-consumption of the chips and pellets produced from pruning for energy production.

Distilleries generate several intermediate biobased products such as grape seeds, tartrate as well as food, neutral and crude alcohol.

No intermediate products are produced during the phenols' extraction. However, after the extraction there is usually a remnant that can be re-introduced in the distilleries process and therefore, these could be considered as an intermediate biobased product.

#### b) Quantities produced at IBLC per year/month [tonnes/year and tonnes/month]

Ash quantities that would be generated when self-consuming biofuels derived from vineyards pruning will depend on the energy consumption of each distillery.

Similar than in the feedstock section, depending on their size, Spanish distilleries process significantly different amounts of intermediate bio-products, which is why this information is provided below by means of wide ranges<sup>22,23,24,25</sup>. In addition, as data was not available for all cases, some of the following figures were roughly estimated through extrapolations:


- 3,000 - 23,000 tonnes/year of grape seeds;
- 1,000 - 7,500 tonnes/year of tartrate;
- 500 - 5,000 tonnes/year of food alcohol;
- 1,000 - 15,000 tonnes/year of crude alcohol;
- 500 - 15,000 tonnes/year of neutral alcohol.

<sup>22</sup> <https://www.alvinesa.com/sobre-alvinesa/instalaciones/>

<sup>23</sup> <http://www.agralco.es/quienes-somos/>

<sup>24</sup> <https://bioenergyinternational.es/alvinesa-coloca-una-tercera-unidad-de-generacion-de-vapor-con-biomasa/>

<sup>25</sup> <https://www.expansion.com/2011/10/25/valencia/1319567425.html>

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In some cases, it is the distilleries themselves that use these intermediate bio-products to obtain final bio-products such as grape seed oil, bioethanol, wine distillates or spirits, grape seed flour, biogas, tartaric acid, colorants or polyphenols.

- c) Quality intermediate biobased product when leaving IBLC (e.g. density, form, size, moisture content, ash content, etc.)

Quality aspects from intermediate biobased products generated in the distilleries:

- Grape seeds have a 17 % oil content<sup>26</sup>;
- Tartrate cannot present a moisture content above 2 % at the time of storage. Lime tartrate has around 50 % tartaric acid content when leaving the distilleries<sup>27</sup>;
- Food alcohol can have a 77 % alcoholic strength for the production of spirits and 94,5 % alcoholic strength when destined to distillates;
- Crude alcohol has around 93 % alcoholic strength<sup>28</sup>;
- Neutral alcohol has around 96 % alcoholic strength<sup>29</sup>.

- d) Price of intermediate biobased products sold by IBLC to final industry [€/tonne]

Prices concerning the intermediate bio-products generated in the distilleries:

- Grape seeds are sold at a price between 100-120 €/tonne;
- Lime tartrate is sold at a price between 1.9-2.1 €/absolute degree;
- Crude alcohol is sold at a price between 0.50-0.70 €/hectograde;
- Neutral alcohol is sold at a price between 1.35-1.55 €/hectograde.

- e) Industries that buy the intermediate products from the IBLC

Each biobased product generated in distilleries has a different market:

- Grape seeds: usually sold to bigger distilleries or other industries that own the proper machinery for performing the extraction of grape seed oil (high volumes make this activity profitable);
- Tartrate: Usually sold to bigger distilleries or other chemical industries that have the necessary equipment to produce tartaric acid;
- Food alcohol: Used in the production of special wines (Port and Sherry) and in the production of Brandy<sup>30</sup>.


<sup>26</sup> <http://www.agralco.es/productos/aceite-de-pepita/>

<sup>27</sup> <http://www.agralco.es/productos/tartrato/>

<sup>28</sup> <http://www.agralco.es/productos/alcohol/alcohol-bruto/>

<sup>29</sup> <http://www.agralco.es/productos/alcohol/alcohol-neutro-o-rectificado/>

<sup>30</sup> <http://www.agralco.es/productos/alcohol/aguardiente-y-destilado-de-vino/>

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- Crude alcohol: Used primarily as a car fuel (bioethanol) mixed with gasoline in varying amounts to reduce consumption of fossil fuel products. The most common blends are: E10 and E85, which contain 10 % and 85 % ethanol, respectively<sup>31</sup>;
- Neutral alcohol: Preferably used as an industrial solvent in the chemical sector: inks, paints, perfumes, etc.

## 2.5 Final market

### Final biobased products

f) *Types of final biobased products (that are made by another industry from the feedstock ‘intermediate biobased products’ delivered by the IBLC)*

Final biobased products derived from the vineyards pruning pathway can be: pellets, chips in bulk and chips in bales (Figure 41).



Figure 41: Final biobased products.


Concerning the phenols' pathway, some of the final products that could be obtained in distilleries are proanthocyanidins, anthocyanins, flavonoids, resveratrol, enocyanine, etc. However, it should be noted that bigger distilleries produce other final biobased products such as, tartaric acid, grape seed oil, bioethanol, grape seed flour, colouring agents, etc. All distilleries produce exhausted grape pomace, which is usually self-consumed in their own facilities.

g) *Quantities produced at IBLC per year/month [tonnes/year and tonnes/month]*

Since most of the vineyards pruning are currently unexploited in Spain, it is impossible to foresee the expected quantities that could be produced at the hypothetical IBLC. However, current production figures of Athisa Biogeneración are reported here as a reference of a small-scale logistics operation:

- Pellets: 15,000 tonnes/year;
- Chips in bulk: 25,000 tonnes/year;
- Chips in bales: 2,000 tonnes/year.

<sup>31</sup> <http://www.agralco.es/productos/alcohol/alcohol-bruto/>

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#### *h) Quality requirements needed to satisfy consumers' preferences*

Quality requirements for the pellets and chips are the following ones.

##### ❖ Pellets:

- Low Heating Value of 4,000-4,300 kcal/kg;
- Density: 660 kg/m<sup>3</sup>;
- Size: 6-8 mm diameter and 3-5 mm length;
- Moisture content: 6-10 %;
- Ash content: <3 %.


##### ❖ Chips:

- Heating value (dry matter): 5.02 MW/tonne;
- Ash melting point: >1,450 °C;
- S content (p/p): 0.03 %;
- Cl content (p/p): 0.01 %;
- N content (p/p): 0.59 %;
- Thin particles: <5 %;
- Density: 180 kg/m<sup>3</sup>;
- Chip size: 50-500 mm;
- Moisture: <12 %;
- Ash content: <3 %.

All the final biobased products are offered according to the quality required in the market, tailored to the customer. In the case of innovative products derived from the phenols' extraction process, the specifications are marked either by the customer or by official regulations such as the European Pharmacopoeia (which marks moisture content, ashes, pesticide residues, heavy materials, etc.), or the content of impurities marked by pharmaceutical, food, nutraceutical and/or cosmetic regulations. Each bio-based product (Table 24) is extracted from different products of the wine sector according to their different features.

*Table 24: Phenols' extractions based on the type of by-product used.*

Phenols' extractions based on the part of the plant used		
	Parts of the plant used	Extract standardised to
	Grape (complete fruit)	20-95 % Total polyphenols
	Seed	30-95 % Proanthocyanidins
	Leaf	2-10 % Flavonoids
	Skin	0.5-5 % Anthocyanins
	Grapevine	0.5-5 % Resveratrol and derivatives
	Wine	30 % Polyphenols Wine powder
	Full plant profile (Natavid)	50 % Proanthocyanidins - 10 % Flavonoids - 0.3 % Resveratrol - 0.5 % Anthocyanins

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*i) Price of final biobased product(s) paid by consumer*

Regarding the vineyards pruning pathway the prices of final biofuels obtained are:

- Chips: 40-45 €/tonne;
- Pellet: 120 €/tonne.

The exhausted grape pomace is usually self-consumed by the distilleries themselves, which is why no data are available on the price of this final bio-product.

On the other hand, the price range of biobased products that can be produced from wineries by-products is very wide, ranging from 6 to 2000 €/kg, although the average price is set between 50-100 €/kg. In general, less richness of the active product is usually linked to products sold at lower prices and large volume and vice versa. Products with lower added value are marketed in areas of geographical proximity while those with high added value are destined for more distant markets with greater purchasing power, such as Japan, where the costs associated with transport in relation to the selling price are not as relevant. In this line, Alvinesa Natural Ingredients' distillery extracts 15 different products at the moment. Their range of prices varies from 3€/per kg of colorants up to 600-700 €/per kg of resveratrol<sup>32</sup>.

*j) Stakeholders involved in the final market*

Biofuels derived from vineyards pruning have different markets depending on their features. For instance, while chips and bales are required by other agro-industries or biomass energy plants, pellets are destined to households' market due to the high-quality requirements of low power equipment. Generally, boilers or burners with higher power capacity allow lower quality biomass than those used by households.

As it has already been mentioned exhausted grape pomace is usually self-consumed by the distilleries.

Biobased products (phenols, tartaric acid, colorants, grape seed oil, etc.) are usually destined to the pharmaceutical, chemical (cosmetic), animal feeding, nutraceutical and functional food markets.


## 2.6 Non-technical issues

### IBLC

*a) Measures, incentives & subsidies that could stimulate starting & setting up an IBLC*

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<sup>32</sup> [https://elpais.com/economia/2019/07/05/actualidad/1562318602\\_801830.html](https://elpais.com/economia/2019/07/05/actualidad/1562318602_801830.html)

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There is a significant need for both regulatory and economic measures in Spain when considering the valorisation of vineyards pruning. Some of these needs and others were identified by Athisa Biogeneración:

- Active participation of the national, regional and local administration in the discouragement of burning (Table 25).

