Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration

Project AGROinLOG "Demonstration of innovative integrated biomass logistics centres for the Agro-industry sector in Europe"
Grant agreement: 727961
From November 2016 to April 2020

Prepared by: Wageningen Food & Biobased Research (WFBR)

Date: 26/03/2019 (Final)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 727961

DELIVERABLE FACTSHEET

Project start date:	November 2016
Project website:	www.agroinlog-h2020.eu
Deliverable number:	D6.3
Deliverable title:	Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration
Lead Partner:	Wageningen Food & Biobased Research (WFBR)
Work Package no. and title:	6. Generic strategies for the development of future IBLCs
Task no. and title:	6.3 Comprehensive identification of opportunities for the production of biomass & biocommodities and for a logistics integration
Version:	Final
Version Date:	26-03-2019

Diffusion list

Dissemination level	
X	PU = Public
	PP = Restricted to other programme participants (including the EC)
	RE = Restricted to a group specified by the consortium (including the EC)
	CO = Confidential, only for members of the consortium (including the EC)

Approvals

	Company
Author/s	WFBR, CIRCE, ZLC, CERTH, RISE, ASAE
Task Leader	WFBR
WP Leader	WFBR
Reviewer	CIRCE

Documents history

Version	Date	Main modification	Entity
1	17/09/2018	First draft	WFBR
2	5/10/2018	Second draft	All
3	10/10/201X	Third draft	All
4	29/10/2018	Fourth draft	All
5	16/11/2018	Fifth draft	All
6	30/11/2018	Sixth draft	All
7	21/12/2018	Final draft	All
Final	26/03/2019	Final	All

DISCLAIMER OF WARRANTIES

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 727961".

This document has been prepared by AGROinLOG project partners as an account of work carried out within the framework of the EC-GA contract no 727961.

Neither Project Coordinator, nor any signatory party of AGROinLOG Project Consortium Agreement, nor any person acting on behalf of any of them:

(a) makes any warranty or representation whatsoever, express or implied,

  (i). with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or

  (ii). that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or

  (iii). that this document is suitable to any particular user's circumstance; or

(b) assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if Project Coordinator or any representative of a signatory party of the AGROinLOG Project Consortium Agreement, has been advised of the possibility of such damages) resulting from your selection or use of this document or any information, apparatus, method, process, or similar item disclosed in this document.

ABBREVIATIONS

CHP	Combined Heat and Power plant
DM	Dry matter
FM	Fresh matter
GWh	gigawatt hour
ha	hectare
HFO	Heavy fuel oil
HTL	Hydrothermal liquefaction
IBLC	Integrated Biomass Logistics Centre
kt	kilo tonne
kWh	kilowatt hour
LFO	Light fuel oil
Ml	mega litre
Mt	mega tonne
OMWW	Olive Mill Waste Water
OOWW	Olive Oil Waste Water
PBS	Polybutylene succinate
R&D	Research and Development
t	tonne
TPOMW	Two-phase olive mill waste

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

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 Forening

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

EXECUTIVE SUMMARY

This report contains the results of the research into the potential and possibilities of establishing Integrated Biomass Logistics Centres (IBLCs) in a number of specific agricultural sectors and industries in Europe. The research was conducted within the framework of the AGROinLOG project, demonstration of innovative integrated biomass logistics centres for agro-industry sector in Europe that is funded from the European Union's Horizon 2020 research and innovation programme. Part of the research and innovation project AGROinLOG concerns the development of generic strategies for the development of future IBLCs in the EU (Work Package 6).

As one of the steps to achieve a wider implementation of the IBLC concept, AGROinLOG has analysed the opportunities of implementing new businesses. The focus was on i) the production of intermediates for bioenergy & biofuels and biocommodities for biobased products, and ii) a logistical integration, in the sectors selected as the most promising for implementing IBLCs in Europe (see AGROinLOG's D6.2 Basic analysis of targeted agricultural sectors). For this purpose, a desk study was carried out by the technical partners of the project (WFBR, ZLC, CIRCE, CERTH and RISE) on the hypothetical opportunities for implementing new businesses in the chosen sectors (taking into account typical sizes, equipment, and prevailing biomass feedstock accessible for those sectors in Europe). These chosen sectors are: 1) vegetable oil extraction, 2) olive oil mills (chain), 3) feed and fodder, 4) wine sector (cellars & distilleries), 5) grain chain (incl. straw until final product biofuel) and 6) sugar industry.

The methodology followed to develop the work is described in the second chapter of this document and included the following steps:

1. Determine methodology;
2. Make detailed action plan and divide work between partners;
3. Draft a long list of possible biobased (intermediate) products (all the possibilities);
4. Draft a long list of possible logistical solutions (all the possibilities);
5. Identify short list theoretical opportunities (selection of most interesting ones);
6. Gather practical opportunities from a range of stakeholders (interaction with task 7.4);
7. Integrate theoretical & practical opportunities;
8. Describe selected opportunities in detail;
9. Finalize report.

The long lists are described in Chapter 3 and Annexes A, B and C with general opportunities for the production of biobased (intermediate) products for bioenergy & biofuels and biobased chemicals & materials. The following step was to determine the selection criteria. As an example Table S1 presents the motivation for the choice of agropellets/briquettes. The short list bioenergy & biofuels with a high implementation potential included the following products: 1) agropellets/briquettes, 2) biogas, 3) bioethanol, 4) solid biofuel, 5) biodiesel and options with a medium-high implementation potential: 6) bio-oil & biochar and 7) syngas. Each individual product is described. For the products bioenergy & biofuels, also a ranking is given based on the conditions of the criteria.

Table S1. Motivation for the choice of agropellets/briquettes.

Score		
Final Product	Raw material	Criteria
Agropellets/ Briquettes	Olive stone Prunings Straw Stalks Husks Nut shells Sugar beet pulp Grape residues Corn cobs	a. Equipment: standard and simple equipment usually found in agro-industries (drier, grinder, air separator, screening, press); b. Investment: low investment required; c. Market: well-functioning and developed market for the product in Europe; d. Technology: manufacturing technologies are mature, efficient and reliable. High TRL (8-9 according to the feedstock used). Wide range of raw materials can be used; e. Demand: growing demand trend for the next years considering the increasing heating and industrial demand, and the increasing price of fossil fuels, e.g. oil, etc.; f. Logistics: high density allows efficient storage and transportation and lower logistics costs, compared to chips; g. Legislation: policies provide incentives to use biomass for electricity generation.
Ranking	1	

To produce biobased chemicals and materials the supply to industries of suitable and defined biomass feedstock is very important. The conversion of heterogeneous biomass to a stable feedstock that can be stored and transported could be an important role of an IBLC. At the IBLC the pre-processing can be performed of lignocellulosic feedstock, carbohydrate or protein rich residues (e.g., pressed oil seed cake, pomace) and perishable residues for the conversion to fermentable or extractable biomass. The selection at the IBLC of suitable pre-processing and preservation steps for the biomass should be technically and economically feasible. A selection was made of bio-based chemicals that are currently produced on industrial scale, and where market growth is expected for the coming years. The shortlist for biobased chemicals included: 1) bioethanol, 2) lactic acid, 3) succinic acid, 4) tartaric acid, 5) furfural, 6) levulinic acid, 7) protein, 8) lignin and 9) phenolics. Furthermore, the shortlist for biobased materials contained: 1) particle board & fibre board, 2) paper pulp and board, 3) dissolving cellulose, 4) granulate & plastic composite and 5) adhesives, coatings, liners, thickeners. Like in the previous case, each individual product was described. Unfortunately, establishing a ranking was enormously difficult for biochemicals and biomaterials. The main reason is that the markets for these products are difficult to compare because they are much more diverse in type of product (paper and board, plastics, antioxidants, flavours, biocides, resins, etc.), size (from niche markets to bulk products) and development stage (often in a starting phase) than the energy market.

In Chapter 4 theoretical opportunities are described per sector (see Table 1) based on the short lists bioenergy & biofuels and biobased chemicals & materials (intermediate) products. The opportunities were rated in three categories based on the expert knowledge of the team members. Theoretical scores (T) were given to the products from the short lists and these scores were also translated to traffic light colours: T1= very suitable (dark green); T2= suitable (light green); T3= less suitable (orange). An example of the assessment of the theoretical opportunities for the feed & fodder sector is given in Table S2.

Table S2. Theoretical opportunities to produce bioenergy & biofuels and/or biobased chemicals & materials at an IBLC in the feed and fodder sector.

Opportunities for intermediate products at an IBLC in the feed and fodder sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Pellets/ briquettes from agricultural residues	T1	• Standard and simple equipment: usually found in agroindustries (drier, grinder, air separator, screening and press). • Very low investment required. • Well-functioning and developed market for the product in Europe. • High density allows efficient storage and transportation and lower logistics costs, compared to chips.
Syngas or bio-oil & bio-char from agricultural residues	T3	• High investment and complex equipment required. • Syngas needs further upgrading. • Bio-oils require further upgrading in many added value applications. • Technology well developed in some applications. • Multiple applications. • Market in place.
Furfural or levulinic acid	T2	• High investment. • Complicated process/extractability and yields to be confirmed. • Versatile utilization. • Increasing demand.
Particle board and fibre board from straws	T1	• Market in place. • Standard and simple equipment.
Granulate and plastic composites	T2	• Standard well-established process. • Market in place. • Optimum process and final properties to be confirmed yet.

Chapter 5 gives practical insight from a range of stakeholders for the development of intermediates and logistical solutions. The information in this chapter was collected involving a range of stakeholders from the different value chains of AGROinLOG. Five workshops were held in Sweden, Spain, Greece, Serbia and Ukraine. Additionally, four interviews to associations were conducted in Brussels. Country workshops focused on a particular sector(s). Interviews to associations in Brussels looked for specific technical and industrial insight.

A first section with “Practical considerations to evaluate possible IBLC business opportunities of intermediate products” collects feedback from all sectors on conditions to favour new business opportunities for IBLCs. It was formulated as questions that may inform the potential of new business opportunities for IBLCs. Each sector in this chapter is sub-divided in four sections. The first section with title “Stakeholders providing input” specifies, in broad categories, stakeholders’ typology participating in each workshop. The second section, “Evaluation of long lists by stakeholders” is divided in:

- Bioenergy and Biofuels: this subsection highlights intermediates as discussed by the stakeholders. Practical opportunities were rated in three categories based on the opinions of the stakeholders. Practical scores (P) were given to the products from the short lists and these scores were also translated to traffic light colors: P1= very suitable (dark green); P2= suitable (light green) and P3= less suitable (orange); an example for the feed & fodder sector is given in Table S3;
- Biocommodities: this subsection highlights intermediates as discussed by the stakeholders. Stakeholder evaluation is represented in a traffic light table (see above for the scores); an example for the grain sector is given in Table S3;
- Input on Logistic Solutions: logistic solutions are specific to their pathway. Feedback for this section was collected in a more general table.

Table S3. Specific bioenergy and biofuel intermediate products mentioned in the food and fodder sector.

Specific products mentioned		
Product	**Code**	Comments given by stakeholders
Pellet	P1	• Solid biofuels like pellets were favored due to reduced investment costs.
Solid biomass (chips)	P1	• Simplicity of production. • The feed and fodder industry already has suitable equipment for the production of solid biofuels.

Table S4. Specific biobased chemicals & materials mentioned in the grain chain sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Biogas	P1	• Politically driven.
Ethanol	P1	• Ethanol is interesting. • A chemical company that attended the workshop explained that the ethanol that they get is from forest origin and has a lot of other substances (methanol from C5) that they don't want; their preferred option would be ethanol produced with agricultural biomass.
Syngas	P1	• Demand from chemical companies.
Lactic acid	P2	• PLA interesting.
Succinic acid	P2	• Possible demand form biomaterial companies.
Proteins	P3	• Proteins from industry are already used profitably in the feed industry.

Chapter 6 combines all these inputs. Based on the theoretical opportunities that were selected and have been described in Chapter 4, and the practical opportunities that were mentioned by the stakeholders in Chapter 5 several promising pathways (two per sector) were identified by the technical partners:

- Vegetable oil extraction: Pathway 'Production of pellets from vegetable oils species lignocellulosic residues';
- Vegetable oil extraction: Pathway 'Production of biodiesel in a vegetable oil plant';
- Olive oil mills (chain): Pathway 'Production of pellets from olive tree prunings in a pomace mill';
- Olive oil mills (chain): Pathway 'Extraction of phenols from olive leaves/ pomace';
- Feed and fodder: Pathway: 'Production of agropellets from straws for the energy sector';
- Feed and fodder: Pathway: 'Production of intermediates for the bioplastics manufacture';
- Wine sector (cellars & distilleries): Pathway 'Production of wood chips from vineyard prunings';
- Grain chain: Pathway 'Production of biogas from grain straw';
- Grain chain: Pathway 'Production of particle boards from straw';
- Sugar industry: Pathway 'Production of succinic acid for PBS (Polybutylene succinate) using sugar beet pulp';
- Sugar industry: Pathway 'Proteins from beet leaves'.

These pathways will be an important starting point for the choice of the cases studies in Task 6.4. Each pathway has been described in a few sentences combined with a schematic picture such as the example in Figure S1.

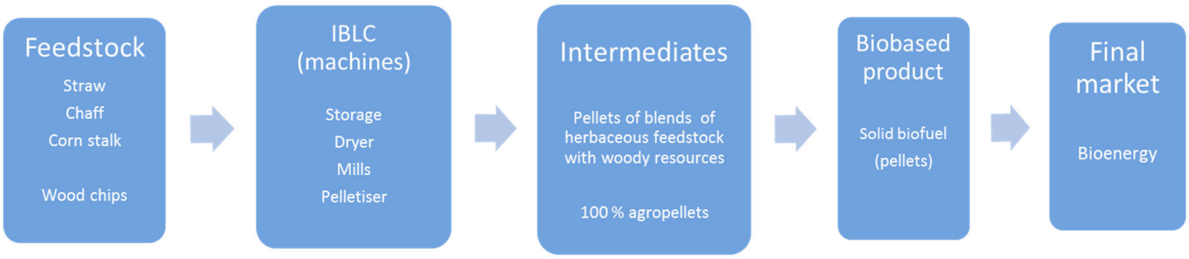


Figure S1. Pathway bioenergy from straw.

The logistical solutions that are needed to grasp the opportunities are described in Chapter 7, where schemes of value chains for the pathways are given. A long list of 43 logistical solutions (also defined as general opportunities) was identified (8 logistical components and 34 logistical concepts) (see Annex C). The list of logistical solutions was used to build different biomass value chains. A biomass value chain connects several logistical concepts to describe the flow process of the feedstock from the collection in the field to its transformation at the IBLC. An example of a woody feedstock value chain description is given in Figure S2. Value chains have been described for several of the pathways that were described in Chapter 6.

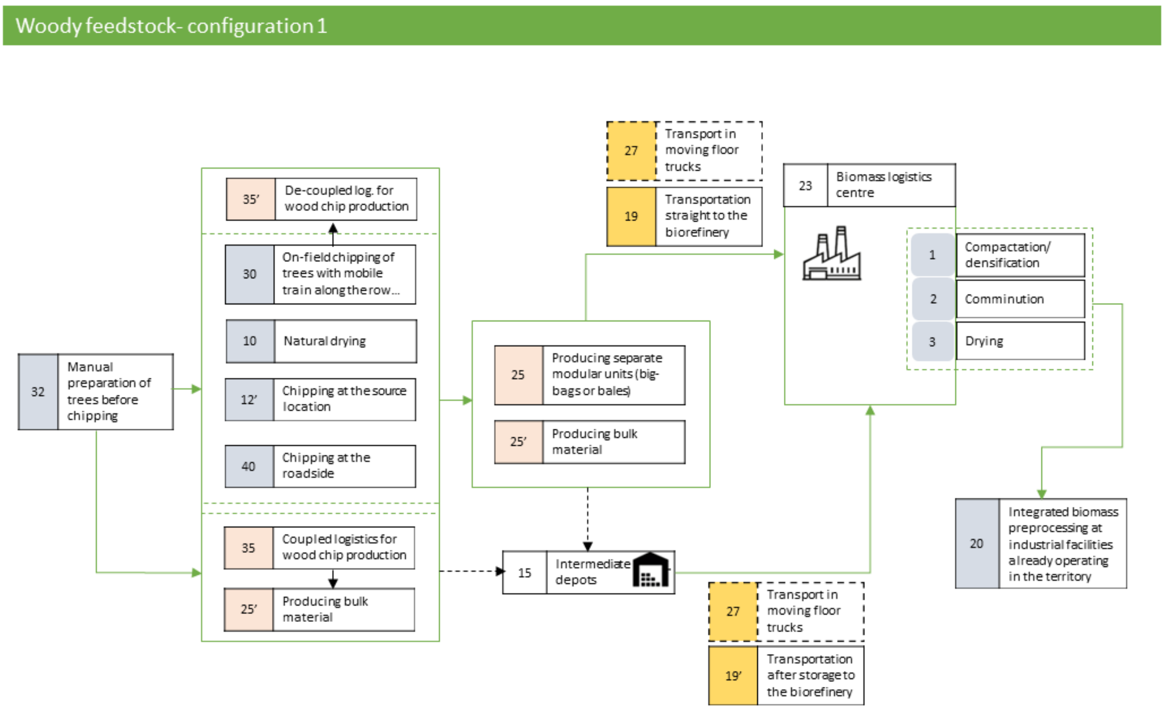


Figure S2. Woody feedstock- configuration 1

Finally, Chapter 8 presets the main conclusions attained in the analysis carried out per sector:

TABLE OF CONTENTS

1 Introduction 1

2 Methodology 2

3 biobased products & logistical solutions 5

3.1 Long list bioenergy & biofuels 5

3.2 Long list biobased chemicals & materials 5

3.3 Selection criteria 6

3.4 Short list bioenergy & biofuels 7

3.5 Short list biobased chemicals 17

3.6 Short list biobased materials 24

4 Theoretical opportunities per sector 29

4.1 Introduction 29

4.2 Vegetable oil extraction..29

4.3 Olive oil mills (chain)..31

4.4 Feed and fodder 34

4.5 Wine sector (cellars & distilleries)..35

4.6 Grain chain (incl. straw until final product biofuel) 37

4.7 Sugar industry..39

5 Stakeholder's opinions on practical opportunities per sector 41

5.1 Introduction..41

5.2 Practical considerations to evaluate possible IBLC business opportunities of intermediate products42

5.3 Vegetable oil extraction..43

5.4 Olive oil mills (chain)..45

5.5 Feed and fodder 48

5.6 Wine sector (cellars & distilleries)..49

5.7 Grain chain (incl. straw until final product biofuel) 51

5.8 Sugar industry..53

5.9 Trans-sectoral considerations 53

6 Description of promising pathways 58

6.1 Vegetable oil extraction: Pathway 'Production of pellets from vegetable oils species lignocellulosic residues' 59

6.2 Vegetable oil extraction: Pathway 'Production of biodiesel in a vegetable oil plant' 60

6.3 Olive oil mills (chain): Pathway 'Production of pellets from olive tree prunings in a pomace mill' 61

6.4 Olive oil mills (chain): Pathway 'Extraction of phenols from olive leaves/ pomace' 62

6.5 Feed and fodder: Pathway: 'Production of agropellets from straws for the energy sector' 63

6.6 Feed and fodder: Pathway: 'Production of intermediates for the bioplastics manufacture' 64

6.7 Wine sector (cellars & distilleries): Pathway 'Production of wood chips from vineyard prunings' 65

6.8 Wine sector (cellars & distilleries): Pathway 'Production of bioethanol from grape pomace' 66

6.9 Grain chain: Pathway 'Production of biogas from grain straw' 67

6.10 Grain chain: Pathway 'Production of particle boards from straw' 68

6.11 Sugar industry: Pathway 'Production of succinic acid for PBS (Polybutylene succinate) using sugar beet pulp' 68

6.12 Sugar industry: Pathway 'Proteins from beet leaves' 70

7 Logistical Solutions 71

7.1 Introduction 71

7.2 Logistical solutions: components & concepts 72

7.3 Building biomass value chains 74

7.4 Examples of biomass value chains for the pathway opportunities 76

8 Conclusions 82

Annex A. Long list bioenergy & biofuels 85

Annex B. Long list biobased chemicals and materials 92

Annex C. Long list logistical solutions 99

Annex D. Subdivision of logistical components 111

1 Introduction

As one of the steps to achieve a wider implementation of the IBLC concept, AGROinLOG has analysed the opportunities of implementing new businesses. The focus was on i) the production of intermediates for bioenergy & biofuels and biocommodities for biobased products, and ii) a logistical integration, in the sectors selected as the most promising for implementing IBLCs in Europe (see AGROinLOG's D6.2 Basic analysis of targeted agricultural sectors). For this purpose, a desk study was carried out by the technical partners of the project (WFBR, ZLC, CIRCE, CERTH and RISE) on the hypothetical opportunities for implementing new businesses in the chosen sectors (taking into account typical sizes, equipment, and prevailing biomass feedstock accessible for those sectors in Europe). The work carried out is summarised in this report, which also addresses ways to achieve a logistical integration (e.g., combination of transport, pre-treatment, storage or pre-processing capacity).

The methodology followed to develop the work is described in the second chapter of this document. Both long and short lists of biobased intermediates (all the possible possibilities and the most interesting ones, respectively), that could be produced at an IBLC, are given in Chapter 3. These biobased intermediates are divided into two groups: i) bioenergy & biofuels and ii) biochemicals and biomaterials. In Chapter 4, the technical partners describe the theoretical opportunities per sector based on the short lists of possible biobased intermediates. Chapter 5 collects practical insight from a range of stakeholders for the development of intermediates and logistical solutions. Then, Chapter 6 combines all these inputs to describe promising pathways that can be used for further case studies in Task 6.4. The logistical solutions that are needed to grasp the opportunities are described in Chapter 7, where schemes of value chains for the pathways are given. Finally, Chapter 8 gives the main conclusions of this study.

2 METHODOLOGY

The methodology that was used to assess the best opportunities for biomass and biocommodities production and for logistics integration in IBLCs included the following steps:

1. Determine methodology;
2. Make detailed action plan and divide work between partners;
3. Draft a long list of possible biobased (intermediate) products (all the possibilities);
4. Draft a long list of possible logistical solutions (all the possibilities);
5. Identify short list theoretical opportunities (selection of most interesting ones);
6. Gather practical opportunities from a range of stakeholders (interaction with task 7.4);
7. Integrate theoretical & practical opportunities;
8. Describe selected opportunities in detail;
9. Finalize report.

This work (Task 6.3) was closely linked to previous AGROinLOG tasks (presented in deliverable D6.2) in which the analysis of the six most promising sectors for establishing IBLCs in Europe were selected. D6.2 also addressed the future requirements of AGROinLOG's Task 6.4 which needs suggestions for relevant case studies (selected to develop deeper IBLCs possibilities insights), and finally to consulting the stakeholders perception in Task 7.4 (Figure 1).

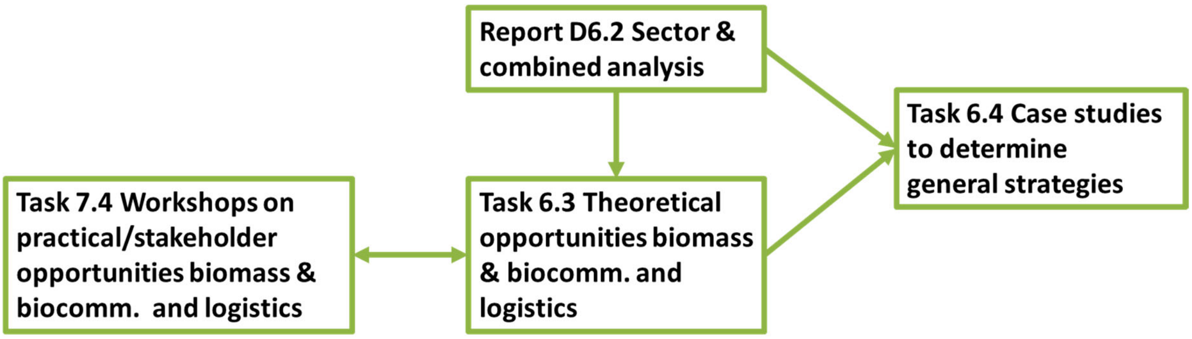


Figure 1. Relation between tasks and deliverables.

Steps 1 and 2 were both performed during a kick-off meeting in which all the project partners included in Task 6.3 participated.

Step 3 was aimed at producing a long list with general opportunities for the production of biobased (intermediate) products. The main considerations were:

- both biomass & biocommodities not yet sector related;
- division of tasks per type of final product:
  - bioenergy (power & heat) - CIRCE & CERTH;
  - biofuels (e.g. bioethanol) - RISE, CIRCE & CERTH;
  - biochemicals - RISE & WFBR;
  - biomaterials - WFBR;

- focus on the opportunities of producing intermediates (at an IBLC) that then can be supplied to a producer of the final product (so no focus on the final production itself unless it can also be performed at the IBLC);
- only very brief description of these opportunities in the long list (table form) with the following aspects to be described:
  - name biobased (intermediate) product (e.g. energy pellets for heat);
  - possible feedstocks to produce (e.g. straw);
  - production facilities needed to produce it (e.g. drier, press, storage silo);
  - type of customer (e.g. household heating);
  - IBLC investment costs;
  - scale;
  - technology readiness level (TRL);
- the long lists have been included in Annexes A. and B.

Step 4 implied delivering a long list of general opportunities for logistical solutions. The main considerations were:

- input from AGROinLOG's WP2 (business and exploitation plans of the IBLC demos) and general logistical expertise was used by ZLC;
- input from recent projects like S2BIOM was supplied by WFBR;
- the long list was initially not related to a specific sector;
- examples of logistical solutions were kept in mind like: combination of transport, pre-treatment, storage or pre-processing capacity;
- only a very brief description was given of the logistical solutions in this long list (in table form) where the following aspects were described:
  - name of the logistical solution (e.g. compaction);
  - what is it/ how does it work? (e.g. press the biomass in order to increase the density);
  - what effect is achieved? (e.g. reduced transport costs because of a higher loading rate);
  - conditions? (e.g. minimum volume required to perform this solution);
  - main stakeholders involved;
- the long lists have been included in Annexes C. and D.

Step 5 was about the selection of short list theoretical opportunities. The work was done by teams per sector (Table 1). The results can be found in Chapter 3 and 4.

Table 1. Teams per sector (L=Lead, X=contributor).

SECTOR	CIRCE	CERTH	RISE	AESA	WFBR
1. vegetable oil extraction	L	X	X	X	X
2. olive oil mills (chain)	X	L	-	X	X
3. feed and fodder	L	-	X	X	X
4. wine sector (cellars & distilleries)	X	L	-	X	X
5. grain chain (incl. straw until final product biofuel)	X	X	L	X	X
6. sugar industry	-	X	L	X	X

Step 6 was about involving the stakeholders and getting their feedback. Several workshops and interviews were held in Task 7.4 that provided the necessary input for this aim. The main considerations were:

- the long lists produced in steps 3 and 4 were also supplied to Task 7.4 (Review of sector analysis and opportunities) including a brief explanation for their distribution and use;
- these long lists were adapted and presented to the stakeholders in the workshops carried out in Task 7.4 to identify practical opportunities; the question was which biomass/ biocommodities can practically be produced at an IBLC in a certain sector, and what logistical solutions are favoured by the sector? Task 7.4 performed the same methodology as the one followed in step 5 but looking from the practical point of view of the stakeholders;
- after the workshops (in five countries) and the bilateral meetings in Brussels, Task 7.4 sent a report with the practical feedback collected from stakeholders[1]. Results are described in Chapter 5.

In Step 7 the theoretical & practical opportunities were combined and led to a list of promising pathways.

In Step 8 the promising pathways (two per sector) were described in more detail. That way Task 6.4 can further build upon them.

Finally, in step 9 this report was finalized.

[1] Note that Task 7.4 was mainly about producing extra input for Task 6.3 and much less about 'reviewing' the work of Task 6.3 due to it was considered that by involving them in the process would lead to better approaches and results.

3 BIOBASED PRODUCTS & LOGISTICAL SOLUTIONS

3.1 Long list bioenergy & biofuels

The development of the long list of bioenergy and biofuels (intermediate) products was based on the various technologies available for converting several agricultural feedstocks into added-value products or intermediates (biocommodities). Firstly, the possible biofuels (e.g. pellets, bioethanol, etc.) that can be derived from any agricultural feedstock were identified and inserted on the list along with their end use (e.g. heating, power generation, etc.). At this point, the long list includes not only “easy to produce” biofuels (e.g. pellets) but also more complicated products (e.g. biokerosene, etc.) in order to present the majority of the theoretical opportunities offered by the available agricultural feedstock. For each biofuel category, the raw material that can be used as feedstock from the agricultural sectors was listed. For each case, based on the raw material and product, the equipment required for such conversion are described. Finally, the long list includes, for each biofuel, the range of the investment cost that is needed, the scale of production on which each biofuel makes sense to be produced and the TRL of each biofuel production technology. For the full long list of bioenergy and biofuels (intermediate) products deriving from various agricultural feedstock, please refer to Annex A.

3.2 Long list biobased chemicals & materials

To achieve the climate goals and reduce the fossil CO_2 emissions one of the options is to find biobased chemicals that can substitute petrochemicals. A long list of biobased chemicals was compiled based on a report of IEA Bioenergy Task 42 Biorefineries[2] that describes the substitution potential of renewable chemicals (Annex B, Table 2). The biochemicals were listed and described systematically, including the platform chemical used as starting material and the manufacturing processes with their potential end-uses. For each biochemical, the technology readiness level (TRL) of the process was included. Based on this long list a selection of promising biochemicals was made.

Biobased materials that can be produced from different agroresidues are listed in Annex B, Table 3. The feedstock for the production of those materials can be selected from biomass liberated in agro-industries and can be lignocellulosics, press cakes or effluents rich in organic materials (Annex B, Table 1). The lignocellulosics can be converted in similar products as wood fibre-based products. The suitability of biomass residues as feedstock for the various fibre applications is dependent on qualitative and quantitative criteria. Commonly, wood-based fibre industries, such as paper pulping and fibreboard manufacturing, are operating on large scale with limited scope for variation in

[2] http://www.ieabioenergy.com/wp-content/uploads/2013/10/Task-42-Biobased-Chemicals-value-added-products-from-biorefineries.pdf

feedstock. The wet biomass residues need to be converted on site where they are produced to avoid deterioration. They may be suitable for fermentation or extraction of valuable constituents. The press cakes commonly find use in animal feed after the oil extraction.

3.3 Selection criteria

With a first draft of the long lists of bioenergy & biofuels and biobased chemicals & materials, the following step was to determine the selection criteria. The most important selection criterion is the feedstock availability. It is necessary to know the current use of residues and the competing claims: are these residues really available at sufficient amounts for an IBLC, or are there any obstacles to guarantee sufficient supply? The following criteria were identified:

- availability of feedstock;
- availability of equipment with idle time at companies that could become an IBLC;
- amount of investment needed to change and update the existing facilities and equipment and/or to obtain extra facilities and equipment;
- access to finance for investments needed. Can the company really raise the required funds?;
- security of supply to meet the market demand; will the IBLC be able to serve this market demand with sufficient supply of intermediate biobased products?;
- TRL for processing a new feedstock; a future IBLC will mainly use proven technologies on the short term;
- compatibility between the new biobased business and the existing food business from the brand image point of view;
- demand for the intermediate products of an IBLC; will there be sufficient demand at a commercial company that wants to use the intermediate biobased product of the IBLC as input for their own processes?;
- availability of logistical solutions; important when building a suitable value chain for the intermediate biobased products;
- favourable legislation and policy supporting the development of biobased products.

From the list above, seven criteria were chosen. In Table 2 an example is given of the representation of the criteria presented in Chapter 3 motivating the choice for a final product. First of all the raw materials that could be sufficiently available (main criterion) are listed. Then the score on several other criteria connected are mentioned (some of them are essential and some are more supportive like f. and g.):

a. Equipment (simple to complex);
b. Investment needed (low – medium – high);
c. Market (state of development and functionality);
d. Technology (TRL);
e. Demand (declining – stable – growing);
f. Logistics (transportation, storage / cost related);
g. Legislation.

