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**Deliverable 2.2**

Title:	
<b>TOOLS (BEWHERE, LOCAGISTICS AND BIOLOCO) ADAPTED TO BE TESTED IN THE SELECTED CASE STUDIES</b>	
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## Table of Content

1	Introduction .....	5
1.1	Introduction and context .....	5
1.2	Content of this deliverable.....	5
2	Overview of tools considered and input-output relations .....	6
2.1	Introduction .....	6
2.2	Integration of tools .....	7
2.3	Integration LocaGISTICS2.0 - BioloCo .....	10
3.	Adoption BeWhere.....	14
3.1	Introduction .....	14
3.2	Brief description of BeWhere.....	14
3.3	Main changes of BeWhere .....	15
4.	Adoption LocaGISTICS2.0 .....	17
4.1	Introduction .....	17
4.2	Main changes of LocaGISTICS .....	17
5.	Adoption of BioloCo tool .....	21
5.1	Introduction .....	21
5.2	Brief description of BioloCo .....	21
5.3	Main changes of the BioloCo electricity & heat version .....	25
5.4	Main changes of the BioloCo biorefinery version .....	26
5.5	Expanding the set of standard data .....	27
6.	Conclusions .....	29
	References .....	30
	Annex A. Standard data collected for BioloCo .....	32
	A1. Collected data on forced drying .....	32
	A2. Collected data on pelletization .....	33
	A3. Collected data on handling .....	34
	A4. Collected data on storage .....	36



# 1 Introduction

## 1.1 Introduction and context

The main objective of the BECOOL (EU) and BioVALUE (Brazil) projects is to strengthen EU-Brazil cooperation on advanced lignocellulosic biofuels. The ultimate objective is providing solutions for highly efficient and sustainable value chains encompassing the whole range of activities from biomass production and diversification to logistics and conversion pathways.

In Work Package 2 (WP2) of BECOOL the logistical design and assessment of value chains is addressed. In this WP2 we work with three logistical assessment tools: BeWhere (national level), LocaGISTICS and BioloCo (both regional level). All three tools were already developed before the BECOOL project started, but a lot of work was done to adopt these tools further to the chain designs and assessment in BECOOL to be applied to the three different case studies selected in WP5 (Integrated assessment).

This deliverable presents how the logistical assessment tools have been further adapted to the need of BECOOL. Attention is paid to the functionalities added to each of the tools and to the input-output relations created between the models. The three logistical assessment tools needed to be tuned and refined with the specific logistic chain designs and evaluation needs developed in the project with other WPs. Adaptations of the tools were also determined by the specific case studies situations.

## 1.2 Content of this deliverable

In the next chapter, first a brief overview is given of the main characteristics of the three logistical assessment tools in a comparative way. This is followed by a description of how the tools were further integrated for the purpose of the assessment needs in the BECOOL project. Attention is not only paid to the three logistical assessment tools developed further in WP2 but also to the GLOBIOM tool that is included in the model chain and used to make the final wider environmental and economic impact assessments in WP5, for evaluating the implementation of advanced biofuel production chains in the EU. Chapter 2 ends with an overview of the integrated modelling framework that was specifically developed in BECOOL.

In the chapters 3, 4 and 5 the three tools are described separately in terms of their functionalities and input needs and output, as specifically developed within the framework of the BECOOL project activities.

Chapter 6 delineates some early conclusions and a discussion of further activities planned for the application of the adapted tools in the three case studies situations and the wider sustainability assessment of advanced biofuel chains designed and developed in the BECOOL project.

## 2 Overview of tools considered and input-output relations

### 2.1 Introduction

The tools taken further in WP2 are three tools that address the logistical organisation of large-scale biomass delivery to a conversion installation. They take account of the spatial dispersion of the biomass and support the identification of best chain set-ups in relation to economic and GHG efficiency. The first tool is BeWhere developed by IIASA<sup>1</sup> (Leduc et al., 2008 and 2010). It is a spatial, techno-economic optimization model. It has been first developed for the identification of optimal locations for siting second-generation production plants in combination with reaching renewable energy targets, minimizing cost and/or maximizing GHG mitigation. It was developed over time for diverse applications (e.g., biogas, Carbon Capture and Storage (CCS)), many types of biomass feedstocks over many countries and regions (e.g., European level) (Wetterlund et al., 2013).

*Table 2.1 Comparison of the three logistical assessment tools.*

Aspect	BeWhere	BioloCo	LocaGIStics
Calculation method	Optimization	Optimization	Simulation
Geographical level	National	Regional	Regional/local
Addressed Stakeholder	Policy maker	Project developer	Project developer
Biomass data detail	Rough grid	Medium grid	Finer grid
Purpose	Optimisation of the possible number of production plants and their geographic positions in a country	Optimisation of the biomass supply chain of a specifically planned production plant with one or more pre-fixed position options in a region	Detailed local simulation of the biomass supply chain of a production plant with a flexible position

BioloCo (Biomass logistics computer optimization) is the oldest model; it was already developed around the year 2000 (Erbrink, 2000). Originally, BioloCo was developed for the optimization of biomass value chains specifically aimed at the production of bioenergy, and the model was updated several times during the following years adding new functionality and applying it to wider biomass uses in biorefinery chains. BioloCo is an optimisation model that calculates the optimal biomass value chain solutions within certain constraints, such as biomass types, transport types, storage facilities, pre-treatment methods and conversion techniques.