*Table 25: Measures, incentives & subsidies of a new IBLC.*

Measures, incentives & subsidies proposed for enhancing IBLCs implementation		
Administration	Restriction of Burning	Stakeholder incentives
National	Enforce the Integrated National Energy and Climate Plan (PNIEC)	Promote incentives for all value chain actors
Regional	Through the promulgation of Laws and Decrees	
Local	Through the promulgation of Municipal Bands	


- Encourage cooperatives and wineries to communicate their members the existing alternatives to the pruning burnt.
- Optimisation of the logistics to increase profitability and make the pruning collection feasible for farmers and agricultural service companies.
- Incentives to provide the collection agents with the necessary material means and to qualify human resources (Comprehensive Qualification and Employment Programme (PICE) of the Chambers of Commerce). Dual training Chamber of Commerce Programme for young people (under 30 years of age).

There is a growing interest in the development of bioeconomy on the part of the administration at regional, national and European level from which agro-industries such as distilleries could take advantage. In addition, the participation in Research, Development & Innovation projects enhances the development of new products and processing centres. In the case of Natac Group's biotech SME they successfully participated in both national (Ministry of Economy (MINECO), Centre for Industrial Technological Development (CDTI), Junta de Andalucía, Operational Groups, etc.) and European (FP7, H2020) Research, Development & Innovation projects, fact that has allowed them to advance in the development of their processing centres.

On the other hand, under the Law: "Ley 24/2013, de 26 de diciembre, del Sector Eléctrico (BOE 27/12/2013)" and the Royal Decree: "Real Decreto 413/2014, de 6 de junio (BOE 10/06/2014)" subsidies to high efficiency cogeneration facilities producing electricity from renewable energy sources, cogeneration and waste are regulated.

In particular, the facilities that would benefit from such remuneration parameters when using solid biomass of agricultural origin for electricity production or cogeneration would be those classified under the groups:

- B.6: 'Electricity generation or co-generation plants using biomass from energy crops, agricultural, livestock or horticultural activities, forestry and other forestry operations in woodlands and green areas as the main fuel. The main fuel is defined as a fuel that accounts for at least 90 per cent of the primary energy used, measured by the lower calorific value'.

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- B.8: "Electricity generation or co-generation plants using biomass from industrial plants in the agricultural or forestry sector as main fuel. The main fuel is defined as a fuel accounting for at least 90 % of the primary energy used, measured by the lower calorific value".

Under this specific remuneration system, the facilities may receive, during their regulatory lifetime, in addition to the remuneration for the sale of energy valued at market prices, a specific remuneration composed of the following terms:

- A term per unit of installed power that covers, when appropriate, the investment costs for each standard facility that cannot be passed on through the sale of energy on the market, referred to as investment remuneration;
- A term for the operation that covers, when appropriate, the difference between the operating costs and the operating income of the corresponding standard facility, which is called the remuneration for the operation.

The remuneration for the investment and, when appropriate, the remuneration for the operation, will make possible to cover the higher costs of the facilities for the production of electricity from renewable energy sources, high-efficiency cogeneration and waste, so that they can compete on an equal footing with the other technologies and obtain a reasonable return by reference to the standard installation applicable in each case<sup>33</sup>.

#### *b) Environmental regulations that apply to the IBLC*

In the same line, Athisa Biogeneración has identified several environmental regulations that could affect the development of an IBLC.


At national level:

- Integrated National Energy and Climate Plan (PNIEC);
- National Atmospheric Pollution Control Program (PNCCA);
- Circular Economy regulations.

At regional level (Castilla-La Mancha). Evaluation of the management model "direct burning at plot level" according to the law:

- Law 22/2011 on Waste and Contaminated Soil: Open burning is not a disposal operation covered by waste regulations. Agricultural pruning waste is considered waste unless it is used as biomass for agricultural or energy purposes.
- Air Quality Act 34/2007: Establishes the burning of agricultural waste as a potentially polluting activity of the atmosphere and must be subject to a series of authorisations and controls.
- The Mitigation Programme of the Climate Change Strategy of Castilla La Mancha includes the energy recovery of agricultural waste among its measures (measures 17, 19 and 20), which goes against burning at the foot of the plot.

<sup>33</sup> <https://energia.gob.es/electricidad/energias-renovables/Paginas/renovables.aspx>

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- The Preliminary Draft of the Circular Economy Law establishes the bases and principles for the reduction of fossil fuel consumption and the use of resources, which goes against burning at the foot of the plot.

c) *Social acceptance of the new activity at the IBLC (e.g. more trucks can cause problem due to noise)*

In the past distilleries used to have social problems due to their emissions that they have successfully solved by installing bag filters and, occasionally, electrostatic precipitators<sup>34</sup>. No complaints from neighbours were reported during the interviews.

In this sense, the integration of the new pathways into these agro-industries is not expected to generate any social problems as there would only be a minor increase of trucks circulation due to the pruning transportation. Extraction of final biobased products generally has a good acceptance because it implies the obtaining of products that already existed, but with a natural base and in a much more sustainable way. In the case of innovative products, market entry is guaranteed by efficiency and because the consumer is interested in "clean labels" on the products, that is, that they include natural components rather than synthetic ones in their formulation.

#### Final biobased products

d) *Measures, incentives & subsidies fostering the uptake of biobased products, the creation of new markets, etc.*


The Castilla-La Mancha Regional Institute for Food and Agricultural Research and Development (IRIAF) has several research projects on new ways of extracting polyphenols from vine pruning, grape pomace and grape seeds. This institute manages the demonstration-scale Clamber's biorefinery, built in 2017. This biorefinery is set in the region of Castilla-La Mancha (Puertollano) and is the only one of its type in Spain. Companies can test their products in these facilities before executing the process on an industrial scale, such as Alvinesa Natural Ingredients and Natac Group have already done.

At present, there are no measures or incentives in Spain to encourage the adoption of biobased products. As in other sectors, market entry is price driven. There are local initiatives such as the one from Athisa Biogeneración, which got in touch with national and regional cooperative representatives, Cooperativas Agro-alimentarias de España and Cooperativas Agro-alimentarias de Castilla-La Mancha to explore new ways of collaboration.

However, distilleries interviewed in the Castilla-La Mancha Region follow up some regulations, funding programmes and initiatives which could foster the creation of new markets such as:

- Castilla-La Mancha Regional Strategy on Forestry Biomass;
- Castilla-La Mancha Strategy on Bio-waste Management;
- Castilla-La Mancha Draft Law on Circular Economy;

<sup>34</sup> <https://bioenergyinternational.es/alvinesa-coloca-una-tercera-unidad-de-generacion-de-vapor-con-biomasa/>

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- FEDER & FOCAL funding programmes.

Regional and supra-autonomous Operational Groups are eligible for support from the European Agricultural Fund for Rural Development (EAFRD), both in terms of setting up the group and preparing its innovation project, and in terms of implementing that project.

#### *e) Social acceptance of the (new) final biobased products*

The integration of the new pathways into these agro-industries is not expected to generate any social problems as there would only be a minor increase of trucks circulation due to the pruning transportation. Extraction of final biobased products generally has a good acceptance because it implies the obtaining of products that already existed, but with a natural base and in a much more sustainable way. In the case of innovative products, market entry is guaranteed by efficiency and because the consumer is interested in "clean labels" on the products, that is, that they include natural components rather than synthetic ones in their formulation.

### 3. Lessons learned

#### *a) Successes*

Regarding vineyards pruning pathway and according to Athisa Biogeneración, the following successes were reported:


- One of the main barriers (the high content of stones, sand and other remnants) was overcome through the implementation of a new technology which has proven to be effective in cleaning both vine uprootings and pruning of fruit trees, and thus, to avoid combustion problems and to increase the quality of the final biofuels. In this sense, the VidBiomasa operational group has also developed the first vine pre-pruning machine that avoids the contact of the vine with the soil, eliminating the problem of soil contamination<sup>35</sup>.
- Reduction of greenhouse gas emissions by promoting the substitution of fossil fuels. The new activity would allow a reduction of 90 % in the carbon footprint for wine production.
- Creation of rural (and young) employment.
- Creation of new agricultural services companies.

As for the activity of polyphenols' extraction, Alvinesa Natural Ingredients' distillery is able to offer high quality products in markets such as pharmaceuticals, cosmetics, etc. Furthermore, in the case of the distillery, this model has allowed it to reduce its greenhouse gas emissions and create rural employment.

#### *b) Difficulties (e.g. technical & economical bottlenecks, conflicts, etc.)*

Several barriers were detected in relation to the valorisation of vineyard pruning and polyphenols' extraction. These barriers could endanger the integration of these activities in the distilleries:

<sup>35</sup> <https://www.heraldo.es/noticias/aragon/2020/03/19/de-la-vid-hasta-los-sarmientos-1364076.html>

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- Lack of knowledge about the market of some bio-products in the agro-industries. However, there is a willingness to discover new solutions that can improve the performance of agro-industries in the wine sector.
- Required high investments, together with the lack of local funding and the long payback period lead to the search for alternative solutions.
- Unfair competition problems (prices) prevent some agro-industries to develop their own Research & Development activities, which, otherwise, could favour the development of the IBLC.
- Climate change is generating sharp pikes of production that affect the supply of the necessary raw material that is needed for their activity.
- Difficulty in convincing farmers and agribusinesses of the need for new forms of collaboration. It is also difficult to bring together actors from different sectors (innovation, farmers, industry, etc.) and have them all benefit in some way.
- Scaling up processes to achieve industrial production.
- Legal consideration of by-products as wastes, provokes administrative burdens that very often discourage agro-industries to implement new business lines such as the ones proposed in this case study.
- The development of an integral multi-product biorefinery requires long maturation times with significant investments in Research, Development & Innovation.
- Difficulties have also been observed in ensuring a regular supply of pruning by farmers/cooperatives.
- Not all distilleries have the financial capacity to make the required investments for the development of the IBLC and/or the volume of activity necessary to guarantee the supply of raw materials.