Table 2. Example of the motivation for the choice.

Score		
Final Product	Raw material	Criteria
Product X	Feedstock 1. Feedstock 2. Etc.	a. Equipment (simple to complex); b. Investment needed (low – medium – high); c. Market (state of development and functionality); d. Technology (TRL); e. Demand (declining – stable – growing); f. Logistics (transportation, storage / cost related); g. Legislation.
Ranking		1

For the products bioenergy & biofuels, a ranking was given based on the conditions of the criteria. Unfortunately, establishing such a ranking was enormously difficult for biochemicals and biomaterials. The main reason is that the markets for these products are difficult to compare because they are much more diverse in type of product (paper and board, plastics, antioxidants, flavors, biocides, resins, etc.), size (from niche markets to bulk products) and development stage (often in a starting phase) than the energy market. Furthermore, criterions f. (logistics) and g. (legislation) were also difficult to score for the products biochemicals and biomaterials, mainly for the same reasons.

3.4 Short list bioenergy & biofuels

The short list bioenergy & biofuels consists of options with a high implementation potential:

1) Agropellets/briquettes
2) Biogas
3) Bioethanol
4) Solid biofuel
5) Biodiesel

and options with a medium-high implementation potential:

6) Bio-oil & biochar
7) Syngas

3.4.1.1 Agropellets/briquettes

According to the most recent AEBIOM's Statistical Report[3], in 2015 wood pellet consumption in the EU-28 reached 20.3 million tonnes, which represented 6 % of total solid biomass used in Europe. The EU produced 14.1 million tonnes of pellets covering 70 % of its demand. Wood pellet production areas are spread throughout the Member States. The majority of the consumption was for heat production, which represented 63.9 %. Pellet consumption for heat can be further divided into three markets – residential heating (42.2 %), commercial heating (15.7 %) and heat generated from combined Heat and Power plants (CHPs) (6 %). The remaining 36.1 % of wood pellets were used for power production.

Table 3. Motivation for the choice of agropellets/briquettes.

Score		
Final Product	Raw material	Criteria
Agropellets/ Briquettes	Olive stone Prunings Straw Stalks Husks Nut shells Sugar beet pulp Grape residues Corn cobs	h. Equipment: standard and simple equipment usually found in agro-industries (drier, grinder, air separator, screening, press); i. Investment: low investment required; j. Market: well-functioning and developed market for the product in Europe; k. Technology: manufacturing technologies are mature, efficient and reliable. High TRL (8-9 according to the feedstock used). Wide range of raw materials can be used; l. Demand: growing demand trend for the next years considering the increasing heating and industrial demand, and the increasing price of fossil fuels, e.g. oil, etc.; m. Logistics: high density allows efficient storage and transportation and lower logistics costs, compared to chips; n. Legislation: policies provide incentives to use biomass for electricity generation.
Ranking	1	

Regarding the investment required, for a pellet plant it can greatly vary according to the local raw material used and its costs (including transportation costs), manufacture process costs, machine wear and maintenance costs, other fixed assets depreciation costs, operation costs and business management costs. For an IBLC the cost will be significantly lower by taking advantage of the existing infrastructure and services, that can be used to produce the new biocommodity,

[3] AEBIOM (European Biomass Association), Statistical Report, 2016. http://www.aebiom.org/wp-content/uploads/2016/12/AEBIOM-KEY-FINDINGS-REPORT-2016.pdf

contributing therefore to decreasing the investment required compared to a pellet plant from scratch.

The pellets' manufacturing process is quite simple and the different steps to produce the new biocommodity are quite optimized nowadays (chipping, screening, drying, pelletizing, cooling and packaging). Furthermore, the production of pellets does not require very complex equipment (drier, grinder, air separator, screening, press) which can be very often found in agro-industries used for the manufacture of the principal product.

3.4.2 Biogas

Cost of biogas production varies significantly according to the raw material used and the digestate treatment applied. For most of the biogas production cases, final cost is higher than the price of the energy sources they replace (natural gas, diesel, etc.). However, since biogas production has the advantage that it can be used to provide flexible power production, being renewable, while environmentally treating and improving some streams, it is supported by different implementation policies. One of the main constraints to implement such initiatives includes the lack of access to funding schemes that would contribute to enhancing investments required to implement such a process (due to some equipment used during the process that is quite specific and expensive).

Table 4. Motivation for the choice of biogas.

Score		
Product	Raw material	Criteria
Biogas	Beet leaves Grape pomace and winery waste water Exhausted olive cake Olive mill wastewater Straw Spent grain (breweries) Maize stalks, sunflower stalks, cotton stalks	a. Equipment: standard and specific equipment required for the process (desulfurizer, digester, dehydrator, pre-treatment tank, grinder); b. Investment: medium to high investment required; c. Market: market in place; economic feasibility can be reached for large scale facilities (medium-large); d. Technology: technology well developed; medium to high TRL (according to the feedstock used); e. Demand: growing demand trend for the next years; f. Logistics: Simple logistics when biogas is connected with the grid; g. Legislation: supportive policy framework for biogas initiatives.
Ranking	2	

In Europe, different configurations can be found according to the existing demand. Anaerobic digesters are mostly linked with heat and power generation using the biogas produced. Furthermore, biogas can be upgraded to biomethane and injected into the natural gas network or used as a transport fuel.

Biogas production has increased in the EU, encouraged by the renewable energy policies, in addition to economic, environmental and climate benefits, to reach 18 billion m^3 methane (654 PJ) in 2015, representing half of the global biogas production. The EU is the world leader in biogas electricity production, with more than 10 GW installed and 17,400 biogas plants, in comparison to the global biogas capacity of 15 GW in 2015. In the EU, biogas delivered 127 TJ of heat and 61 TWh of electricity in 2015; about 50 % of the total biogas consumption in Europe was destined to heat generation[4].

Most bio-heat is derived from solid biomass resources, but biogas is becoming a more important source of heat, reaching about 4 % of the bioheat worldwide in 2015. In high-income countries, biogas is used primarily in electricity-only and CHP plants, with only small amounts used in heat-only plants, while in low-income countries biogas is mostly used for cooking or lighting[4].

The number of Compressed Natural Gas (CNG) vehicles (18 million worldwide) and fuelling stations (22,000 filling stations worldwide) create good opportunities for the use of gaseous biofuels, such as biomethane, in transport. The infrastructure for delivering natural gas as transport fuel is available, with about 3,500 CNG vehicle filling stations in Europe and about 1,400 in the United States, of which about 700 vehicle filling stations in Europe in 2015 offer biomethane[5].

The recent developments on biogas electricity production brought the electricity production from biogas at 40 % above the projections for 2015 and close to the expected level of 63.9 TWh biogas electricity in 2020. The investments in biogas electricity capacity, in comparison to the whole biomass sector, have brought the share of biogas in the biomass electricity to more than 34 % in 2015[6].

[4] Scarlat, N., J.-F. Dallemand & F. Fahl, 2018. Biogas: Developments and perspectives in Europe. Renewable Energy Volume 129, Part A, pp 457-472.

[5] Kapoor, R.M. & V.K. Vijay, 2017. Evaluation of Existing Low Cost Gas Bottling Systems for Vehicles Use Adaption in Developing Economies. The Natural & Bio Gas Vehicle Association (NGVA), Statistical Report 2017. https://www.ngva.eu/wp-content/uploads/2018/01/170648_NGVA_Europe_statistical-Report_2017_5-2.pdf.

[6] Scarlat, N., J.F. Dallemand, F. Monforti Ferrario, M. Banja & V. Motola, 2017. Renewable energy policy framework and bioenergy contribution in the European Union – an overview from national renewable energy action plans and progress reports, Renew. Sustain. Energy Rev., Volume 51, pp. 969-985.

3.4.3 Bioethanol

Bioethanol has been identified as the most used biofuel worldwide since it significantly contributes to the reduction of crude oil consumption and environmental pollution. It can be produced from various types of feedstock such as sucrose, starch, lignocellulosic and algal biomass through a fermentation process by microorganisms. Bioethanol is known as the most widely used biofuel in the transportation sector and it has a long history as alternative fuel[7].

Ethanol production from sugar containing raw materials is a well-known and mastered process. On the contrary, production of third generation bioethanol from algae is still in an immature stage and confined to the laboratory research, while other types of biomass (lignocellulosic biomass such as agricultural residues, energy crops, forestry and wood residues) have shown potential as second generation bioethanol feedstock on commercial scale.

Table 5. Motivation for the choice of bioethanol.

Score		
Product	Raw material	Criteria
Bioethanol	Molasses Straw Maize/sunflower/cotton stalks	a. Equipment: complex equipment required for the process (hydrolyser, fermenter, distillation column, molecular sieve, etc.); b. Investment: high investment required; c. Market: market in place; economic feasibility for large scale facilities; d. Technology: technology well developed; medium to high TRL (according to the feedstock used). Use of feedstock with high fermentable carbohydrates; e. Demand: growing demand trend for the next years; f. Logistics: medium logistics demands/ costs (regarding transportation and storage); g. Legislation: legislation promotes this type of biofuel to replace fossil fuels and therefore decrease GHG emissions related to transport sector.
Ranking	3	

The sector is constantly innovating in several ways. New enzymes and yeasts are being developed to further increase ethanol yields. New techniques are introduced to extract oil from maize and wheat and every year the industry becomes more energy efficient. Best practices have been implemented to ensure that production plants are as sustainable as possible and to ensure that the

[7] S Mohd Azhar, R Abdulla, S Jambo, H Marbawi, J Gansau, A Mohd Faik, K Rodrigues. Yeasts in sustainable bioethanol production: A review. Biochem Biophys Rep. 2017, Volume 10, pp 52-61.

waste level goes to zero or is harmless. Water use is, for example, kept to a minimum and waste water is treated before discharge, and several plants are water neutral[8].

In 2014, the sector benefited from low feedstock prices and restrictive measures on bioethanol imports, and as a result, EU bioethanol production rose to about 5.3 billion litres. In 2016, EU bioethanol production dipped due to financial problems within the sector but is forecast to recover to nearly 5.4 billion litres. EU bioethanol production is forecast to slightly increase in 2017 and 2018. This anticipated expansion is mainly based on increased use of existing capacity and growing demand by member states as they attempt to reach their 2020 targets. Total EU ethanol production capacity, for fuel, industrial and food uses, is estimated at about 8.9 billion litres. Further expansion of first generation bioethanol is expected to be limited. Expansion of second generation cellulosic bioethanol production is restrained due to the lack of certainty in the EU policymaking process. While EU bioethanol production has stagnated since 2015, consumption has been on the decline since 2011. This trend can mainly be explained by lower gasoline use and the adjustment of national blending mandates. Another factor is the blending of biofuels, which count double towards the mandate. The reduction of fossil fuel prices did not have a significant effect on biofuel consumption in the markets, which are regulated by mandates, and consumption of biofuels is fixed. Price increases have been tempered by the weakening of the Euro against the US$. Sales of the higher ethanol blends have been significantly affected by the low gasoline prices[9].

Regarding biofuels European policy (applicable to both bioethanol and biodiesel)[10]:

- The Directive on the promotion of the use of energy from renewable sources requires 10 percent of the energy used in transport to come from renewables by 2020. Although no dedicated quota was allocated to specific energy sources, most of this 10 percent is expected to come from liquid biofuels. This regulation replaces Directive EC 2003/30, which established a non-binding target of 5.75 percent for biofuels consumption in 2010.
- The Fuel Quality Directive requires greenhouse gas emissions from transport fuels be reduced by 6 percent by 2020.

The so-called ILUC Directive, which amends the two previous texts as far as indirect land use change, is concerned. The participation of conventional biofuels in the 10 % target is limited to 7 %. The indicative target for advanced biofuels is 0.5 %. Based on this Directive, EU member states have elaborated their national action plans to reach the 10 percent target. Most of them have adopted mandatory blends and some countries provide fiscal incentives.

[8] ePURE. Renewable ethanol: driving jobs, growth and innovation throughout Europe. State of the Industry Report, 2014.

[9] EU Biofuels Annual 2017. GAIN Report Number: NL7015.

https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_6-19-2017.pdf

[10] http://sugarcane.org/global-policies/policies-in-the-european-union/policy-overview-ethanol-in-europe

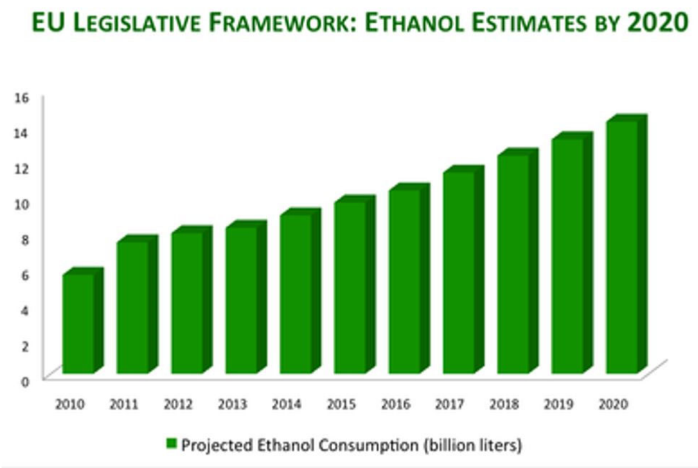


Figure 2. Projected Ethanol Consumption by 2020[11]

3.4.4 Solid biofuel

These solid biofuels are by-products of olive oil and pomace mills, canneries, nut hulling industries, wineries or other agroindustries.

Table 6. Motivation for the choice of solid biofuel.

Score		
Product	Raw material	Criteria
Exhausted olive cake Olive stones Fruit pits Chips/ hog fuel	Exhausted olive cake Fruit pits Prunings	a. Equipment: standard and simple equipment: usually found in agro-industries (drier, grinder, air separator and screening); b. Investment: low investment required; c. Market: market in place (country-based); d. Technology: high TRL (9). Biofuels to be used mainly at industrial scale, heat production and CHP units; e. Demand: stable demand trend for the next years; f. Logistics: Simple logistic configuration needed. Low energy density of biofuel; Logistics are economical feasible for small distance; g. Legislation: No specific framework (country-based). Policies provide incentives to use biomass for electricity generation.
Ranking	4	

[11] National Renewable Action Plans (NRAP): https://ec.europa.eu/energy/renewables/transparency_platform/action_plan_en.html

In most cases, the companies are burning these fuels to cover their own energy needs (self-consumption), e.g. to produce heat for drying. Any surplus can be sold as a solid biofuel, with markets developed mostly with other industries in the regions near the production site. For example in Spain and Greece approximately 800,000 and 360,000 t DM/y respectively of exhausted olive cake are consumed as industrial biofuel. Of these, around 60 % is self-consumed by the pomace mills[12].

3.4.5 Biodiesel

The EU is the world's largest biodiesel producer. Biodiesel is also the most important biofuel in the EU and, on an energy basis, represents about eighty percent of the total transport biofuels market. Biodiesel was the first biofuel developed and used in the EU in the transportation sector in the 1990s. At the time, rapid expansion was driven by increasing crude oil prices, the Blair House Agreement and resulting provisions on the production of oilseeds under Common Agricultural Policy set-aside programs, and generous tax incentives, mainly in Germany and France. EU biofuel goals set out in Directive 2003/30/EC (indicative goals) and in the RED 2009/28/EC (mandatory goals) further pushed the use of biodiesel.[9]

Table 7. Motivation for the choice of biodiesel.

Score		
Product	Raw material	Criteria
Biodiesel	Vegetable oil	a. Equipment: complex equipment required for the process (esterification reactor, transesterification reactor, washing tanks, methanol removal); b. Investment: medium investment required. c. Market: market well developed in place; d. Technology: technology well developed; high TRL (8-9); e. Demand: stable- growing demand trend for the next years; f. Logistics: Long term storage is prohibitive; g. Legislation: legislation promotes this type of biofuel to replace fossil fuels and therefore decrease GHG emissions related to transport sector.
Ranking	5	

Biodiesel (FAME & HVO) consumption is driven almost exclusively by Member State mandates and to a lesser extent by tax incentives. In 2017 and 2018, EU biodiesel consumption was expected to

[12] Biomasud Plus, 2016. DLV 2.1. Residential heating biofuels market state of the art. Report of Greece. http://biomasudplus.eu/wp-content/uploads/2017/09/D2.1-Market_report_Consolitated-6.pdf

increase by 3.4 and 5.3 percent, respectively, as a result of mandate increases in a number of Member States.

On October 5th, 2015, the ILUC (Indirect Land Use Change) Directive (EU) 2015/2013 entered into force. The ILUC Directive amended the Renewable Energy Directive (RED) with the goal to support the market for advanced biofuels. On November 30, 2016, the EC published its legislative proposal on the further revision of the RED (RED II). The RED II sets a target to produce at least 27 percent of its energy from renewable sources by 2030. For the information that backs up the last statement regarding the legislation, please review the previous section (bioethanol).

3.4.6 Bio-oil & biochar

Pyrolysis oil is a dark-brown liquid made from plant material by a thermo-chemical process called fast pyrolysis, whereby biomass particles are heated in the absence of oxygen, vaporized, and condensed into liquid. The process typically yields 65-70 % liquid BioOil (dry feed basis), 15-20 % char (a black charcoal-like powder), and non-condensable gases. Common feedstocks for pyrolysis oil are forest waste, such as sawdust and bark, and agricultural waste, such as sugar cane bagasse. Manufacturing pyrolysis oil is at the commercial stage for the past ten years.

Table 8. Motivation for the choice of bio-oil & bio-char.

Score		
Product	Raw material	Criteria
Bio-oil & bio-char	Prunings Straws Maize/sunflower/cotton stalks Sunflower/soybean/rice husks Corn Cobs	a. Equipment: Complex equipment required for the process (pyrolysis reactor, cyclone, condenser, furnace); b. Investment: high investment required; c. Market: market in place; economic feasibility can be reached for large scale facilities; multiple bio-oil applications; a large range of feedstock can be introduced; d. Technology: technology well developed; high TRL (8-9); e. Demand: growing demand trend for the next years; f. Logistics: easy to transport bioliquid. High energy density; g. Legislation: no specific framework/ legislation.
Ranking	6	

Char is a significant co-product of the pyrolysis process. It is a granular solid with properties similar to coal [13]. Pyrolysis oil can substitute heavy fuel oil (HFO), light fuel oil (LFO) or natural gas in a number of applications, including pulp mill limekilns, power plants and district heating. Char can be

[13] Bradley D. European Market Study for BioOil (Pyrolysis Oil). 2006.

co-fired with coal, but so can pyrolysis oil. Additional applications include greenhouses, sawmill dry kilns, stationary diesel engines and industrial boilers.

3.4.7 Syngas

Syngas can be produced from a variety of feedstock, which has little effect on the quality of syngas. In addition, the cost of production of syngas is directly related to the cost of feedstock, which gives manufacturers the flexibility to use many of them. This flexibility in the use of feedstock for the production of syngas is driving the market for syngas, globally. Syngas can be used to produce power (market size, 2016: approx. 25 million t/y) or chemicals like ammonia or methanol with mature markets already in place (2016: 180 million t/y and 85 million t/y respectively) [14].

Table 9. Motivation for the choice of syngas.

Score		
Product	Raw material	Criteria
Syngas	Prunings Straws Maize/sunflower/cotton stalks Sunflower/soybean/rice husks Corn Cobs	a. Equipment: complex equipment required (gasifier, gas cleaning unit, grinder); b. Investment: high investment required; c. Market: market in place; economic feasibility for small or large scale facilities; multiple syngas applications after refining; d. Technology: technology developed (TRL depends on feedstock); e. Demand: growing demand trend for the next years; f. Logistics: High cost logistics regarding transportation and storage; g. Legislation: no specific framework/ legislation.
Ranking	7	

3.4.8 Intermediates for bioenergy & biofuels to be produced at an IBLC

The list for bioenergy & biofuels involves many intermediate products. For example, syngas is produced and then it can be refined into other added value product such as gasoline, kerosene, aviation fuels, etc. Thus, it is an intermediate product that is used directly or converted into other products. Another example could be chips of prunings that can be used directly (without converting them into something else) for the production of bioenergy or could be transformed into pellets, bioethanol, bio-oil, etc.

[14] Hands R. Market drivers for the syngas industry. Gasification and Technologies Conference, Colorado Springs, 16 October 2017

3.5 Short list biobased chemicals

To produce biofuel or biobased chemicals the supply to industries of suitable and defined biomass feedstock is very important. The conversion of heterogeneous biomass to a stable feedstock that can be stored and transported could be an important role of an IBLC. At the IBLC the pre-processing can be performed of lignocellulosic feedstock, carbohydrate or protein rich residues (e.g. pressed oil seed cake, pomace) and perishable residues for the conversion to fermentable or extractable biomass. The selection at the IBLC of suitable pre-processing and preservation steps for the biomass should be technically and economically feasible. A selection was made of bio-based chemicals that are currently produced on industrial scale, and where market growth is expected for the coming years.

The focus within biobased chemicals (BC) is on (see orange fields in Annex B, Table B2):

1) Bioethanol
2) Lactic acid
3) Succinic acid
4) Tartaric acid
5) Furfural
6) Levulinic acid
7) Protein
8) Lignin
9) Phenolics

3.5.1 Bioethanol

Bioethanol production for transportation fuel uses has received significant attention and has been commercially implemented. The value of bioethanol (Table 10) is 1.50 - 1.90 €/l (depending on water %). Conversion by fermentation to ethanol of lignocellulosic feedstocks is possible, instead of sugar or starch – the so-called 2nd generation bioethanol – but remains a challenge as the costs for chemicals and enzymes are high and conversion rates are not maximized. In lignocellulosic feedstocks up to 40-50 % C6 sugars are present that are obtained by hydrolysis, while in addition C5 sugars and lignins are present. Value addition to these components is of high relevance for the economic feasibility of 2nd generation processes.

Table 10. Motivation for the choice of bioethanol.

Score		
Product	Raw material	Criteria
Bioethanol	Pruning Straws Sunflower/soybean/rice husks Corn Cobs Grape pomace	a. Equipment: complex; b. Investment needed: high; c. Market: demand for transportation fuel; d. Technology TRL: 9 /Industrial (sugar based); e. Demand: growing.

The use of ethanol as platform chemical for production of ethylene derivatives and polymers is common practice in the petrochemical industries. Biopolyethylene (BioPE) or Biopolyester (BioPET) are of high interest and production based on lignocellulose sources would avoid the use of food grade resources[15]. Large petrochemical companies like Dow and Neste invest in biopolymer production as drop-in for polyethylene[16].

The 2nd generation bioethanol production from straws may become economically feasible when the lignin fraction and C5 fraction can be valorised as well. At the IBLC the straw pre-treatment can be performed to extract the C5 and lignin fractions before cellulose is depolymerized (to C6) by hydrolysis at another conversion site or also at the IBLC. The last option is part of the AGROinLOG demonstration work package in Sweden.

3.5.2 Lactic acid

Lactic acid (2-hydroxy propionic acid) is obtained by anaerobic fermentation of C6 (sugar) on commercial scale as a monomer for the manufacturing of polylactic acid (PLA). However, has also significant outlet in food and pharmaceutical industries (flavour, preservative and acidity adjuster). The value of lactic acid (Table 11) is 0.70 - 3.00 €/kg for feed to pharma grades. PLA is a biodegradable plastic that finds increasingly application in packaging, fibres and foam. The global production capacity is estimated at 700 kt (2013), with a 12.5-18 % estimated annual growth (CAGR) to 2,000 kt by 2020. The most important producers are Corbion (Purac), Cargill, ADM, Galactic, Ning Xia Hypow and Henan Jindan. The sources of C6 commonly are easy accessible carbohydrates such as starch, molasse or sugar. Alternatively, deprotonated exhausted oilseeds or 2nd generation lignocellulose C6 may be used as source for fermentation.

[15] http://bio-based.eu/market_study/media/files/13-06-21MSBiopolymersExcerpt.pdf

[16] https://bioplasticsnews.com/2018/07/23/neste-is-becoming-a-major-bioplastics-producer/

Table 11. Motivation for the choice of lactic acid.

Score		
Product	Raw material	Criteria
Lactic acid	Pruning Straw Molasses	f. Equipment: complex g. Investment needed: high h. Market: demand for bioplastics i. Technology TRL: 8 / industrial (sugar based) j. Demand: growing

Lactic acid can be obtained as optical pure (D(-) or L(+) form) or in racemic (D,L mix) form. The L(+) form is preferred for polymer production. The fermentation process uses C6 that can be derived from sugar, lactose, starch or hydrolysed cellulose (2nd generation) from lignocellulose[17, 18].

3.5.3 Succinic acid

Succinic acid (SA) is currently produced mainly from petrochemical sources. It is produced on relatively small scale (35 kt/y) and is used with 1,4 butanediol for the production of polybutylene succinate (PBS). It can be used for the manufacturing of other polymers (PBT, BDO, etc.) as well. The market value of succinic acid (Table 12) is 4.00 - 10.00 €/kg. Alternatives for the production of "bio-amber" by anaerobic bacterial fermentation[19, 20, 21] starting from **C6 (sugar)** with CO_2 supply, have been reported to be commercial. In literature also **C3 (glycerol)** was shown to be converted by certain microorganisms to succinate. Producer companies are: Succinity GmbH (DE), Bio-Amber (USA), Reverdia (NL), Myriant (USA) and Mitsubishi (JP).

Table 12. Motivation for the choice of succinic acid - butanedioic acid.

Score		
Product	Raw material	Criteria
Succinic acid - butanedioic acid	Molasses Grape pomace Bio-diesel residue (C3)	a. Equipment: complex; b. Investment needed: high; c. Market: small niche for engineering plastics; d. Technology TRL: 7 / industrial (sugar based); e. Demand: growing.

[17] https://www.european-bioplastics.org/market/

[18] http://www.lactic-acid.com/production_process.html

[19] https://www.intratec.us/free-tools/how-to-make/succinic-acid-manufacture-technology

[20] https://ocw.tudelft.nl/course-lectures/best-practice-industrial-process-development-succinic-acid-2/

[21] https://www.chemicals-technology.com/projects/bioamber-bio-based-succinic-acid-production-ontario/

3.5.4 Tartaric acid

Tartaric acid (Table 13) is a common by-product from the **wine industries**. The value of tartaric acid is 1.50 - 3.00 € /kg. Commercial production of tartaric acid for uses in food, beverages and pharma is established[22].

Table 13. Motivation for the choice of tartaric acid.

Score		
Product	Raw material	Criteria
Tartaric acid	Wine by-product (lees)	a. Equipment: simple; b. Investment needed: medium; c. Market: existing product with potential of expansion; d. Technology TRL: industrial; e. Demand: growing.

Producer companies are: Caviro Group (Italy), ATP Group (US), Merck (Germany), Omkar Specialty Chemicals (India), Changmao Biochemical Engineering (China), Tarac Technologies (Australia), PAHI (Spain), Distillerie Mazzari (Italy), Distillerie Bonollo (Italy), Derivados Vínicos (Argentina), Industrias Vínicas (US), and Tártaros Gonzalo Castelló (Spain).

3.5.5 Furfural

Furfural is produced commercially from residues by acid hydrolysis and dehydration at elevated temperature of pentosan rich lignocellulosics (straw, bagasse, corncobs). The value of furfural (Table 14) is 1.00 - 2.00 €/kg. Global production capacity is ca. 800 kt/y. Hydrogenation will yield furfuryl alcohol. The conversion efficiency of **pentosan (C5)** to furfural is ca. 50 % but may increase to 70 %. Depending on the pentosan content of the biomass the furfural yields are between 15 and 20 %. Typical by-products are methanol (5 %), acetone (5 %) and acetic acid (7-10 %).

Table 14. Motivation for the choice of furfural.

Score		
Product	Raw material	Criteria
Furfural	Straw, stalks, bagasse, corncobs	a. Equipment: complex; b. Investment needed: medium; c. Market: resins and wood preservation chemicals, foundry; d. Technology TRL: industrial; e. Demand: growing.

Suppliers are: IFC Central Romana Co/ Quacker Oats, Dominican Republic; TFC Belgium; Xingtai Chunlei Furfuryl Alcohol Co., Ltd., China; Illova Sugar, South Africa / Harborchem.

[22] http://smea-srl.com/en/our-business/industrial-design/tartaric-acid-production-plant/

3.5.6 Levulinic acid

Levulinic acid (LA) production is relatively low while the demand is increasing. A market growth (CAGR) of 14 % is expected as the prices are high. The value of levulinic acid (Table 15) is 5.00 - 8.00 €/kg. LA is currently used as plasticiser, as cross-linker and solvent in coatings and resins, in pharmaceutics and cosmetics, in fertilizers and pesticides and is a promising platform chemical. LA can be produced together with formic acid (FA) from different (residual) biomass **containing C6 (starch, cellulose, etc.)** by heating with acid. At a 50-60 % conversion yield of lignocellulose (containing ca 40 % C6) 1 kg yields 0.20-0.24 kg LA, 0.08-0.10 kg FA and also 0.50 kg char[23]. Plans for upscaling production are considered in EU[24].

Table 15. Motivation for the choice of levulinic acid - 4-oxo-pentanoic acid.

Score		
Product	Raw material	Criteria
Levulinic acid - 4-oxo-pentanoic acid	Pruning Straw Molasses	a. Equipment: complex; b. Investment needed: medium; c. Market: plasticiser, solvent, cross-linker; d. Technology TRL: 9; e. Demand: growing.

Companies involved are: Biofine, DSM, Segetis / GFBiochemicals, Italy (now upscaling from 2,000 to 10,000 t/y)[25], Avantium (NL), DuPont.

3.5.7 Protein

The extraction of proteins from green plants is receiving much attention in food industries, where the search is for meat substitute products[26]. The value for proteins (Table 16) is 0.40 - 30.00 €/kg and extremely depending on its application in feed or food. The rubisco protein can be found in all green plants and crops (e.g. sugar beet leaves, vine leaves, olive leaves, sunflower leaves, etc.) and is isolated from the **green press juice**. The conditions need to be mild to avoid denaturation of the proteins and removal of phenolics will be important for the protein quality. The perishable nature of fresh juice requires appropriated tools to preserve the extracts.

[23] http://www.biobasedgarden.nl/wp-content/uploads/2016/12/Levulinic-Acid-Platform-9-Mar-16-DSM.pdf

[24] https://biconsortium.eu/library/case-studies/levulinic-acid-production

[25] http://www.gfbiochemicals.com/_media/Document/2017/4/26/GF%20Low%20Quality.pdf

[26] https://www.wur.nl/nl/project/GreenProteins-Isolation-of-hydrophobic-proteins-from-green-plant-materials.htm

Table 16. Motivation for the choice of protein.

Score		
Product	Raw material	Criteria
Protein	expelled oil seeds green leaves press juice	a. Equipment: complex; b. Investment needed: medium; c. Market: alternative protein sources for meat substitute products; d. Technology TRL: 9, industrial; e. Demand: growing.

Protein extraction from **(oil) seeds** is performed as well. All seeds contain oil, protein and storage carbohydrates in different proportions. Most proteins from oil seed press cake are used for animal feed production. Rapeseed (Canola) is the most important oilseed produced in the EU-28. The rapeseed meal consists mainly of proteins (40-45 %). Cruciferin (12S globulin) and napin (2S albumin) are the major proteins found in rapeseed isolate.

Grape seeds[27], olive stones[28,29] and exhausted oil seed cakes have been studied for their protein content and potential uses. The extracted proteins may contain anti-nutritional components, anti-oxidants and phenolics that need to be separated before food or feed uses are possible.

Conversion of the (denaturized) protein fractions to mixed amino acids may yield high value food or feed additives. The pure amino acids commonly are produced by fermentation industries, except methionine that is produced by chemical synthesis. Glutamine, lysine and methionine are produced in the largest volumes.