<sup>1</sup> [www.iiasa.ac.at/bewhere](http://www.iiasa.ac.at/bewhere)

The optimization is based on a single chosen optimization criterion (either financial, energetic or emission) or on a combination of these single optimization criteria (using goal programming).

LocaGIStics was developed in the S2BIOM project (Annevelink et al., 2017), and is a regional simulation tool aimed at designing and reviewing different biomass delivery chain solutions. The tool supports the user to design optimal biomass supply chains and networks at regional level and analyze in a comparative way (for different biomass supply chains) the spatial implications and the environmental and economic performance. The tool was specifically developed to support regional and local stakeholders to review options, to develop their bio-based economy and to make use of sustainable local biomass resources. The scale of assessment can be as detailed as data allow in the case studies for which the tool is applied.

Global Biosphere Management (GLOBIOM<sup>2</sup>) model (Havlik et al., 2014) is a global recursive dynamic Partial Equilibrium model of the forest and agricultural sectors, where economic optimization is based on spatial equilibrium modelling (Takayama and Judge, 1971). The model projects developments on the forestry and agricultural markets, international trade, impacts on land use, and GHG emissions and removals for the Agriculture, Forestry, and Other Land Use sector (AFOLU).

In WP5 of the project the GLOBIOM model is used to assess potential environmental and land use consequences generated by a potential large-scale uptake of advanced biofuel value chains in the EU. The assessment will indicate the impacts of the chosen value chains on aspects such as land use change, biodiversity, LULUCF emissions, trade, and employment. The assessment with GLOBIOM will be performed on the level of EU Member States. For this assessment input-output relations are created between GLOBIOM model and the BeWhere tool used and further developed in WP2.

## 2.2 Integration of tools

The integrated assessments of optimal logistical solutions and the wider socio-economic and environmental impacts of large-scale uptake of the advanced biofuel solutions developed in BECOOL will need to be performed through the use of these four models which are linked through input-output relations as described in the BECOOL model framework (see Figure 2.1).

- The model chain starts with the GLOBIOM model that computes and provides input to the BeWhere tool in terms of biomass potentials based on land availability for dedicated biomass production in a certain region (e.g. NUTS2), year and scenario combination. The regional biomass potentials are complemented by roadside spatially explicit supply costs and related GHG emissions which are also provided back to BeWhere.
- BeWhere uses this cost-supply potentials of biomass as input for finding optimal supply locations in European countries and to identify best locations to site new advanced biofuel production plants, given pre-set targets for advanced fuel demand and GHG mitigation. The solutions of BeWhere are then translated in downscaled NUTS2 cost supply curves for advanced biofuels including the logistics and conversion costs and emissions. These are then given back from BeWhere to GLOBIOM which can use them for adapting the product conversion pathway efficiencies and supply costs to the ones in BeWhere. Accordingly, GLOBIOM will perform the final assessment of land use needs for filling the

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<sup>2</sup> <http://www.globiom.org/>

national biofuel demands and consequential assessment of impacts, consistently with BeWhere. Several iterations can take place between BeWhere and GLOBIOM exchanging further the cost-supply cost and GHG emissions levels at every time step for more optimal solutions.

- The advanced biofuel plant locations sited in BeWhere in a certain region in the EU can be delivered as input to the LocaGISStics model. This information from BeWhere should consist of characteristics of the conversion plant (size, efficiency), yearly biomass demand and biomass sourcing area.
- In LocaGISStics, the location of the conversion plants from BeWhere are simulated for different logistic chain set-ups, with direct biomass sourcing and decentral sourcing through one or more intermediate collection points/biomass yard locations. LocaGISStics also enables the assessment to take into account higher resolution data on biomass availability and local factors such as detailed road networks, spatial and environmental constraints which cannot be taken into account at such detailed level in BeWhere. The solutions generated in the focus region by LocaGISStics can be compared to the BeWhere solutions. It can then be reviewed whether there is a need to adjust the chain set-ups in BeWhere resulting from the detailed regional simulation with LocaGISStics.
- The biomass chain solution(s) generated in BeWhere and also in LocaGISStics are also input into the BioloCo model. Input is provided only in terms of biomass cost supply per large spatial grid. Biomass supply chains can then be modelled in BioloCo by means of a network structure, where “nodes” correspond with source locations, collection sites, or conversion sites and where “arcs” correspond with transport routes. Pre-treatments are performed at the beginning or the end of an arc. The simulation in this network structure helps to identify the optimal chain organisation in terms of cost and GHG saving. The result of this simulation can then be compared with the chain set-ups identified in LocaGISStics and BeWhere. It can then be reviewed whether there is a need to re-run the chain solutions again in the LocaGISStics and/or BeWhere model taking the differences in chain set-up.