#### *c) Solutions for problems*

- Offering financial compensation to all stakeholders involved in the value chain.
- Involvement of cooperatives in dissemination actions, encouraging the change of some habits in agricultural practices such as the burning of the pruning.

#### *d) Things to avoid*


Business models in which it is considered that the under-exploited biomass will be obtained at no cost should be avoided. All operators should benefit, as noted above.

## **4. Recommendations for this specific sector**


### *a) Recommendations*

It is necessary to:

- Search formulas that can bring together agents from very different sectors;
- Seek innovative business models that allow all agents to generate profits;
- Overcome the conservative thinking.

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Moreover, the implementation of an IBLC for the valorisation of vineyards pruning requires the active collaboration of farmers and cooperatives, reason why it is needed an economic incentive. Support from administration is also needed through regulative or incentive aspects that will discourage farmers from burning the pruning.

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## ANNEX F. DATA CASE STUDY 5. GRAIN CHAIN SECTOR - LANTMÄNNEN - SWEDEN

### 1. General introduction case study for specific sector

#### *a) Size of the sector in the country/region*


The total area of cereals was on average 1,011,307 ha in Sweden 2012-2016. This accounted for around 40 % of the total arable land in Sweden. The distribution between the different types of cereals was as following: 328,716 hectares of winter wheat, 83,468 hectares of spring wheat, 22,917 hectare of rye, 14,213 hectares of winter barley, 337,082 hectares of spring barley and 182,128 hectares of oats. Between 2012 and 2016, the total annual grain harvest was approximately 5.5 million tonnes. The largest harvest obtained was winter wheat, averaging at 2.3 million tonnes, or 42 % of total grain harvest. The next three largest grain crops (spring barley, oats and spring wheat) were together averaging at 50 % of total grain harvest. The average standard yield was around 5,700 kg/ha for cereals in the region for the proposed IBLC site. The area of cereals has decreased over time, but an increased hectare yield for cereals has compensated for this decrease. Sweden is self-sufficient in cereals and usually has a grain surplus that is exported mainly to other EU countries, but also to countries outside the EU. The cultivation of cereals generates around 3,080 annual work units (AWU) in Sweden (LRF, 2016). The milling and starch industry generate around 1,587 AWU in Sweden, the bakery industry 14,505 AWU and the malt brewing industry 2,060 AWU.

#### *b) Main economic activities of the sector*

Cereals are utilized to produce a wide range of products in Sweden, mainly various feed and food products but also industry applications like ethanol, biogas and alcohol beverages. One large food product is flour, where mainly wheat and rye are used. Different types of grains are utilized for feed and feed products. The largest share of barley used for food purposes is malt barley to the brewery industry. A smaller share of barley and oats for food consumption consist of grains and flour that are grounded at mills. The use of wheat for industrial purposes has increased due to increased ethanol production in the Östergötland region. The production capacity of ethanol on the plant in Norrköping is 230,000 m<sup>3</sup>. Other products that come out of the process is Distilled dried grains (DDGS) and carbon dioxide.

#### *c) Existing and newly planned production plants of the sector in the country/region*

We have not heard on any new investments in cereal facilities. The company Stockholm Exergi are planning to build a new production facility for biochar with a production capacity of 5,000 tonnes of biochar. Their feedstock will be wood chips. Several other investments in pyrolysis facilities are in the pipeline on other sites in Sweden.

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#### d) General description of the suggested IBLC within the sector

One of the residues from the cereal production chain that could currently be used is chaff. Chaff is the dry, scaly protective casings of the seeds of cereal grain. It also consists of dust and damaged seeds. The chaff is sorted out in the seed cleaning process. The material is difficult to handle due to dust. The chaff is utilized in energy recovery today. One possible new utilization for the chaff is the production of biochar. Production of biochar can refine the management of several waste streams, such as chaff, that are difficult to utilize for anything more useful than energy recovery.

At the proposed cereal handling site, they receive many different types of cereals and seeds. There are two different facilities on the site. One facility is cleansing seeds and one facility is drying and cleansing different types of material such as cereal grains and fodder peas. Around 5 % of the material is sorted out as chaff at both facilities.

Possible IBLC equipment that can be utilized in the suggested IBLC is found in an old feed factory on the site that was shut down many years ago. Examples of equipment that can be found there is a pelletizing machine and a grinder. The pyrolysis equipment does not exist on the site today, a new investment is needed for this.

Biochar is a solid material obtained from the carbonisation of biomass and is produced from intentionally heating a biomass feedstock via pyrolysis (without oxygen) or gasification (limited oxygen). Biochar can be used as a product itself or as an ingredient within a blended product. One possible further processing of the biochar is pelletizing. There are several possible markets for biochar, such as soil improvement, carbon capture, filtration material, animal feed additive and bioenergy, Figure 42.

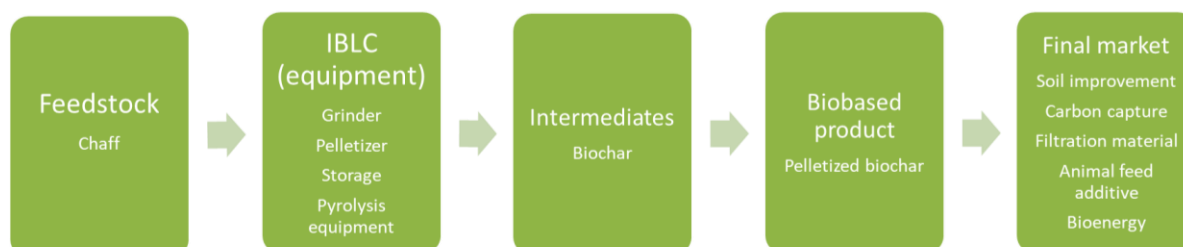



Figure 42: Suggested IBLC

## 2. Description of the six stages of the chosen pathway

### 2.1 Feedstock supply

a) Types of available feedstock (e.g. agriculture, forestry, livestock, side-streams, residues, waste, etc.)

Chaff, a side-stream from cereal production.

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*b) Yearly amount of the total production per feedstock in the region (and sometimes neighbouring regions) that is not currently being used for existing industries, and that is thus available for IBLCs [tonne dry matter or tonne fresh matter combined with moisture content]*

The site receives 55,000-70,000 tonnes of cereals and 30,000 tonnes of seeds per year. They clear away around 5 % of the material they receive. Which means that they get around 2,750-3,500 tonnes of chaff from the cereals and around 1,500 tonnes of chaff from the seeds, in total around 4,250-5,000 tonnes of chaff. Today the chaff and the aspiration dust are sent away to be combusted in a nearby region. It is not the people working at the grain handling site that decides to what it should be used for and to where it should be sent.

At a greater cereal handling site than the proposed, around 2,200 tonnes chaff are produced yearly. At a third cereal handling site in the region, around 1,600 tonnes chaff are produced yearly.

*c) Seasonality pattern per feedstock (in what periods will it become available e.g. harvested in September-October)*

The proposed site receives between 40,000-50,000 tonnes cereals per year between the 1<sup>st</sup> of July to the 15<sup>th</sup> of October (this is the so called "high season" for the cereal handling site). After the 15<sup>th</sup> of October, they receive additional 15,000-20,000 tonnes dried cereals. They receive 30,000 tonnes seeds, the "high season" for these lasts around 10 weeks. They receive no rye, but all other types of cereals.

*d) Distribution per feedstock (specify actual locations of areas where it is produced in the region/neighbouring regions)*

There are also other cereal handling sites in the region. They could cooperate with the proposed site. Maximal transport distance is 90 km.

*e) Quality feedstock before it enters the IBLC (e.g. density, form, size, moisture content, ash content, etc.)*


A lot of farmers in the region have their own drying facility. All the residues from the seed facility are dried. They do not dry any seeds on the proposed IBLC site, they just cleanse it. The cereals that are not dried on the farms are dried at the cereal handling sites. The handling of the residues (chaff) is hard work, the working environment is bad due to the dust. If it would be possible to wet the chaff before it is fed into the facility that would allow to improve the conditions since it would be a way to avoid the dust. There are problems related to the storage of the chaff. It can, for example, be self-igniting. It is important to find a handling process for the chaff that does not harm the health of the employees.

*f) Unit on-farm storage costs when storage happens on the farm [€/tonne dry matter or €/m<sup>3</sup>]*

No on-farm storage.

*g) Price of feedstock at roadside (before transport, when sold by farmer to IBLC) [€/tonne dry matter or €/tonne fresh matter combined with moisture content]*

No feedstock sold at roadside.

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## 2.2 Logistics

### Transportation

#### *a) Transportation types used including average capacity*

Container trucks on road are used for 70 % of the transport of the chaff. Each container truck can transport 36 tonnes of chaff. Transport of the containers on the site can be done with a tractor or a truck.

#### *b) Transportation distances (average/related to distribution of feedstock) [km]*

80-90 km from proposed IBLC site to two different cereal handling sites.

#### *c) Transportation losses [%]*

Transport losses is zero when transported in containers.

#### *d) Transportation energy/fuel consumption [MJ/km or l/km]*

Fuel consumption 0.4-0.5 l/km (Diesel, some trucks RME or HVO100)

#### *e) Transportation costs [€/km]*

Transportation costs 6,3 €/km.


## 2.3 IBLC design

### Synergy with existing machinery, storage, labour & infrastructure

#### *a) Available pre-treatment & handling machinery, storage facilities, labour and other infrastructure types including average capacity per period (month)*

There are silos on the site, but the company do not want to have the chaff in the silos (it is a very difficult residue to handle). It would be possible to use the bunker silo as a storage site, but the chaff is very "dusty", so it is necessary to be aware of that in the way the material is handled. The most optimal way to handle the chaff according to those who work on the site would be to have a pit with conveyors so that there will be as little handling of the material as possible. It would also be optimal if the chaff can arrive in containers to the site. And that the material is just tipped down into the pit. The material should also be stored in containers.