3.5.8 Lignin

Lignin (Table 17) is a by-product of lignocellulose pulping and biorefinery. The value of lignin is 0.60 - 3.00 €/kg. Lignin is present in the cell walls of all land plants. Lignins from soft and hard woods or grasses are slightly different in composition and reactivity. Woody plant materials may consist of up to 30 % lignin (dry weight base) in soft wood. Hardwood and grasses commonly are lower in lignin (10-20 %). Lignin is liberated as black liquor from the cell wall structure when paper pulping processes are applied. Most lignins on the market are Kraft lignin and lignosulphonates. Potentially, lignin is a very suitable raw material for the production of biobased chemicals. Application development for lignins are found in cement additives (plasticiser), resins, as bitumen substitute (bioasphalt) or component in polymer composite materials, as (bio)fuel additive or in animal feed.

---

[27] Fantozzi, P. "Grape seed: a potential source of protein." *Journal of the American Oil Chemists' Society* 58.12 (1981): 1027-1031.

[28] Rodríguez, Guillermo, et al. "Olive stone an attractive source of bioactive and valuable compounds." *Bioresource technology* 99.13 (2008): 5261-5269.

[29] Matos, Marina, M. Filomena Barreiro, and Alessandro Gandini. "Olive stone as a renewable source of biopolyols." *Industrial Crops and Products* 32.1 (2010): 7-12.

Table 17. Motivation for the choice of lignin.

Score		
Product	**Raw material**	**Criteria**
Lignin	Pruning Straws Maize/sunflower/cotton stalks Sunflower/soybean/rice husks Corn Cobs	a. Equipment: complex; b. Investment needed: high; c. Market: resins, plasticiser, functional additives in asphalt, coatings, aromatics; d. Technology TRL: 9; e. Demand: growing, but slow due to availability.

There is also great interest in the development of biobased aromatic compounds from biomass. Aromatic chemicals are among the most important chemical ingredients for use in fuels, base chemicals or polymers, but also polymer additives, dyes, fragrances and aromas (vanillin), agrochemicals and raw materials for pharmaceuticals. Recently, lignin has received increasing attention from the chemical industry as an alternative renewable source of aromatic chemicals production. Aromatic compounds are unsaturated hydrocarbon compounds, as occurs in benzene, toluene and xylene (BTX), phenol and terephthalic acid, which are the most common monomeric aromatic compounds. Nowadays, these light olefins and aromatic hydrocarbon compounds (C6-C8) in the petrochemical industry are produced by cracking of naphtha together with the paraffins (C9-C12). Worldwide consumption of benzene comprises about 40 Mt as solvent and chemical raw material[30]. Various technologies are being developed to convert lignin into aromatic chemicals, preferably monomers.

Moreover, the use of lignin in chemical industries for the production of carbon fibre is investigated.

The market for lignin is expected to grow significantly in the years to come. As most of the generated lignin in pulping industries are used for process energy generation, the availability of large volumes of (low priced) lignin of defined quality remains an obstacle for full-scale industrial development. Lignins derived from lignocellulose biorefineries and fermentation may become relevant when 2nd generation feedstock is used.

Producers:

- kraft lignins: Ingevity (US); Domtar (CND), Stora Enso (FI);
- sulphite (lignosulfonates): Borregard (NO), Tembec (CDN, FR); Domsjö (SE); Rochette (FR); Nippo Paper (JP);
- soda lignin: Greenvalue (CH).

Lignin as by-product from lignocellulose biorefineries could be a product that is liberated and stored at IBLCs. The further conversion to value added products has to be explored.

[30] Cherubini, Francesco, and Anders H. Strømman. "Chemicals from lignocellulosic biomass: opportunities, perspectives, and potential of biorefinery systems." *Biofuels, Bioproducts and Biorefining* 5.5 (2011): 548-561.

3.5.9 Phenolics

Phenolics (Table 18) obtained by extraction from crop residues may have a high value of 20.00 - 25.00 €/kg. In most plants various monomeric or polymeric phenolic components (other than lignin) are present in significant amounts (so called secondary metabolites). Examples of natural phenols are catechol, chlorogenic acid, salicilic acid, gallic acid, flavonoids, anthraquinones, lignans and tannins, that may occur in bark, leaves or seed hulls. The phenolics are protective agents that function as anti-oxidant, against insect or fungal attack, etc.

Table 18. Motivation for the choice of phenolics.

Score		
Product	Raw material	Criteria
Phenolics	Pruning / bark Olive stones, leaves, pomace Grape seeds	a. Equipment: complex; b. Investment needed: medium; c. Market: coatings, adhesives, flavours, dyes and preservative; d. Technology TRL: industrial; e. Demand: limited but with potential in pharma and food.

Grape seeds and olive residues are rich in phenolics, that can be extracted and may find use in high added value products for pharmaceutical and cosmetics industries, in food and feed and as coatings, adhesives, flavours, dyes and preservatives. For example, oleuropein, as found in extracts of olive leaves, is commercialized as nutrasupplement in capsules and elixirs because of its pharmacological effects.

At IBLCs the extraction of phenolics may be performed for biomass value addition. The instalment of such an extraction unit should be close to the spot where the selected biomass is liberated. It has to be noted that the extracted components may be present only in a small percentage of the total biomass. The remaining extracted biomass would need further treatment.

3.6 Short list biobased materials

The final biobased materials that can be manufactured with these intermediates are (see orange fields in Annex B, Table B3):

1) particle board & fibre board;
2) paper pulp and board;
3) dissolving cellulose;
4) granulate & plastic composite;
5) adhesives, coatings, liners, thickeners.

3.6.1 Particle board & fibre board

The manufacturing process of particle boards and fibre boards (Table 19) is using wood chips, or agricultural residues (straw, flax or hemp shives) as basis. Woody prunings of olive trees will require debarking and chipping to make suitable particles. Manufacturing of straw boards will require the conversion of the hollow straw stem to fibres. The suitability of the particles for particle board production are depending on aspects such as the particle density, porosity and suitability for adhesion of the resins. In fibre board production the chips are refined to smaller fibres. The particles are hot pressed with addition of a thermosetting resin (UF, PF, MDI) to produce panels. Different qualities of panels are produced, depending on the density and resins used. The top and bottom maybe covered with a decorative top-layer. The common uses are found in furniture, cupboards, kitchens and indoor separation walls.

Table 19. Motivation for the choice of particle board & fibre board.

Score		
Product	Raw material	Criteria
Particle board & fibre board	Pruning Straws Maize/sunflower/cotton stalks	a. Equipment: simple; b. Investment needed: medium; c. Market: competition with established wood based panel industries; d. Technology TRL: 9, industrial; e. Demand: stable.

In the IBLC chipped or refined fibres may be produced and (dry) stored for the supply to a board manufacturing mill. Compaction for transport is one of the possible activities.

3.6.2 Paper pulp and board

Most paper is currently produced from wood as fibre source. Paper pulping (Table 20) is usually performed on large industrial scales (more than 100,000 t/y) with high efficiency. The pulping industries are especially important in Nordic countries. Long softwood fibres (pine and spruce) are usually mixed with shorter hardwood fibres (eucalyptus and birch) for paper production. Non-wood pulping is only performed on small scale for specialty papers (e.g. hemp for cigarette paper; cotton for security paper or art paper). Straw pulping has become obsolete in the last decades, due to problems in logistics and high costs of chemical recovery.

Table 20. Motivation for the choice of paper pulp and board.

Score		
Product	Raw material	Criteria
Paper pulp and board	Pruning Straws Maize/sunflower/cotton stalks	a. Equipment: complex; b. Investment needed: high; c. Market: established / competition with wood based pulping; d. Technology TRL: 9, industrial; e. Demand: stable.

Non-wood pulps from agro-residues have been shown to have potential use. For example, tomato leaves and stems were pulped and used for the manufacturing of moulded tomato food containers[31]. Similarly, other lignocellulose residues may be converted on small-scale to suitable pulp that can be used for wrapping papers and moulded board packaging products. Olive tree pruning can be used for (Kraft) pulping and paper making process[32].

3.6.3 Dissolving cellulose

Dissolving cellulose (Table 21) can be produced from pulped lignocellulose, by further purifying and bleaching the cellulose fraction to high purity (>90 %). Non-wood pulping or biorefining using alternative chemical or enzymatic processing conditions (e.g. acetosolv, organosolv, etc.) could use biomass generated from IBLCs. Small-scale operations for dissolving pulp production at an IBLC are less likely. However, non-wood lignocellulose supplies to a pulping mill could be of interest in some cases.

Table 21. Motivation for the choice of dissolving cellulose.

Score		
Product	Raw material	Criteria
Dissolving cellulose	Pruning Straws Maize/sunflower/cotton stalks	a. Equipment: complex b. Investment needed: high c. Market: bioplastics, textiles and cellulose derivatives d. Technology TRL: industrial e. Demand: growing

The dissolving cellulose is used for the production of cellulose derivatives and cellulose-based plastics (cellulose acetate) as well as for the production of regenerated cellulose yarns (viscose, lyocell). The market for dissolving cellulose is growing and non-wood cellulose is potentially an interesting source for its production. Besides the existing markets, dissolving cellulose is the basis for cellulose whiskers and nanocellulose production.

3.6.4 Granulate & plastic composites

Lignocellulosic fibres can be mixed with thermoplastic matrices such as PP or PE, for the manufacturing of natural fibre reinforced composites. The fibre and polymer are mixed by an extrusion process to form granules. Subsequently, the granulate (Table 22) can be converted by injection moulding into 3D shaped plastic reinforced composite products for manufacturing of light weight (interior) car parts and furniture.

At an IBLC the preparation of the fibrous feedstock maybe in the form of pellets produced from agro-residues such as corn stalks, wheat straw or prunings. For the compounding process with thermoplastics the pellets need to be disintegrated again for good dispersion in the polymer

[31] Da Silva, FIDG Pereira, and E.R.P. Keijsers. *Tomaten verpakken in tomatenbladverpakkingen*. No. 1400. Wageningen UR-Food & Biobased Research, 2013.

[32] Requejo, A., et al. "TCF bleaching sequence in kraft pulping of olive tree pruning residues." *Bioresource technology* 117 (2012): 117-123.

matrix. This will have a negative effect on the fibre mechanical properties. An alternative route could be that the fibrous pellets are pre-mixed at the IBLC with (a certain percentage of) the thermoplastic polymer, which would avoid damaging of the cellulose fibres and yield better quality of composite products.

Table 22. Motivation for the choice of granulate & plastic composites.

Score		
Product	Raw material	Criteria
Granulate & plastic composites	Pruning Straws Maize/sunflower/cotton stalks	a. Equipment: medium; b. Investment needed: medium; c. Market: composites, moulded automotive parts; d. Technology TRL: 9, industrial; e. Demand: stable.

3.6.5 Adhesives, coatings, liners, thickeners

Free fatty acids and (unsaturated) plant oils find industrial use in the manufacturing of paints, varnishes and coatings, surfactants, soaps, etc. Besides that, the press cake can be used for extraction of proteins and fermentable carbohydrates. Protein based applications in non-food and non-feed products can be found in formulations for adhesives, coatings and liners, foaming agents and thickeners (Table 23). The suitability of plant proteins for industrial uses requires information on the (thermal and pH) stability of the product and functional properties such as solubility, rheology, reactivity and surface behaviour. Proteins from green leaves (rubisco) have high surfactant activity and can be applied in foams.

Table 23. Motivation for the choice of adhesives, coatings, liners, thickeners.

Score		
Product	Raw material	Criteria
Adhesives, coatings, liners, thickeners	free fatty acids / plant oils oil seed press cake green foliage	a. Equipment: complex b. Investment needed: high c. Market: biobased additives in polymers, and coatings d. Technology TRL: 8 e. Demand: growing

3.6.6 Intermediates for biobased chemicals & materials to be produced at an IBLC

The focus within intermediates at the IBLC that can be used for the final production of biobased chemicals and materials is on the manufacturing of raw materials to supply the biorefineries or chemical manufacturing industries. The intermediate forms of biomass that are suitable for conversion are:

- bales;
- chips;
- fibre;

- fibre pulp;
- granulate;
- pyrolysis oil;
- biogas;
- fermentation feedstock;
- extraction feedstock;
- crude protein.

The demands for each application may be different and the biomass pre-processing steps need to be agreed with the companies that are processing the biomass.

4 Theoretical opportunities per sector

4.1 Introduction

Theoretical opportunities have been described per sector (see Table 1) based on the short lists bioenergy & biofuels and biobased chemicals & materials (intermediate) products. The opportunities were rated in three categories based on the expert knowledge of the team members. Theoretical scores (T) were given to the products from the short lists and these scores were also translated to traffic light colors:

- T1= very suitable (dark green)
- T2= suitable (light green)
- T3= less suitable (orange)

4.2 Vegetable oil extraction

The vegetable oil extraction sector involves facilities that extract and process oils and fats from a variety of seeds, grains, and nuts. In a European context these mainly include rapeseed, soybean, cotton seeds and sunflower. However, other raw materials are being also used as grape seeds, maize germ, etc. Additionally covered are crude oil production and refining processes, from the preparation of raw materials to the bottling and packaging of final products for human or animal consumption.

Vegetable oil processing activities generate important amounts of organic solid waste, residues and by-products such as crop's straw, seed husks and oils and water wastes which could be used for implementing IBLC's strategies. These by-product streams are already used in some facilities for cattle feed or bioenergy purposes. However, still there is a significant amount of feedstock available which could be used for energy or for chemical purposes (e.g. extraction of waxes or phenolic compounds) by an IBLC.

Taking advantage of the residues left on the soil in the harvesting stages to produce biofuels for the energy market or for self-consumption offers an important opportunity for many installations to become an IBLC. In addition to production and market aspects, possible application of the residues to the soil as an organic amendment as well as the final quality of the fuel produced should be taken into account. Though not very specific equipment is needed in the process (screens, grinder, dryer, pelletiser, etc.), they normally are not present in these installations. Though not excessively high investments or complex processes are required to produce pellets or briquettes, the whole scheme (collection of the residues, transport, idle periods or production capacity, biofuel production and final use) should be properly assessed as a whole to evaluate the alternative.

Biogas or biodiesel could also be produced by taking advantage of some wastewater or refuse streams with oil content but the investments needed for this type of plants generally are a barrier to be overcome.

On the other hand, residues obtained in the extraction process like pomaces could be used as raw material for the production of waxes or other chemical industry biocommodities as fibres or antioxidants like phenols by solvents extraction or by supercritical CO_2 technologies.

The most promising opportunities to produce new biocommodities in the vegetable oil extraction sector by implementing the IBLC strategy are listed in Table 24.

Table 24. Theoretical opportunities to produce bioenergy & biofuels and/or biobased chemicals & materials at an IBLC in the vegetable oil extraction sector.

Opportunities for intermediate products at an IBLC in the vegetable oil extraction sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Pellets/ Briquettes from crops' straw or stalks	T1	• Standard and simple equipment: (drier, grinder, air separator, screening, press). • Normally, the required equipment is not available in these facilities. Low investment required for the purchase. • Well-functioning and developed market for the product in Europe. • Quality attained in the products is lower than the ones that woody pellets have. Uses (normally industrial final users) and markets have to be properly addressed. • Manufacturing technologies are mature, efficient and reliable. High TRL (8-9 according to the feedstock used). • Growing demand trend for the next years considering the increasing heating and industrial demand and the increasing price of fossil fuels. • High density allows efficient storage and transportation and lower logistics costs compared to chips.
Biogas from exhausted seeds or waste waters	T1	• Medium to high investment required. • Technology well developed. • Market in place. • Multiple biogas applications. • Supportive policy framework for biogas initiatives.
Biodiesel from residual oils or streams	T1	• High investment required. • Technology well developed. • Market in place. • Supportive policy framework, especially for biodiesel produced from residues or non-edible oils.
	T3	• High investment required.

Opportunities for intermediate products at an IBLC in the vegetable oil extraction sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Bio-oil & biochar from crops' straw or stalks		• Complex equipment required. • Technology well developed in some applications. • Multiple applications. • Market in place. • Bio-oils require further upgrading in many added value applications.
Syngas from crops' straw or stalks	T3	• High investment required. • Syngas needs further upgrading. • Multiple applications. • Technology well developed in some applications. • Market in place.
Phenols from seed cakes or pomaces	T2	• Further investigation due to low scale extraction rates. • Marketability issues due to the exploitation of process waste into food market or cosmetics and pharmaceuticals.

4.3 Olive oil mills (chain)

The olive oil sector is an aggregation of several industries with specific roles through all the olive oil production process stages. Olive oil mills, oil refineries and the olive pomace oil industries could be considered as the most relevant ones when dealing with the IBLC concept implementation. Olive oil industries offer many synergies for implementing the IBLC concept. Apart from their central position near biomass sources (olive tree prunings, olive pomace, olive stones, olive leaves, etc.), olive oil industries offer synergies with available workforce, assets and biomass processing equipment (warehouses, conveyor belts, dryer, scales, tractors, etc.) that can be exploited during their idle time.

Several theoretical opportunities to produce biofuels and/or biobased chemicals and materials at an IBLC in the olive oil sector exist. A major opportunity appears on the exploitation of the untapped biomass feedstock, olive prunings, which are currently mainly burned in open fires. Olive prunings can either be used as feedstock for the production of pellets (mainly industrial quality) or even consumed directly in chip format at industrial boilers. For both biofuels, low investment on equipment is needed for their production. Another residue from the olive oil chain that can be used directly as a fuel is that of olive pits. Olive pits, when separated from the fruit, consists of a fuel with a significant higher heating value (HHV) and low ash content. It is already being produced at certain cases. Another opportunity appears on the exploitation of exhausted olive cake and olive mill wastewater as feedstock for biogas production. However, the existing agro-industry should advance to investments for the anaerobic digestion of these feedstocks.

In addition, olive prunings, apart from their potential energy use, can be utilised as feedstock for the production of particle boards. For this end-product, the intermediate product at an IBLC will be chips derived from olive tree prunings.

Furthermore, olive leaves, that in the majority of cases remain unexploited, are rich in phenolic content. Thus, olive leaves are an excellent candidate for further processing for extracting phenolic content (hydroxytyrosol, oleuropein, triterpenes, etc.) that can be used in the pharmaceutical, cosmetic or food sector (as antioxidants). There are existing cases where olive leaves are used for such products. However, the technologies for phenols extraction have to be further investigated due to low scale applications.

The most promising theoretical opportunities to produce biofuels, biobased chemicals and materials at an IBLC in the olive oil sector are listed in Table 25.

Table 25. Theoretical opportunities to produce bioenergy & biofuels and/or biobased chemicals & materials at an IBLC in the Olive Oil sector.

Opportunities for intermediate products at an IBLC in the Olive oil sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Pellets/ Briquettes from olive prunings	T1	• Standard and simple equipment, usually found in agroindustries (drier, grinder, air separator, screening, press). • Low investment required. • Well-functioning and developed market for the product in Europe. • Manufactured technologies are mature, efficient and reliable. High TRL (8-9 according to the feedstock used). • Growing demand trend for the next years considering the increasing heating and industrial demand and the increasing price of fossil fuels. • High density allows efficient storage and transportation and lower logistics costs, compared to chips. • Wide range of raw materials can be used.
Biogas from exhausted olive cake and olive mill wastewater	T1	• Medium to high investment required. • Technology well developed. • Market in place. • Multiple biogas applications. • Supportive policy framework for biogas initiatives.
Chips from olive prunings	T1	• Standard and simple equipment: usually

Opportunities for intermediate products at an IBLC in the Olive oil sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
		found in agroindustries (drier, grinder, air separator, screening). • Low investment required. • Market in place (country-based).
Direct use of olive stones as a fuel	T1	• Standard and simple equipment: usually found in agroindustries (drier, grinder, air separator and screening). • Low investment required. • Market in place (country-based).
Bio-oil from olive prunings	T3	• High investment required. • Complex equipment required for the process (pyrolysis reactor, cyclone, condenser and furnace). • Large scale is preferable.
Syngas from olive prunings	T3	• High investment required. • Complex equipment required for the process. • The produced syngas needs further upgrading for an added value product.
Chips/ Fibres from olive prunings for particle/ fibre board production	T1	• Low investment required.
Phenols from leaves	T1	• Already existing technologies for acquiring phenols from olive leaves, however, still under further investigation due to low scale extraction rates.
Ethanol from exhausted olive cake	T3	• High investment required. • Complex equipment required.
Phenols from olive pomace	T2	• Further investigation due to low scale extraction rates. • Marketability issues due to the exploitation of process waste into food market or cosmetics and pharmaceuticals.
Phenols from olive mill wastewater	T2	• Feedstock rich in phenols. • Further investigation is needed due to low scale extraction rates. • Marketability issues due to the exploitation of process waste into food market or cosmetics and pharmaceuticals.
Phenols from olive pits/	T3	• Further investigation is needed due to

Opportunities for intermediate products at an IBLC in the Olive oil sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
stones		low scale extraction rates. • Feedstock already used as a fuel for domestic heating.
Proteins from olive pits	T2	• Extraction technologies need further development (higher extraction rates are needed).
Proteins from olive pomace (press cake)	T2	• Extraction technologies need further development (higher extraction rates are needed).
Furfural from olive pit	T2	• Low production rate. • Medium to high investment needed.

4.4 Feed and fodder

The feed and fodder sector brings together all the compound feed & pre-mixtures companies, the specialty feed ingredients and their mixtures industries as well as the installations that process herbaceous matter for better preservation of the nutritious elements. By mixing several raw materials (cereals, vegetable and animal by-products, etc.) and other components (oils & fats, molasses, vitamins, minerals, etc.), or by silage, haymaking and dehydration processes in the fodder installations, these industries produce balanced animal nutrition solutions.

Feed and fodder installations, especially the fodder industries, use compatible equipment with biomass processing activities, have idle periods and already work with some materials that can be used for biofuels and other biocommodities production so that implementing IBLC strategies is a great opportunity for their development.

Although Lucerne is the main raw material processed by the fodder industries, agricultural residues as cereal straw or corn stalks are also used in these installations to complete or integrate some of the dried fodder produced. Though they normally are installations featured by their almost null residues generation, they are used to handle other agricultural residues like straw. These materials or other agricultural residues can be also used to produce agricultural pellets, either being 100 % agripellets or pellets blended with woody resources to reach different quality and market segments. Final biofuels quality achieved and its relation with the conversion equipment fed with them and the possible interactions with fodder quality caused by the incorporation of remaining materials in some equipment have to be specifically assessed.

On the other hand, new pellets produced could also be used to be part of boards or bioplastics, or other biobased chemicals like furfural or levulinic acid, new and different markets for these companies that are being explored in order to determine the conditions at which they can become a reality.

The most promising opportunities to produce new biocommodities in the feed and fodder sector by implementing IBLC strategies are listed in Table 26.

Table 26. Theoretical opportunities to produce bioenergy & biofuels and/or biobased chemicals & materials at an IBLC in the feed and fodder sector.

Opportunities for intermediate products at an IBLC in the feed and fodder sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Pellets/ briquettes from agricultural residues	T1	• Standard and simple equipment: usually found in agroindustries (drier, grinder, air separator, screening and press). • Very low investment required. • Well-functioning and developed market for the product in Europe. • High density allows efficient storage and transportation and lower logistics costs, compared to chips.
Syngas or bio-oil & bio-char from agricultural residues	T3	• High investment and complex equipment required. • Syngas needs further upgrading. • Bio-oils require further upgrading in many added value applications. • Technology well developed in some applications. • Multiple applications. • Market in place.
Furfural or levulinic acid	T2	• High investment. • Complicated process/extractability and yields to be confirmed. • Versatile utilization. • Increasing demand.
Particle board and fibre board from straws	T1	• Market in place. • Standard and simple equipment.
Granulate and plastic composites	T2	• Standard well-established process. • Market in place. • Optimum process and final properties to be confirmed yet.

4.5 Wine sector (cellars & distilleries)

Wine industries like wineries and distilleries offer many opportunities for the implementation of the IBLC concept. Wine industries already have a wide experience in the transport, management and processing of their residues. During the low season period of wine production facilities could process their by-products for energy and bio-based materials production, utilizing existing assets/ resources like available storage, drying equipment and workforce.

An IBLC in the wine sector would have several opportunities for the production of biofuels and biobased chemicals and materials. Vineyard prunings can be valorised with simple and relatively inexpensive equipment (e.g. chipper, mill and pellet press) for the production of solid biofuels. Chips are more easily produced, but pellets have higher density that allows for more efficient storage and transportation. The market for pellets in Europe is well-functioning and developed and there are already examples of companies producing pellets from vineyard prunings (Spain).

Large volumes of wastewater are generated from the wine industry sector. Several distilleries reduce the organic matter in their waste stream by anaerobic digestion. The market for the biogas that is produced is already in place in Europe. Furthermore, grape seed oil and flour can be produced from the separated grape seeds. There is already a market in Europe for grape seed oil due to its pharmaceutical and cosmetic uses. Spain, for example, produced 11,000 tonnes of grape seed oil in 2016[33]. Finally, another by-product generated in the wine sector that can be exploited, is that of lees. Tartaric acids, in the form of dissolved tartaric salts, can be recovered in a four-step process from delocalized lees.

The most promising theoretical opportunities to produce biofuels, biobased chemicals and materials at an IBLC in the wine sector are listed in Table 27.

Table 27. Theoretical opportunities to produce bioenergy & biofuels and/or biobased chemicals & materials at an IBLC in the wine sector.

Opportunities for intermediate products at an IBLC in the wine sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Pellets/ briquettes from vine prunings and wine residues	T1	• Low investment required. • Well-functioning and developed market for the product in Europe. • High density allows efficient storage and transportation and lower logistics costs, compared to chips.
Chips from vine prunings	T1	• Low investment required, • Lower density leads to less efficient storage and transportation and higher logistics costs, compared to pellets.
Biogas from winery wastewater and grape pomace	T1	• Medium to high investment required. • Well developed technology and market already in place.
Syngas from vine prunings and grape stalks	T3	• High investment and complex equipment required. • Syngas needs further upgrading.
Pyrolysis oil from vine prunings and grape stalks	T3	• High investment and complex equipment required.

[33] FEDIOL - www.fediol.be

Opportunities for intermediate products at an IBLC in the wine sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Fibres from vine prunings and stalks	T2	• High investment costs.
Grape seed oil	T1	• Market in place.
Grape seed flour	T1	• Market in place.
Extraction feedstock (crude oil – saponins, polyphenols, tocophenol – from grape seeds)	T2	• Complicated process/low extractability.
Ethanol from grape pomace	T2	• High investment and complex equipment required.
Tartaric acid from lees	T1	• Market in place.
Phenols (anthocyanin, flovonol) from grape skins	T2	• Complicated process/low extractability.

4.6 Grain chain (incl. straw until final product biofuel)

The primary grain feedstocks are mainly wheat, barley, oats but also rye and triticale. The main products of the grain processing chain are various feed and food products but also industry applications like ethanol, biogas and alcohol beverage. Mostly wheat and rye are used in flour production. For feed products the main cereals are barley, oats, triticale and mixed grains, but also wheat to some extent. By-products are bran, husks (the dry outer covering the grain) and straw.

Many theoretical opportunities to produce biocommodities from residues from the grain chain at an IBLC have been identified, such as biobased chemicals, solid and liquid biofuels, bioenergy and biomaterials. Straw represents the largest residual stream within the grain chain and is mainly left in the field today or used for feed and bedding and in some cases incinerated on field. Straw can be used in the production of a large number of biobased chemicals, such as furfural and 2nd generation ethanol. Grain bran can also be utilized to produce many different biobased chemicals. The production of 2nd generation bioethanol from cereal straw could be an alternative valorisation whenever the lignin fraction and C5 fraction can be valorised as well. Bio-oil and bio-char are examples of products that can be produced from these two fractions.

Another opportunity is to produce biogas and biofertilizer from straw, husks and waste grain. Straw is of high interest for biogas production. However, the intricate composition of the lignocellulosic material, often restricts the biodegradability and consequently results in low bio-digestion efficiency and methane production. The biodegradability can be increased by a biological, chemical, thermal or mechanical pre-treatment.

Husks and straw from cereals could also be used for production of biocomposite material for the production of furniture and coffins as an example. New biomaterials could also be produced from vinasse (residue generated in the breweries) for bones regeneration materials as one example. Another way of vinasse valorisation is the production of biofuels.

Straw and husks can be used as components in the manufacturing of panels, insulation and filler solid in building materials. It can also be utilized in the production of agropellets and/or briquettes.

The most promising theoretical opportunities to produce biofuels, biobased chemicals and materials at an IBLC in the grain chain are listed in Table 28.

Table 28. Theoretical opportunities to produce bioenergy & biofuels and/or biobased chemicals & materials at an IBLC in the grain chain sector.

Opportunities for intermediate products at an IBLC in the grain chain		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Agropellets/briquettes from straw and/or husks	T1	• Standard and simple equipment. • Profitability depends on final use.
Biogas from straw and/or husks	T1	• Market in place. • Medium to high investment required. • Technology well developed.
Bio-oil and bio-char from straw and/or husks (HTL)	T2	• High investment costs. • Technology well developed. • Market in place. • Complex equipment.
Syngas from straw and/or husks	T3	• High investment costs. • Complex equipment.
Furfural from straw and/or bagasse	T2	• Versatile utilization. • Market in place.
Levulinic acid from straw	T2	• Versatile utilization. • Increasing demand. • High investment. • Complicated process/extractability and yields to be confirmed.
Second generation ethanol from straw	T1	• Supportive policy framework. • Available techniques and equipment. • High investment required. • Market in place. • Utilization of lignin is important.
Lactic acid from straw	T2	• High competition from first generation production from sugar cane outside EU.
Succinic acid from straw	T2	• Market in place, but mainly from petrochemical sources today.

Opportunities for intermediate products at an IBLC in the grain chain		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	• Remarks
Lignocellulosic fibres	T3	• Low quality fibres. • High ash (silica) content. • High investment cost.
Particle board and fibre board from straw and/or husks	T1	• Market in place. • Standard and simple equipment.
Granulate and plastic composite	T2	• Standard well-established process • Low density of straw still is a problem.

4.7 Sugar industry

The EU is the world's largest producer of beet sugar and the principal importer of raw cane sugar for refining. The sugar production starts in the field with the sugar beets and ends with a diversity of products, including sugar products, feed products (molasses, beet pulp), sugar factory lime, stones, beet soil and water. Examples of different players are sugar beet growers and sugar manufacturers. By-products are beet fibers and beet leaves amongst others.

Several theoretical opportunities for production of biocommodities from the sugar industry in an IBLC have been identified. Sugar beet pulp and molasses are produced as side streams in the sugar production process. They are primarily utilized as feed material in the feed industry and as feed today. Another utilization is as silage agent and substrate in biotechnological production. Both sugar beet pulp and molasses can be utilized as feedstock to produce biofuels or biobased chemicals such as lactic acid, levulinic acid and succinic acid. Sugar beet pulp is suitable for biogas production and can also be utilized to produce agropellets or briquettes. Molasses can be used as feedstock for bioethanol.

Beet leaves is another possible residue. Most of the sugar beet leaves are left in the field today and ploughed into the soil. Sugar beet leaves have high water content at harvest, which makes them difficult to store. It is therefore essential to use sugar beet leaves as fresh material. An identified opportunity for an IBLC is to extract proteins from the beet leaves. The beet leaves are also a possible substrate for biogas production.

The most promising theoretical opportunities to produce biofuels, biobased chemicals and materials at an IBLC in the sugar sector are listed in Table 29.

Table 29. Theoretical opportunities to produce bioenergy & biofuels and/or biobased chemicals & materials at an IBLC in the sugar sector.

Opportunities for intermediate products at an IBLC in the sugar sector		
Name intermediate product	Suitability to manufacture intermediate product at IBLC in this sector	Remarks
Agropellets/briquettes from sugar beet pulp	T1	• Standard and simple equipment. • Profitability depends on final use.
Beet leaves for biogas	T1	• Market in place. • Technology well developed. • Storage of beet leaves still an issue.
Molasses for bioethanol	T2	• Supportive policy framework. • Available techniques and equipment. • High investment required. • Market in place.
Sugar beet pulp and molasses for lactic acid	T2	• High competition from first generation production from sugar cane outside EU.
Sugar beet pulp and molasses for levulinic acid	T2	• Versatile utilization. • Increasing demand.
Sugar beet pulp and molasses for succinic acid	T2	• Market in place, but mainly from petrochemical sources today.
Sugar beet pulp and molasses for furfural	T2	• Versatile utilization. • Market in place.
Sugar beet pulp for biogas	T1	• Market in place. • Technology well developed.
Proteins from beet leaves	T2	• Growing market, but still uncertain. • Techniques needs to be further developed.