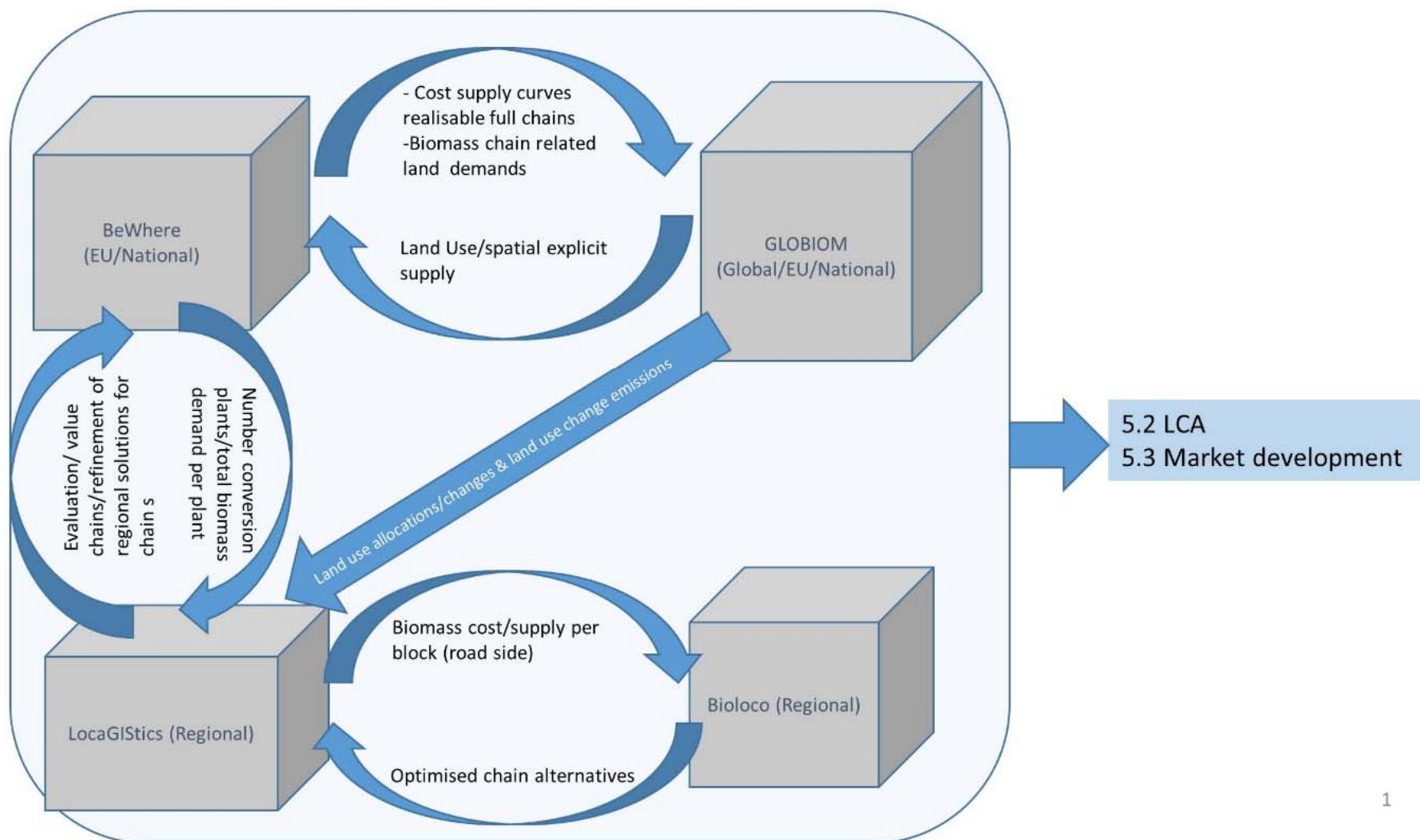


Figure 2.1 WP 2 and 5 Tool interaction

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No. 744821

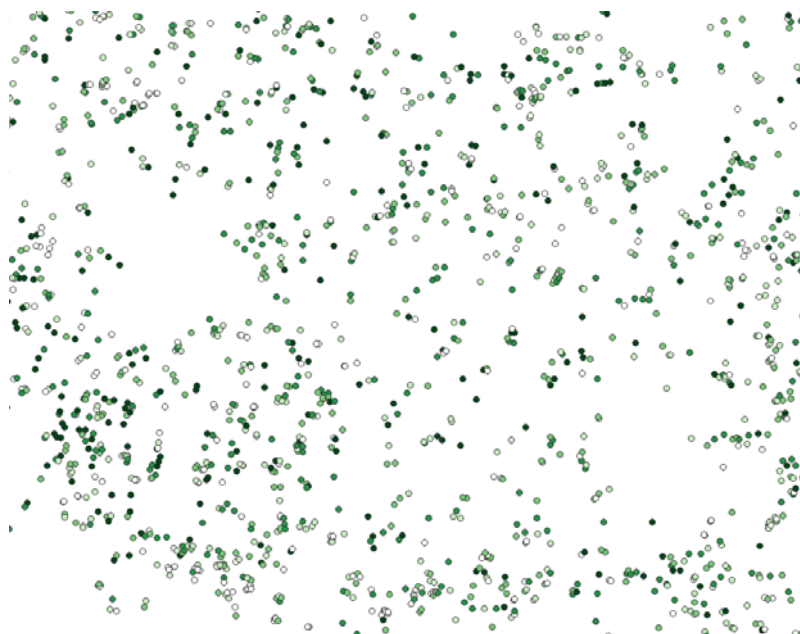
### 2.3 Integration LocaGISStics2.0 - Biolooco

The tools LocaGISStics2.0 and Biolooco need to be integrated in BECOOL. The strength of LocaGISStics2.0 is that it can generate location specific feedstock supply data, which are needed to describe the (limited amount of) sources in the supply chain network in Biolooco.

LocaGISStics2.0 can generate quantities of a specific biomass feedstock per source (parcel or raster) and repeat that for all the different feedstock types in that source. LocaGISStics2.0 can also generate the transport distance from each source point towards the next point in the value chain. For that purpose the exact positions of all the (non-feedstock) points further-on in the value chain can be chosen on the GIS map. Such a next point could be e.g. an Intermediate Collection Point (ICP) or the Final Conversion Point (FCP).