There is currently an existing equipment for pelletising on the site, this could be utilized for pelletizing the chaff which is another way to simplify the handling of the chaff.

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*b) Idle period of available and suitable pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

The drying equipment cannot be utilized for the chaff, because of the dust hazards. At the feed industry that was shut down a couple of years ago on the site there is a pelletizing machine, balers and mixers amongst others that could be utilized in the IBLC.

The chaff could be tipped indoor in a bunker silo. The biochar can be stored in bulk on concrete with a roof above.

*c) Efficiency: losses during production, storage and pre-treatments [%]*

Examples of energy losses during the production can be 5-10 % kW out of 100 % kW biomass that goes into the process where 60 % kW turns into biochar and 30 % kW into pyrolysis gas (Gustafsson, 2013). Depending on whether the focus is on producing biochar, synthesis gas or bio-oil the energy balance changes. To get started the process requires an external energy source called start-up energy. This is negligible at a continuous process. The overall efficiency was between 90 % and 95 % in the facilities that was visited in a study by Gustafsson (2013).

If the chaff is handled in containers the risk of losses is minimized. Pelletising the chaff can decrease the storage and transport volume by around 93 % compared to uncompressed chaff (Weiß & Glasner, 2018).

*d) Machinery energy consumption [MJ/tonne dry matter] & operation rate*

The theoretical estimated operation rate was around 580 kg/h for scenario 1 and around 1050 kg/h for scenario 2, based on an assumption of 8,000 operating hours/year).

According to a study by Gustafsson (2013) the energy consumption of a pyrolysis equipment (slow pyrolysis, no biooil) from Pyreg the energy consumption of the unit would be around 0,03 MJ of electricity for each tonne DM of biomass processed. The thermal requirement of the pyrolysis plant will vary with the plant design and the moisture content of the biomass.

*e) Costs of used pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

The cost for pelletizing of the chaff can be around 60 euros/hour. But it might be cheaper if the pelletizing equipment in the old feed factory can be utilized.

The company does not want to publish the numbers of the other costs.


*f) Intermediate biobased products obtained (see 2.4)*

Biochar and heat.

New machinery, storage & infrastructure

*g) Additional required investments for new machinery/infrastructure (CAPEX)*

Based on numbers from the Australian company, BiGchar ([www.pyrocal.com.au](http://www.pyrocal.com.au)), the investment cost for the biochar production facility that can handle between 2,500 and 25,000 tonnes of biomass

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per year is around 0,4 million euro/ktonne biochar/year. This gives a facility cost of around 0.4 million euro for scenario 1 and around 0.7 million euro for scenario 2. The facility can produce up to 3,000 tonnes biochar per year. The investment cost is stated to be low compared to other market alternatives.

Based on numbers from a French company, Biogreen ([www.biogreen-energy.com](http://www.biogreen-energy.com)), the investment cost for the biochar production facility is around 0.55 million euro/ktonne biochar/year. This gives a facility cost of around 0.6 million euro for scenario 1 and around 1.0 million euro for scenario 2. The facility can produce 3,300 tonnes biochar per year.

Based on numbers from a German company, Pyreg ([www.pyreg.de](http://www.pyreg.de)), the investment cost for the biochar production facility was around 0,26 million euro for a plant that can be fed with 1,000 tonnes of biomass per year (cost from 2013). Cost for input device and chip pocket were added with 50,000 euro. Pyreg stated that operation- and maintenance cost is about 5 % of the total investment cost.

#### *h) Additional amount of (part time) personnel required*

There are no established models for staffing levels on pyrolysis, but the following was assumed by Gustafsson (2013):

- The case includes the organizing of the chaff handling, the supervision of the plant, the management of heat distribution and sales of biochar. Resulting in that half-time service was required for running the pyrolysis equipment and the tasks that comes with it
- The operational time commitment to keep the plant running is considered low.

#### *i) Additional maintenance requirements (e.g. cleaning costs, machine resetting costs for switching between feed stocks) [€/tonne dry matter]*

Some examples from existing biochar production plants:

Biochar production facility from BiGchar ([www.pyrocal.com.au](http://www.pyrocal.com.au)) – the plan has to be shut down ones a week for a two hours inspection. A maintenance shutdown has to be conducted around every fifth month depending on the circumstances.


Biochar production facility from Biogreen ([www.biogreen-energy.com](http://www.biogreen-energy.com)) – the plant has to be shut down one time every second week for a lighter maintenance. The plant has to be shut down for a maintenance shutdown every third month. An operator has to be present when the plant is started or stopped, the plant is automatic the rest of the time but needs to be supervised.

#### *j) Additional operational costs for personnel, maintenance, management [€/tonne dry matter]*

Operating and maintenance cost for a pyrolysis plant was roughly estimated to around 25-37,5 euros/tonne dry matter chaff.

#### *k) Current state of IBLC design (TRL, technology maturity) and future improvements foreseen (coming 5 years)*

Existing product used successfully in operating environment, TRL 9. The strengths of pyrolysis technology are the flexibility to choose different types of feedstocks, low emissions and little

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negative environmental impact. The weaknesses are market-related; undeveloped Swedish market and uncertainties when it comes to the utilization of the biochar.

## 2.4 Intermediate biobased products

### Intermediate biobased products

#### *a) Types of intermediate biobased products made at IBLC*

Biochar

#### *b) Quantities produced at IBLC per year/month [tonnes/year and tonnes/month]*

Calculations are done on two different scenarios: 1. Only chaff from the proposed cereal handling site, 2. Chaff from three cereal handling sites in the region as the proposed one. The calculated theoretical quantities of biochar that can be produced were based on the assumption that 25 % of DM biomass will be transformed into biochar. Calculations are based on a DM content of 87 % for the chaff (Carlsson & Uldal, 2009).

Scenario 1. Estimated yearly amount of biochar that can be produced at the IBLC was around 1,000 tonnes/year or around 80 tonnes/month.

Scenario 2: Estimated yearly amount of biochar that can be produced at the IBLC with materials from the three cereal handling sites was around 1,800 tonnes/year or around 150 tonnes/month.

#### *c) Quality intermediate biobased product when leaving IBLC (e.g. density, form, size, moisture content, ash content, etc.)*

Different characteristics of biochar are presented in Table 26.


*Table 26: Content of biochar.*

Content of biochar			
Characteristics	Biochar		Source
Density	1.4-1.8	g/cm <sup>3</sup>	Lehmann & Joseph (2009)
Specific surface	300 – 450	m <sup>2</sup> /g	Lehmann & Joseph (2009)
Pore volume	0.05 – 0.4	cm <sup>3</sup> /g	Lehmann & Joseph (2009)
Volume weight	0.5	kg/liter	Hasselfors (2019)
pH-value	8.0		Hasselfors (2019)
Electric conductivity	5	mS/m	Hasselfors (2019)
Heating value	15-30	MH/kg	Pecha & Garcia-Perez (2015)

#### *d) Price of intermediate biobased products sold by IBLC to final industry [€/tonne]*

Price data lacking.

There is a need for heat sink near the proposed IBLC site, otherwise the case will be unprofitable.

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#### *e) Industries that buy the intermediate products from the IBLC*

Companies that produce soil improvement, soil and fertilizers, such as Gyllebo Gødning and Hasselfors Garden.

The biochar could be sold to a company selling climate compensation, such as the Swedish company Ecoera. Biochar is very stable in the soil and is estimated to have a half-life of 150-5,000 years. Biochar is considered a carbon sink from a climate point of view and in 2018 it was classified as a Negative Emission Technology by IPCC (biokol.org).

A municipality, such as Stockholm city, that utilize biochar in applications such as urban tree plantations, green roofs, football fields and rain gardens.

#### Competing intermediate (biobased) products

#### *f) Competing alternative intermediate (biobased) product types*

No biobased competing products were identified.

## **2.5 Final market**

### Final biobased products

#### *a) Types of final biobased products (that are made by another industry from the feedstock 'intermediate biobased products' delivered by the IBLC)*

Soil improver and bioenergy.

#### *b) Quality requirements needed to satisfy consumers' preferences*

It is important to remember that the market for biochar is quite an immature market, so the customers sometimes do not know what type of quality requirements they have.


The biochar carbon content must be higher than 50 % of the dry mass (DM) to get an EBC certificate (European Biochar, 2019). The nutrient contents of different biochar's are subject to major fluctuations. The biochar pH value is an important criterion regarding its specific use in substrates, soil amendments, or for binding nutrients in animal husbandry. The biochar's PAH content (sum of the EPA's 16 priority pollutants) must be under 12 mg/kg DM for basic grade and under 4 mg/kg DM for premium grade biochar.

#### *c) Price of final biobased product(s) paid by consumer*

An estimation was done that customers are willing to pay around 200-300 €/m<sup>3</sup> for biochar in Sweden for utilization in soil improvement.

The German company Pyreg, mentioned a market price on biochar for soil improvement on 600 euros per tonne and around 1,200 euro per tonne for use as additives in animal feed.

Price for climate compensation by company Ecoera is around 150 euro/1 tonne CO<sub>2</sub> in Sweden.

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*d) Stakeholders involved in the final market*

Granngården, Plantagen, ETC and Stockholm City.

## 2.6 Non-technical issues

### IBLC

*a) Measures, incentives & subsidies that could stimulate starting & setting up an IBLC*

"Klimatklivet" - is an investment aid for local and regional measures that reduce emissions of carbon dioxide and other gases that affect the climate. The invested funds should provide the greatest possible emission reduction per invested SEK. Companies amongst others can be granted support. The calculation of emission reductions is one of the most important supporting documents in the application. Applicants should be able to show how the emissions would look both with and without investment support. Finance and repayment time are also important parts of the Swedish Environmental Protection Agency's review; own financing is an important prerequisite for implementation.