5 STAKEHOLDER'S OPINIONS ON PRACTICAL OPPORTUNITIES PER SECTOR

5.1 Introduction

The information contained in this chapter was collected involving a range of stakeholders from the different value chains of AGROinLOG. Five workshops were held in Sweden, Spain, Greece, Serbia and Ukraine. Additionally, four interviews to associations were conducted in Brussels. Country workshops focused on a particular sector(s). Interviews to associations in Brussels looked for specific technical and industrial insight. Table 30 lists countries and sectors represented in each workshop.

Table 30. Countries and sectors represented in each workshop.

COUNTRY AND SECTORS REPRESENTED IN WORSHOPS		
COUNTRY	SECTOR	DATES
GREECE	Olive oil	17th of October 2018
SPAIN	Feed and fodder and vegetable oil	18th of September 2018
SWEDEN	Grain chain and sugar	25th of June 2018
SERBIA	Wine sector	2nd of October 2018
UKRAINE	Grain and vegetable oil	17th of October 2018

Workshop activities followed a Participatory Leadership methodology. The aim of participatory leadership methodologies is to facilitate stakeholder engagement and tap into collective intelligence. The selected workshop activity was a World Café. During a first World Café session, stakeholders were asked general questions about the business environment for IBLCs. For the second World Café, stakeholders were presented with long lists of biochemicals & biomaterials, bioenergy & biofuels and possible logistic solutions. Sector lists only contained products and materials that one would find in the specific sector.

This chapter is divided as follows:

- A first section with "Practical considerations to evaluate possible IBLC business opportunities of intermediate products" collects feedback from all sectors on conditions to favour new business opportunities for IBLCs. It was formulated as questions that may inform the potential of new business opportunities for IBLCs. Note that although this input was asked per sector, the answers were deemed not sector specific. Hence, this section stands independently;
- Each sector in this chapter is sub-divided in four sections:
    - The first section with title "Stakeholders providing input" specifies, in broad categories, stakeholders' typology participating in each workshop;

- A second section, "Evaluation of long lists by stakeholders" is divided in:
    - Bioenergy and Biofuels: this subsection highlights intermediates as discussed by the stakeholders. Stakeholder evaluation is represented in a traffic light table. Practical opportunities were rated in three categories based on the opinions of the stakeholders. Practical scores (P) were given to the products from the short lists and these scores were also translated to traffic light colors: P1= very suitable (dark green); P2= suitable (light green) and P3= less suitable (orange);
    - Biocommodities: this subsection highlights intermediates as discussed by the stakeholders. Stakeholder evaluation is represented in a traffic light table (see above for the scores);
    - Input on Logistic Solutions: logistic solutions are specific to their pathway. Feedback for this section was collected in a more general table.

It is worth mentioning that as a whole, the long lists of intermediates and logistic solution were too technical for workshop participants to provide specific feedbacks. To overcome this, the long lists were additionally discussed in one-to-one interviews with staff from European Associations. This Chapter 5 should be used to *complement* more technical considerations in Chapters 3 and 4 and adds practical insight to new business opportunities for IBLCs.

5.2 Practical considerations to evaluate possible IBLC business opportunities of intermediate products

Table 31 collects feedback from of all the sectors on conditions to favour new business opportunities for IBLCs. It is formulated as questions that may inform the potential of new business opportunities for IBLCs.

Table 31. Practical considerations to evaluate possible IBLC business opportunities of intermediate products suggested by the stakeholders.

Practical considerations	
	• Is there demand for this product? • Is the biocommodity/bioenergy/biofuel a solution to a current need? (or is it a new product with need of a new market?) • Can the development of the product be marketed in combination with other products or the same product from other sectors? • Can the product produced within IBLCs guaranty a constant supply/demand? • Are the final by-products standardized (as requested by the market)? • Are feedstocks stable or seasonal? Is feedstock local? • Can the intermediate/bioenergy solution be produced by a broad material base? • Are the logistics facilities needed to develop this biocommodity/bioenergy/biofuel flexible? Can they be used with different feedstock or can they produce different biocommodities/ bioenergy/biofuels? • Does the technology exist to develop a specific intermediate product in an IBLC or can it be adapted from other sectors?

Practical considerations
• Does the intermediate product have the end-user on board? • Are alliances between distributors, suppliers or costumers likely? For example, are yearly contracts a possibility? • Is the value chain in the IBLC vertically integrated? • Are farmers organised in cooperatives? • Are there any other possible associations, chambers of commerce or private parties that could bring support to the implementation of IBLCs? • Is it a biocommodity/bioenergy/biofuel that could go under public procurement procedures? • Awareness of biobased materials. Is the material known/accepted by policy makers and public? • Are there funding or marketing opportunities of products that might be produced in IBLCs? • Are financial or tax incentives in place to support the intermediate? • Does the current regulatory framework favour production of the proposed intermediate? • Is the classification of the feedstock to produce the biocommodity/bioenergy/biofuel one that facilitates or deters development of product? i.e., is it waste, co-product, side-stream? • Is there political commitment for the development of this product? • Are R&D projects being currently developed to create added value for the specific intermediates proposed?

5.3 Vegetable oil extraction

5.3.1 Stakeholders providing input

The practical input for the vegetable oil extraction sector was collected in workshops developed by AGROinLOG`s partners (Task 7.4) on the 18th of September of 2018 in Spain, and on the 17th of October 2018 in Kiev. The stakeholders that participated were producers-processors, research and academia, co-op representatives and finally members from inter-professional associations (Figure 3).

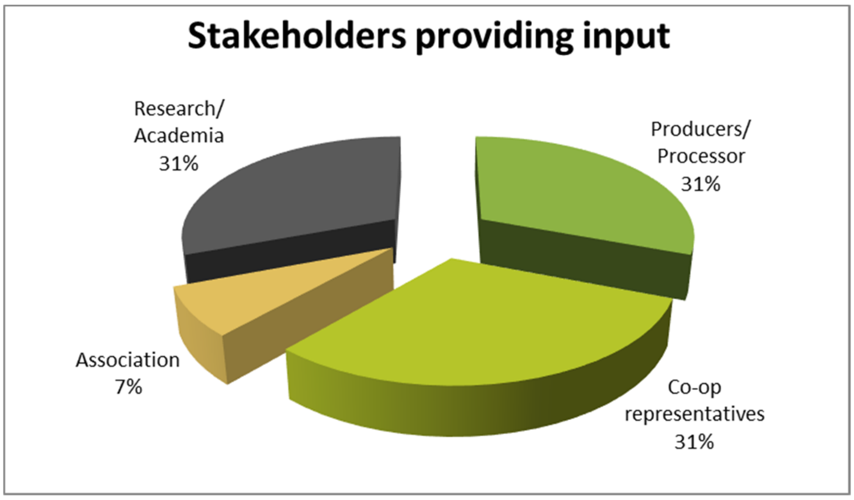


Figure 3. Distribution of stakeholders providing practical input in the vegetable oil extraction sector.

5.3.2 Evaluation of long lists by stakeholders

During the workshops developed in Task 7.4, stakeholders were presented with a long list of possible intermediate products tailored to the vegetable oil sector. Comments and evaluations given by participants can be found summarized in the Tables 32 and 33. Note that some bioenergy and biofuel products appear in two long lists and therefore some products were evaluated twice.

Bioenergy & biofuels

Table 32. Specific bioenergy and biofuel intermediate products mentioned in the vegetable oil extraction sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Pellet, chips and lighters	P1	• Suitability of raw material readily available. • Consumer market for solid biofuels is growing. • Quality, traceability and export regulations will define the product market and its profitability.
Biodiesel	P2	• Biodiesel requires high investments. • Stakeholders considered that the market favoured this product in the medium-long term. • Solid biofuels are widely preferred and considered as the most feasible final products for new business models in IBLCs.
Biogas	P2	• Demand and technology exist. • Industries are already experimenting using biogas for their own energy needs.

Biobased chemicals & materials

Stakeholders presented with the long lists of biobased chemicals and materials did not have sufficient knowledge on the intermediates proposed. Therefore, the feedback collected represents only a partial view of the possibilities in the sector and does not include all the products. In general, it was considered that products that require simpler production processes were favoured.

Table 33. Specific biobased chemicals & materials mentioned in the vegetable oil extraction sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Biodiesel	P2	• High investments considered to put the industry off.
Pentose	P2	• Pentose could be produced from maize residues.
Ethanol	P2	• Ethanol could be produced from maize residues.
Fatty Acids	P2	• Potential for biodiesel production but conditioned by the market.
Crude Proteins	P2	• Rapeseed and sunflowers residues could be used to produce proteins.

5.3.3 Input for logistic solutions

Logistic solutions depend on the particular biocommodity/bioenergy/biofuel and value chain. Table 34 summarises favoured logistical solutions and practical considerations suggested by stakeholders for the vegetable oil extraction sector.

Table 34. Practical considerations suggested for logistic solutions mentioned in the vegetable oil extraction sector.

Practical considerations suggested for logistic solutions
• Location of the agro-industry will determine if the new business model could be feasible or not (costs, distances) • Are there existing and compatible storage sites for products? • Is the equipment present in the industry able to process the new product line? • To avoid the risk of cross-contamination, specialization of production plants is deemed necessary. • Intermediate logistic platforms could enhance the global running of IBLC's. • Is it possible to increase product density in origin?

5.4 Olive oil mills (chain)

5.4.1 Stakeholders providing input

The practical input for the olive oil mills sector was collected in workshops developed in Greece (Task 7.4) on the 17th of October of 2018. The stakeholders that participated were largely divided in two groups: olive oil and pomace oil associations and farmers and cooperatives (Figure 4).

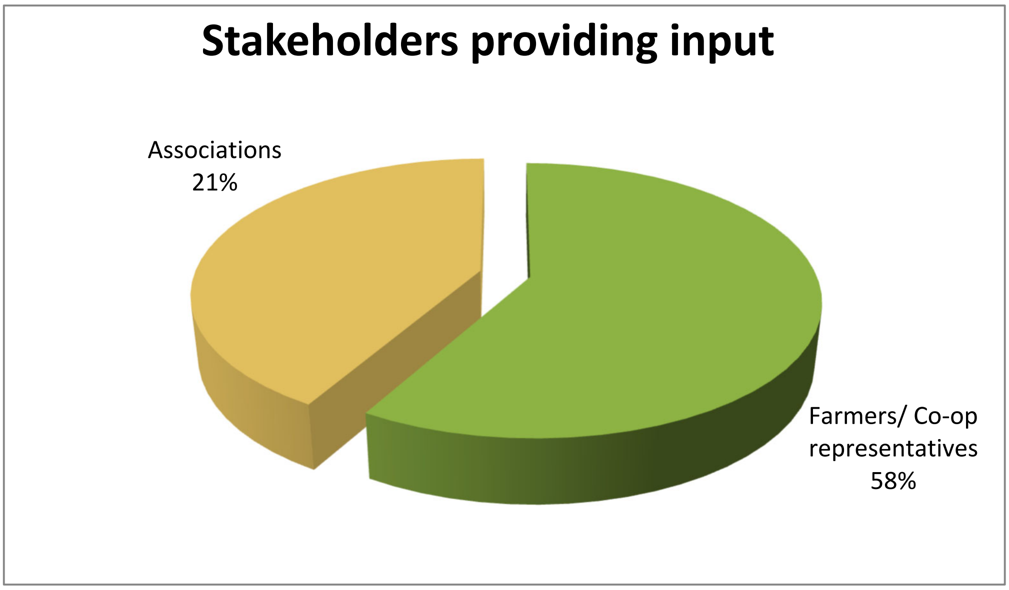


Figure 4. Distribution of stakeholders providing practical input in the olive oil mills (chain) sector.

5.4.2 Evaluation of long lists by stakeholders

During the workshops developed in Task 7.4, stakeholders were presented with a list of possible intermediate products tailored to the olive oil sector. Comments and evaluations given by participants can be found summarized in Tables 35 and 36. Note that some bio-fuel and bioenergy products appear in two long lists and therefore some products were evaluated twice.

Bioenergy & biofuels

Table 35. Specific bioenergy and biofuel intermediate products mentioned in the olive oil mills (chain) sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Pellet/ Briquettes	P1	• Mature market. • The equipment for production is simple. • Could be used for CHP plants for power and heat production. Electricity could be sold to the grid and heat could cover local industrial demand. • Cheap pellets made with sunflower seeds (cost around 70-80 €/t) may hamper the development of this product for energy production.
Solid biomass (chips)	P1	• Simplicity of production. • Could be used for CHP plants for power and heat production. Electricity could be sold to the grid and heat could cover local industrial demand.
Olive pits	P2	• Suitable fuel (good fuel quality). • End users for this product already exist.
Biogas	P2	• Potential from olive mill wastewater/exhausted olive cake.
Syngas	P3	• Complex production processes. • High investment costs.
Bio-oil	P3	• Complex production processes. • High investment costs.

Biobased chemicals & materials

Like for the vegetable extraction sector, stakeholders presented with the long lists of biocommodities did not have sufficient knowledge of the intermediates proposed. Therefore, the feedback collected represents only a partial view of the possibilities in the sector and does not include all the products. In general, products that require simpler production processes and have existing markets were favoured.

Table 36. Specific biobased chemicals & materials mentioned in the olive oil mills (chain) sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Particle boards	P1	• Possible to do with olive tree pruning. • "Simple" production. • Market potential.
Phenols	P2	• May be produced with olive mill residues such as leaves and pomace. • Market potential.

5.4.3 Input for logistic solutions

Logistics solutions depend on the particular biocommodity/bioenergy/biofuel and value chain (Table 37). The table below includes practical considerations suggested by stakeholders on logistical solution for the olive oil sector.

Table 37. Practical considerations suggested for logistic solutions mentioned in the olive oil mills (chain) sector.

Practical considerations for logistic solutions	
	• Location of the IBLC will be a key factor as it reduces transportation costs. • Intermediate storage site should have a positive impact on logistics.

Logistic solutions for each stage of the olive oil sector value chain are presented in the diagram in Figure 5. Participants to the workshop gave their input on the most appropriate/efficient value chain for pruning for the following products pellets, briquettes, chips and pruning bales.

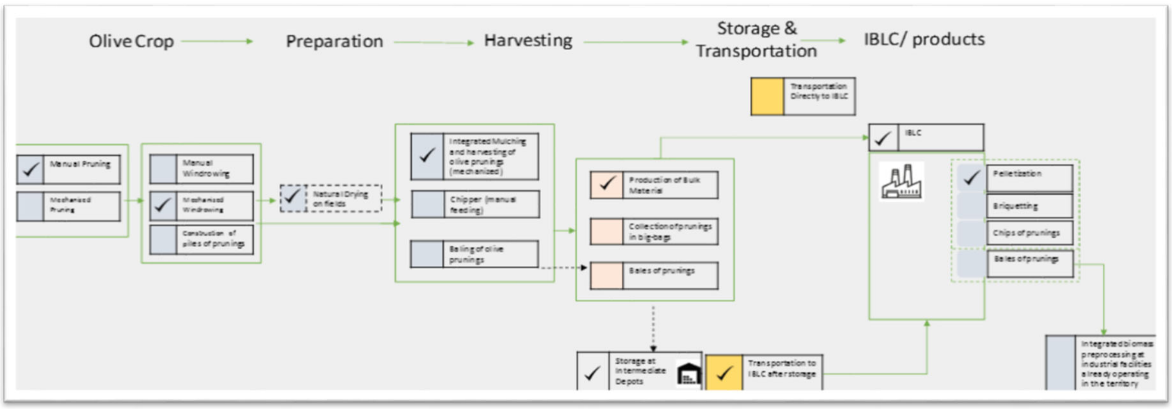


Figure 5. Logistic solutions for each stage of the olive oil sector value chain.

5.5 Feed and fodder

5.5.1 Stakeholders providing input

The practical input for the feed and fodder sector was collected in workshops developed (Task 7.4) in Spain on the 18th of September, 2018. The stakeholders that participated were mainly producers-processors, cooperative representatives, some members of research and academia and inter-professional associations (Figure 6).

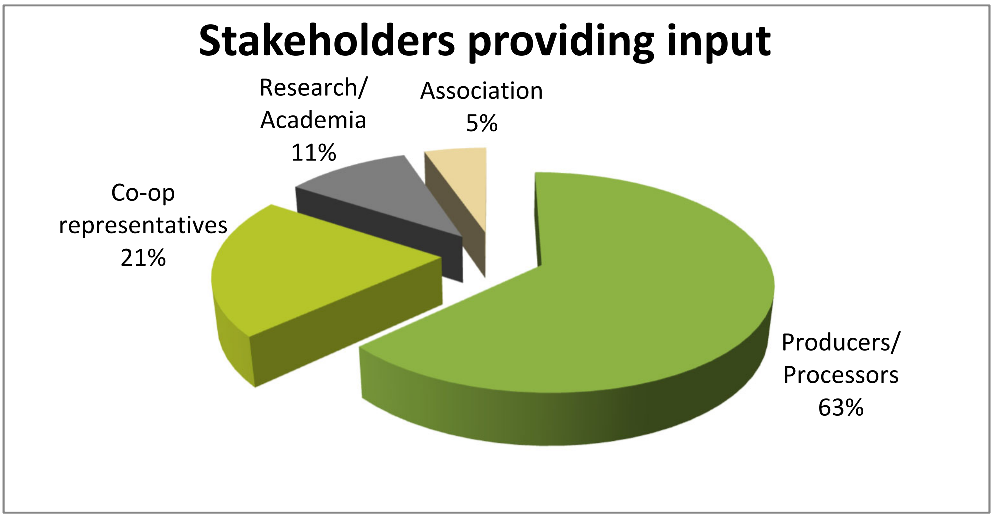


Figure 6. Distribution of stakeholders providing practical input in the feed and fodder sector.

5.5.2 Evaluation of long lists by stakeholders

Like it was described in the previous cases, stakeholders were presented with a long list of possible intermediate products tailored to the feed and fodder sector, their comments and evaluations are summarized in Tables 38 and 39. Note that some bioenergy and biofuel products appear in two long lists and therefore some products were evaluated twice.

Bioenergy & biofuels

Table 38. Specific bioenergy and biofuel intermediate products mentioned in the food and fodder sector.

Specific products mentioned		
Product	**Code**	**Comments given by stakeholders**
Pellet	P1	• Solid biofuels like pellets were favored due to reduced investment costs.
Solid biomass (chips)	P1	• Simplicity of production. • The feed and fodder industry already has suitable equipment for the production of solid biofuels.

Biobased chemicals & materials

Table 39. Specific biobased chemicals & materials mentioned in the vegetable food and fodder sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Pellet, chips and lighters	P1	• Final products with simple production processes are favoured. • Widely preferred and considered the most feasible.

5.5.3 Input for logistic solutions

Table 40 summarises favoured logistical solutions and practical considerations suggested by stakeholders regarding logistical solution for the feed and fodder sector.

Table 40. Practical considerations suggested for logistic solutions mentioned in the food and fodder sector.

Practical considerations for logistic solutions	
	• Location of the agro-industry will determine if the new business model could be feasible or not (costs, distances). • Are there existing and compatible storage sites for products? • Is the equipment present in the industry able to process the new product line? • Specialization of production plants could avoid cross-contamination optimise resources. • Intermediate logistic platforms could enhance the global running of IBLC's. • Is it possible to increase product density in origin?

5.6 Wine sector (cellars & distilleries)

5.6.1 Stakeholders providing input

The practical input for the wine sector was collected in the workshop organized in the University of Belgrade, Serbia, on October 2nd, 2018. Ten stakeholders participated in the workshop. The number of participants in the workshop in Serbia was low due to the grape harvesting season and low awareness of the stakeholders of the benefits of the IBLCs. In addition, the workshop organisers stated that Serbian stakeholders are not familiar with more dynamic ways of interacting such as workshops. The pie chart in Figure 7 illustrates the distribution of participating stakeholders.

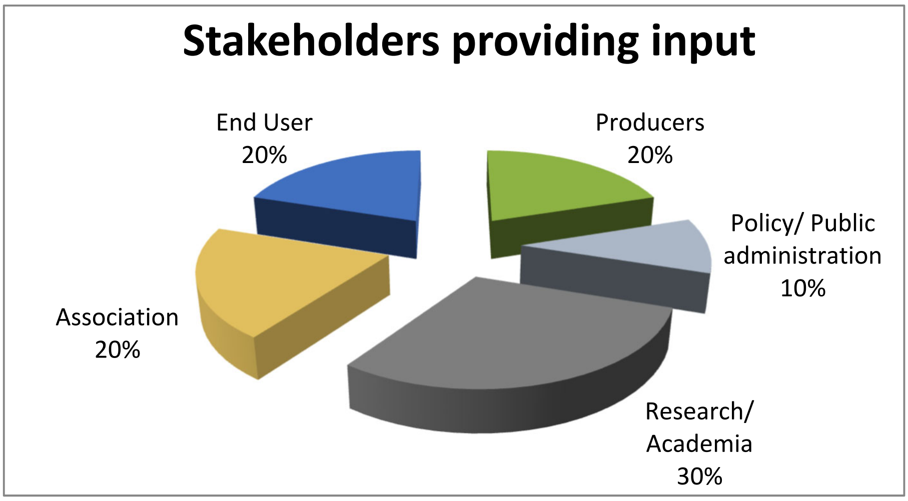


Figure 7. Distribution of stakeholders providing practical input in the wine sector.

5.6.2 Evaluation of long lists by stakeholders

Comments and evaluations given by participants are summarized in Tables 41 and 42. Like in the previous cases, some products were evaluated twice.

Bioenergy & biofuels

Table 41. Specific bioenergy and biofuel intermediate products mentioned in the wine sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Pellet	P1	• Easy to produce from pruning residues.
CHP	P1	• Wine production needs of constant heat production and cooling of facilities. • CHP is regarded as the best solution for the bio energy production.

Biobased chemicals & materials

Table 42. Specific biobased chemicals & materials mentioned in the wine sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Bioethanol	P2	• Used in collaboration with fruit processing and liquor plants.
Bio-oils	P1	• Residues from grape mulching could be used for production of bio-oils as a raw material for the pharmaceutical industry.
Heat	P1	• Heat could be sold as a final product.

5.6.3 Input for logistic solutions

Table 43 summarises favoured logistical solutions and practical considerations suggested by stakeholders for the wine sector.

Table 43. Practical considerations suggested for logistic solutions mentioned in the wine sector.

	Practical considerations suggested for logistic solutions
	• Possibilities for application of same or similar technologies in different business or sectors. • To share and face the common constrains regarding the transport and storage issues. • Local authorities should support the sector by simplifying the procedures for different actions related to formation and implementation of IBLCs. • Business associations and cooperatives could be more active in order to update the producers for raising possibilities. • Integration with solar and wind energy facilities could be introduced in order to establish continuity in energy production during the season production in the wine sector.

5.7 Grain chain (incl. straw until final product biofuel)

5.7.1 Stakeholders providing input

The practical input for the Grain chain sector was collected in the workshop developed (Task 7.4) on the 25th of June, 2018 in Sweden. The stakeholders that participated were mainly a mix of producers and researchers. Policy makers were represented and there was the contribution of a participant of a related EU funded project. Figure 8 shows the distribution of stakeholders providing practical input.

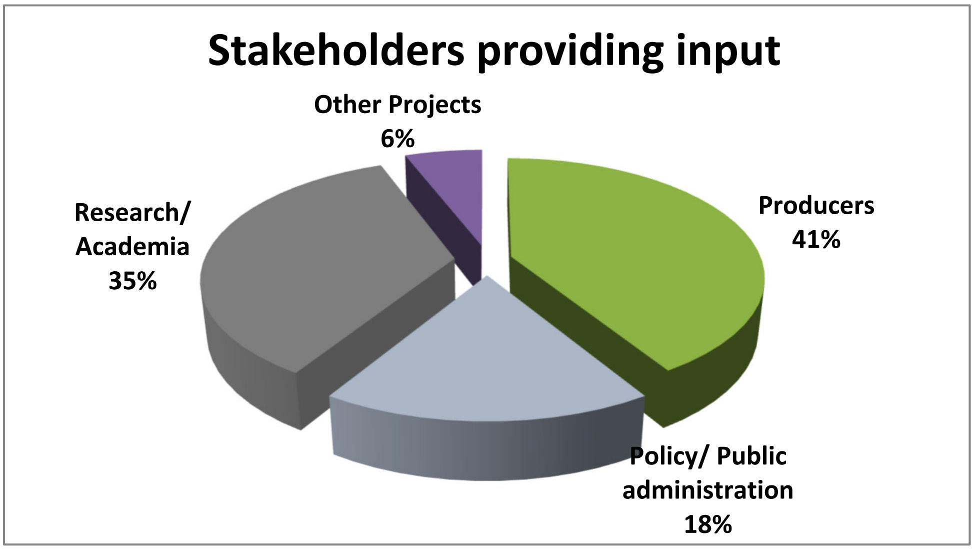


Figure 8. Distribution of stakeholders providing practical input in the grain chain sector.

5.7.2 Evaluation of long lists by stakeholders

During the workshops developed in Task 7.4, stakeholders were confronted with the long lists presented in Annexes A, B and C. Comments and evaluations given by participants can be found summarized in Tables 44 and 45. Note that some biofuel and bioenergy products appear in two long lists therefore some products were evaluated twice.

Bioenergy & biofuels

Table 44. Specific bioenergy and biofuel intermediate products mentioned in the grain chain sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Biogas	P1	• Flexibility. • It can handle side-streams from different sectors (e.g. agriculture, waste, water treatment). • Additional societal benefits such as manure management, waste management and nutrient concentration. • Flexible on the type on energy it produces (Combined Heat and Power, upgrade to vehicle fuel, grid injection, etc.).
Agropellets	P1	• Easy market access. • Possible to develop product further.
Syngas	P3	• Expensive, high CAPEX.
Torrefied Pellets	P3	• Hygroscopic material.
Vegetable oil	P2	• Substitute to diesel.
Hydrogen	P2	• Potential solution to challenges concerning renewable energy storage.

Biobased chemicals & materials

Table 45. Specific biobased chemicals & materials mentioned in the grain chain sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Biogas	P1	• Politically driven.
Ethanol	P1	• Ethanol is interesting. • A chemical company that attended the workshop explained that the ethanol that they get is from forest origin and has a lot of other substances (methanol from C5) that they don't want; their preferred option would be ethanol produced with agricultural biomass.
Syngas	P1	• Demand from chemical companies.
Lactic acid	P2	• PLA interesting.
Succinic acid	P2	• Possible demand form biomaterial companies.
Proteins	P3	• Proteins from industry are already used profitably in the feed industry.
Cyclohexanol	P2	• Potential to produce phenols.

5.7.3 Input for logistic solutions

Table 46 summarises favoured logistical solutions and practical considerations suggested by stakeholders regarding logistical solutions for the grain sector.

Table 46. Practical considerations suggested for logistic solutions mentioned in grain chain sector.

Practical considerations suggested for logistic solutions	
	• Hubs and direct transport are the preferred logistic solution. o Hubs with pre-treatment facilities would increase the flexibility for better logistical systems. • Are logistical costs proportionate to product costs? • What type of geographic opportunities or constraints should be considered i.e. access to ports, waterways. • Associate IBLC with companies producing side-streams. • Is it possible to benefit from a "biomass stock exchange" platform for the specific product? • Is it possible to do a pre-treatment before storage?

5.8 Sugar industry

5.8.1 Stakeholders providing input

The sugar sector was under-represented in the workshops with only two participants. Specific contributions from the sector are hence very limited and could not be analysed in the same way as the other sectors. Table 47 shows that proteins were mentioned as a specific product.

Table 47. Specific biobased chemicals & materials mentioned in the sugar sector.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Proteins	P3	• Proteins from industry are already used profitably in the feed industry, hence alternative markets are not expected to be developed.

5.9 Trans-sectoral considerations

Four staff members of European Associations were personally interviewed with the bioenergy and biofuels and biobased chemicals & materials long lists. Interviewees had a chance to go through the lists and give feedback onto what their industry might be interested in. It must be noted that although staff from European Associations was available to give feedback, the particular associations did not want their name disclosed. For this reason, this chapter collects general industry recommendations but does not disclose the particular source of information.

5.9.1 Bioenergy and biofuels

Table 48 includes suggestions given by the staff of European Associations on the long list of Bioenergy and Biofuels. The interviewees were asked what products in the list would be easier to develop and what criteria should be used to select these products. Some comments were given specifically about how we described the information in our long list. Namely:

- investment costs should be defined for a fair comparison (e.g. ranges of cost);
- TRL should be in line with the specific feedstock not with the bio-based product.

Table 48. Practical considerations bioenergy and biofuels.

Practical considerations

• Criteria to define what pathways are closer to market will need to include:
  ○ Profitability: Investment costs and scale do not give enough information to define what pathway is appropriate. Profitability must be considered including pay-back time of investment;
  ○ Technical aspects: for example, using straw to produce torrefied pellets can cause fire risk; size of material or density has to be assessed specifically for machinery;
  ○ Size and capacity of the plant will dictate the type of end use/clients that have to be considered.
• District heating offers possibilities of using agri-feedstocks (e.g. Austria fuels part of its district heating with agricultural waste).
• In general, these biofuels require a larger scale to be developed.

Some products from the long lists were specifically discussed (see Table 49).

Table 49. Specific products mentioned for bioenergy and biofuels.

Specific products mentioned		
Product	Code	Comments given by stakeholders
Chips, Olive Stones, Fruit pits and exhausted olive cake	P1	• Easiest business line to develop. • Simple pathway, there is potential to make a profitable business with these feedstocks through combustion. • Product for sale would be heat and not residue. • Heat contracts and procurement could offer business lines for these products. • IBLCs could collect residues and work as "trade centres" ensuring, for example, homogeneity of product quality. These "trade centres" could collect fuels from different origin (e.g. on a 50 km radius). • The Common Agricultural Policy includes incentives for farmers to keep hedges and trees, however, they must be maintained. This could potentially open up a source of woody feedstock.
Agropellets/ Briquettes	P2	• Agricultural residues are not the ideal feedstock (in general) because of their high content of moisture ○ Particular processes or additives will be needed to develop agropellets/ briquettes from the selected residues. Know-how will need to be furthered; • Depending on the size of plants, investments can also be high. • Note that scale will depend on the plant, large plants are also an option (not considered in list).
Torrefied pellets	P3-P2	• Needs economies of scale • Using materials like straw poses health and safety challenges (combustion) that need to be addressed. • Less recommended as it multiplies the barriers and is the most complicated • Specifically, stakeholders commented on how torrefied pellets were presented in our theoretical long list:

Specific products mentioned		
Product	Code	Comments given by stakeholders
		o Investment costs are low to medium but actually the investment costs are not low. o Equipment is described as "relatively simple equipment", which is deemed incorrect. o TRL is not 9 as there are currently no commercial plants in Europe.
Biogas	P3- P2	• Expensive to produce, would need large scale plants. • It requires a high investment so profitability must be considered • Specifically, stakeholders commented on how biogas was presented in our theoretical long list: o Straw is not suitable for a biogas plant as degradation of straw is not ideal for biogas production (combustion would be better). o Investment costs can also be low (for example, China counts with many small plants that are very "cheap".
Syngas	P3- P2	• It's commercial and can be done in a small scale. • Types of biomass must be further defined i.e. gasification will really depend on the input. • TRL is 8-9 ONLY for wood feedstock (as presented on our theoretical long list). Agricultural biomass is more complicated.
Bioethanol	P3-P2	• Bioethanol is an option for large companies but not for small businesses. • Production from molasses is interesting. • Production from straw and maize may be a challenge because of scale. • TRL is not 8-9 but more like 5-7. There are only small pilot plants in Europe for lignocellulosic material.
Bio-oil and bio-char	P3	• Risky technically and commercially. • TRL is not 8-9, there is only one pilot unit for two large companies.
HTL Bio-oil	P3	• Still in development, not a realistic option.
Bio-methane	P2	• Favoured option of the list. • It might be worth inquiring about possible upgrades from biogas into bio-methane (there is a plant in Finland).
FT Liquids	P3-P2	• Large investment costs, hence development limited to large companies, bio-refineries.
Biodiesel	P3	• Biodiesel needs of oil and mill residues have only a small amount. • Costs are unclear although small bio-diesel units exist.
Bio-SNG	P3	• High investment costs. • Complicated developments, at the minute only large companies are looking into it.
Hydrogen	P3	• Low potential in an IBLC. • Requires a larger scale only supported by larger companies. • Pathway described not ideal.