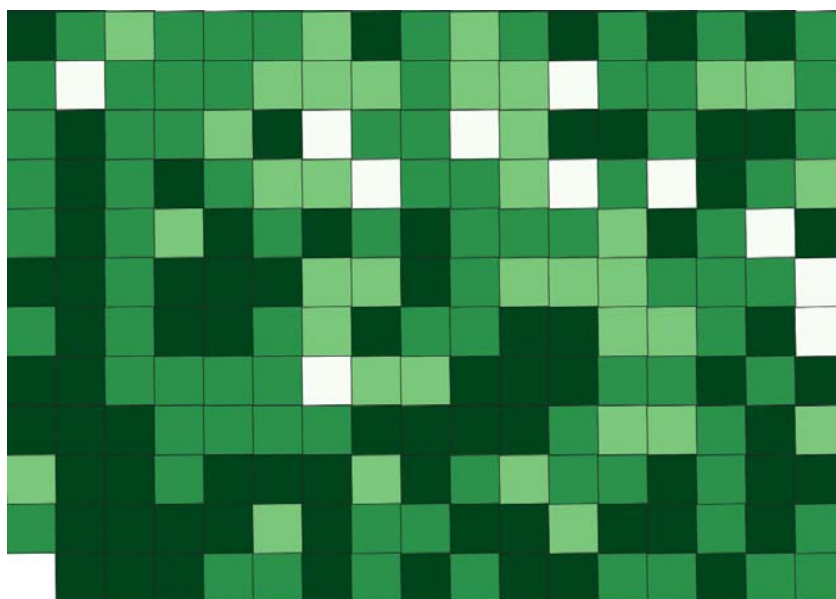
There are two main ways to model the feedstocks in source locations on a GIS map in LocaGISStics2.0:

- an overview of the actual agricultural fields in the area (Figure 2.2), with the total yield per year and per parcel of the specific crop that is grown or which can be grown (new energy crops) on the field (or the residues that can be collected from the field, like straw);



*Figure 2.2 Centroids of parcels colored according to available amount of feedstock for studies using data on biomass availability at agricultural parcel level.*

- a raster structure with a combination of all the agricultural fields within standard grid cells (e.g. 2.5x2.5 km; Figure 2.3), containing the total yield per year of all the agricultural fields of a specific crop (or residue) in the specific grid cell.



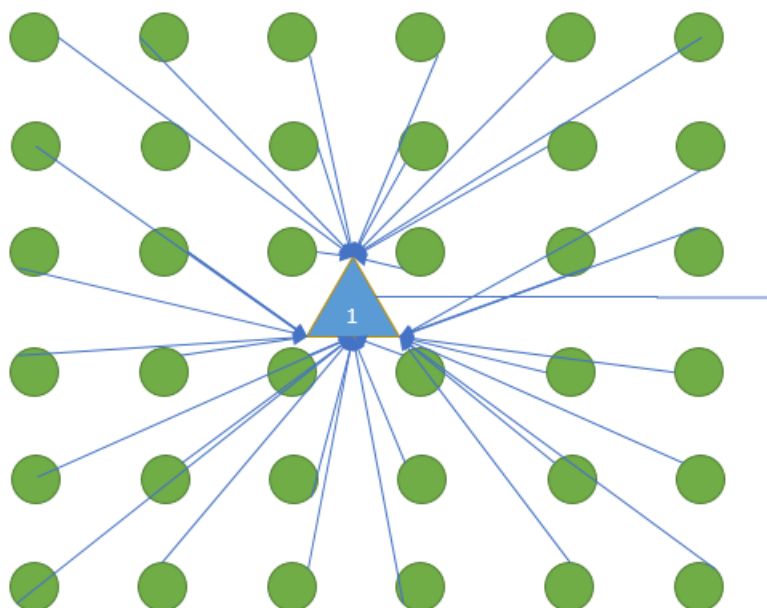
*Figure 2.3 Aggregated amounts of feedstock to raster cells can also be used as input to LocaGISTics.*

Afterwards, these available feedstocks that are modelled in LocaGISTics2.0 need to be translated to a limited number of individual feedstock sources for BioloCo (around 100 source locations is still workable). This could be done in several ways, for the first LocaGISTics2.0 modelling option:

- each field could be a source, with its own specific transport distance; however this would give too many sources in BioloCo, and the optimization model would not be able to find a solution because of the large size of the network;
- a combination of a certain number of fields could be a source (e.g. with a minimum total amount of feedstock), with an average transport distance; this would reduce the number of sources; if that reduction is sufficient depends on the amount of feedstock that is combined.

For the second modelling option there are also several ways:

- each grid cell could be a source, with its own specific transport distance; however depending on the size of the grid cell, this would still give too many sources and the optimization model would not be able to find a solution because of the size of the network;
- larger grid cells (which is the same as aggregating several smaller grid cells to one big grid cell) could be used to reduce the number of sources in BioloCo. This is indicated in Figure 2.4.