Formas has funded research and development projects to a value of approx. 7 M€ investigating sustainable conditions for a circular and bio-based economy during 2017-2019, which was the fifth call within the programme for bio-based macroeconomics.

The European Commission and the European Investment Bank (EIB) have announced the completion of the public procurement process for the selection of an investment advisor to set up and manage the European Circular Bioeconomy Fund (ECBF).

*b) Environmental regulations that apply to the IBLC*

The company has to apply for both environmental and building permits. There is very little knowledge about pyrolysis facilities at authorities and therefore there is also a lack of regulations. The problem for the authorities lies in the fact that they cannot determine if a pyrolysis plant is a gas producing plant, a combustion plant or both.

*c) Social acceptance new activity at the IBLC (e.g. more trucks can cause problem due to noise)*


No problems were identified regarding social acceptance.

There will be more trucks coming and going to the site, but this is not seen as a problem since the site is relatively far away from residential houses.

### Final biobased products

*d) Measures, incentives & subsidies fostering the uptake of biobased products, the creation of new markets, etc.*

VINNOVA - Sweden's innovation agency have an initiative called Challenge-Driven Innovation that aims to solve social challenges that require broad cooperation to overcome. Projects operating within the programme can tackle everything from climate change and health challenges to problems of inequality and the uneven distribution of resources.

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A state investigation (Ministry of the Environment in Sweden) is currently investigating negative emissions where carbon binding is included, amongst other things.

#### *e) Social acceptance of the (new) final biobased products*

A product that binds in carbon dioxide as biochar does is very much in line with what is socially accepted today due to climate change.

### **3. Lessons learned**

#### *a) Successes*

The investment in the pyrolysis plant is quite cheap compared to other possible investments in biorefineries etc. The investment is very much in line with the goal of society when it comes to sustainability.

A possible success is to create a value from an already sorted out residue that is utilized for heat and power generation today.

#### *b) Difficulties (e.g. technical & economical bottlenecks, conflicts, etc.)*

The only existing plant that produce biochar from chaff in Sweden today, the Skånefrö plant, was struggling to produce biochar with a profit even though they have a heat sink nearby the plant.

The biochar market is immature.

The chaff is difficult to handle due to risks in the working environment amongst others.

Companies that build biochar plants tend to be small start-ups or university spinouts and cannot necessarily guarantee that their technology will work at specific efficiency levels nor can they provide precedents for how the technology has worked in other cities. The city of Stockholm found it was difficult to find the time to negotiate a middle ground with the manufacturer when they invested in a biochar producing unit.


#### *c) Solutions for problems*

It is necessary to create a market with added value for the biochar. Research and development are needed to create new possible usages for the biochar, such as for feed additives and as filling material in concrete.

Some of the difficulties with the chaff can be minimized by pelletizing and by handling it in containers.

#### *d) Things to avoid*

Investing in the plant without having an available heat sink.

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## 4. Recommendations for this specific sector

### a) Recommendations

Before the investments can be done in the IBLC/Pyrolysis equipment a secure market for the biochar has to be identified, preferable with an increased market need.

A biochar production that is not only focused on energy production but on both energy and material recycling of local biomass resources is a sustainable way forward. This is the way to create added value for both the customers, the region and the environment.

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## ANNEX G. DATA CASE STUDY 6. SUGAR SECTOR - NORDIC SUGAR FACTORY ÖRTOFTA - SWEDEN

### 1. General introduction case study for specific sector

#### *a) Size of the sector in the country/region*


There is only one sugar factory (Örtofta) and one sugar refinery (Arlöv, is moving to Örtofta) in Sweden, it is situated in the Skåne county (the most southern). In Sweden most of the sugar beets are grown in Skåne. About 2 million tonnes of sugar beets are produced every year in Sweden (Nordic Sugar, 2019a). During the first decade of the 21st century, the number of beet growers in Sweden was reduced with 50 % (Jordbruksverket, 2016). Nordic Sugar has produced sugar in Örtofta/Skåne for more than 100 years and today the company is part of the Nordzucker Group based in Germany. The economic turnover of Nordic Sugar AB was 286,385,400 euro in 2018 (Allabolag, 2019). All cultivation of sugar beets in Sweden is contracted by Nordic Sugar. The sugar beets are locally produced, and some raw sugar is imported. Nordic Sugar has a total of 1,500 employees, of whom 330 work in Sweden. Örtofta is one of the largest and most efficient sugar-producing facilities in northern Europe. The yearly production of sugar at Örtofta is 382,000 tonnes/year (Nordic Sugar, 2019). In the primary production the production of sugar beets accounts for 300 work year equivalents in Sweden. The sugar industry accounts for 481 work year equivalents in Sweden. (LRF, 2016).

#### *b) Main economic activities of the sector*

The sugar industry is associated with the secondary economic sector that refines the sugar beets produced on the arable land into consumer products such as sugar and animal feed. Typical economic activities related to the sugar sector is production of sugar, purchasing of inputs, marketing, sale and distribution of sugar and co-products.

#### *c) Existing and newly planned production plants of the sector in the country/region*

Today there is one sugar factory on one site (Örtofta) and one sugar refinery on one site (Arlöv) in the region and in the country. At the Örtofta site the sugar is produced from the around 2 million tonnes of sugar beets that are delivered during each production season. In Arlöv many different special sugar products are manufactured for a wide range of applications, mainly for the food industry. Some examples of special products are vanilla sugar, icing sugar, syrup, cube sugar, liquid sugar and nib sugar. But Nordic Sugar are planning to discontinue operations in Arlöv and move all its production to the site in Örtofta. It means a billion investment but also staff reduction. An efficiency study conducted by Nordic Sugar shows that there are substantial savings and efficiency improvements to be made if all the production is gathered by the plant in Örtofta. No other production plants are planned for in the future in Sweden in the sugar sector.

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#### *d) General description of the suggested IBLC within the sector*

The sugar industry is struggling with decreasing profitability partly due to the elimination of sugar quotas. To increase profitability and access new markets Nordic sugar is interested in increasing the value of its side streams. Sugar is produced in campaigns that usually last from late September to January, outside of the campaign on-site production capacity would potentially be available. In the production of sugar from sugar beets several co-products, are generated. Beet pulp is the co-product generated in largest quantities. Globally there is a huge demand for bio-based materials to be used in, for example, packaging. The global demand for bio-based plastics is estimated to increase with around 2 million tonnes/year in the coming five years. In the suggested IBLC the beet pulp is utilized as feedstock for production of succinic acid (SA). This production could be conducted during the time of the year when there is no production in the sugar factory. SA is a water-soluble crystal, traditionally made from fossil resources, that is used as a chemical intermediate in a high number of chemicals and products. SA could be utilized as raw material to produce PBS (polybutylene succinate), a biodegradable polymer that can replace plastics.

## **2. Description of the six stages of the chosen pathway**

### **2.1 Feedstock supply**

*a) Types of available feedstock (e.g. agriculture, forestry, livestock, side-streams, residues, waste, etc.)*

Beet pulp, a co-product from the sugar industry.

*b) Yearly amount of the total production per feedstock in the region (and sometimes neighbouring regions) that is not currently being used for existing industries, and that is thus available for IBLCs [tonne dry matter or tonne fresh matter combined with moisture content]*


In total around 317,000 tonnes of pressed pulp (23 % DM, Örtöfta, SE, and Nykøbing, DK). Today this is mainly used for feed production.

*c) Seasonality pattern per feedstock (in what periods will it become available e.g. harvested in September-October)*

The material is produced continuously during the sugar campaign, from late September to January.

*d) Distribution per feedstock (specify actual locations of areas where it is produced in the region/neighbouring regions)*

At Örtöfta sugar industry (Sweden) on average 217,000 tonnes of pressed pulp (23 % DM) is produced each year. And at Nykøbing sugar industry (DK) an average of 100,000 tonnes of pressed pulp (23 % DM) is produced each year.

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e) *Quality feedstock before it enters the IBLC (e.g. density, form, size, moisture content, ash content, etc.)*

Table 27: Content of sugar beet pulp. Source: Kühnel et al. (2011)

Content of sugar beet pulp		
Content	HP pulp	
Total dry matter	23	% of tot
Carbohydrates	68	% of DM
Uronic acids	18	% of DM
Arabinose	18	% of DM
Xylose	2	% of DM
Glucose	22	% of DM
Galactose	5	% of DM
Rhamnose	2	% of DM
Mannose	1	% of DM
Saccharose	4	% of DM
Protein	8	% of DM
Ferulic acid	0.5	% of DM
Acetic acid	1.6	% of DM
Methanol	0.4	% of DM
Lipids and salt	17.5	% of DM (calculated value)

f) *Unit on-farm storage costs when storage happens on the farm [€/tonne dry matter or €/m<sup>3</sup>]*

No storage on farm.

g) *Price of feedstock at roadside (before transport, when sold by farmer to IBLC) [€/tonne dry matter or €/tonne fresh matter combined with moisture content]*

Feedstock not sold by farmer to IBLC.


## 2.2 Logistics

Two scenarios: 1.) Only beet pulp from Örtöfta (SE), no transportation of beet pulp 2.) Beet pulp from both Örtöfta and Nykøbing (DK).

### Transportation

a) *Transportation types used including average capacity*

Beet pulp is transported on road in trucks of the same type that are used for transportation of concrete. The capacity is 36-43 tonnes/truck (Foria, 2019).

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*b) Transportation distances (average/related to distribution of feedstock) [km]*

Scenario 1.) No transports, Scenario 2.) Distance 200 km Nykøbing (DK) to Örtöfta (SE).