5.9.2 Biobased chemicals & materials

Table 50 includes suggestions given by the staff of European Associations on the long list of Biobased Chemicals and Biobased Materials. The interviewees were asked what products in the list would be easier to develop and what criteria should be used to select these products.

Table 50. Practical considerations biobased chemicals & materials.

Practical considerations

- What are the specific regulatory requirements for the authorisation of the chemical product or material (EFSA)?
    - Reduced authorisations dossiers for EFSA are preferable as they are less expensive for the industry
- Avoid all potentially cancerigenous substances (i.e. formaldehyde, aromatics and phenolic)
- Monomers for bio-plastics and packaging have potential.
    - They benefit both from policy support and consumer demand.
    - All monomers that are approved by the Food Contact Materials - Regulation (EC) 1935/2004 and Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food (there is a list of monomers for packaging).
- Products that are fermented with GMOs (genetically modified organisms) or GMMs (genetically modified microorganisms) are not favoured by the industry as they have a "bad reputation" among consumers.
- Products, including additives, that enable "green marketing" and the "100 % Natural" labels are favoured by industry.
- Products proposed in the long list can be used as feed materials with consideration to:
    - Volume of supply and availability throughout the year.
    - Nutritional value and stability of the nutritional value of the product.
    - % of lignin and cellulose. Higher content means generally less value of the product.
    - Price, logistics, % moisture, compliance with feed safety regulations.
    - Cleanness of product i.e. soil residues in the product are a problem.
    - Products that enable meals formulation for a number of species are favoured.
- Many products from our long list are currently feed additives *Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition* and could be potentially interesting for feed additive industry. However, substances must be in line with the specification found in the *Register of Feed Additives pursuant to Regulation (EC) No 1831/2003 Annex I*. This includes aspects such as:
    - Purity of the substance.
    - Authorised uses (i.e. certain products may be used in feed for certain farm animals and not others).
    - Status of authorisation.
    - Patent rights.

    Note that export markets for feed additives exist and may broaden commercial opportunities for bio-based intermediate products.

Some specific products from the long lists were specifically discussed (see Table 51).

Table 51. Specific products mentioned for biobased chemicals & materials.

Specific products mentioned		
Product	**Code**	**Comments given by stakeholders**
Citric acid	P1	• EFSA approved. • There is demand.
Polilactic acid	P1	• Monomer for plastic.
Tartaric acid	P2 or P3	• Industrial applications. Viability would depend on the scale.
Xilitol	P1	• Natural sweetener. • Product demanded by the industry. • Additionally attractive if it enables labelling the product as 100 % natural.
Threonine	P2 or P3	• Authorised as feed additive but only if produced by fermentation (involving certain types of well-defined microorganisms most if not all being GM). • Our table suggests threoninine produced by hydrolysis which would be favoured by industry BUT would require an (expensive) authorisation dossier.

6 DESCRIPTION OF PROMISING PATHWAYS

Based on the theoretical opportunities that were selected and have been described in Chapter 4 and the practical opportunities that were mentioned by the stakeholders and that are summarized in Chapter 5 several promising pathways (two per sector) were identified by the technical partners. These pathways will be an important starting point for the choice of the cases studies in Task 6.4. Each pathway has been described in a few sentences combined with a schematic picture. Per pathway the following aspects have been more or less described:

- In what sector does the pathway occur?
- Which feedstock(s) can be used?
- What (idle) capacity can be used at an IBLC (equipment, storage capacity, personnel, etc.)
- What intermediates will be produced at the IBLC?
- For what final market (end-products) will the intermediates be used?
- What logistical solutions are needed?
- Other issues.

6.1 Vegetable oil extraction: Pathway 'Production of pellets from vegetable oils species lignocellulosic residues'

The amount of residues left on the soil in the vegetable oils species harvesting activities (sunflower, rapeseed or cotton stalks, for example) together with market possibilities and equipment required for the process are the reasons behind the selection of this pathway by the stakeholders as one of the most promising alternatives to set up new IBLCs strategies in the vegetable oils sector.

Generally speaking, these companies rarely have idle periods in which these new activities could be integrated. Moreover, equipment required for the process (dryer, mill, pelletiser) normally does not exist in these plants and 'only' storage capacity, network of contacts (suppliers of the raw material) and already existing trained personnel could be utilised by the IBLC new business strategy.

New equipment to be installed would not be very restrictive as it is well known by the sector and well developed and easily available. However, final quality of the pellets produced and its acceptance by the final consumers is important. The pathway depicted in Figure 9 suggests the collection of the available lignocellulosic residues left on the soil (availability might be conditioned by soil properties sustainability) and transportation to the plant where it should be stored and processed (dried, milled and pelletised) before its distribution to the distributor or the final user.

Quality of produced pellets as a fuel is one of the most important parameters to be properly set to guarantee market penetration. Several strategies could be followed to achieve the requirements defined by the segment of the market at which products are focused. In Figure 9 one of the possible ways, blending resources with woody pellets is included. Due the characteristics of these raw materials medium to large boilers designed to work with lower grade pellets (compared to 100 % woody pellets) seem to be the most interesting market to be supplied.

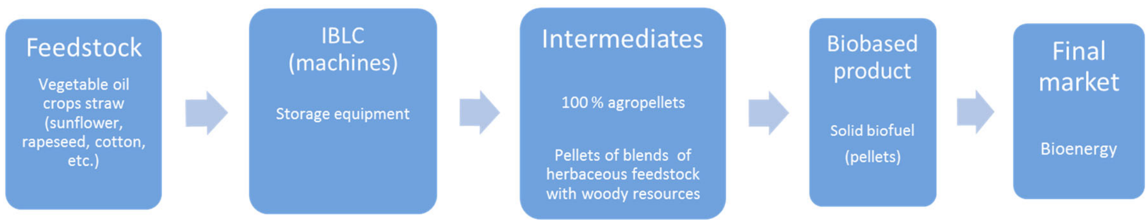


Figure 9. Pathway bioenergy from lignocellulosic residues in the vegetable oil extraction sector.

6.2 Vegetable oil extraction: Pathway 'Production of biodiesel in a vegetable oil plant'

Stakeholders suggested that the production of biodiesel is a promising alternative to set up a new business strategy in the vegetable oil extraction sector, despite some scale or economic barriers that should be overcome in the project.

Edible oils production plants generate some refuses with oil content which could be used to produce biodiesel for the energy sector. In general terms, the amount produced and the oil content makes difficult to ensure the feasibility of a biodiesel plant which normally requires large production volumes to be profitable enough in the market.

Nevertheless, taking advantage of these residue streams if they exist (they could also have alternative markets to which they can be destined, e.g., cattle feed) even including other residue streams coming from the plant surrounding area (refused oils, waste cooking oils, etc.) could be considered.

Biodiesel production is a mature technology which strongly depends on market conditions (raw materials prices and logistics, by-product market issues and biodiesel - first or second generation - price) but also on socio-political conditions. All these factors should be deeply assessed in every specific case before setting up an IBLC business strategy in an existing vegetable oil extraction plant.

The pathway presented in Figure 10 not only considers using vegetable oils plant's own residues, it also opens the door of becoming an IBLC in which logistics related to the collection of other potential oil transformable streams is included in order to improve biodiesel production feasibility. Some storage tanks and plant equipment could be used for the biodiesel production, nevertheless the IBLC should accomplish the rest of the investment required.

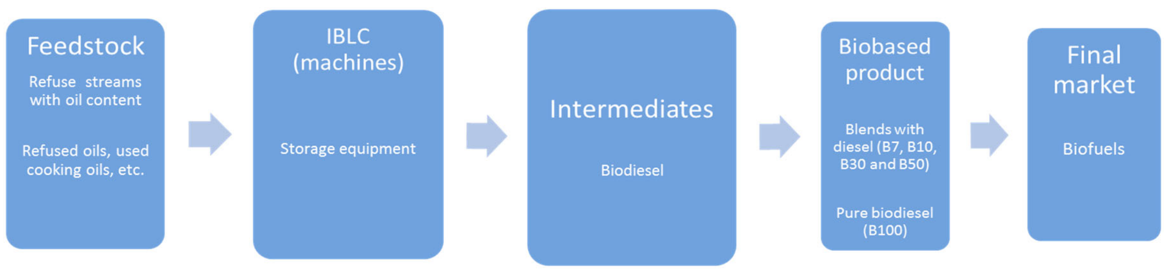


Figure 10. Production of biodiesel in a vegetable oil extraction plant.

6.3 Olive oil mills (chain): Pathway 'Production of pellets from olive tree prunings in a pomace mill'

The shortlist of bioenergy & fuels ranks the alternative 'Agropellets/Briquettes' as the first one to be explored because of its simple production. The production of pellets/briquettes is ranked as a very suitable theoretical opportunity in an olive sector IBLC, due to the low investment and the mature technology required, along with the well-developed market of the solid biofuel produced. The stakeholders in the olive oil sector also perceive the production as very realistic. Stakeholders that were consulted during workshops suggested the use of pellets for either CHP plants or industrial boilers for power and heat production. Additionally, they envisioned electricity produced this way sold to the grid and heat covering local industrial demand. Members of European associations identified this pathway as the easiest business.

Pomace mills fully operate during the months October- February, hence being idle for many months. During their idle period, pomace mills could exploit a so far untapped biomass source, olive prunings, and thus implement the IBLC concept. In the proposed pathway, the feedstock utilized for the suggested application is harvested olive tree prunings. Instead of letting prunings burn in open fires, the suggested pathway regards the harvesting of olive prunings with a mechanized integrated harvester that mulches and harvests olive prunings (in chip form). The harvested prunings are then transported to the IBLC for further processing.

The pathway suggests the production of pellets from harvested olive prunings inside the IBLC. For the pellet production, the IBLC would need a small investment in several types of equipment such as a pellet press and a grinder mill. On the other hand, there are already several components/ synergies offered by the IBLC that can be exploited during its idle times, such as storage site, dryer for drying prunings, weighbridge, tractors and experienced personnel.

The produced pellets can find various end-users. They can be sold to large consumers (industrial or semi- industrial) such as greenhouses, bakeries or other industries that have high heat demands. The market for pellets is already in place and mature already, thus, offering a stable demand for olive pruning derived pellets.

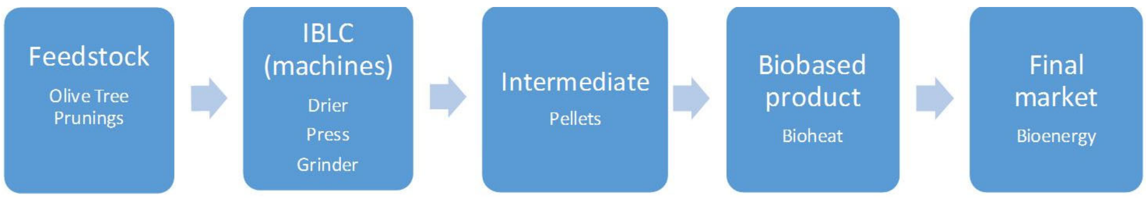


Figure 11. Pathway bioenergy from olive prunings.

6.4 Olive oil mills (chain): Pathway 'Extraction of phenols from olive leaves/ pomace'

In the shortlist of biobased chemicals & materials phenolics are mentioned. Extraction of phenols from olive residues is a complex process. However, phenols have a growing market potential in pharma, food and cosmetics applications. The production of phenols from both pomace and olive leaves is considered a suitable theoretical opportunity to be implemented in an IBLC. The stakeholders ranked the production of phenols as a realistic pathway, mainly based on its high market potential and due to the exploitation of an untapped biomass source, such as olive leaves.

The suggested pathway refers to the extraction of phenols from olive mill residues at the IBLC, which is implemented by olive oil industries. The feedstock of the suggested pathway is olive leaves and/or olive pomace. Both feedstocks have a significant polyphenolic amount in their content and are by-products derived in the olive oil mills during olive oil production.

For the extraction of phenols from olive oil sector residues, an investment in new equipment is essential in the IBLC such as extractors where solid liquid extraction or adsorption via resins will occur. Nonetheless, the existing personnel and the available storage facilities and tractors of the IBLC could offer synergies to the suggested pathway.

Polyphenols in olive wastes have shown to be antioxidant, antibiotic, antimicrobial, and have antifungal activity. The extracted phenols can find numerous applications. Formulas of these olive-derived substances can be used as nutrition supplements or skin cosmetics. Due to their antimicrobial properties, they are also used as antimicrobial agents in detergents and rinsing and cleaning agents. Hydroxytyrosol is the most active component of them and it can be used as a food preservative and, in pharmacology and cosmetology in topical preparations with anti-aging and anti-inflammatory action. The global market for natural anti-oxidants is expected to grow in the coming years, thus making the suggested pathway very promising.

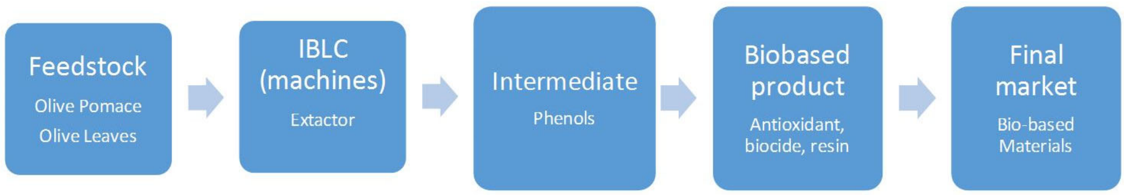


Figure 12. Pathway bio-based materials from olive oil sector residues

6.5 Feed and fodder: Pathway: 'Production of agropellets from straws for the energy sector'

Besides being selected as the first option in the shortlist of bioenergy & fuels, the production of agropellets for the energy sector was considered by the stakeholders as the most promising alternative to be explored and developed by an IBLC set up in an industry belonging to the feed and fodder sector.

Though it finally depends on the raw material used, the feed and fodder companies campaign mainly takes place from March to November, having from December to February a significant idle period in which some of the companies' resources (e.g. personnel or equipment as the dryer, grinder, mill or the pelletiser) could be employed to produce pellets produced with straws (wheat, barley, maize stalks, etc.) for the energy sector. Besides lucerne, these industries also work with these materials in their conventional business so that no special difficulties would be found in the process even though some production differences might appear and some contamination risks should be avoided.

Compared to woody pellets, herbaceous agropellets show worse characteristics as a fuel, especially because their higher tendency to show ash-related problems (fouling, sintering and slagging). Different actions could be adopted to minimize these inconveniences, being the production of blends with woody materials and the addition of additives the most usual ones. Final quality achieved as well as processing and final product costs should be balanced in order to produce a fuel with enough quality and a competitive price to satisfy market requirements.

The pathway depicted in Figure 13 suggests as the first option working with woody materials in order to produce blends of herbaceous and woody resources to ensure fuel quality and final user's satisfaction. Pure agropellets could also be produced and marketed if consumers having equipment that could satisfactorily deal with these more complex fuels could be included in the customer portfolio.

In the idle period, straw and woody resources will be dried if needed in the existing dryer (raw materials storage could be optimized to reduce drying requirements), milled and pelletised (mills and pelletiser performance with the new resources should be assessed and optimized. Pellets could be sold in a bulk format or in others (bags, big-bags, etc.) for which some investment would be required.

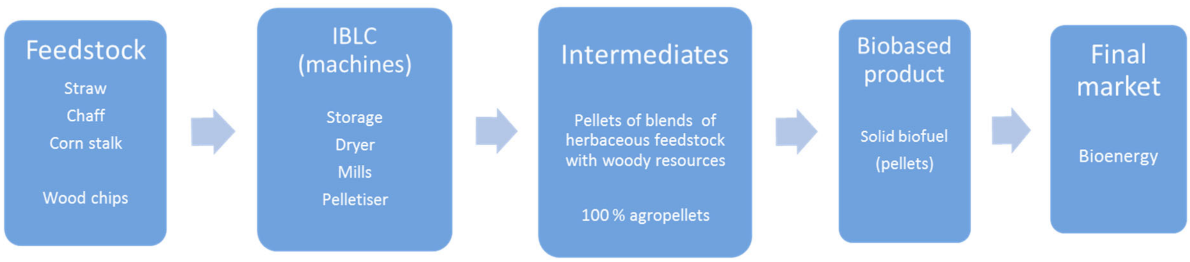


Figure 13. Pathway bioenergy from straw.

6.6 Feed and fodder: Pathway: 'Production of intermediates for the bioplastics manufacture'

Stakeholders pointed out that most of the alternatives that were included in the biobased chemicals & materials short lists are not easily affordable and reachable in the short term by the sector, mainly because from their point of view neither the production schemes nor the market conditions are mature enough. Nevertheless, they were aware of some existing cases in which pathways as the one presented in Figure 14 could be implemented.

In this case, the feed and fodder industry would be in charge of producing an intermediate (densified straws in a granulated or pellet form) that would be used as a raw material in the production of bioplastics. Bioplastics are mainly composed by a matrix (resin) and a reinforcement of natural fibres (usually derived from plants or cellulose)[34]. Depending on the raw material used and the final application of the bioplastic produced, the amount of organic material in the matrix varies.

Like in the previous case (Section 6.5), the feed and fodder industry would take advantage of its equipment and personnel in the idle period to dry (if necessary), mill and pelletize straw that would be transported to the place in which the final bioplastic would be manufactured. Generally, this densified format would be the most appropriate one for the subsequent processes, though working with pulverised material could be also considered if transport would allow saving the pelletizing process.

In this case the IBLC would produce an intermediate, a densified or granulated material from the collected or baled straw because of its improved homogeneity and transport and manufacturing advantages. This intermediate could be also adequate for other biocommodities production from these raw materials (lactic acid, levulinic acid, lignin, etc.) so that this pathway could be used for several applications.

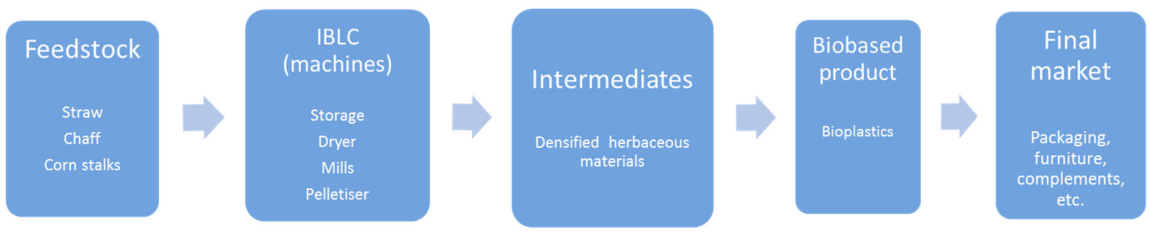


Figure 14. Pathway bioplastics from straws.

[34] http://www.chemeurope.com/en/encyclopedia/Bioplastic.html

6.7 Wine sector (cellars & distilleries): Pathway 'Production of wood chips from vineyard prunings'

The production of chips from vine prunings consist of a promising and suitable pathway for IBLCs, due to the simple equipment and low investment required for their production, and due to the exploitation of the so far untapped biomass source in the wine sector (vine prunings). Chips, deriving from vine prunings can find various applications. Mainly they can be used in CHP plants for heat and power production, in industrial boilers for heat production or further converted into pellets or other products. Stakeholders that were consulted identified this pathway as an "easy" business line to develop. In addition, they suggested that this pathway could be combined with the collection of other residues. IBLCs could collect residues and work as "trade centres" ensuring, for example, homogeneity of product quality.

The active period of the wine sector is limited to only five months, from October to February. The pruning of vineyards takes place from February to March and the common practice at this time is to burn the prunings in open fires or to mulch them into the soil. During the idle time of the wine sector, the personnel and the storage facilities could be involved in the valorization of the vine prunings.

In the suggested pathway the prunings are transported to the IBLC to be chipped and sieved in order to ensure the intermediate product has the required particle size thresholds. Alternatively, prunings could be chipped at the field using a portable chipper. Optionally, before they are chipped prunings can be sun dried, were applicable. After sieving the intermediate product (wood chips) is stored at the IBLC.

The produced chips could have various end-users. They could be sold to a large consumer as fuel, or to a pellet factory as raw material for pellet production. A more attractive option is their use in a CHP plant, for the production of electricity and heat. The electricity will enter the grid and the heat could either cover the heating needs of a nearby facility or be used for district heating.

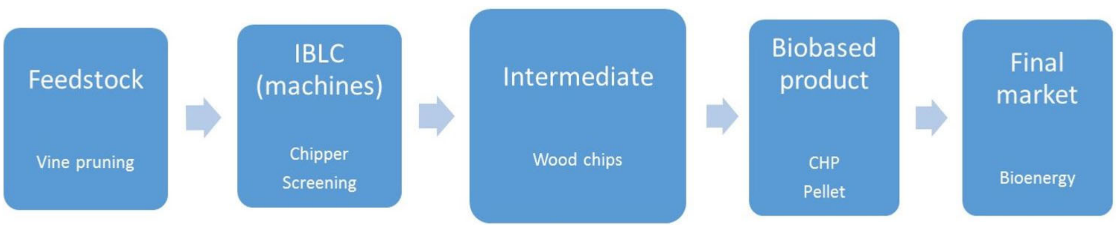


Figure 15. Pathway bioenergy from vine prunings.

6.8 Wine sector (cellars & distilleries): Pathway 'Production of bioethanol from grape pomace'

Bioethanol is identified as the most used biofuel worldwide and listed in the short list of bioenergy & biofuel. Thus, bioethanol produced from grape pomace has been considered a promising pathway for an IBLC in the wine sector, due to its high market potential and various applications and despite the high investment and complex equipment that is needed for such process. Furthermore, the production of bioethanol from wine residues was selected as an interesting pathway for the wine sector IBLCs by the stakeholders consulted. In addition, they suggested that this pathway may be developed in collaboration with facilities involved in fruit processing and liquor plants. However, they also pointed out that there are only small pilot plants in Europe that actually work with lignocellulosic material. Finally, the production of bioethanol was deemed an option for large companies but not for small businesses.

Grape pomace is the solid remaining from grapes after the pressing stage. It contains the skins, pulp, seeds and stems of the fruit. The carbohydrate fractions of grape pomace are a potential source of fermentable sugars that are of commercial interest to the wine industry. During the idle time of the wine sector, the personnel and the storage facilities could be involved in the valorization of the grape pomace.

In the suggested pathway, the polysaccharides in grape pomace (cellulose, hemicellulose, starch and pectin) are at least partially degraded with acid-hydrolysis to release mono- and disaccharides that are subsequently fermented by yeasts for the production of bioethanol. The produced bioethanol, after further processing, can be used either as transportation biofuel (blends with gasoline) or as a biochemical. Bioethanol can be used for the production of biodiesel (Fatty Acid Ethyl Esters) and butanol, which are also used as biofuels. Bioethanol is also used as solvent in paints, varnishes and perfumes.

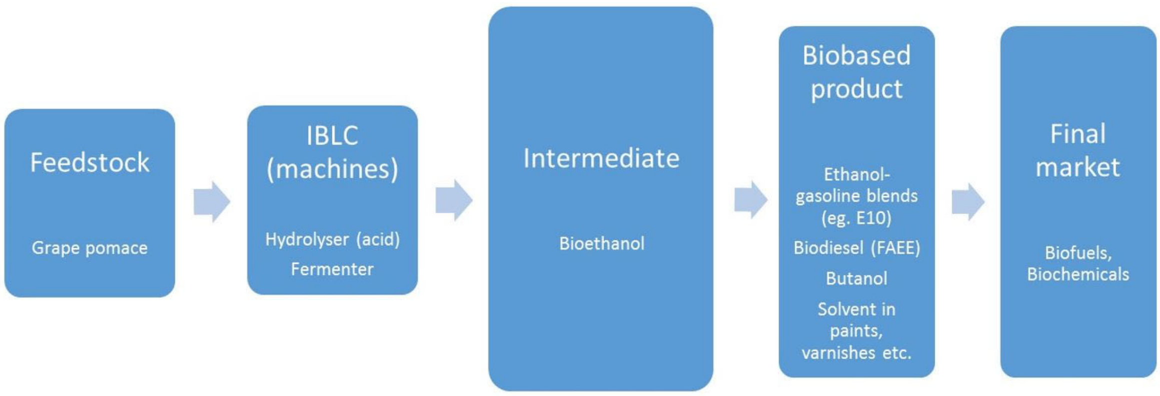


Figure 16. Pathway biofuels and biochemicals from grape pomace.

6.9 Grain chain: Pathway 'Production of biogas from grain straw'

As a theoretical opportunity straw is of high interest for biogas production, also the market is in place and the technology is well developed. But stakeholders consulted identified this pathway as an expensive option only feasible for large companies. Biogas from straw requires high investments hence, profitability must be carefully considered. Also, more research is needed regarding increased biodegradability in the straw by a biological, chemical, thermal or mechanical pretreatment.

Straw is easier to transport and easier to feed the biogas plant if it is pretreated and compacted into pellets or briquettes. During briquetting or pelleting, a certain pre-treatment with grinding, heat and pressure is performed, which changes the structure of the straw and makes it easier to be transformed into biogas. Typical levels of straw for biogas use are from 10,000 t/y or higher. The idle time for production of biogas from straw could be when there is no possibility to utilize fresh crops in the biogas plant, which is mainly during the winter and spring months. In light of this, stakeholders consulted valued the production of biogas from straw as a flexible process that can overcome idle periods with side-streams from different sectors (e.g. other agriculture residues, waste or water treatment).

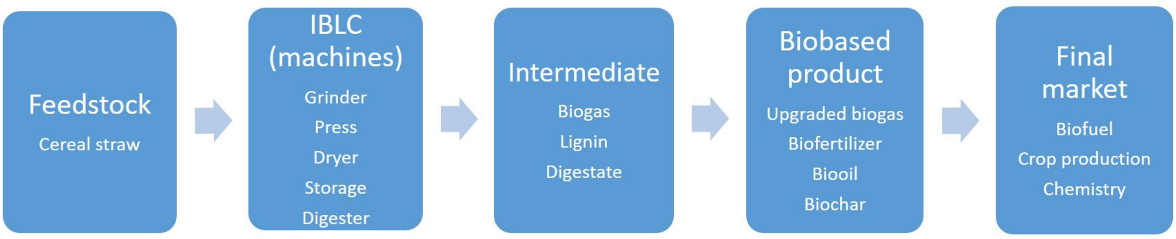


Figure 17. Pathway straw to biogas in the grain chain sector.

6.10 Grain chain: Pathway 'Production of particle boards from straw'

According to the identified theoretical opportunities the equipment to produce particle boards is simple and standard. Also, the market for particle boards is already in place. This shows that as a theoretical opportunity the production of particle boards from straw is ranked as very suitable using the idle time to become an IBLC. In the "Short list biobased materials" it is stated that the investment cost is low and that the demand is stable for particle boards.

Particleboard is an important material in furniture making, but increased competition for raw materials has forced the manufacturers to search for new strategies for producing good and affordable products. One possibility is to utilize straw as raw material, instead of leaving the straw in field. Cereal straw offers great promise and new challenges as replacement for wood in the production of particleboards. Particleboards are manufactured by mixing disintegrated straw together with a resin and forming the mixture into a sheet. There are possibilities to replace fossil resins with biobased today. The production of particle boards could be during the winter and spring months where there are smaller amounts of cereals to handle on the site.

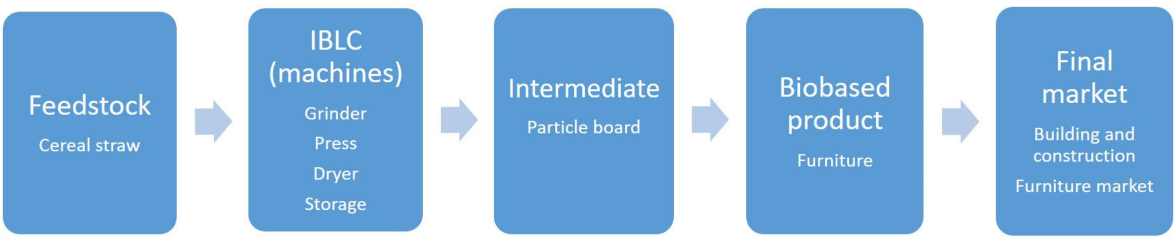


Figure 18. Pathway particle board from straw in the grain chain sector.

6.11 Sugar industry: Pathway 'Production of succinic acid for PBS (Polybutylene succinate) using sugar beet pulp'

According to the short list biobased chemicals the equipment to produce succinic acid for PBS is complex and the investment needed is high. It is also said that the demand is growing but today the market is a small niche for engineering plastics. The production of succinic acid from sugar beet pulp and molasses is on the list of the most promising theoretical opportunities to produce biofuels, biobased chemicals and materials at an IBLC in the sugar sector.

The sugar industry has a seasonal production, which means that there is a potential on-site production capacity during part of the year (between March and July). The feedstock utilized for the suggested application is sugar beet pulp. The beet pulp is processed into two products today, pressed sugar beet pulp and molassed sugar beet pellets. They are both used for feed and other purposes today. The molassed sugar beet pellets consist of approximately 90 % dried beet fibres and about 10 % molasses. Today the pressed sugar beet pulp is ensiled before usage. In the suggested pathway the beet pulp does not need to be processed into these products anymore. Sugar pulp is built up from both C5 and C6 sugars, to optimize resource efficiency, both types of sugars will be converted into succinic acid, which is the intermediate product of this pathway. Because of its versatility, succinic acid is expected to develop as a platform chemical with a broad range of applications. The equipment at the sugar factory site that could be utilized in the IBLC is the silos for storage, the dryer and the biogas plant for residual streams (it may also be possibly to use other equipment such as the extraction tower or crystallization tower as fermenter but that needs to check with the sugar company).

One possible application of succinic acid is PBS (polybutylene succinate). The end products of PBS range from disposables in food service ware, including cutlery, cups and lids, agricultural mulching film and compostable bags. PBS can also be made into composites and as additives in paint. Looking at the various applications, the demand in the PBS application is expected to reach 44,000 tonnes by the end of 2025 with a growth rate of 10 % per year according to the Nova Institute.

The beet pulp would need to be stored during the sugar production period until it will be used in the following production of succinic acid. Today the molassed sugar beet pellets are dried and the pressed sugar beet pulp is ensiled. Drying or ensiling are possible solutions also when the beet fibres will be used in the new application, but the best solution needs to be decided depending on the production process.

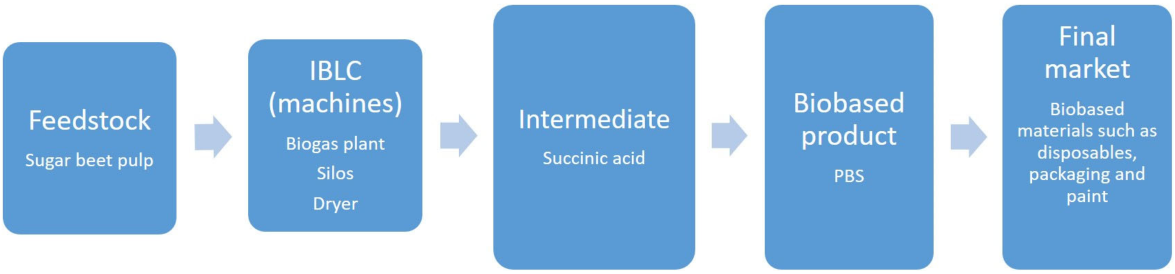


Figure 19. Pathway biobased materials from sugar beet pulp.