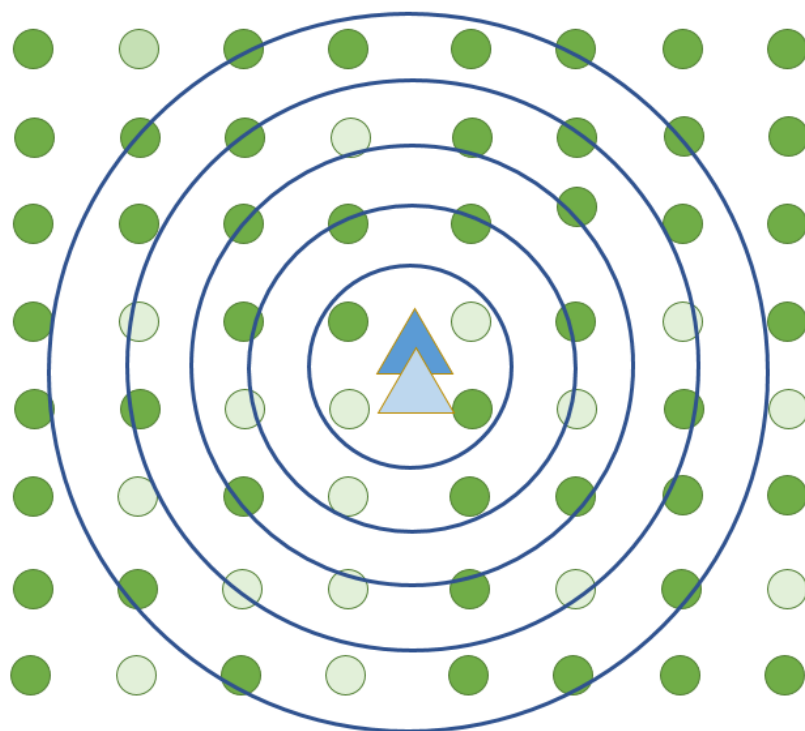


*Figure 2.4 Source of biomass feedstocks per grid cell (second modeling option).*

Finally, there is a way that could be used for both types of modelling options in LocaGISTisc2.0:

- draw a limited number of circles around the next point in the value chain (e.g. 0-5 km, 5-10 km, etc.), and make a combination of all (parts of) parcels or grid cells that lie within the circle. This is indicated in Figure 2.5.

Besides these location specific feedstock data, it will also be necessary to synchronize the other data that are used by both LocaGISTisc2.0 and Biolooco, using a specific data exchange table to transfer the information, e.g. regarding biomass (density, moisture content, cost, etc.), means of transport (capacity, costs, etc.), pre-treatment options and conversion processes. However, this can be done relatively easy, and does not require further description in this section.



*Figure 2.5. Source biomass feedstocks per circle, containing different amounts of biomass.*

### 3. Adoption BeWhere

#### 3.1 Introduction

The BeWhere model ([www.iiasa.ac.at/bewhere](http://www.iiasa.ac.at/bewhere)) is a spatial, techno-economic optimization model. It has been first developed for the identification of the optimal location of the second-generation production plants at the country level (Leduc et al., 2008). It has been developed over time for diverse applications (e.g., biogas, CO<sub>2</sub> capture and use) (Patrizio et al., 2015; Patrizio et al., 2018), many feedstock (e.g., woody biomass, algae, municipal waste) (Leduc et al., 2010; Slegers et al., 2015; Wetterlund et al., 2013) over many countries and regions (e.g., European level) (Wetterlund et al., 2013). BeWhere will be applied in the BECOOL project at the European level.

#### 3.2 Brief description of BeWhere

The BeWhere model calculates the cost and emissions of the supply chain which includes and is limited to (1) feedstock production and collection, (2) feedstock transport to the intermediary pre-process plant and (3) further to the production plant for the final process, (4) and finally the distribution of the final commodity to the demand points. The production of the second-generation biofuel will be compared to the conventional fossil fuels in respect with costs and emissions. To reach competition, subsidies or carbon taxes can also be accounted for in the model.

BeWhere is based on the minimization of the cost for the supply chain, which is defined as:

$$[\text{supply chain cost} + (\text{supply chain emission}) \cdot (\text{carbon cost})]$$

The model optimizes the number of production plants that will operate for each time step. Based on the objective function defined above, the model optimizes the following key outputs:

- (1) Optimal locations of the production plants
- (2) Optimal technology of the production plants
- (3) Optimal capacity of the production plants
- (4) Optimal number of production plants

From these key outputs, the flows of feedstock are optimized, and thus pinpointing the origin and quantity of the feedstock. Moreover, all costs and emissions of each segment of the supply chain can be identified. The IIASA GLOBIOM model provides land use potentials for biomass to BeWhere under different developments of future land uses. BeWhere returns as feedback to GLOBIOM specific cost supply curves and land demand in function of locations and sizes of production plants. This exchange between BeWhere and GLOBIOM would ensure the consistency of WP2 results and WP5 assessments.

The main improvement of the soft-linkage of the BeWhere model will be realized with the LocaGISStics model as presented below.

### 3.3 Main changes of BeWhere

To prepare BeWhere for this project, we improved the soft link with the LocaGISStics model. The BeWhere model is first run at the European level at a 40\*40 km<sup>2</sup> spatial grid resolution. The results from BeWhere will provide the main technological direction that could optimally be adopted at the country level, based on a European approach for the scenarios identified. The LocaGISStics model will use the information derived from BeWhere for the number of conversion plants and capacities as a starting point for the resolution of the problem. The BeWhere model will be run for specified case studies which are of interest and of high potential for the production of second-generation biofuel.