*c) Transportation losses [%]*

~1 % transport losses (Jensen, 2019).

*d) Transportation energy/fuel consumption [MJ/km or l/km]*

Fuel consumption 0.4-0.5 litre per km (Diesel) (Foria, 2019).

*e) Transportation costs [€/km]*

Cost of pulp transport is 14.7 €/tonne delivered to Örtöfta from a storage at Nykøbing (Nordic Sugar, 2019b).

## 2.3 IBLC design

### Synergy with existing machinery, storage, labour & infrastructure

*a) Available pre-treatment & handling machinery, storage facilities, labour and other infrastructure types including average capacity per period (month)*


Evaporators and centrifuges are examples of existing equipment that can be utilized in the IBLC. The sugar industry has a highly optimized system for evaporation, despite this the existing equipment must be adapted to be integrated with the IBLC. Existing cleaning equipment can be utilized. The infrastructure for steam, electricity, water, computer systems, laboratories etc. could also be utilized. The existing process operators, electricians and laboratory employees could work in the new IBLC.

*b) Idle period of available and suitable pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

The equipment on the site is not utilized during March to August (six months). But it might be necessary to run the process also during the sugar campaign since there is no storage area on the site for the pressed beet pulp. Maximum storage height on the HP pulp is 2.2 meter to avoid losses of effluents.

*c) Efficiency: losses during production, storage and pre-treatments [%]*

In the pre-treatment one possible assumption is that 90 % of C6 and C5 sugar is released. In the fermentation process it can be assumed that 50 % of the sugars are converted to succinic acid (SA). For the downstream processing a yield of 90 % in each step can be assumed (in total five steps). In some of the steps e.g. centrifugation, a higher yield could be possible and perhaps are not all 5 stages necessary. The largest losses are in the purification process.

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*d) Machinery energy consumption [MJ/tonne dry matter] & operation rate*

Examples of possible values retrieved from Patel et al. (2006): Sterilization: 0.2-0.8 kg steam/kg medium, agitation and aeration in fermentation: 1-5 kW/m<sup>3</sup>, centrifugation 0.7-25 kWh/m<sup>3</sup> depending on what is separated, evaporation: 0.01-1.25 kg steam/kg evaporated water or 0.01-0.9 kg steam and 0.002-0.04 kWh electricity/kg evaporated water.

*e) Costs of used pre-treatment & handling machinery, storage facilities, labour and other infrastructure*

Operating costs follow a similar pattern as environmental impacts, steam in pre-treatment and chemicals used in fermentation are large costs. No more detailed costs were possible to retrieve.

*f) Intermediate biobased products obtained (see 2.4)*

SA (209 tonnes/day), biomass (49 tonnes/day), other organic acids (201 tonnes/day) and residuals (409 tonnes/day), the numbers are estimated for 120 days ("the sugar campaign").

New machinery, storage & infrastructure

*g) Additional required investments for new machinery/infrastructure (CAPEX)*

Sugar beet pulp must be pre-treated in order to break down cellulose and hemicellulose into fermentable sugars. Acid and enzymatic pre-treatment will be applied. The two stages of pre-treatment will probably be done in two separate tanks. A purification step may be necessary after pre-treatment to separate compounds that may inhibit the fermentation. Fermenters for production of SA will be needed. After the fermentation the SA must be separated from the fermentation broth. This will be done in several stages including crystallization, re-solubilization, filtration, centrifugation and evaporation. Most of this equipment must be purchased for this particular purpose. The existing wastewater treatment plant needs to be enlarged.

*h) Additional amount of (part time) personnel required*

This is difficult to estimate since it is a theoretical case.

*i) Additional maintenance requirements (e.g. cleaning costs, machine resetting costs for switching between feed stocks) [€/tonne dry matter]*


Estimated additional maintenance is 1.5-2.0 % of the total investment cost, but we were not able to calculate the total investment cost.

*j) Additional operational costs for personnel, maintenance, management [€/tonne dry matter]*

This is difficult to estimate since it is a theoretical case.

*k) Current state of IBLC design (TRL, technology maturity) and future improvements foreseen (coming 5 years)*

First-generation SA is produced on industrial scale and has a high TRL. In these processes pure sugar is the feedstock. The production of second-generation SA based on cellulosic materials, i.e. residual streams from the sugar industry, is on a lower TRL, around 5-7. In the case presented here, both C5

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and C6 sugars are utilized in the production of SA. The PBS available on the market today is at the most 50 % bio-based since the butanediol part is fossil based. There are processes to produce butanediol via SA Nghiem et. al. (2017), which can be a possible future improvement of the process. There are also possibilities to combine the HP pulp with biomass rich in starch as feedstock, pure sugar or thick juice to increase the produced volume.

## 2.4 Intermediate biobased products

### Intermediate biobased products

#### *a) Types of intermediate biobased products made at IBLC*

SA, biomass, other organic acids, residuals and water. Production of other organic acids should be minimized. Most likely the purification of these will not be economically viable. Biomass and residuals could be used for production of biogas (equipment that could also be shared with the sugar factory).

#### *b) Quantities produced at IBLC per year/month [tonnes/year and tonnes/month]*

Scenario 1.) Theoretical production of SA 9,900 tonnes/year (50 % of sugars, C6 and C5, converted to SA).

From fermentation, ammonium succinate 145 tonnes/day, bacterial biomass 27 tonnes/day and other organic acids 113 tonnes/day. After purification SA crystals are obtained at a rate of 82 tonnes/day which corresponds to 9,900 tonnes/year.

Scenario 2.) Theoretical production of SA 13,800 tonnes/year (50 % of sugars, C6 and C5, converted to SA).

From fermentation, ammonium succinate 203 tonnes/day, bacterial biomass 38 tonnes/day and other organic acids 157 tonnes/day. After purification SA crystals are obtained at a rate of 115 tonnes/day which corresponds to 13,800 tonnes/year.

The size of existing first-generation plants for SA in the world today are between 10,000-15,000 tonnes/year (Miriant, Reverdia DSM and Succinity/BASF). Bioamber are no longer in operation but produced 30,000 tonnes/year when they were in operation.


#### *c) Quality intermediate biobased product when leaving IBLC (e.g. density, form, size, moisture content, ash content, etc.)*

The SA produced at the IBLC will be used for production of bio-based PBS. It is necessary to have a SA of very high purity if PBS is to be produced. SA will leave the factory in form of pure crystals.

#### *d) Price of intermediate biobased products sold by IBLC to final industry [€/tonne]*

The HP pulp is today sold as feed for between 0.12 and 0.22 euro/kg DM (Nordic Sugar, 2019a).

Since there is no existing market on second generation biobased SA it has not been possible to find data on price of it as an intermediate product. Data were also difficult to retrieve on first generation biobased SA. Platform chemicals are sold on an international market, and bio-based SA is one of the platform chemicals that is currently the most popular among chemical companies globally (Lane,

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2015). Bio-based SA shows indications of being one of the most dynamic developments and having the largest growth rate among bio-based building blocks (Choi et al., 2015; Nova institute, 2015).

*e) Industries that buy the intermediate products from the IBLC*

Polymer manufacturer such as BASF, Mitsubishi and Sumitomo.

Competing intermediate (biobased) products.

Competing intermediate (biobased) products

*f) Competing alternative intermediate (biobased) product types*

Lactic acid (LA) can be a possible competing alternative intermediate (biobased) product type. LA can be polymerized to Polylactic acid (PLA). Also, ethanol could be a competing bio-based product. Ethanol could be used as a fuel or for production of bio-based polyethylene.

*g) Quality of competing alternative intermediate (biobased) products compared to intermediate biobased products from IBLC*

The advantage of lactic acid (LA) for production of PLA is that LA can be produced at higher yields which will increase potential profitability. However, the purification of LA is more complex than the purification SA which will increase cost.

Example of a pros of PLA is the good availability compared to other biobased polymers. Examples of cons are low thermal stability, poor mechanical recyclability, not biodegradable in natural conditions. Example of a pros of PBS is good mechanical features and an example of cons is that it is still expensive.

*h) Price and market share of competing alternative intermediate (biobased) products [€/tonne]*

PLA has a competitive price of around 2 €/kg.

## 2.5 Final market


Final biobased products

*a) Types of final biobased products (that are made by another industry from the feedstock 'intermediate biobased products' delivered by the IBLC)*

The final product is polybutylene succinate (PBS). PBS is a polyester made from SA and 1,4-butanediol (1,4-BDO). PBS is used for films and sheets for food packaging and agriculture, compost bags, fishing nets and automotive industry. PBS can also be utilized in hygiene products, cosmetics, toys etc.

*b) Quality requirements needed to satisfy consumers' preferences*

The quality requirements depend on the specific customer and/or application. The quality aspect is more important for drop-in plastics. One quality requirement is the purity, the length of the polymers. A biodegradable and biobased plastics as PBS has to have a better or equal quality as a fossil-based plastic. The quality can be compared with a fossil-based polypropylene. Biodegradability

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can be a quality argument that apply to come customers, but it can also give less favourable qualities on the product.

*c) Price of final biobased product(s) paid by consumer*

Consumers are unlikely to purchase pure PBS, but rather one of the products containing it and the price differs depending on the different applications. The price for PBS is around 3-4 EUR/kg. Consumers will be offered a large variety of products that contain PBS. The price for second generation biobased PBS is difficult to say since there is no market for second generation biobased PBS today.

*d) Stakeholders involved in the final market*

Examples of companies involved in the final market is Mitsubishi Chemical, Showa Denko K. K., SK. Chemicals, PTT MCC and Biochem. Other examples are IKEA and GAIA biomaterials etc.