6.12 Sugar industry: Pathway 'Proteins from beet leaves'

Stakeholders consulted stated that proteins from the sugar industry are already used profitably in the feed industry, hence alternative markets are not expected to be developed. According to the short list on biobased chemicals the equipment needed for protein extraction from beet leaves is complex and the investments needed is on medium level. The focus on the market is the search for meat substitute products. In the identified theoretical opportunities, it is stated that the market is growing but still uncertain. It is also stated that the techniques need to be further developed.

Leaves from certain arable crops are recognized as a potential protein source for food applications based on their nutritional profile and their large availability in agricultural waste streams. Sugar beet leaves are reported to contain around 23 % crude protein on dry matter basis. The leaves have also more to offer than proteins, such as minerals vitamins, phytochemical substances and fibres. While the beets are used for sugar production, the leaves are mainly left on the fields today and are ploughed into the soil. There have been several attempts on how to find high-value uses of beet leaves through biorefining, including protein extraction for food and feed.

There are some specific challenges with protein extraction from leaves due to seasonal availability and high water content, which include the need for an initial stabilization process to prevent losses. The high moisture content of the beet leaf implies large volumes of biomass to be transported and requires fast stabilization to avoid spoilage. The idle time for production probably needs to overlap with the sugar production to some extent because good storage possibilities are lacking for the beet leaves. However, the production could also continue after the sugar production has ended.

A lot of research is focusing on the extraction of protein concentrates from beet leaves, to protein feed for animals such as chicken and pig, and pilot plants for this purpose are located in different locations in Europe. There are countless food ingredients that, in processed or unprocessed form, can serve as vegetable protein. However, it still has limited availability in the store, or consumers do not know what to do with it. There is an increased potential for dairy and plant proteins in blended formulations and a growing market for condition-specific nutrition, as well as satiety and weight management nutrition.

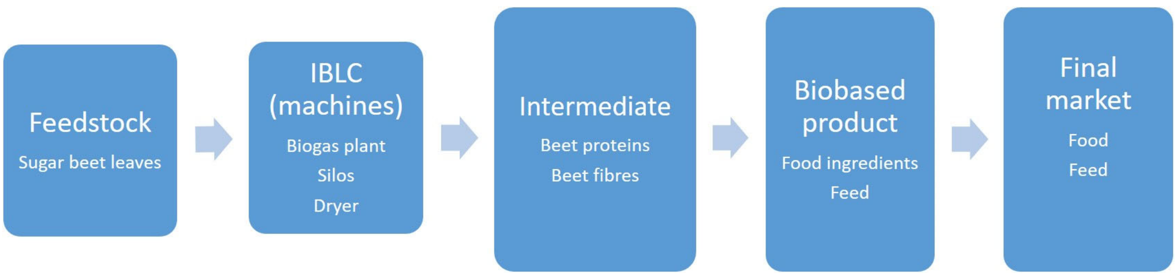


Figure 20. Pathway proteins from beet leaves in the sugar sector.

7 Logistical Solutions

7.1 Introduction

Logistics allows the rational use of resources (people, materials, inventory and equipment). This section aims to take advantage of the existing knowledge regarding logistics in agroindustry to be applied to the IBLC concept. For this, a review of European projects focused on agroindustry has been performed, e.g. S2biom[35], Europruning[36], BioBoost[37], LogistEC[38] and Infres[39].

A long list of 43 logistical solutions (also defined as general opportunities) was identified (8 logistical components and 34 logistical concepts) (see Annex C). Within this context, AGROinLOG adopted the definition provided in S2biom[40] and consider that logistical components "are used to solve problems in the biomass value chain from the original biomass source to the final conversion". Meanwhile, "a logistical concept is broader and more general than a specific biomass value chain. A chosen logistical concept always still needs to be further specified and translated in order to obtain a specific biomass value chain (specify all the components). Often several possible biomass value chains fit within that general logistical concept".

This list gathers solutions without regard to the sector implied. Four aspects were described (in Annex C):

- Logistical concept or component: the logistical solution was named, e.g. compaction.
- Description of the logistical solution to understand how it is applied in the value chain, answering the question 'what is it/how does it work?', e.g. press the biomass in order to increase the density.
- Description of the effect achieved in the value chain, e.g. reducing transport costs because of a higher loading rate.
- Description of the conditions that affect the solution, e.g. minimum volume required to perform this solution.
- Main stakeholders involved in the application of the solution.

[35] https://www.s2biom.eu/en/

[36] http://www.europruning.eu/

[37] http://www.bioboost.eu/home.php

[38] http://www.logistecproject.eu/

[39] http://www.infres.eu

[40] Bert Annevelink, Igor Staristky, Nike Krajnc et al. S2Biom survey and logistical concepts. 24th European Biomass Conference and Exhibition, 6-9 June 2016, Amsterdam, The Netherlands

7.2 Logistical solutions: components & concepts

From the initial list, two solutions were removed: (1) Trade-off between the use of residual feedstock and energy crops; and (2) Many small-scale conversion plants versus only one large scale conversion plant to meet product demand. These solutions were removed because the IBLC concept is based on the use of raw material to take advantage of the unexploited resources, and the use of an existing agroindustry during idle periods.

Next, the list was split by selecting the relevant components of the value chain based on the implicit feedstock typology. Two feedstocks were considered: woody feedstock and straw. The logistical components considered can be seen in Table 52 and the logistical concepts are shown in Table 53.

Table 52. Logistical components applied to both types of feedstock. Source: D3.1 S2Biom Project. A more detailed classification of each component can be seen in Annex C.

No.	Name (logistical component)
1	Compaction/ densification
2	Comminution
3	Drying
4	Feedstock handling
5	Harvesting/ collection
6	Other pre-treatments that influence feedstock quality
7	Storage
8	Transportation technologies

Table 53. Logistical concepts by type of feedstock.

No.	Name (logistical concept)	Woody feedstock	Straw
9	Biomass size reduction: chipping versus shredding	x	
10	Low enough moisture content (Natural drying)	x	x
11	Pre-treatment integrated with harvesting/collecting	x	x
11’	Stand-alone pre-treatment later on in the biomass supply chain	x	x
12	Collecting prunings in bales that will be chipped later on in the value chain	x	
12’	Chipping immediately at the source location	x	
13	Application of the most efficient equipment	x	x
14	Combination of different feedstock types and quality in one value chain	x	x
15	Optional use of intermediate depots	x	x
16	Decentral biomass conversion to improve transport properties	x	x

No.	Name (logistical concept)	Woody feedstock	Straw
17	Economic upgrading to marketable bioenergy products in large central plants	x	x
19	Transportation straight to the biorefinery	x	x
19'	Transportation after storage to the biorefinery	x	x
20	Integrated biomass processing at industrial facilities	x	x
21	Effect of moisture content on the logistics and biomass processing	x	x
22	Combination of different transport modes	x	x
23	Biomass logistics centre- biomass yards	x	x
24	Smart logistics and cost-effective transportation	x	x
25	Producing separate modular units (big-bags or bales)	x	
25'	Producing bulk material (hog wood)	x	
26	Front mounted shredding	x	
26'	Rear towed chipping	x	
27	Transport of bulk and packed biomass (big-bags or bales) in moving floor trucks	x	
28	Mechanised felling of fruit trees	x	
28'	Mechanised cut of trees with shear	x	
29	Shear mounted in front of the tractor	x	
29'	Shear mounted in the arm of a walking excavator	x	
30	On-field chipping of trees with mobile train along the row of felled trees	x	
31	On field utilisation regular agricultural trailers with relevant volumetric capacity	x	x
32	Manual preparation of trees before chipping	x	
32'	Mechanised pruning of trees before chipping	x	
33	Manual windrowing of prunes before chipping	x	
33'	Mechanised windrowing of prunes before chipping	x	
34	Integrated harvesting	x	x
35	Coupled logistics for wood chip production	x	
35'	De-coupled logistics for wood chip production	x	
36	Multi-tree handling	x	
37	Two-stage grinding	x	

No.	Name (logistical concept)	Woody feedstock	Straw
38	Single product harvesting	x	x
39	Integration of different biomass value chains	x	x
40	Chipping at the roadside	x	
40'	Chipping at the terminal	x	
41	European/ worldwide biomass value chains based on standardized biocommodities	x	
41'	Regional biomass value chains based on locally sourced 'raw' material	x	
42	'Intensive' pre-treatments in decentral plants, efficient transport to central plants for upgrading to final product	x	

7.3 Building biomass value chains

The list of logistical solutions can be used to build different biomass value chains. A biomass value chain connects several logistical concepts to describe the flow process of the feedstock from the collection in the field to its transformation at the IBLC. This section presents some examples according to the two feedstock typologies considered (see Figures 21, 22 and 23).

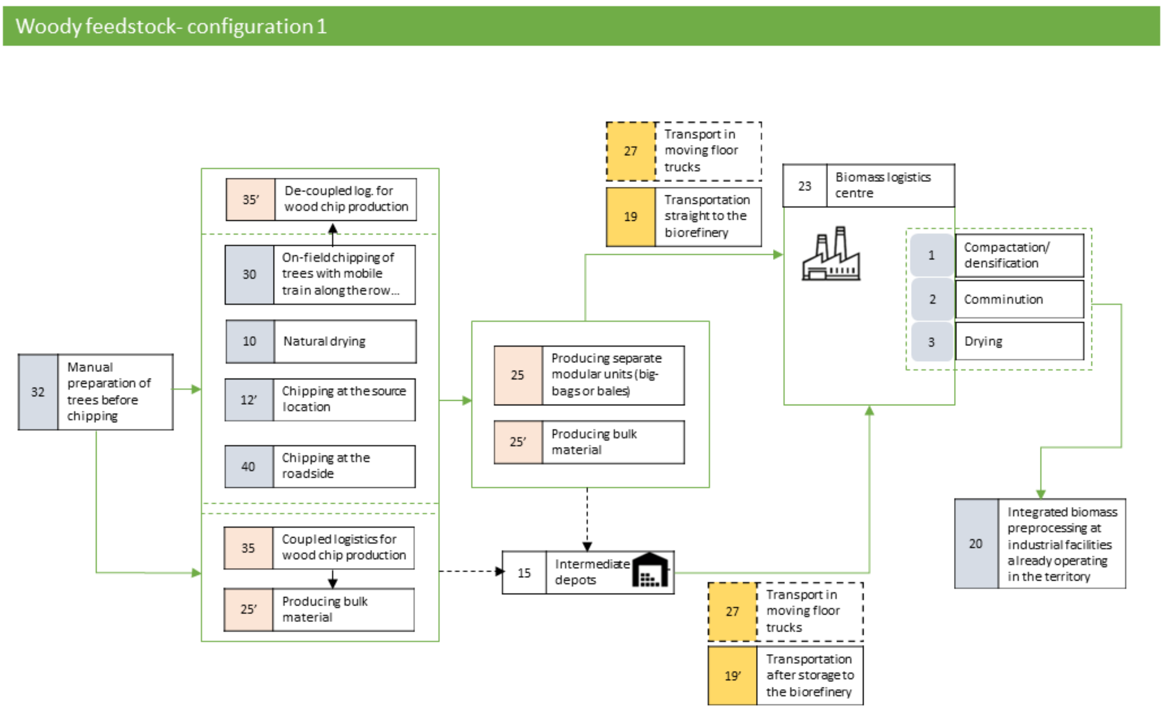


Figure 21. Woody feedstock- configuration 1

Woody feedstock- configuration 2

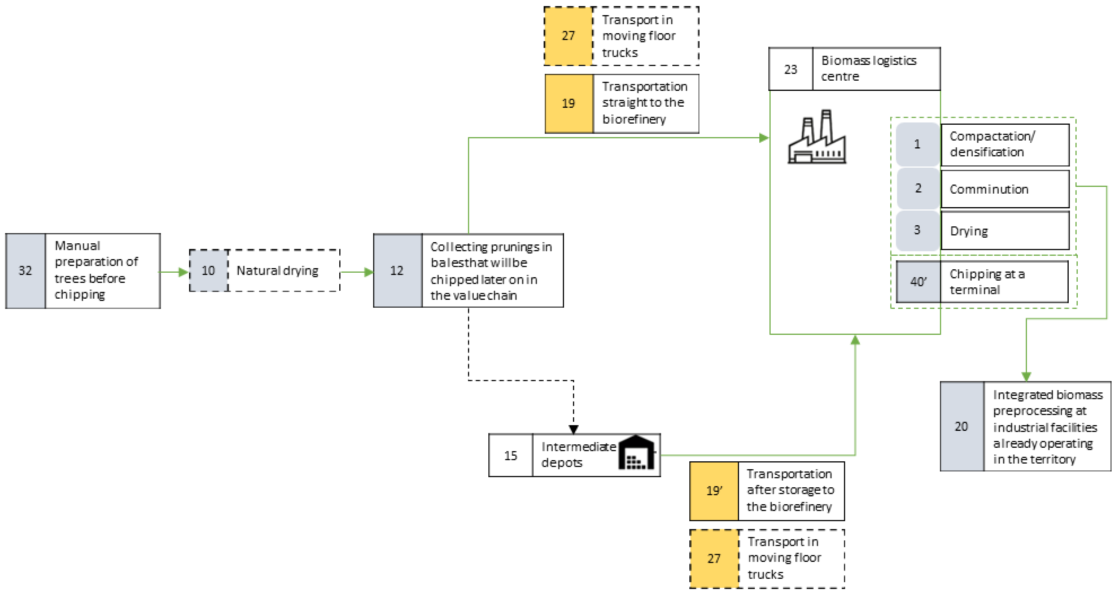


Figure 22. Woody feedstock- configuration 2

Straw

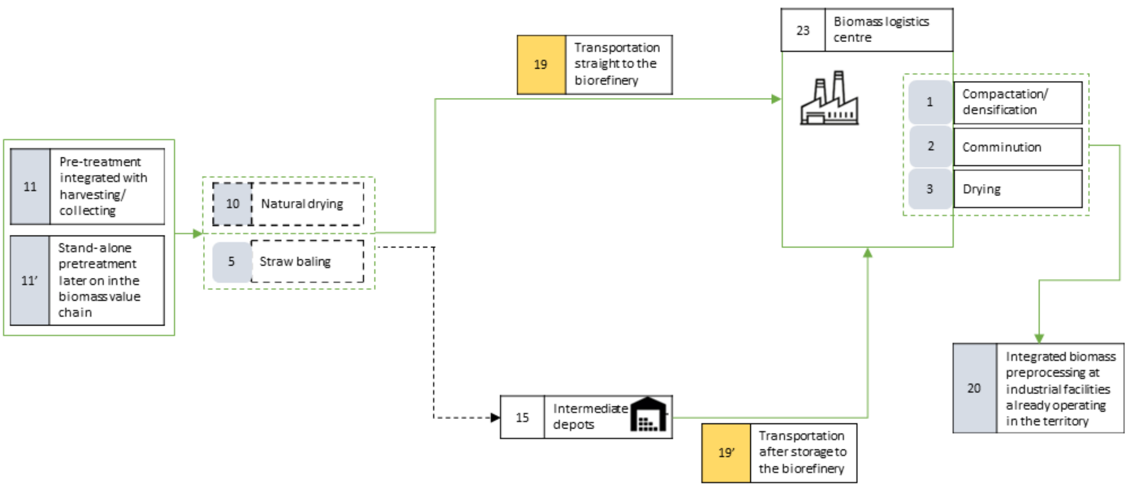


Figure 23. Straw configuration.

It is worth noting that some of the logistical solutions are optional depending on the configuration of the value chain, e.g. in 'Woody feedstock- configuration 1' (see Figure 21), 26, 28', 30 or 35 logistical concepts could be adopted, and at the biomass logistics centre (19) different pre-processing solutions could be adopted (1, 2, 4 or 5).

7.4 Examples of biomass value chains for the pathway opportunities

This section shows some examples from the pathway opportunities presented in Chapter 6. Seven pathways have been selected as an example:

1. production of pellets from olive tree prunings in a pomace mill (Section 6.3);
2. extraction of phenols from olive leaves/ pomace (Section 6.4);
3. production of wood chips from vineyard prunings (Section 6.7);
4. production of bioethanol from grape pomace (Section 6.8);
5. production of biogas from grain straw (Section 6.9);
6. production of succinic acid for PBS (Polybutylene succinate) using sugar beet pulp (Section 6.11);
7. proteins from beet leaves (Section 6.12).

7.4.1 Production of pellets from olive tree prunings in a pomace mill

Figure 24 presents a generic configuration of an olive prunings logistics chain for the production of pellets in a pomace mill. Several options at each stage (olive crop, preparation, harvesting, storage and transportation, IBLC/ products) of the supply chain can be adopted.

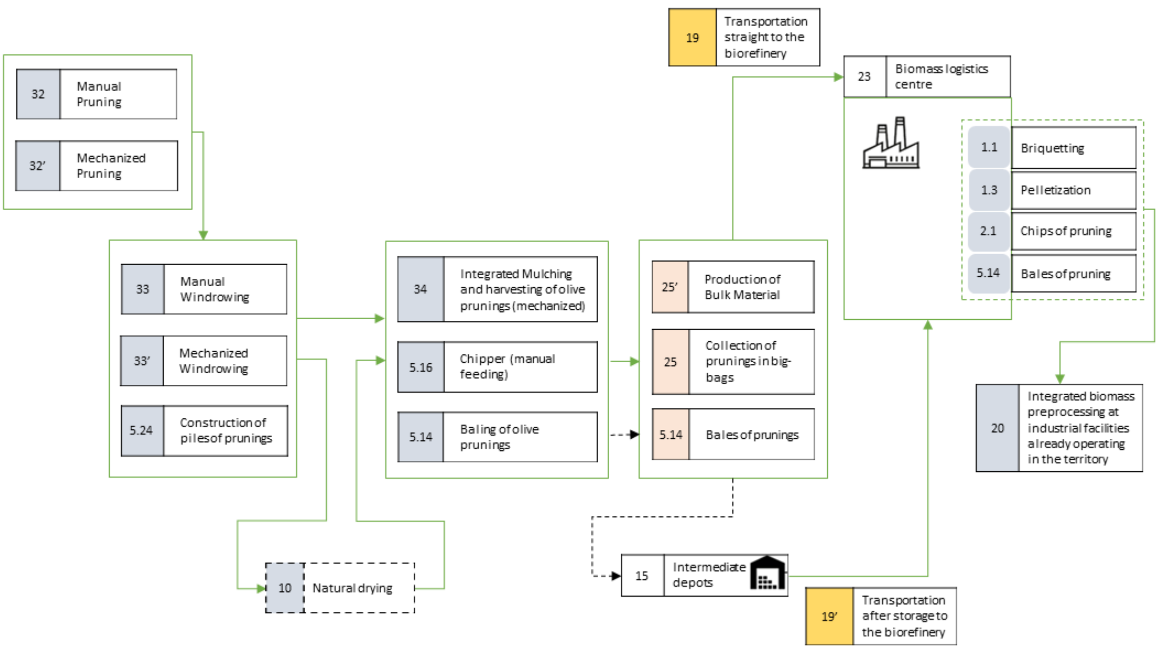


Figure 24. Production of pellets from olive tree prunings in a pomace mill.

This configuration (see Section 6.3) of the value chain was designed and validated by CERTH in a workshop carried out with Greek farmers. The participants selected the optimal (understood as the best option) value chain for the exploitation of olive prunings (see Figure 24): 32 → 33' → 10 → 34 → 25' →19 → 23 (1.3).

7.4.2 Extraction of phenols from olive leaves/ pomace

This pathway (see Section 6.4) refers to the extraction of phenols from olive mill residues at the IBLC. Three possibilities are considered: i) the use of leaves from prunings, ii) the use of pomace extracted from alperujo (by-product obtained after processing olives for olive oil extraction), and iii) the use of leaves after being separated from fruits before processing.

The logistics chain of the use of leaves from prunings can be based on the previous one (production of pellets from olive tree prunings, Figure 24), as the raw material also comes from prunings. The main different steps are the procedures to be carried out at the IBLC. In fact, a procedure for the separation of leaves from the wood should be included. Traditional natural drying (i.e. sun and wind drying) is proposed. However, as it may influence the final quality of the product, industrial drying processes at the IBLC could also be applied[41].

The use of pomace extracted from alperujo depends on the primary transformation of olives into oil. Furthermore, the use of leaves after they have been separated from fruits before processing depends on the harvesting of the olive. Thus, a logistics chain for the harvesting of olives and the leaves is presented (Figure 25). The main difference between both logistics chains will be at the necessary transformation processes at the IBLC.

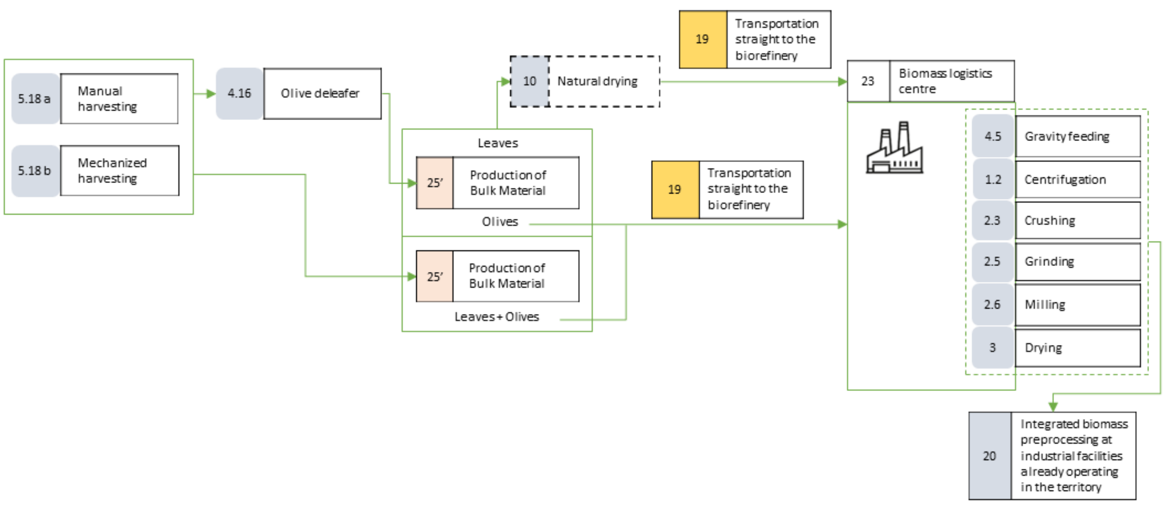


Figure 25. Extraction of phenols from olive leaves/ pomace.

[41] Leila Abaza, Amani Taamalli, Houda Nsir and Mokhtar Zarrouk, 2015. Olive Tree (Olea *europeae* L.) Leaves: Importance and Advances in the Analysis of phenolic Compounds. *Antioxidants*, 4, 682-698.

7.4.3 Production of wood chips from vineyard prunings

This pathway (see Section 6.7) takes advantage of the vineyard prunings for the production of wood chips. A generic configuration of the logistics chain can be seen in Figure 26. Both manual and mechanised pruning are considered. In addition, chipping can be performed at the field or at the IBLC. Similarly, drying can be natural or performed at the IBLC before chipping.

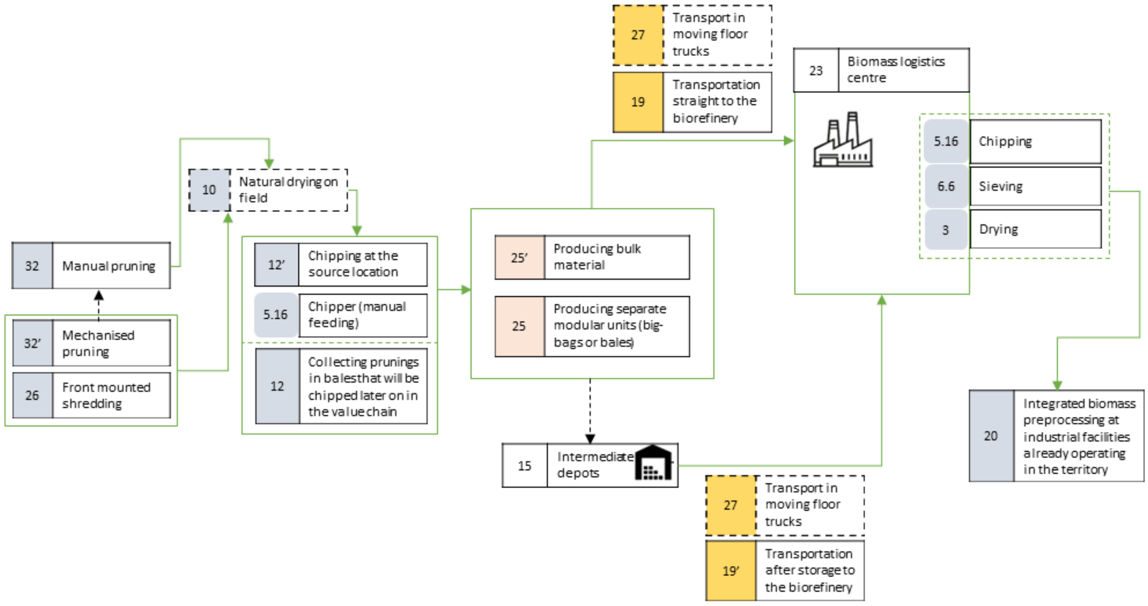


Figure 26. Production of wood chips from vineyard prunings.

7.4.4 Production of bioethanol from grape pomace

This pathway (see Section 6.8) refers to the production of bioethanol from grape pomace (see Figure 27). Grape pomace is obtained after pressing the fruit to extract the grape juice. It is a pulpy residue. This logistics chain is based on the harvesting of grapes for wine production (previous step for obtaining grape pomace). Thus, as the grape harvested is not used as a fruit (domestic consumption), harvesting options such as the production of separate modular units (boxes) has not been considered. Processes at the IBLC include the destemming of the grape previous to the primary transformation, pressing/crushing of the grapes. A hydrolyser and fermenter are used for obtaining bioethanol.

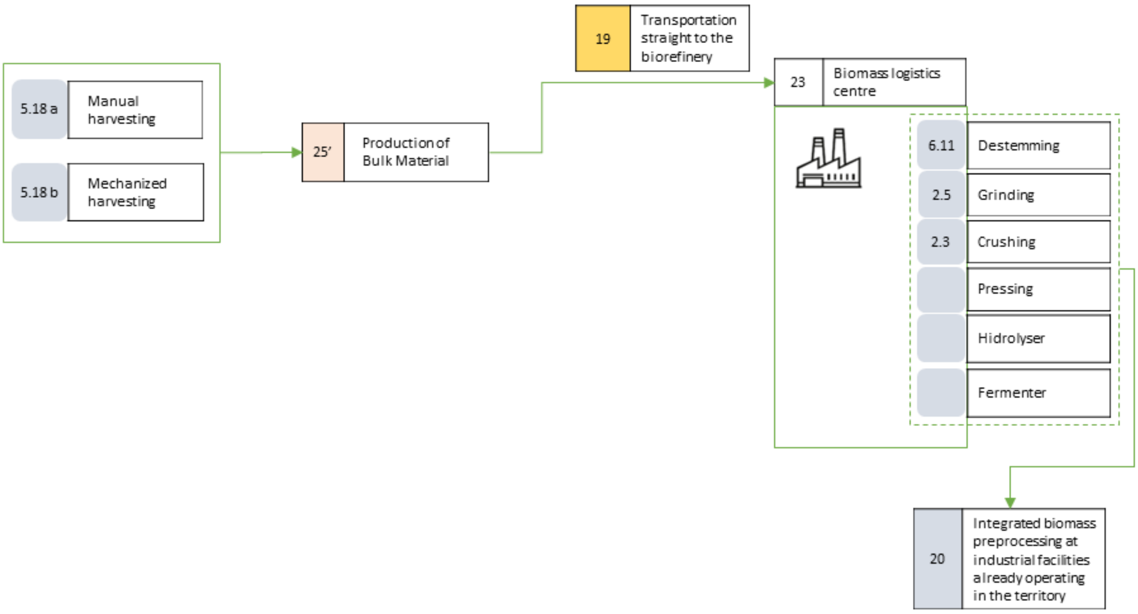


Figure 27. Production of ethanol from grape pomace

7.4.5 Production of biogas from grain straw

This pathway (see Section 6.9) considers the production of biogas from grain straw in the grain chain sector. The logistics chain presented in Section 7.3 in Figure 23 has been used as a basis, and new processes at the IBLC are included according to the typology of pathway (see Figure 28). The main differences can be observed at the processes to be performed at the IBLC. In addition to the pre-treatment processes applied to the straw it is considered the storage, the use of a press, a digester and a biogas plant.

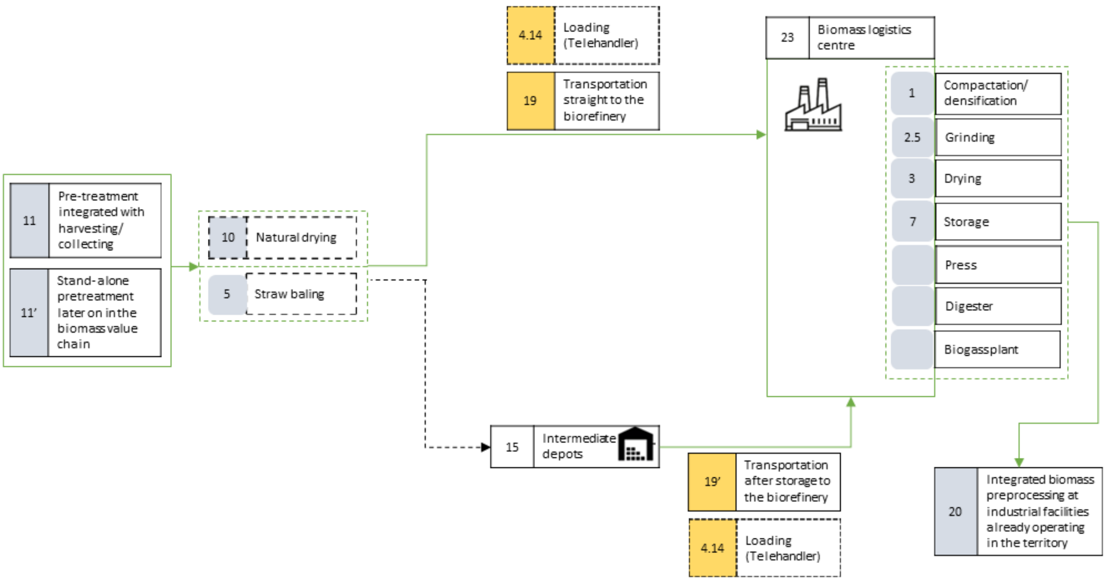


Figure 28. Production of biogas from grain straw in the grain chain sector

7.4.6 Production of succinic acid for PBS (Polybutylene succinate) using sugar beet pulp

This pathway (see Section 6.11) considers the production of succinic acid for PBS using the sugar beet pulp residue from the sugar industry. It has only been considered the use of beet in the logistics chain (see Figure 29) as the residue used is obtained after pressing the beet. Either mechanised or integrated harvesting is commonly used for the beet harvesting. The IBLC processes include the existence of a biogas plant and dryer for residual streams, and silos for storage.