We are then facing two cases:

- (1) the results from the LocaGISStics model present a solution that is competitive in terms of cost and promising in respect with the emission reduction of the production. The results are then robust.
- (2) the runs from the LocaGISStics model cannot reach to a solution or differ to a large extent from the ones provided by BeWhere. The BeWhere model then will run again the scenarios with improved constraints. LocaGISStics model then will provide detailed information back to BeWhere on the biomass availability, usage and other relevant information that causes divergence in the solutions. BeWhere will run again the scenarios with the new sets of input or constraints, until both models agree on a convergence of the results.

The sequences are presented in Figure 3.1.

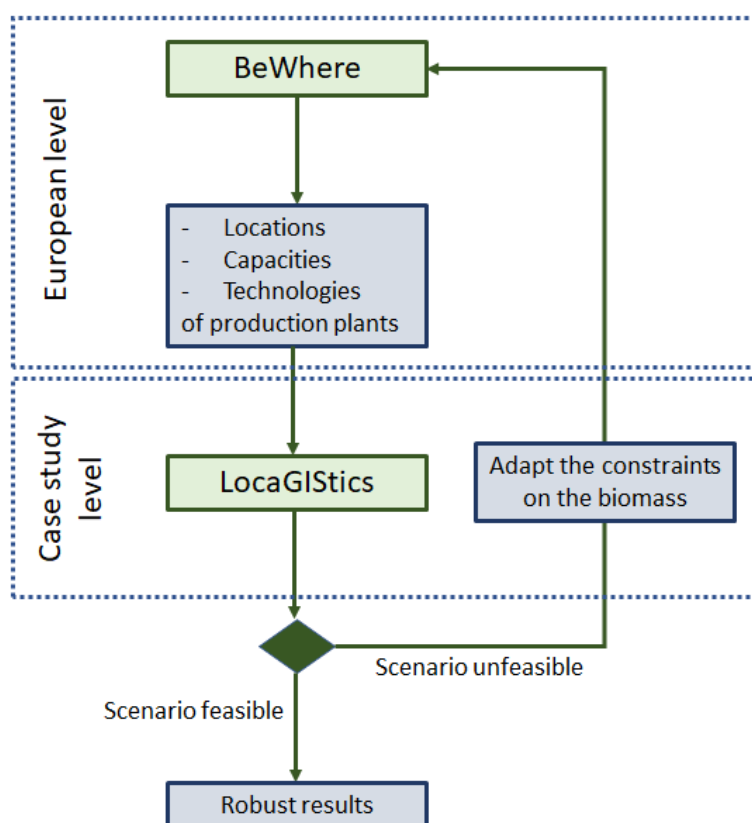


Figure 3.1 Illustration of the soft link between BeWhere and LocaGISStics models.

The possible technologies that BeWhere will consider in the analyses are studied in WP3 and WP4 and are extensively described in Deliverable 2.3.

Based on a large amount of technical options, the model will identify the most promising ones per region/country, based on the local infrastructure, policy already in place and potential incentives that could be implemented above it.



## 4. Adoption LocaGIStics2.0

### 4.1 Introduction

LocaGIStics is a regional biomass supply chain assessment tool that simulates the supply of biomass from the fields to a conversion plant. It consists of a network of modules that can be connected to form a complete biomass supply chain. Each module represents an operation or process (e.g. transport, drying, or harvesting) and is independently constructed with a set of inputs and outputs. Costs, energy use, and GHG emission common to all operations and processes are gathered into individual modules as well. As the LocaGIStics tool is still under construction, these modules (i.e., the supply chain cost, energy use, GHG emission modules) were first constructed in an Excel spreadsheet and imported to the model. The same is true for the biomass production module which is simulated using CERES-EGC model but can also be obtained from other models (e.g. GLOBIOM) and then imported to the LocaGIStics for further mapping and assessments.

In the LocaGIStics tool, biomass moves from one module to the next one through a connector. The strength of LocaGIStics is its flexibility and ability to model multiple types of feedstock and conversion processes, and its attention for discrete logistic process details. It can accommodate other models such as CERES and supply chain modules built outside the LocaGIStics. Its geospatial features allow it to determine the biomass used and transport distance required, based on the biomass availability maps. The tool handles both single and multi -modes of transport and can help the user to design and analyse a diversity of delivery chains. Assessment of costs, energy use and GHG emissions are done in excel ‘playsheets’ and then included again in the spatial part of LocaGIStics.

### 4.2 Main changes of LocaGIStics

The first version of the locaGIStics model was developed as a GIS tool in the ME4 project ‘Integrated framework to assess spatial and related implications of increased implementation of biomass delivery chains’. It was then further developed in the S2BIOM project into an open source internet tool. The spatial assessment module was developed in PostGIS and visualisation via GeoServer. The data management was a PostgreSQL application. Every calculation and visualisation had to be programmed before hand which made the system very inflexible and it became too time consuming to add new functionalities.

It was therefore decided to rebuild the LocaGIStics model as part of the BECOOL activities as a stand-alone-version enabling design and evaluation of more complex biomass delivery chains and more flexibility in functionalities and spatial analysis.

The LocaGIStics model now consists of two parts, the spatial part (in QGIS) and the non-spatial part (in Excel) (see Figure 4.1). The results of the spatial assessment are exported to the nonspatial part of LocaGIStics, the “playsheet”, where the effects of different scenarios can be analysed in detail.

Spatial part (QGIS):

- Biomass feedstock types and amounts are taken from a polygon layer, either a fishnet or individual parcels (see Figure 4.2).