## 2.6 Non-technical issues

### IBLC

*a) Measures, incentives & subsidies that could stimulate starting & setting up an IBLC*

"Klimatklivet" is an investment aid for local and regional measures that reduce emissions of carbon dioxide and other gases that affect the climate. The invested funds should provide the greatest possible emission reduction per invested SEK. Companies amongst others can be granted support. The calculation of emission reductions is one of the most important supporting documents in the application. Applicants should be able to show how the emissions would look both with and without investment support. Finance and repayment time are also important parts of the Swedish Environmental Protection Agency's review; own financing is an important prerequisite for implementation.

Formas, the Swedish governmental research council for sustainable development, has funded research and development projects to a value of approx. 7 M€ investigating Sustainable conditions for a circular and bio-based economy during 2017-2019, within the programme for Bio-based macroeconomics.


The European Commission and the European Investment Bank (EIB) have announced the completion of the public procurement process for the selection of an investment advisor to set up and manage the European Circular Bioeconomy Fund (ECBF).

*b) Environmental regulations that apply to the IBLC*

Wastewater handling have to be applied for from Länsstyrelsen (Regional Swedish authority) when expanding existing business.

*c) Social acceptance new activity at the IBLC (e.g. more trucks can cause problem due to noise)*

The IBLC is expected to give a higher turnover on the site and an increased market for other companies such as GAIA Biomaterials (a Swedish company that develops, manufactures and sells

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biomaterials from renewable sources). The Örtofta plant has a good location in the region which gives good conditions for success. The increased numbers of trucks that come with the new IBLC part in the plant are not expected to cause any problems.

#### Final biobased products

*d) Measures, incentives & subsidies fostering the uptake of biobased products, the creation of new markets, etc.*

Recently fossil dominance was challenged, which has stimulated the development of renewable alternatives, which, in turn, influences the development of bio-based SA. For instance, the political ambition to increase the share of renewable energy in the transport sector has a strong influence on the prospects of using residual streams from the agro-industry for chemicals and materials. A key example is the EU Renewable Energy Directive (European Commission, 2009), which mandates that 20 % of all energy usage in the EU, including at least 10 % of all energy for road transport fuels, is to be produced from renewable sources by 2020.


In Sweden, the development of biofuels based on renewable residual streams was supported with a range of economic incentives and support schemes over the last three decades. These include energy- and CO<sub>2</sub>-tax exemptions for various biofuels and incentives that stimulate the market for environmental cars and supply of alternative fuels (SFS, 2005; SOU, 2013). Compared to biofuels, bio-based chemicals and materials have, thus far, been much less affected by Swedish and European policy incentives.

Support for bio-based building block chemicals and materials is also available in the form of international and national funding schemes for research and innovation, such as:

- “BioInnovation” a strategic innovation programme financed by the Swedish Innovation Agency VINNOVA, the Swedish Energy Agency and the Swedish Research Council Formas, and by the participating organisations. BioInnovation gather ideas and the players who want to transform ideas into innovation. The aim of BioInnovation is to create the best possible conditions to produce new bio-based materials, products and services with a high value for customers, serving markets worldwide.
- VINNOVA, has circular and bio-based economy as one of five prioritised areas , with three funding programmes: 1) The strategic innovation programme for bio-innovation (bio-based materials, see above), 2) The strategic innovation programme RE: Source (minimise and use waste streams), and 3) Challenge-driven Innovation. Furthermore, VINNOVA has a mandate to support the cooperation program “The circular, bio-based economy”.
- Existing programmes at the EU level, such as the BBI JTI (part of H2020), make available grant funding for BBI and BE projects up to flagship/FOAK level.

*e) Social acceptance of the (new) final biobased products*

The utilization for beet fibres today is mainly for feed, the new utilization to produce intermediate chemicals, can be difficult to understand for some stakeholders such as animal producers.

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There is a positive attitude in society towards replacing fossil-based raw materials with renewable ones, as this is considered an important step towards sustainable development. Societal norms and values may also affect the premises for the acceptance of specific technologies used. There is a concern that public opinion against genetically modified organisms (GMO) may hamper Swedish production of SA, considering that it is expected to use genetically modified organisms in the fermentation process.

Biobased polymers are gaining increased prominence in the minds of consumers, as increased awareness of climate change and plastic pollution continues to grow. However, the range of biobased alternatives to the main plastics we encounter in our daily lives continues to limit its potential adoption.

### 3. Lessons learned

#### a) Successes

The involved companies Nordic Sugar and GAIA Biomaterials are interested in new collaborations and to produce SA and PBS on a more regional scale.


The economic feasibility of a production of bio-based SA depends on a range of factors including total capital investment, labour, and maintenance as well as revenues from products and by-products produced. As the technology of the case study is yet premature, data for a techno-economic assessment is lacking. A review on SA by Nghiem et al. (2017) of companies and industrial consortia developing industrial production of bio-based SA shows a range of production capacity on existing and planned sites from 10,000 to 63,500 tonnes per year, with 10,000 tonnes and above as the absolute majority. Given that a production process often requires a certain size to be economically feasible, it is assumed that the theoretical estimated production capacity in Örtöfta of between around 10,000 to 13,800 tonnes of SA per year (based only on co-products from sugar industry) could be economical feasible.

If Nordic Sugar can utilize the production site better for example with IBLC the profit will most likely increase. An improved value chain can create conditions for Nordic Sugar Örtöfta to be able to convince the farmers to continue to grow sugar beets. Even if the sugar price would fluctuate it would be possible to give a good price to the farmers for the sugar beets. Increased profitability can be a driving force to compensate the sugar beet growers for a lower sugar price.

#### b) Difficulties (e.g. technical & economical bottlenecks, conflicts, etc.)

Even if the IBLC is integrated with an existing sugar factory significant investment will be necessary. Also, actors' willingness and capacity to act and collaborate as well as policies, norms, and values in society are critical for the success or failure of the possible investment in an IBLC.

A study by Rex et. al (2018) that investigated the possibilities to produce SA from municipal solid waste concluded that even though, from a technical feasibility and resource availability perspective, production seemed possible, it lacks institutional support and actor commitment and alignment for development in Sweden. This problem can also appear in the case regarding the production of SA from beet fibres.

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To bring about novel technology development and market implementation, it is necessary that actors along the whole value chain are aligned in a network that strives towards a common goal of advancing the technology. Considering that commercial production of SA from beet fibre is a theoretical case, there is not yet an aligned network of actors that actively work throughout the value chain. For an example today there is no polymer manufacturer in the region that can polymerize the SA to PBS which is necessary for the business case.

#### *c) Solutions for problems*

Technical research including experiments on different scales to prove the concept and systems studies for assessment will be necessary to be able to conduct a techno economic assessment and a more realistic business case.

The companies Nordic Sugar and GAIA Biomaterials has started a dialog about the production of SA in Örtofta and PBS in the Skåne county. This can be a starting point for a potential future SA network. These and additional actors are expected to be useful in the future realization of a potential SA value chain from beet fibres to polymer products and related markets.

#### *d) Things to avoid*

Being aware of the fact that the beet pulp is mainly utilized as feed today and this needs to be considered in the business case both for economic reasons and to avoid negative publicity due to environmental effects i.e. fuel vs. food.


### **4. Recommendations for this specific sector**

#### *a) Recommendations*

Establishing an IBLC in Örtofta is potentially promising but more research and development is necessary before any recommendations can be given.

First generation biobased SA is already produced commercially by several companies today, often through the biotechnological fermentation of refined sugars or starch from cultivated crops (e.g. corn). This can be a way to start the production of SA for Nordic Sugar and then move forward towards utilizing both C5 and C6 sugar as in the case with beet fibres. However, emissions caused by land use change (iLUC) should be added in this case to mirror long-term sustainability issues caused by increased production of agricultural crops.

Actors' in the value chain needs to be willing and have the capacity to act and collaborate if the case study is going to be realised. Also, there needs to be a need for policies, norms, and values in society that support the development of the IBLC.

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## ANNEX H. INPUT DATA FEED & FODDER SECTOR MIP CASE STUDY

### RAW MATERIAL TRANSPORT DISTANCES AND AVAILABILITY

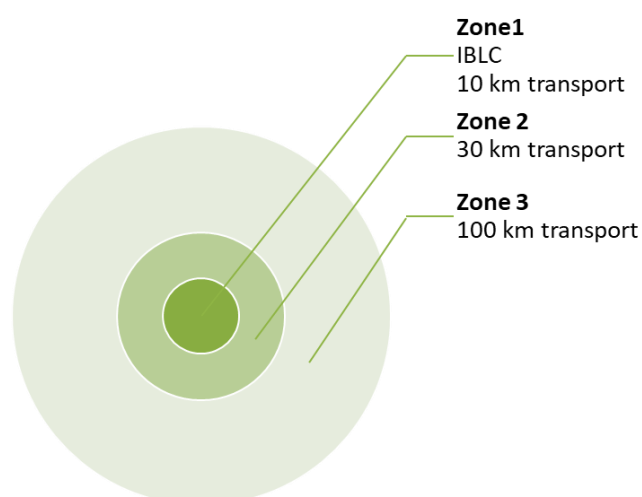



Figure 43: Raw material transport distances to IBLC.

Table 28: Raw material availability.

Raw material availability							
	From	Until	# of months	Zone 1 10 km (kton/ month)	Zone 2 30 km (kton/ month)	Zone 3 100 km (kton/ month)	Total (kton/y)
Lucerne bulk	Apr	Nov	8	2	2	0	32
Lucerne bales	Apr	Nov	8	0.5	0.5	2	24
60% Straw 40% Wood	Jul	Aug	2	0	0	17	34

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## RAW MATERIAL, PROCESSING, AND PRODUCT PARAMETERS

Table 29: Parameters of raw materials and processing.