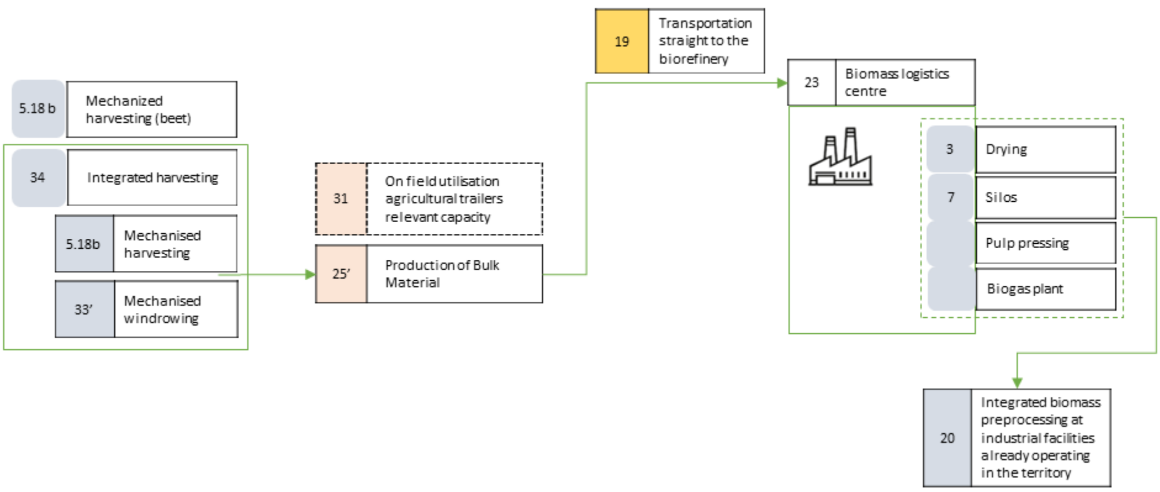


Figure 29. Production of succinic acid for PBS using a residue from the sugar industry

7.4.7 Proteins from beet leaves in the sugar sector

This pathway (see Section 6.12) considers the production of proteins by using beets leaves in the sugar sector. Several machineries can be used in the harvesting of sugar beet. Mechanised harvesting can consider the separation of the leaf or not, and the possibility to automatically harvest the beet or having an intermediate step (windrowing). There is also possibility to carry out an integrated harvesting where the beet is defoliated and the leaves are collected in parallel by using a trailer. At the same time the soil is mechanically dug and a self-loader introduce the beet in a deposit within the harvester. The main processes at the IBLC include the drying of the leaves, the use of silos for storage and a biogas plant. A generic configuration of the logistics chain can be seen in Figure 30.

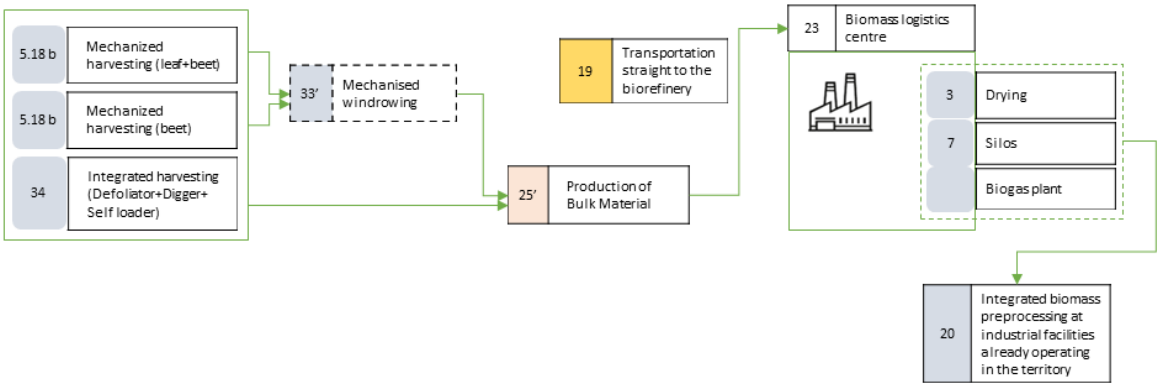


Figure 30. Production of proteins from beet leaves in the sugar sector

8 Conclusions

The potential and possibilities of establishing Integrated Biomass Logistics Centres (IBLCs) in a number of specific agricultural sectors and industries in Europe have been assessed and presented. Theoretical and practical opportunities have been integrated by combining desk studies of possibilities and the perspective or vision of different stakeholders involved in the processes. The production of intermediates for bioenergy & biofuels or biocommodities for biobased products, and the logistical integration of processes in the sectors selected in previous AGROinLOG's tasks as the most promising for implementing IBLCs in Europe has been evaluated. The following epigraphs present the main conclusions attained in all of them.

Vegetable oil extraction

The vegetable oils production sector is used to utilising waste streams obtained during oil production and companies rarely have significant idle periods in which other alternatives could be introduced. However, some opportunities to implement the IBLC business strategy still can become a reality in this sector. Taking advantage of lignocellulosic residues produced in the harvesting of the oily raw materials, which normally are left on the soil, to produce fuels for the energy market (pellets or briquettes) is an opportunity that stakeholders consulted took a positive stance. Concerning biobased chemicals & materials using residue streams to produce biodiesel or biogas could be another interesting alternative to be explored even though marketable plants scale could be an important barrier to be overcome. This is due to the large investments involved and the amount of inputs required to work them out. IBLC strategies to complement raw materials required by including new and additional logistics for the collection of other raw materials (e.g. refused oils collection for the biodiesel production) could be also implemented.

Olive oil sector

The olive oil sector offers several opportunities of biofuels and biobased chemicals & materials to be produced via the implementation of the IBLC concept. The exploitation of olive prunings as biofuel in different forms (chip, pellets or briquettes) is a major opportunity. Furthermore, the separation of olive pits and their use as solid biofuel offer another opportunity, as olive pits consist a high quality fuel that can be used at domestic heating. Moreover, the exploitation of olive mill wastewater and exhausted olive cake as feedstock for biogas production consist an interesting opportunity for an IBLC in the olive oil sector. Regarding the production of biobased chemicals and materials, great potential appears in the production of particle boards from olive prunings and the extraction of phenolic compounds from olive leaves and olive pomace.

Feed and fodder sector

Companies included in this sector normally have idle periods and equipment compatibility to implement the IBLC concept related to the production of biofuels for the energy market. These installations commonly work with straws, corn stalks or other herbaceous agricultural 'residues' to produce some of their products so that they are used to this type of raw materials. Incorporating the logistics of additional materials, producing suitable pellets for the energy market demands (quality and price) and including the logistics related to its distribution to a supplier or to the final users seems to be an interesting alternative to be deeply explored. Furthermore, granulated materials produced could be used as an interesting input for biobased chemicals & materials initiatives. Bioplastics, levulinic acid, lactic acid, etc., are different alternatives that could be exploited by means of using densified herbaceous residues as raw material. In this case, the implementation of the IBLC concept to produce these intermediates seems to be more attractive for the stakeholders than implementing the whole business line.

Wine sector

The wine sector offers various opportunities for the implementation of the IBLC concept. Vineyard prunings can be valorised with simple and relatively inexpensive equipment for the production of solid biofuels in the form of chips or pellets. Large volumes of several by-products are produced at wine industries that offer additional opportunities. Grape pomace, for example, can be used as raw material for the production of bioethanol that can be mixed in fuel blends or exploited as biochemical. In addition, large volumes of wastewater are generated from the wine industry sector that can be used, along with pomace, as feedstock for anaerobic digestion and biogas production. Finally, tartaric acids can be recovered from lees that can be used as anti-oxidant, food additives or in pharmaceuticals.

Grain chain

Straw represents the largest residual stream within the grain chain and is mainly left in field today or used for feed and bedding. It is of high interest to look more into straw for biogas production, but the biodegradability needs to be increased by a pre-treatment process. The production of 2nd generation bioethanol from cereal straw is also a very interesting utilization of straw to look more into if the lignin fraction and the C5 fraction can be valorised as well. Bio-oil and bio-char are examples of products that can be produced from these two fractions. One interesting possibility is to build a bio-char production facility at the grain mill. It is also interesting to look more into straw and husks as components in the manufacturing of panels, insulation and filler solid in building materials.

Sugar industry

The time of the year when there is no production on the sugar industry production site it may be possible to utilize the site for other types of production. One interesting possibility to look more into is the production of biofuels or biobased chemicals such as lactic acid, levulinic acid, bioethanol and succinic acid from sugar beet pulp and/or molasses. Another two interesting possibilities that can be interesting to look further into is the production of biogas from sugar beet pulp and/or beet leaves. Extraction of proteins from the beet leaves is a very interesting identified opportunity for an IBLC that needs to be further investigated.

Moreover, knowledge regarding logistics in agroindustry has been identified and applied to the IBLC concept. For this, a review of European projects focused on agroindustry has been performed, e.g., S2biom, Europruning, BioBoost or Infres. A final list of 41 logistical solutions was considered. The list of logistical solutions was used to build seven biomass value chains from the pathway opportunities identified in Chapter 6. The following pathways were included: i) production of pellets from olive tree prunings in a pomace mill; ii) extraction of phenols from olive leaves/ pomace; iii) production of wood chips from vineyard prunings; iv) production of bioethanol from grape pomace; v) production of biogas from grain straw in the grain chain sector; vi) production of succinic acid for PBS (Polybutylene succinate) using sugar beet pulp; and vii) proteins from beet leaves.

By considering the results attained in each sector and the all the pathways and possibilities assessed, different cases studies in which the IBLC strategy implementation is going to be deeply evaluated are going to be selected within AGROinLOG in order to promote IBLCs approach for agroindustries.

ANNEX A. LONG LIST BIOENERGY & BIOFUELS

	Biobased product		Feedstock	Production Facilities	End Use	IBLC investment cost L: low, M: medium, H: high		Scale S: small, M: medium, L: large		TRL
	Agropellets/ Briquettes	olive stone	exhausted olive cake	drier screening air separator press	domestic, industrial heating, power generation, CHP	L	Simple extra equipment needed	S-M	Transportation of raw material (long distances) would propably hamper larger production plants	8-9
		prunings	fruit trees, vineyrads	grinder drier press						
		straw	straw (rice, wheat, oats, barley, soybean, rapeseed)	grinder drier press						
		stalks	maize stalks, sunflower stalks, cotton stalks	grinder drier press						
		husks	sunflower seed husks, soybean husks, rice husks	grinder drier press						
		nut shells	groundnut, almond, pistachio, walnut, hazelnut shells	grinder drier press						
			grape stalks, grape pomace, grape seeds	grinder drier press						
			sugar beet pulp	grinder drier press						
			corn cobs	grinder drier press						

	Biobased product		Feedstock	Production Facilities	End Use	IBLC investment cost L: low, M: medium, H: high		Scale S: small, M: medium, L: large		TRL
d products for energy/ heat)	Torrefied pellets	prunings	fruit trees, vineyrads	pre-drier torrefaction grinder press	domestic, industrial heating, power generation, CHP	L-M	Relatively simple equipment needed	S-M	Transportation of raw material (long distances) would propably hamper larger production plants	8-9
		straw	straw (rice, wheat, oats, barley, soybean, rapeseed)	pre-drier torrefaction grinder press						
		stalks	maize stalks, sunflower stalks, cotton stalks	pre-drier torrefaction grinder press						
		husks	sunflower seed husks, soybean husks, rice husks	pre-drier torrefaction grinder press						
			grape stalks, grape pomace, grape seeds	pre-drier torrefaction grinder press						
			sugar beet pulp	pre-drier torrefaction grinder press						
			corn cobs	pre-drier torrefaction grinder press						
	Exhausted olive cake		exhausted olive cake	Produced directly from pomace mills	industrial heating, power generation, CHP	L	No extra equipment	S-M		9

	Biobased product	Feedstock	Production Facilities	End Use	IBLC investment cost L: low, M: medium, H: high		Scale S: small, M: medium, L: large		TRL
Bioenergy (biobase	Olive stones	exhausted olive cake	drier screening air separator	domestic, industrial heating, power generation,	L	Simple extra equipment needed	S-M	Small would make the most sense given the nature of these residues	9
	Fruit pits	pits from peaches, prunes, cherries, apricots	drier	domestic, industrial heating, power generation,	L	Simple extra equipment needed	S-M		9
	Chips / Hog fuel	prunings (fruit trees, vineyrads)	grinder drier	industrial heating, power generation, CHP	L	Simple extra equipment needed	S-M		9
	Biogas	beet leaves	pretreatment tank digester desulfurizer dehydrator	heat & power	M-H	Cost depends mostly on the scale of the facility	M-L	The investment cost of small units is prohibitive	9
		grape pomace, winery waste water	pretreatment tank digester desulfurizer dehydrator						5-7
		exhausted olive cake, olive mill wastewater	pretreatment tank digester desulfurizer dehydrator						5-7
		spent grain (breweries)	pretreatment tank digester desulfurizer dehydrator						8-9
		straw (rice, wheat, oats, barley, soybean, rapeseed)	grinder pretreatment tank digester desulfurizer dehydrator						9

	Biobased product	Feedstock	Production Facilities	End Use	IBLC investment cost L: low, M: medium, H: high		Scale S: small, M: medium, L: large		TRL
		maize stalks, sunflower stalks, cotton stalks	grinder pretreatment tank digester desulfurizer dehydrator						5-7
	Syngas	prunings (fruit trees, vineyrads)	grinder drier gasifier gas cleaning	heat & power	M-H	Complex equipment needed	S-L	Small (< 2 MW) or large units would make more sense given the nature and uses of syngas. Medium scale units are not competitive with combustion.	8-9
		straw (rice, wheat, oats, barley, soybean, rapeseed)	grinder drier gasifier gas cleaning						
		maize stalks, sunflower stalks, cotton stalks, grape stalks	grinder drier gasifier gas cleaning						
		sunflower seed husks, soybean husks, rice husks	grinder drier gasifier gas cleaning						
		corn cobs	grinder drier gasifier gas cleaning						
		molasses	grinder cooker fermenter Distillation collumn molecular sieve						9

	Biobased product	Feedstock	Production Facilities	End Use	IBLC investment cost L: low, M: medium, H: high		Scale S: small, M: medium, L: large		TRL
	Bioethanol	straw (rice, wheat, oats, barley, soybean, rapeseed)	grinder pretreatment tank (hydrolysis) cooker fermenter Distillation collumn molecular sieve	automotive fuel, heating	H	The need for pretreatment increases the cost	M-L	Larger units would make more sense given the complexity of the equipment, especially if the raw materials require pretreatment	8-9
		maize stalks, sunflower stalks, cotton stalks	grinder pretreatment tank (hydrolysis) cooker fermenter Distillation collumn molecular sieve						5-7
	Bio-oil & bio-char (pyrolysis)	prunings (fruit trees, vineyrads)	grinder drier pyrolysis reactor cyclone condenser furnace	Bio-oil: heat & power, automotive fuel (diesel), Bio-char: heating or other bioproducts (e.g. activated carbon)	H	Complex equipment needed	M-L	Larger units would make more sense given the high investment cost	8-9
		straw (rice, wheat, oats, barley, soybean, rapeseed)	grinder drier pyrolysis reactor cyclone condenser furnace						
		maize stalks, sunflower stalks, cotton stalks, grape stalks	grinder drier pyrolysis reactor cyclone condenser furnace						
			grinder						

	Biobased product	Feedstock	Production Facilities	End Use	IBLC investment cost L: low, M: medium, H: high		Scale S: small, M: medium, L: large		TRL
Biofuels		sunflower seed husks, soybean husks, rice husks	drier pyrolysis reactor cyclone condenser furnace						
		corn cobs	grinder drier pyrolysis reactor cyclone condenser furnace						
	HTL Biooil	lignocellulosic biomassm (algae)	Hydrothermal Liquefaction reactor (Hydrolysis, depolymerization, chemical and thermal decomposition, dehydration, decarboxylation and recombination)	bio-oil from HTL can be used as-produced in heavy engines or it can be hydrogenated or thermally upgraded to obtain diesel-, gasoline- or jet-fuels by existing refinery technology	M-H	Under assessment in AGROinLOG project	M-L		6-7 (3-5)
	Bio-methane	biogas	CO_2 removal (ab/desorption columns) and H_2S removal	NG grid (heat, power, automotive fuel)	L		M-L	see biogas	9
	FT (Fisher-Tropsch) liquids	syngas	Fisher-Tropsch reactor Distillation collumn	automotive fuels (naphtha, diesel), aviation fuels	M		M-L	see syngas	9

	Biodiesel	spent bleatching earth (vegetable oil refineries)	residual oil extraction esterification reactor transesterification reactor washing tanks/phase separators dehydration/ methanol removal	automotive fuel	M	M		8-9
	bio-SNG	syngas	SNG reactor (methanation, shift) SNG upgrading compressor	NG grid (heat, power, automotive fuel)	L-M	M-L	see syngas	9
	Hydrogen	bio-methane	scrubber steam reformer	automotive fuel	M-H	M-L	see biogas	6-7
	Bio-kerosene	Oil crops, microalgae	Catalytic hydrotreating (deoxygenation, desulfurization and denitrogenation through hydrogenation reactions with catalyst)	Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene	H	M-L	Larger units would make more sense given the high investment cost	5-7
		Woody energy crops, agricultural residues, forestry residues, algal biomass, waste	Gasification, gas cleaning and conditioning and Fischer Tropsch plant	Fischer-Tropsch-Synthetic Paraffinic Kerosene				
		Sugar, starches, woody crops, agricultural residues, forestry residues	catalytic dehydration, Oligomerization, distillation and hydrogenation,	Alcohol-to-Jet Synthetic Paraffinic Kerosene				
		Wood crops, agricultural residues, forestry residues	Pirolysis + hydrotreating	Pyrolysis-to-Jet – Synthetic Paraffinic Kerosene				3-5
		Sugars	fermentation/catalytic chemical processing	Fermented Renewable Jet – Synthetic Paraffinic Kerosene				

ANNEX B. LONG LIST BIOBASED CHEMICALS AND MATERIALS

Table B1 - Selected crops with their field and mill residues

Crops	Latin name	Field residues	Mill residues	Scale
Sugar beet				
sugar beet	*Beta vulgaris*	leaves	tails/pulp	L
		coppice	molasses	
Wine				
grapes	*Vitis vinifera*	prunings	grape skins	S-M-L
		stalks	stalks	
			seeds	
			grape pomace	
			lees	
Olive oil				
olive	*Olea europea*	prunings	olive pomace	S-M
		leaves	pits	
			press cake	
			waste water	
Vegetable oils				
rapeseed	*Brassica napus*	straw	seed hull	L
			press cake	
			(meal)	
sunflower	*Helianthus annuus*	stalks	heads	L
			seed hull	
			press cake	
soybean	*Glycine max*	stalks	pods, press cake	L
peanut	*Arachis hypogaea*	stalks	seed hull	M
cotton	*Gossypium sp*	stalks	linter	S-M
		burrs	seed hull	
			press cake	
Grain / cereals				
corn	*Zea mays*	stem	cobs	L
wheat	*Triticum vulgare*	Straw, chaff	bran / germ	L
rye	*Secale cereale*	straw	hulls	M
barley	*Hordeum vulgare*	straw	hulls	M
oats	*Avena sativa*	straw	hulls	M
Feed and fodder				
corn	*Zea mays*	-	-	M
clover	*Trifolium repens*	-	-	S
alfalfa (lucerne)	*Medicago sativa*	-	-	S

Table B2 – Overview of biobased chemicals

Scale	Platform	Biobased chemical	CAS	Formula	Process	End-product	TRL
	C1						
S-M	biomass	biogas (methane)	74-82-8	CH_4	fermentation	energy	Ind
L	syngas	methanol	67-56-1	CH_4O		solvent	Ind
LL	biomass	syngas	-	CO, H_2	Fisher-tropsch	fuel, olefins	9
L	syngas	dimethylether	115-10-6	CH_3OCH_3			
L	methanol	formic acid	64-18-6	CH_2O_2	oxidation	presrivative	
L	methanol	formaldehyde	50-00-0	CH_2O	oxidation	resin	
	C2						
S-M	C6	ethanol	64-17-5	C_2H_6O	fermentation	fuel, solvent	ind
L	ethanol	ethylene	74-85-1	C_2H_4	dehydration	bio-PE	ind
L	ethylene	ethylene oxide	75-21-8	C_2H_4O	oxidation		
	ethylene	ethylene glycol (ethanediol)	107-21-1	$C_2H_6O_2$			ind
M	ethanol	acetic acid	64-19-7	$C_2H_4O_2$	oxidation		ind
	formaldehyde	glycolic acid	79-14-1	$C_2H_4O_3$	carbonylation		9
	lactic acid	oxalic acid	144-62-7	$C_2H_2O_4$	oxidation, decarboxylation		ind
L		vinyl chloride	75-01-4	C_2H_3Cl		PVC	
	C3						
L	acetone	propylene	115-07-1	C_3H_6	reduction, dehydration	bio-PP	ind
M	acetone	iso-propanol	67-63-0	C_3H_8O			9
L		3-hydroxy-propionic acid	503-66-2	$C_3H_6O_3$			9
L	glycerol	1,3-propanediol	504-63-2	$C_3H_8O_2$			ind
L		propylene glycol	57-55-6	$C_3H_6O_3$			
L	lactic acid	propionic acid	79-09-4	$C_3H_6O_2$	reduction		
M-L	plant oils	Glycerol	56-81-5	$C_3H_8O_3$	hydrolysis		ind
M-L	C6	Acetone	67-64-1	C_3H_6O	fermentation	solvent	
M-L	C6	lactic acid	50-21-5	$C_3H_6O_3$	fermentation	PLA	ind
L	lactic acid	acrylic acid	79-10-7	$C_3H_4O_2$	dehydration	PAA	9
	C4						
M-L	C6	n-butanol	71-36-3	$C_4H_{10}O$	fermentation		ind
L		butane	624-64-6	C_4H_8			9
L	ethanol	butadiene	106-99-0	C_4H_6	dehydrogenation, condensation dehydration		
L		iso-butanol	78-83-1	$C_4H_{10}O$	fermentation	solvent	9
L	butadiene	butanediol (BDO)	110-63-4	$C_4H_{10}O_2$			9
M-L		succinic acid	110-15-6	$C_4H_6O_4$	fermentation	PBS	ind
L	furfural	maleic acid	110-16-7	$C_4H_4O_4$	oxidation		
L		fumaric acid	110-17-8	$C_4H_4O_4$			
L		malic acid	6915-15-7	$C_4H_6O_5$			
M-L		tartaric acid	526-83-0	$C_4H_6O_6$		antioxidant	ind
L		3-hydroxy-butyrolactone	58081-05-3	$C_4H_6O_3$			
	furfural	tetrahydrofuran (THF)	109-99-9	C_4H_8O	hydrogenation		ind
	C5						
M-L	xylose	xylitol	87-99-0	$C_5H_{12}O_5$	reduction		ind
M-L	C5	furfural	98-01-1	$C_5H_4O_2$	hydrolysis		ind
L	furfural	furfuryl alcohol	98-00-0	$C_5H_8O_6$	hydrogenation	resin	
M-L		itaconic acid	97-65-4	$C_5H_6O_4$	fermentation		9
M-L	C6	levulinic acid	123-76-2	$C_5H_8O_3$	hydrolysis		9
L	rubber	isoprene	78-79-5	C_5H_8			9
L	rubber	(farnesene)	502-61-4	$C_{15}H_{24}$			

Table B2 – Overview of biobased chemicals (continued)

Scale	Platform	Biobased chemical	CAS	Formula	Process	End-product	TRL
	C6						
L	Glucose	sorbitol	50-70-4	$C_6H_{14}O_6$	reduction		ind
L	C6	hydroxymethylfurfural (HMF)	67-47-0	$C_6H_6O_3$	dehydration		
L	HMF	2,5-furan dicarboxylic acid (FDCA)	4282-24-0	$C_6H_4O_5$	oxidation	PEF	9
M-L	Glucose	glucaric acid	576-42-1	$C_6H_{10}O_8$	oxidation		9
M-L	Glucose	gluconic acid	526-95-4	$C_6H_{12}O_7$	oxidation		
M-L	C6	adipic acid	124-04-9	$C_6H_{10}O_4$	fermentation		9
M-L	C6	citric acid	77-92-9	$C_6H_8O_7$	fermentation		ind
	sorbitol	isosorbide	652-67-5	$C_6H_{10}O_4$	dehydration		ind
	C8-18 Fatty acids						
	plant oil	fatty acids	-	-	hydrolyis		ind
	Amino Acids						
	protein	glutamic acid	56-86-0	$C_5H_9NO_4$	hydrolysis		ind
		aspartic acid	56-84-8	C_4H9NO_4	hydrolysis		
		serine	56-45-1	$C_3H_7NO_3$	hydrolysis		
		threonine	72-19-5	$C_4H_9NO_3$	hydrolysis		
		lysine	56-87-1	$C_6H_{14}N_2O_2$	hydrolysis		ind
	Aromatics						
L	black liquor	lignin	8068-05-1	$nC_9H_{10}O_2$	Kraft pulping		Ind
L		lignosulfonates	8061-52-7	$C_{20}H_{24}O_{10}S_2$	sulphite pulping		ind
M-L		pyrolysis oil	-	-	pyrolysis		ind
		ferulic acid	1135-24-6	$C_{10}H_{10}O_4$			
M-L	tannin	gallic acid	149-91-7	$C_7H_6O_5$			
		phenolics					ind

Table B3 – Overview of biobased materials.

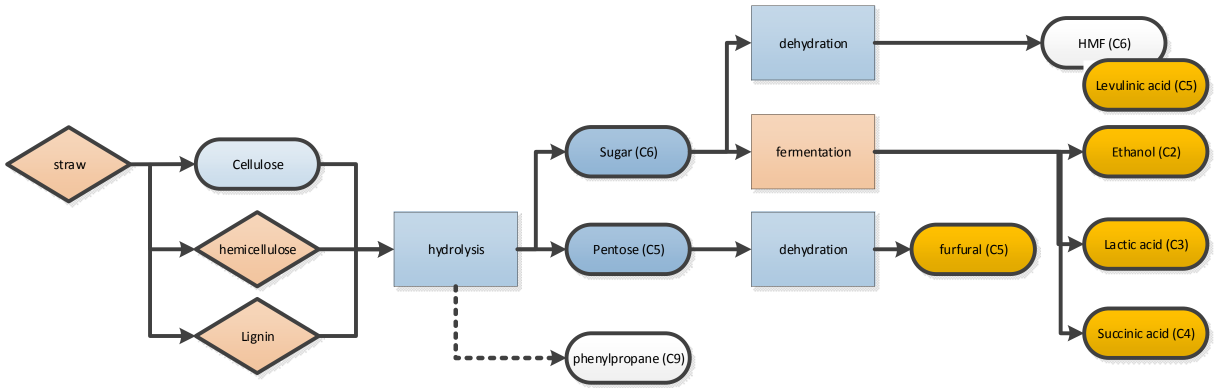
Source	Intermediate at IBLC	End-use product	Scale
Ligno-cellulose	bales		
	chips	particle board	M-L
	chips	paper pulp	L
	fibre	fibre board	M-L
	fibre	granulate	S-M
	fibre pulp	paper and board	L
	fibre pulp	dissolving cellulose	M-L
	granulate	plastic composite	M
	pyrolysis oil	chemicals	M
	biogas	chemicals	S-M
Wet biomass	fermentation feedstock	ethanol, chemicals	S-M-L
	extraction feedstock	phenols	S-M
Press cake	crude protein	adhesive, liner	M
	crude protein	thickener	S-M-L
	fermentation feedstock	ethanol, chemicals	S-M-L

Table B4 – Biobased chemicals and materials based on residues per sector

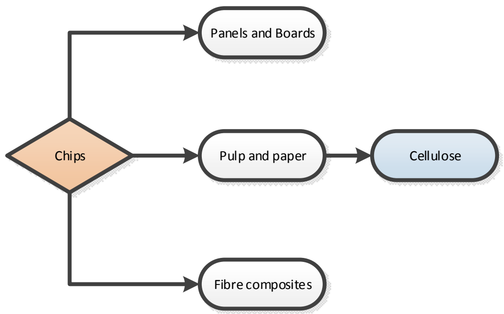
Crops	**Field residues**	**Mill residues**	**Production facilities at IBLC**	**Investment costs at IBLC**	**Intermediate product at IBLC**	**End-use product (chemical/material)**	**Scale at mill**
Sugar sector							
sugar beet	leaves	-	filter press	++	protein (rubisco)	Surfactant	L
	coppice	-			-		
	-	tails			-		
	-	pulp			-		
	-	molasses			-		
Wine sector							
grapes	prunings	-	chipper/ refiner	+++	fibres	fibre board	S-L
	stalks	-	chipper /refiner	+++	fibres	fibre board	S-L
	-	stalks			-		
	-	grape skins			phenols (anthocyanin, flavonol)	antioxidant, flavour	M-L
	-	seeds	press	+	crude oil, (saponis, polyphenols, tocopherol)	anti-oxidant	
	-	grape pomace	fermentor, destillery	++	ethanol		M-L
	-	lees			tartaric salts	anti-oxidant, additive	M
Olive oil sector							
olive	prunings	-	chipper/ debarker/ screener	++	chips, fibres	particle board	S-M
	prunings	-	refiner/ cooker	+++	fibres	fibre pulp, lignin	L
	leaves	-	extractor	+	phenols	antioxidant, biocide, resin	S
	-	olive pomace	extractor	+	phenols	antioxidant, biocide, resin	S-M
	-	pits / stone	grinder/ extractor	++	protein , phenols	antioxidant, biocide, resin, surfactant	S-M
	-	press cake	centrifuge/ ultrafiltration/ drier	+++	protein	antioxidant, biocide, resin, surfactant	S-M
	-	waste water	centrifuge/ ultrafiltration/ drier	+++	phenols	antioxidant, biocide, resin	S-M
Vegetable oil sector							
rapeseed	straw	-	chipper /refiner / extruder	+++	fibres	fibre board, composites	L
	-	seed hull	extractor	++	phenols, sterols	antioxidants	M-L
	-	press cake	centrifuge/ ultrafiltration/ drier	+++	crude protein	protein, glucosinolate	M-L

Crops	Field residues	Mill residues	Production facilities at IBLC	Investment costs at IBLC	Intermediate product at IBLC	End-use product (chemical/material)	Scale at mill
sunflower	stalks	-	chipper/ refiner / extruder	+++	fibres	fibre board, composites	L
	-	heads	extractor	+	pectin	thickening agent	M
	-	seed hull	briquetting/ pelletizer	+	pellets, briquettes, mulch		
	-	press cake	centrifuge/ ultrafiltration/ drier	+++	crude protein	protein, phosphatides (lecitin)	M-L
soybean	stalks	-	chipper/ refiner / extruder	+++	fibres	fibre board, composites	L
	-	pods	grinder/	+	meal		
	-	press cake	centrifuge/ ultrafiltration/ drier	+++	crude protein	protein concentrate	M-L
peanut	stalks	-					M
	-	seed hull	composter	+		mulch	S-M
cotton	stalks	-	chipper/ debarker/ screener	++	chips	particle board	S-M
	burrs	-	composter	+		mulch	S-M
	-	linter	refiner/ cooker	++	pulp	fibre pulp	L
	-	seed hull					
	-	press cake	centrifuge/ ultrafiltration/ drier	+++	crude protein	protein concentrate	M-L
Grain / cereals sector							
corn	stem/stover	-	briquetting/ pelletizer	+	pellets, briquettes	ethanol, pentosan	L
	-	cobs	briquetting/ pelletizer	+	pellets, briquettes	ethanol, pentosan	L
wheat	straw, chaff	-	chipper/ refiner / extruder	+++	fibres	fibre board, composites	L
	straw, chaff	-	refiner cooker	+++	pulp	pulp, lignin, pentosan, ethanol	M-L
	-	bran / germ	reactor	++		fibre, pentosan	M-L
rye	straw	-	chipper/ refiner / extruder	+++	fibres	fibre board, composites	M
	-	hulls	reactor	++		fibre, pentosan	M-L
barley	straw	-	chipper/ refiner / extruder	+++	fibres	fibre board, composites	M
	-	hulls	reactor	++		fibre, pentosan	M-L
oats	straw	-	chipper/ refiner / extruder	+++	fibres	fibre board, composites	M
	-	hulls	reactor	++		fibre, pentosan	M-L