- Each feedstock location (polygon) gets a unique identifier (uuid) to be able to trace back from which parcels/fishnet polygons biomass feedstock were obtained.

Non spatial part (Excel “playsheet”) (Figure 4.3):

- Optimal feedstock collection was formerly done only by minimizing the transport distances (costs) . The updated version has been extended to support minimizing on energy and GHG emissions as well.
- Some graphing of results is added in the playsheet as an additional functionality (Figure 4.4)

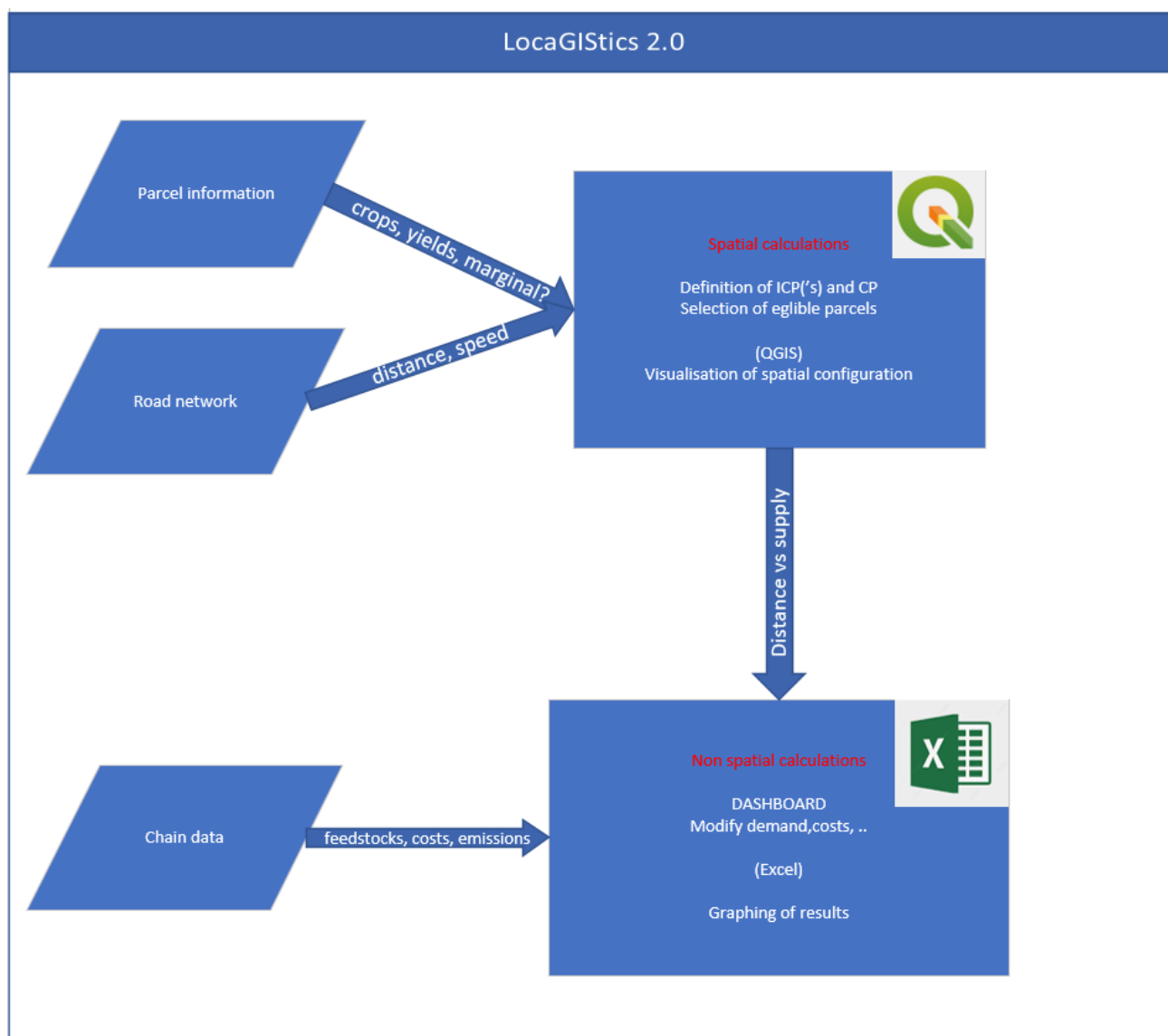


Figure 4.1 Schematic overview of LocaGISStics components

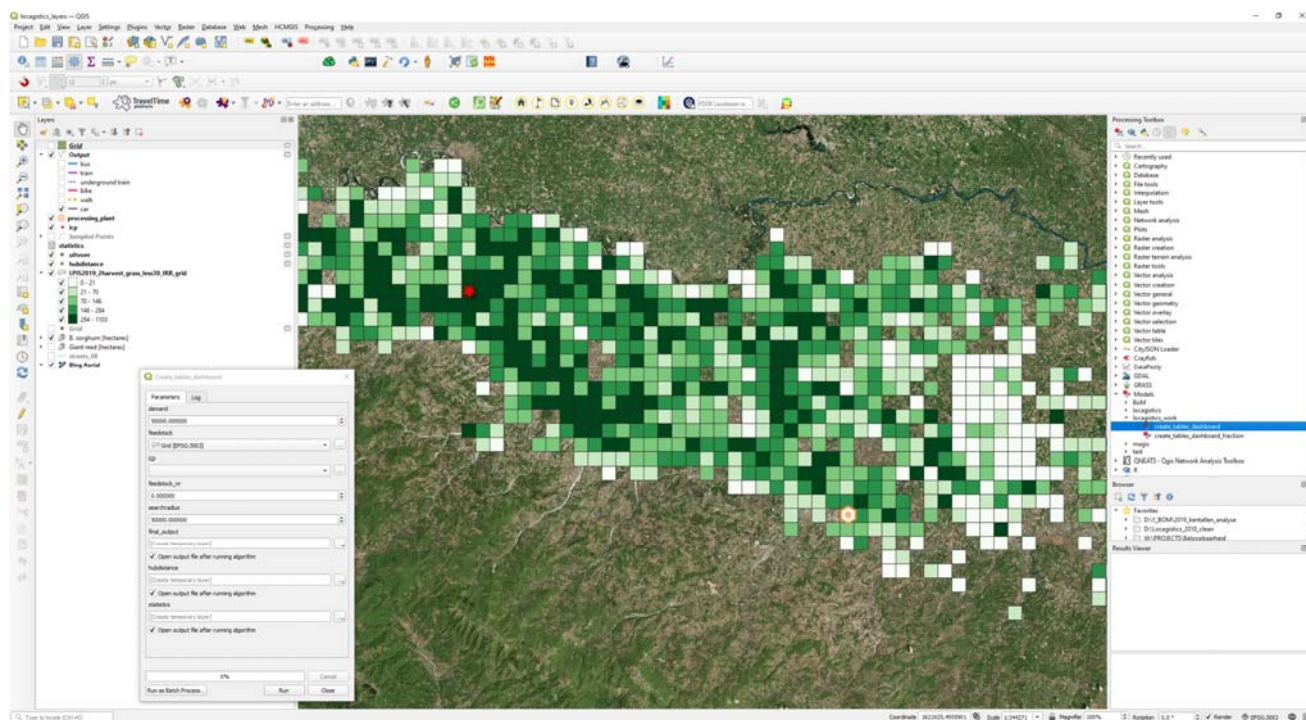


Figure 4.2 GIS (QGIS) part of LocaGISTICS, using 2.5 km “fishnet” in Emilia Romagna region

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1			Total Demand (ton)																											
2																														
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Figure 4.1 Dashboard for playing with precalculated spatial results (modifying demand, costs, etc..)