Parameters for raw materials and processing						
	Raw material			Processing		
	Density	price	Average	Yield	Costs	Costs
	(ton/m <sup>3</sup> )	(no transp) (€/ton)	transport (km)	(P/RM)	(€/ton P)	(€/ton RM)
Lucerne bulk	0.250	112.5	20	0.840	50.0	42.0
Lucerne bales	0.250	77.5	73	0.800	45.0	36.0
60% Straw 40% Wood	0.225	46.8	100	0.826	51.8	42.8


Table 30: Product parameters.

Product parameters			
	Density	Transport	Selling price
	(ton/m <sup>3</sup> )	(km)	(€/ton)
Feed bales	0.380	400	225
Feed pellets	0.600	400	180
Energy pellets	0.562	250	143

## EXTRA EQUIPMENT CAPACITY AND COSTS

Table 31: Extra equipment capacity and costs. The costs are annualized by distributing the investment costs over 10 years.

Extra equipment capacity and costs		
	Extra capacity	Extra equipment costs
	(ton/month)	(k€/y)
Wood grinder	600	5
Grinder	3,000	10
Hopper	600	10
Mill	3,000	6.5
Dryer	4,000	90
Baler	4,000	25
Pelletizer	3,000	19
Mizer	3,000	6.5
Cooler 1	4,000	3.5
Cooler 2	3,000	3
Storage	5,775	25

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## ANNEX I. DETAILED COMPARISON OF CURRENT AND BASELINE SCENARIO FEED & FODDER SECTOR MIP CASE STUDY

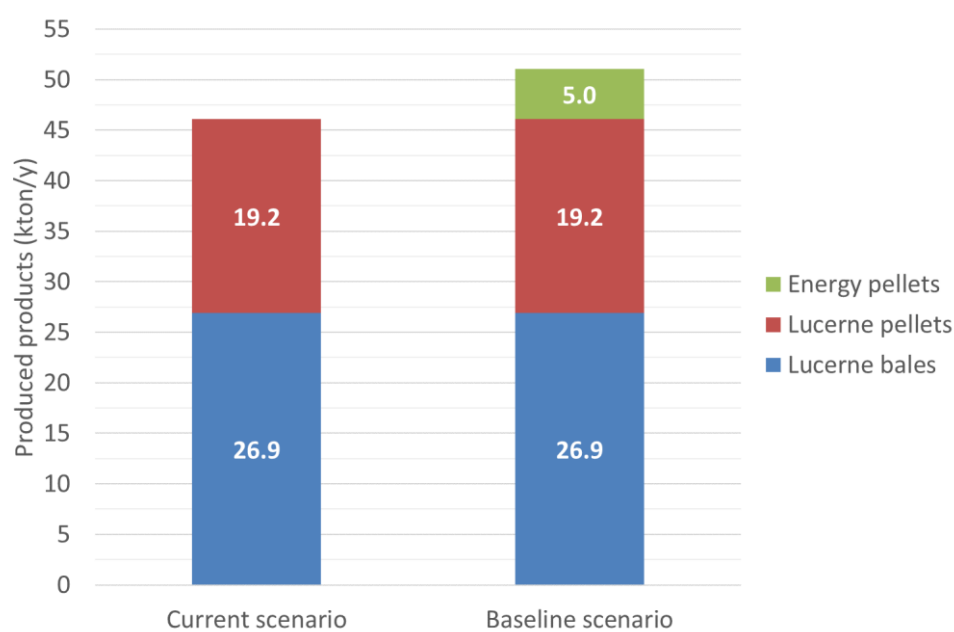


Figure 44: Annual produced products for current and baseline scenario.

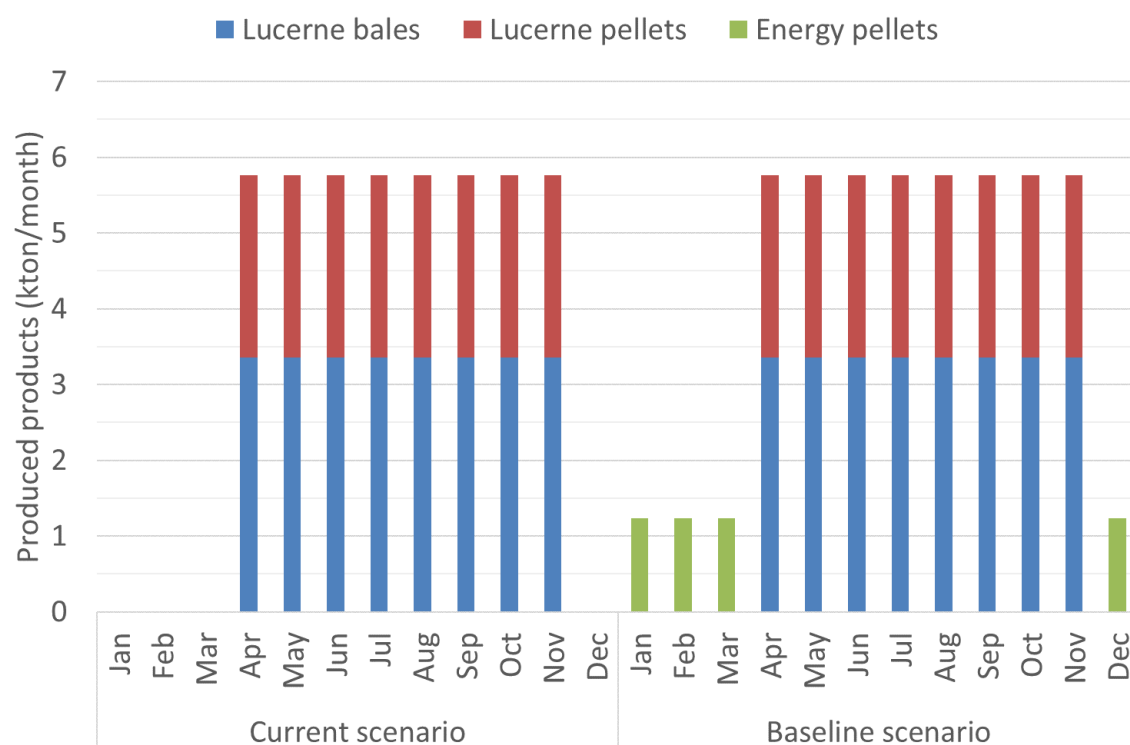



Figure 45: Produced products per month for current and baseline scenario.

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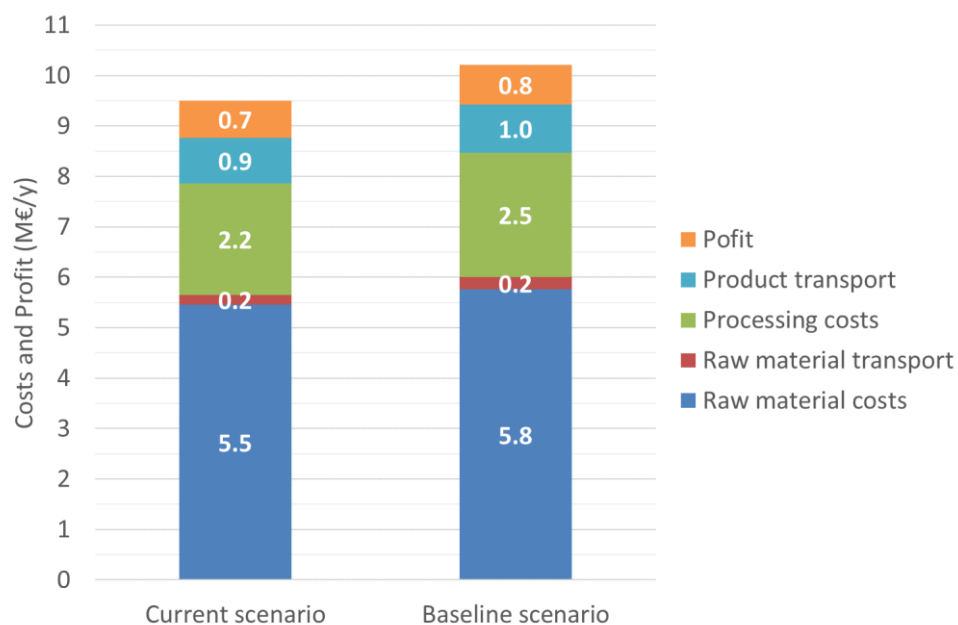



Figure 46: Annual costs and profit for current and baseline scenario.

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## ANNEX J. INPUT DATA OLIVE OIL SECTOR MIP CASE STUDY

### RAW MATERIAL TRANSPORT DISTANCES AND AVAILABILITY

Table 32: Raw material availability.

Raw material availability									
	From	Until	# of months	At IBLC 0 km	Zone 1 5 km	Zone 2 10 km (kton/ month)	Zone 3 15km	Zone 4 20 km	Total (kton/y)
Exhausted pomace	Nov	Jun	8	7.2					57.2
Prunings	Feb	Apr	3		1.2	2.9	4.7	4.9	40.8

### RAW MATERIAL, PROCESSING, AND PRODUCT PARAMETERS

Table 33: Parameters of raw materials (RM) and processing (P).

Parameters for raw materials and processing							
	Raw material				Processing		
	Moisture	Density	Harvesting costs	Transport costs (10 km)	Yield	Costs	Costs
	(% of WW)	(ton/m <sup>3</sup> )	(€/ton DW)	(€/ton)	(P/RM)	(€/ton P)	(€/ton RM)
Exhausted pomace	50 %	1.000			0.556	43.6	24.2
Prunings	30 %	0.230	45.7	12.5	0.778	20.2	15.7
Dried prunings	10 %	0.230			0.900	70.0	63.0

Table 34: Product parameters.

Product parameters				
	Moisture (% of WW)	Density (ton/m <sup>3</sup> )	Transport costs (€/ton)	Selling price (€/ton RM)
Solid fuel	10 %	0.670	10	100
Energy pellets	10 %	0.670	10	160