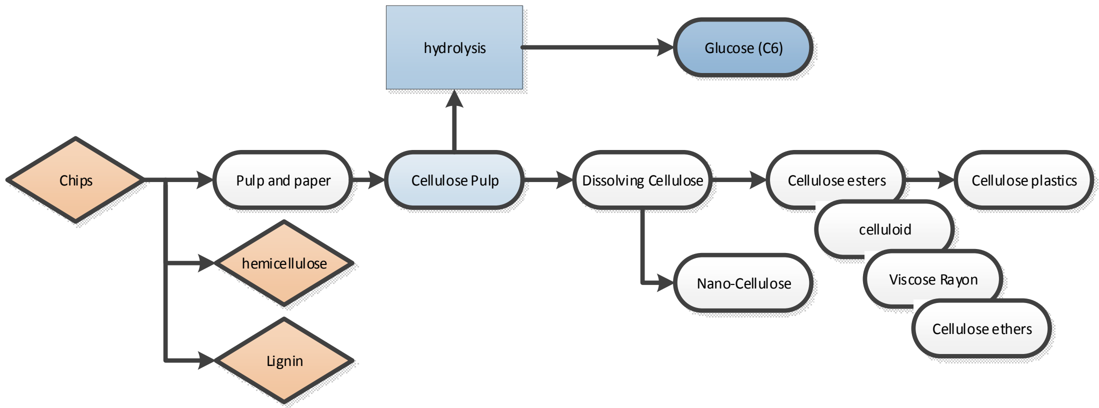
B5. Production schemes



Scheme 1. Simplified scheme of biochemicals production from straw / lignocellulose



Scheme 2. Lignocellulose derived materials



Scheme 3 – cellulose derived products

ANNEX C. LONG LIST LOGISTICAL SOLUTIONS

The following items are on the long list of logistical solutions:

A) Types of logistical components (see subdivision in Annex D):

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
1	Compaction/ densification	Press the biomass in order to increase the density. Some technologies can be applied (Annevelink et al., 2014): briquetting; centrifugation; pelletizing; bundling.	Reduced transport costs because of a higher loading rate.	Minimum volume required to perform this solution	Supplier
2	Comminution (size reduction)	It is a fundamental processing step for lignocellulosic biomass feedstocks to reduce its size. Some technologies can be used (Annevelink et al., 2014): chipping; chunking; crushing; debarking; grinding; milling; screening; Shredding.	An improvement in the quality of the feedstock (homogeneous), and reduced transport costs because of higher loading rate.	Biomass moisture significantly influences comminution energy consumption.	Supplier
3	Drying	Processing to decrease the moisture content of the biomass. Two different types can be distinguished (Annevelink et al., 2014): active/forced drying (artificial): belt dryer; dryer equipment; heating with residual heat; rotary drum dryer; ventilation with fans or blowers passive drying (natural): inside in barn; outside covered; outside in open air and sun.	An improvement in the quality of the feedstock (homogeneous). It will have an impact on the price of the feedstock and storage options. When performed in the field is related with the facility in transport, having an impact in transportation costs.	Pest control of the feedstock. With the current market prices, at this time, artificial drying of the material would only be justified when it is used for energy applications of higher added value such as densified elements, pellets and briquettes.	Supplier, IBLC
4	Feedstock handling	Needed throughout the biomass value chain to move the biomass between different components e.g. loading biomass from storage to a means of transportation. Another use for feedstock handling is to move biomass from one position to another, where the transport distance is relatively low.	Efficient use of the material. Reduction of time and costs.	Dependent of the size of the raw material.	All stakeholders

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
5	Harvesting/ collection	Methods used in the harvesting/ collection of the raw material.	Efficient use of the material. Reduction of time and costs.	Dependent of the type of raw material A restrictive factor is the fact that grown biomass and primary agricultural and forestry residues always are released de-centrally/regionally. The total amount of biomass that can be removed from an agricultural field or forest plot is limited by various reasons, like preventing erosion, maintaining soil fertility, ecological reasons, etc. During harvesting or collecting biomass pollution (e.g. with soil or stones) needs to be prevented. Secondary and tertiary residues need to be collected on the location where they originate.	Supplier
6	Other pre-treatments that influence feedstock quality	Pre-treatments to be applied to the crop in the field or in the IBLC for the transformation of the raw material.	An improvement in the quality of the raw material or in the resulting product after the transformation process.	Dependent on the production process	Supplier, IBLC
7	Storage	Important in relation to buffering biomass either over a longer period somewhere in the supply chain (e.g. to compensate for seasonal effects of biomass supply from forests and nature area, where it is impossible to harvest year-round) or on the short term just before delivering to the final conversion process. Both relatively dry biomass (e.g. wood) and wet biomass (e.g. grass) can be stored.	Stored and conserved of the materials in optimal conditions for its use when required.	During storage, since biomass is an organic material, whenever its moisture content is higher than 20%, fermentation will occur and this process will lead to heat development. This natural process on the one hand helps to reduce the moisture content but on the other hand it can also have a negative effect generating energy loss, ignition risks and health problems for the operators (related to microorganism growth). When choosing a storage method it is important to take into account handling.	LSP, IBLC
8	Transportation technologies	Technologies used for the transportation of the raw material. Four means of transport are considered: Inland waterway, maritime, rail, and road.	Movement of the material from one point of the logistics chain to another.	Dependent on the transport infrastructure.	Supplier LSP

B) Logistical concepts:

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
9	Biomass size reduction: chipping versus shredding	Both chipping and shredding are processes used to reduce the size of the feedstock. Chippers are better for heavy stalks and large woody materials.	An improvement in the quality of the feedstock (homogeneous), and reduced transport costs because of higher loading rate.	Size of the particle. Depends on the destination of the raw material, e.g. if it going to be used for the manufacture of boards derived from wood, it is necessary to get a chip of higher quality and more homogeneous in size.	Supplier
10	Get a low enough moisture content by natural drying: - date of the harvesting - flip the biomass over the field by ranking	Normally, residual forest biomass presents high moisture content (over 100% in dry base), which raises a series of problems in the conditioning for use for energy purposes. Natural drying is based on taking advantage of favorable environmental conditions to facilitate Dehydration of residues.	Related with the easiness in transport, having an impact in transportation costs.	Pest control of the feedstock; Fire control by self-combustion.	Supplier
11	Pre-treatment (e.g. comminution and densification) integrated with harvesting/collecting versus stand-alone pre-treatment later on in the biomass value chain	An example is the development of the combined harvester, where cutting the stalks with the grain and threshing it to separate the grain from the straw are combined in one machine. In case of biomass harvest from prunings, the integrated collection concept differs from annual crops. Pruning and fruit/olive/grape harvesting is done in two different moments of the crop cycle, and so, the integration of main product harvesting with the harvest of the residue is not possible.	Save one or more extra rides with a machine on the field. Lower overall costs per tonne for the combination of operations. Better biomass quality (e.g. less contamined with soil). Save extra biomass handling. Possibility of direct loading in transport vehicle.	More expensive machine for initial investment. More complex machinery including system with multiple purposes. Heavier machine with needs to be compensated (with larger tires). Slower harvesting rate. Failure in the biomass system may abort the harvest of the main product.	All stakeholders
12	Collecting prunings in bales that will be chipped later on in the value chain versus chipping immediately at the source location	By chipping at the source a higher density of material is transported. This gives less complexity in handling at collection points.	A compaction of the material is achieved given the lower complexity of handling, transportation costs will be lower.	Moisture control; Location of the prunings; Access to the feedstock.	Supplier
13	Application of most efficient equipment	Use of equipment that allows carrying out the processes in the shorter possible time, with the lower costs (energy, people…). The equipment should be applied in all stages of the process (handling, treatment, loading, unloading, transport, conversion…)	A reduction of the general costs of the process.	Ratio Investment/ Profitability.	All stakeholders

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
14	Combination of different biomass feedstock types and quality in one value chain (i.e. residual biomass, energy crops, loose/chipped/pelletized woody biomass)	Combine different types of biomass in different months of the year.	Sharing of storage facilities, conversion technologies and transportation. Cost-efficient logistics.	Feedstock typology.	All stakeholders
15	Optional use of intermediate depots	Network of distributed biomass processing centers (Eranki et al., 2011), that use one or several biomass types to generate uniform feedstock 'commodities'. These 'commodities' are intermediates with consistent physical and chemical characteristics that meet conversion quality targets and at the same time leverage the spatial variability in supply quantities and costs by improving flowability, transportability (bulk density), and stability/storability (dry matter loss reduction).	Standard depots: Primary function improve feedstock stability, storability, flowability, bulk density by creating physically (and chemically) homogeneous feedstock. Quality depot: In addition to the standard function: create on-spec feedstock by actively addressing feedstock quality. In addition to the standard function, create intermediates that meet specific biorefinery needs and reduce processing intensity downstream.	Location driven by feedstock supply, logistical infrastructure, community support, social capital, potential link to existing industry (e.g., agriculture or wood processing), low energy prices.	All stakeholders
16	Decentral biomass conversion to energy carriers to improve transport properties	Conversion of residual biomass into high energy density intermediate energy carriers for heat, electrical power, transportation fuels and chemicals production.	Conversion of biomass feedstock by fast pyrolysis, catalytic pyrolysis or hydrothermal carbonisation to intermediate energy carriers for subsequent use in different applications. It can be utilised either directly in small scale combined heat and power (CHP) plants or in large scale applications for the synthesis of transportation fuels and chemicals.	Dry as well as wet residual biomass and organic waste are used as feedstock for conversion (lignocellulosic materials).	Supplier, IBLC
17	Economic upgrading to marketable bioenergy products (e.g. transportation fuel) in large central plants (due to unit of scale effect and/or synergies)	Upgrading follows a series of extractions and hydrotreatments to remove small acids and phenols, reducing the hydrogen demand in upgrading to transportation fuel. This step is envisaged in refineries profiting of available know-how, infrastructure and co-processing from commercial facilities.	NA	Supply/ demand. Synergies.	All stakeholders

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
18	Trade-off between the use of residual feedstock and energy crops	Energy crops are typically densely planted, high-yielding crop species which are processed to bio-fuel and burnt to generate power. Residual feedstock comes from crops used for feeding both people and animals. It can be used for competitive purposes such as bedding, organic farming, heating purposes (pellets).	NA	Soil	Supplier
19	Transportation straight to the biorefinery versus transportation from the farm (after storage) to the biorefinery	NA	Storage plays a major role allowing for the bio resources to be gathered in convenient facilities until they are exploited in the biorefinery.	Seasonality of resources.	Supplier LSP
20	Integrated biomass pre-processing (e.g. wood chipping and pelletization) at industrial facilities already operating in the territory	NA	NA	NA	IBLC
21	Effect of moisture content on the logistics (e.g. seasoning, transport cost) as well as on biomass processing efficiency at the biorefinery	Wood is usually harvested throughout the year, but mainly consumed in winter. It also requires seasoning in storage in order to lower the moisture content of the fuel. Biomass can be stored either comminuted (as chips or firewood) or uncomminuted (whole trees, stem wood and logging residues). Drying wood in piles by natural air drying is the cheapest method significantly to reduce the moisture content. This is the single most critical quality factor of biomass. It plays a decisive role in all the stages of the supply chain and has even a direct effect on the pricing of the fuel. It also affects the efective heating value of the fuel (Europruning 2.1). In the case of the use of biomass in power plants, the moisture content of the feedstock is an important factor when referring to the boiler efficiency (as it affects fuel heating value and the fluid dynamic phenomenon inside the boiler), electrical consumption of	On a regional level, fuel supply chains have to be optimized in terms of material sources, terminals, transport means, delivery locations, costs and greenhouse gas (GHG) emissions. However, the supply of energy wood is challenging because of high supply costs and rapidly increasing as well as changing demand. Over the last decade, mathematical modelling in forestry started to focus on biomass supply driven by the need to make it more economical. Drying positively affects both transport costs and GHG emissions. It can be concluded that the strategic optimization of wood fuel supply on a regional level can result in a significant profit increase and GHG emissions decrease. Again, the significant impact of pre-drying material in the forest has to be pointed out.	Natural drying of biofuels disposed in a pile is a process conditioned by the air renovation level inside the pile itself, as it is a result from the moisture exchange between the biofuel and the ambient till the equilibrium is achieved. The highest or lowest influence of external ambient conditions on the process depends on various factors which limit the particle contact with the external environment: particle size (depending on climate conditions of the location, chipping would be advisable to achieve higher drying velocities but in other cases is better to store in the uncomminuted format to avoid high deterioration), degree of compaction of the material (achieved naturally and influenced by particle size and moisture content or acquired because of the machinery used during the building process), shape of the pile prismatic or conic, higher or wider) and handling of the pile (forced ventilation through a fan or turning over at certain stages of the process,	Supplier LSP

		the auxiliaries (grinding, pneumatic transport system, etc.) and transportation costs from the harvesting area (decreasing the useful matter for combustion per volume transported).		for instance).	
	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
22	Combination of different transport modes (e.g. trucks/rail/barges)	The traditional method for transporting biomass is road transport. However, alternatives could be transport by rail or by waterway.	The feasibility of multi-modality transport increases in combination with the use of a biomass yard and/or with pre-treatment. Advantages: - enables optimal choice of transport type for each section of the transport route. - for longer transport distances cheaper transport modes (ship or train) can be chosen. Disadvantages: - more handling during transhipments. - higher loading & unloading costs. - not all locations can be reached by alternative transport modalities.	The choice for a certain type of transport is determined by: - Transport distance; - Accessibility.	Supplier LSP
23	Biomass logistic centre - biomass yards	Several types of biomass supplied by different sectors (e.g. agriculture, forestry, nature management) are collected efficiently on a central location (biomass yard) in a region.//The following operations are carried out at the logistics center: (i) drying of round wood (uncovered or covered in piles) – natural drying, and storage; (ii) production of wood chips chipper mounted on truck with crane; (iii) storage of wood chips in the storage house; (iv) drying of wood chips (with hot air); and (v) selling of high quality wood chips.	Centralization of the operations; Exploitation of synergies in terms of facilities, equipment and staff capabilities.	Acceptance of stakeholders. Organization of operations.	All stakeholders
24	Smart logistics and cost-effective transportation	Prediction of quality depending on resource and weather conditions. Farmers, drivers, owners of storage centres and logistic operators are able to enter the system for up-dating. GPS best route is integrated in the smart-box tool to reduce decision making efforts and transport costs.	Optimize environmentally and economically efficient and effective handling of agricultural residues along the whole supply chain.	Collaboration between stakeholders. Technology.	All stakeholders

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
25	Producing separate modular units (big-bags or bales) versus bulk material (hog wood)	Transport with bulk chips allows two options: use big-bags compatible with auto-discharge (telehandler elevates the big-bag above the truck box and then the discharge rope is pulled). Another option is the discharge on the paved soil and subsequent load with a shovel of large volumetric load capacity.	The former system is more compatible with small trucks, since the load and unload time of big-bags is substantial; the latter is more interesting for large volumes. Big-bags are anyway not a system for large scale distribution, but for local consumption, by users preferring to receive big-bags instead bulk material.	The price of a big-bag is considerable respect the 300 kg of biomass contained. Therefore use of big-bags is assumed to be a returnable item.	Supplier LSP
26	Front mounted shredding versus rear towed chipping / baling units (the former avoids tractor to drive over the prunings)	On-field size reduction technologies.	A reduction of the feedstock size.	Size of the particle. Depends on the destination of the raw material, which implies the need for a level of quality and more/ less homogeneous particle size.	Supplier
27	Transport of bulk and packed biomass (big-bags or bales) in moving floor trucks	Two options are feasible: use big-bags compatible with auto-discharge (telehandler elevates the big-bag above the truck box and then the discharge rope is pulled). Another option is the discharge on the paved soil and subsequent load with a shovel of large volumetric load capacity.	The former system is more compatible with small trucks, since the load and unload time of big-bags is substantial; the latter is more interesting for large volumes. Big-bags are anyway not a system for large scale distribution, but for local consumption, by users preferring to receive big-bags instead bulk material.	Distribution volume.	Supplier LSP
28	Mechanised felling of fruit trees versus mechanized cut with a shear	EuroPruning implemented a fifth pilot scale biomass value chain based on the wood of the whole tree, which is removed at the end of the commercial life of a fruit plantation. The whole tree was cut down with an hydraulic shear mounted either in front of an agricultural tractor or a walking excavator.	NA	Trees required a previous preparation prior being fed into a regular forestry chipper with horizontal feed-in system. The preparation consisted in a cut done in the intersection between the main branches with the basal stem to facilitate the feeding in form of a bundle with the claw into the chipper.	Supplier
29	Shear mounted in front of a tractor versus mounted in the arm of a walking excavator	The wood of the whole tree is used in the value chain. This logistical solution is based in a pilot scale biomass value chain implemented in EuroPruning.	The whole tree is cut down with a hydraulic shear mounted either in front of an agricultural tractor or a walking excavator.	Trees require a previous preparation prior being fed into a regular forestry chipper with horizontal feed-in system. The preparation consisted in a cut done in the intersection between the main branches with the basal stem to facilitate the feeding in form of a bundle with the claw into the chipper.	Supplier
30	On field chipping of trees with mobile train (tractor – chipper – trailer) along the row of felled trees	NA	Reduction of the feedstock size prior to transportation.	Previous preparation of the trees needed. The preparation consisted in a cut done in the intersection between the main branches with the basal stem to facilitate the feeding in form of a bundle with the claw into the chipper.	Supplier

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
31	On field utilisation regular agricultural trailers with relevant volumetric capacity (30 m3)	NA	Reduced transport costs because of a higher loading rate.	Accesibility.	Supplier LSP
32	Manual preparation of trees before chipping versus mechanised pruning of trees before chipping	The pre-pruning takes away important parts of the shoots and branches, in order to reduce the manual work to be carried out later on by workers.	Affects the use of machinery for chipping. Trees required a previous preparation prior being fed into a regular forestry chipper with horizontal feed-in system. The preparation consisted in a cut done in the intersection between the main branches with the basal stem to facilitate the feeding in form of a bundle with the claw into the chipper.	Accessibility.	Supplier LSP
33	Manual windrowing of prunes before chipping versus mechanised windrowing of prunes before chipping	Manual windrowing requires the adaptation of the manual pruning work so that the pruning is placed in the centre of rows. Mechanised windrowing can be carried out by integrating windrowers with the harvester.	Preparation of material before harvesting.	Equipment available. Accessibility.	Supplier
34	Integrated harvesting	“In the agricultural sector there is already a long tradition of integrating several operations during the harvesting process. A good example is the development of the combine harvester, where cutting the stem with the grain and threshing it to separate the grain from the straw are combined in one machine. Sometimes this is even combined with baling the straw. In case of biomass harvest from prunings, the integrated collection concept differs from annual crops. Pruning and fruit/olive/grape harvesting is done in two different moments of the crop cycle, and so, the integration of main product harvesting with the harvest of the residue is not possible. Pruning is carried out usually manually with shears or with mechanically assisted tools (electric shears or chainsaws, e.g.), even though there is a trend to execute non-selective mechanised pre-pruning operations”. “Also in the forestry sector integration of chipping with felling is possible in easy terrain, if the soil bearing capacity is good and yarding distances short. In Finland and Sweden	“Advantages: · Save one or more extra rides with a machine on the field. · Lower overall costs per tonne for the combination of operations · Save extra biomass handling · Better biomass quality (e.g. less contaminated with soil, ...) · Possibility of direct loading in transport vehicle. Disadvantages: · More expensive machine for initial investment · More complex machinery including system with multiple purposes · Heavier machine which needs to be compensated (with larger tires) to avoid soil compaction · Slower harvesting rate · Failure in the biomass system may abort the harvest of the main product” (S2Biom)	Equipment available.	Supplier

		chipping in the forest is no more practised due to logistical challenges and high costs (Routa et al., 2012)".			
	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
35	Coupled vs. de-coupled logistics for wood chip production	"The coupled biomass supply chains are defined by those where the chipper (primarily mobile truck-mounted chipper or a chipper on a forwarder) is either directly or indirectly coupled with the transporting activity. In these operations, the chipper operates in or near the stand along forest roads and loads directly into a truck or container for transporting wood chips to a terminal or heat plant facility". "The de-coupled biomass supply chains are defined by those where the chipping activity and the transportation activity are separated and function independently of each other. These decoupled supply chains are typical for conditions where accessibility becomes an issue, steep terrain, mountainous conditions and particularly inaccessible for large trucks. In these hillside and mountain operations it is common to have a landing pad inaccessible to heavy road vehicles, and connected to a proper roadside landing by a low-standard trail, only accessible with tractors, forwarders and light tree-axle trucks". (INFRES D3.3)	The theoretical advantage of chipping on the pad is that chips can make for a heavier payload compared to loose residues, while its disadvantage is that bigger and more productive chippers can be used at the roadside landing. However, this is a theoretical statement, valid only to a point, where one can actually mount an industrial chipper on an all-terrain vehicle and take it to the pad. Under ideal conditions where the terrain and accessibility are not constraining factors, generally coupled supply chains offer greater cost efficiencies given the ability to increase load density and thereby cost efficiency early in the supply chain (in the stand or forest road). In addition, these coupled systems offer fewer steps and less equipment to purchase, relocate and operate. However, there are many areas where ideal conditions do not exist and some form of de-coupling must occur. Under these conditions it is important to understand the parameters that influence production efficiency in the de-coupled environment.	What is optimal depends on many factors, including: the distance to be covered, the type of chipper one can take to the pad, the payload that can be moved by the forwarding units with the different products (i.e. un-comminuted wood and chips), the speed that can be reached by the forwarding units and finally the interactive delays inherent to each system (Stampfer & Kanzian 2006, Holzleitner et al. 2013).	Supplier
36	Multi-tree handling	Harvesting heads possess extra arms to enable the head to handle two or more trees at a time. The replacement of delimbing knives with smooth bars allows leaving the needle nutrients on the forest floor whilst maximising the energy wood harvested.	Preparatation of bundles. The bundles are easy to handle then being re-loaded, dry out during storage, and the comminution can effectively be done using large scale systems.	Diameter of the tree. Number of handled trees per crane cycle. The operational cost of the bundle harvester is higher than for conventional harvesters, therefore the systems suitability is dependent on tree size harvested and transportation distances. Terrain.	Suppliers LSP

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
37	Two-stage grinding	Both logging residues and stumps are bulky materials leading to low load utilisation on trucks transporting these materials to the heating plants. One way to remedy this problem is to comminute the material on the landing, as this will increase the density and homogeneity of the material (Björheden 2008).	This enables the use of chip trucks that, due to their lighter weight, have a higher legal pay load than trucks for loose residues and are able to fully utilise that load weight. Chipping residues at the landing results in the lowest total costs when the chips are transported medium to long distances, even though the chipping can be done more efficiently at a plant or at a terminal using a large stationary machine. Similarly, comminution of stumps at the landing has the potential to increase load weights and thus reduce transport costs (von Hofsten and Granlund 2010). By grinding stumps to a coarse fraction, e.g. a target size of 200 mm or more, it is possible to sieve the material after grinding and get rid of a large proportion of the soil contaminants that reduce the heating value of the stumps (Fogdestam et. al. 2012).	Machinery	Suppliers LSP
38	Single product harvesting versus integrated harvesting where a combination of products is obtained	NA	The latter allows the delivery of different products at the same time, and different transformation processes are applied.	NA	Supplier LSP
39	Integration of different biomass value chains	E.g. Integrated harvesting of roundwood, residues & stumps; integrated harvesting of pulpwood& energy wood.	Different types of products are delivered at the same time.	NA	All stakeholders

	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
40	Chipping at the roadside versus chipping at a terminal	"The most common and in many cases most cost efficient chipping operation is chipping at the roadside. This method is very common in most of the European countries and enables, in most circumstances, an efficient operations. Chipping operations at a terminal are suitable when larger amounts of material is handled and in case the chipping operation can be done more effectively at such a terminal. The material is then brought to the terminal as whole trees where the comminution is done efficiently with either truck-mounted machines or electric or diesel powered crushers or grinders. The raw material transportation distance to the terminal as well as chip transportation to the plant are crucial factors that have to be taken into account. Terminals are also used in case the material is reloaded to other transportation options such as railways or ships. There are three possibilities for terminal chipping: 1. The chipping terminal is at a harbor with loading possibilities to ships 2. The chipping terminal is at a loading point for trains 3. The chipping terminal with loading point for trucks".	See "What is it" section	The raw material transportation distance to the terminal as well as chip transportation to the plant are crucial factors that have to be taken into account.	Suppliers LSP
41	European/world-wide biomass value chains based on standardized biocommodities (e.g. wood pellets, ethanol or pyrolysis oil) versus regional biomass value chains based on locally sourced 'raw' biomass	This concept was provided in S2Biom project. The LocaGIStics tool was used to further detail the biomass value chain of one of different possible solutions (on a regional level). In addition, it was used a quality check of the biomass collection, capacity, and therefore the validity of the chosen location. Some logistical concepts can be tested: (i) mixing different biomass types; (ii) applying pretreatment technology to densify the material in order to lower the transportation costs and increase handling properties; (iii) switching between different types of	Easier to trade (inter)nationally. Better transportability. Increased storability through stability. Better quality that can be measured.	Sufficient market volume is needed. Higher pretreatment costs need to be compensated (e.g. by lower transportation costs).	All stakeholders

		transport means; and (iv) direct delivery to a power plant vs putting an intermediate collection point in the value chain. The BeWhere tool was used to assess EU- and country-level biomass value chain.			
	Name logistical solution	What is it/ how does it work?	What effect is achieved?	Conditions	Main stakeholder involved
42	'Intensive' pre-treatments like (catalytic-) pyrolysis, hydrothermal carbonisation, torrefaction in decentral plants with feedstock capacities up to several 100,000 t/a, efficient energy carrier transport (by railway) to central plants for upgrading to final energy product	The feedstock demand of the envisaged decentral catalytic and fast pyrolisis plants is in the order of several 100,000 tonnes per year. The produced intermediate bioenergy carriers biosyncrude (Fast Pyrolysis), bio-oil (Catalytic Fast Pyrolysis) and biocoal (Hydrothermal Carbonisation) are characterised by an increased energy concentration (up to 300 %) and improved handling (e.g. pumpable), enabling efficient long distance railway transport to central upgrading plants. These may have a large size (several Giga-Watts) or they are integrated in refineries and they profit of scale-of-unti-effects (production costs reduction per unit with increasing capacity) or synergies.	This procurement chain is compatible to forest residues from thinning and logging as well as for woody biomass from land management and roadside clearing.	The high feedstock demand of decentral plants requires the utilisation of the most efficient technologies for feedstock procurement typically operated by dedicated subcontractors.	All stakeholders
43	Many small-scale conversion plants versus only one large-scale conversion plant to meet product demand	The choice for the scale of the conversion leads to either shorter transport distances or longer transport distances.	Advantages: - short transport distance. Disadvantages: - higher conversion costs per unit.	According to the scale-of-unit-effect, the production costs of an item decrease with the plant capacity. The optimum between transport efforts and production costs depends on the relative importance of the two cost items transport and conversion. the processing costs of a pellet mill are relatively low and the wood chip transport has a higher contribution to the overall costs compared to a synfuel plant.	All stakeholders

ANNEX D. SUBDIVISION OF LOGISTICAL COMPONENTS

The logistical components mentioned in Annex C. can be subdivided which is shown below:

1. Compaction / densification[42]
   1.1. Briquetting
   1.2. Centrifugation
   1.3. Pelletizing
   1.4. Bundling

2. Comminution (size reduction)
   2.1. Chipping
   2.2. Chunking
   2.3. Crushing
   2.4. Debarking
   2.5. Grinding
   2.6. Milling
   2.7. Screening
   2.8. Shredding

3. Drying
   3.1. Active/ forced drying (artificial)
      - Belt dryer
      - Dryer equipment
      - Heating with residual heat
      - Rotatory drum dryer
      - Ventilation with fans or blowers
   3.2. Passive drying (natural)
      - Inside in barn
      - Outside covered
      - Outside in open air and sun

[42] The categorization from 1 to 8 of the logistical components has been obtained from D3.1 of the S2Biom Project

4. Feedstock handling
    4.1. Bucket grab
    4.2. Conveyor
        - Belt
        - Bucket
        - Chain
        - Screw
    4.3. Crane
        - Wood crane
    4.4. Front loader
    4.5. Gravity feed
    4.6. Intake system
    4.7. Loading/ unloading system
        - Ship
        - Train
        - Truck
    4.8. Pneumatic blower
    4.9. Pumped flow
    4.10. Screw type auger feed
    4.11. Shovel
    4.12. Squeeze loader
    4.13. Stacker
    4.14. Telehandler
    4.15. Tipping platform (raising front trailer)
    4.16. Deleafer

5. Harvesting/ collection
    Agriculture
    5.1. Bale wrapper
    5.2. Baling
        - Round bales
        - Square bales
    5.3. Bio flail mulcher
    5.4. Chopping
    5.5. Cutter
    5.6. Forage harvester
    5.7. In field hauling
    5.8. Loading
    5.9. Mower
    5.10. Mower conditioner
    5.11. Raking
    5.12. SRC harvester

- Chips
- Whole stem

5.13. Sugar cane harvester

Forestry

5.14. Baling
5.15. Cable yarding
5.16. Chipping
5.17. Forwarding
5.18. Harvesting

- Manual
- Mechanised

5.19. Road transport
5.20. Skidding
5.21. Stump extraction

Landscape management

5.22. Pruning
5.23. Whole tree harvesting
5.24. Piles of prunings

6. Other pre-treatments that influence feedstock quality

6.1. Biological pre-treatments (fungi)
6.2. Blending
6.3. Conservation (e.g. silage)
6.4. De-watering
6.5. Separation (e.g. S/L)
6.6. Sieving
6.7. Sorting out metal with a magnet
6.8. Ultrasonic pre-treatment
6.9. Washing
6.10. Torrefaction and hydrothermal upgrading (HTU)

7. Storage

7.1. Indoors bunker
7.2. Indoors container
7.3. Indoors silo
7.4. Indoors tank
7.5. Outdoors bunker – covered
7.6. Outdoors bunker – uncovered
7.7. Outdoors container – covered
7.8. Outdoors container – uncovered
7.9. Outdoors on asphalt - big bag
7.10. Outdoors on asphalt - ensiled
7.11. Outdoors on asphalt - pile - covered

7.12. Outdoors on asphalt - pile - uncovered
7.13. Outdoors on asphalt - stack - covered
7.14. Outdoors on asphalt - stack - uncovered
7.15. Outdoors on bare soil - big bag
7.16. Outdoors on bare soil - ensiled
7.17. Outdoors on bare soil - pile -covered
7.18. Outdoors on bare soil - pile -uncovered
7.19. Outdoors on bare soil - stack -uncovered
7.20. Outdoors on bare soil - stack –covered
7.21. Outdoors on bearers - big bag
7.22. Outdoors on bearers - ensiled
7.23. Outdoors on bearers - pile - covered
7.24. Outdoors on bearers - pile -uncovered
7.25. Outdoors on bearers - stack -covered
7.26. Outdoors on bearers - stack -uncovered
7.27. Outdoors on concrete floor - big bag
7.28. Outdoors on concrete floor - ensiled
7.29. Outdoors on concrete floor - pile -covered
7.30. Outdoors on concrete floor - pile -uncovered
7.31. Outdoors on concrete floor - stack -covered
7.32. Outdoors on concrete floor - stack -uncovered
7.33. Outdoors silo
7.34. Outdoors tank

8. Transportation technologies

8.1. Inland waterway

- Deck barge
- Dry bulk cargo barge
- Hopper barge
- Tug-boat

8.2. Maritime

- Handymax bulk carrier
- Handysize bulk carrier
- Panamax bulk carrier

8.3. Rail

- Closed bulk wagon
- Closed wagon with rolling roof
- Open bulk wagon
- Open wagon
- Wagon suitable for 3 TEU containers
- Wagon suitable for Wood Tainersystem

8.4. Road

- Bulk van/chip van
- Farm trailer
- Flatbed trailer
- Log trailer
- Open-end bulk van
- Removable cargo container lorry/trailer
- Tanker, grain or animal feed vehicle
- Timber haulage wagon
- Tipper trailer or truck
- Walking floor trailer/self-unloading floor/live floor