	Scenario 1m			Scenario 2m			Scenario 3_m		
	Costs	Energy	GHG	Specific Costs	Specific Ener	Specific GHG	Specific Costs	Specific Ener	Specific GHG
	(€)	(MJ)	(kgCO2)	(€)	(MJ)	(kgCO2)	(€)	(MJ)	(kgCO2)
Feedstock production	1109781.8	4116361.8	60868.5	1082102.4	4013694.6	59350.4	1121860.3	4161163.3	61531.0
Feedstock Transport	444649.9	743246.1	46543.8	478841.2	4512932.2	282610.2	568497.6	5311039.9	332589.6
Feedstock handling	32925.6	188146.4	10975.2	32104.4	183453.8	10701.5	33284.0	190194.2	11094.7
Feedstock Storage	70554.9	42332.9	21166.5	68795.2	41277.1	20638.6	71322.8	42793.7	21396.8
Feedstock Drying	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feedstock pretreatment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feedstock Conversion									
Total	1657912.2	5090087.3	139554.0	1661843.3	8751357.8	373300.6	1794964.7	9705191.1	426612.1

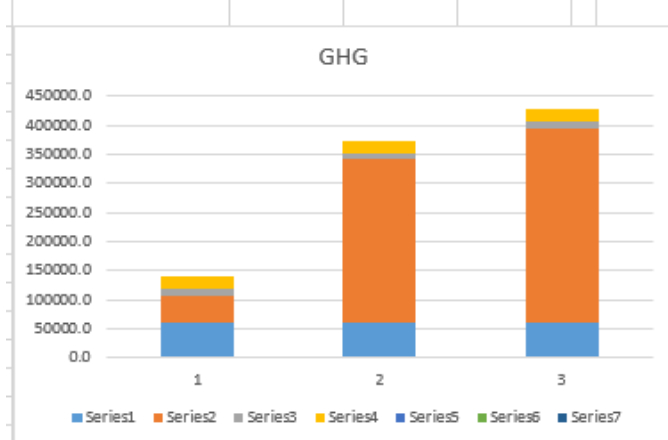
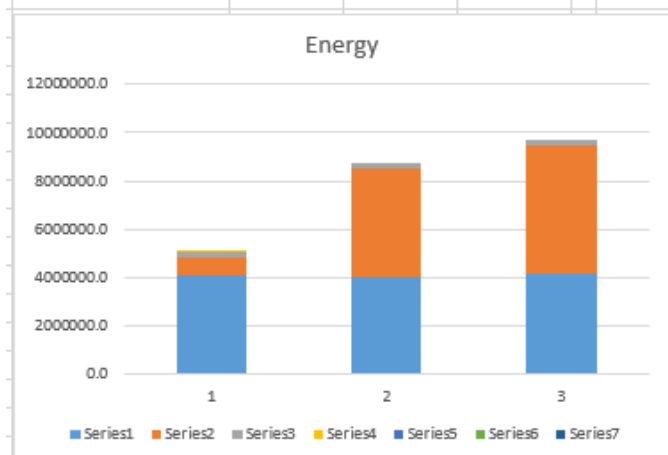
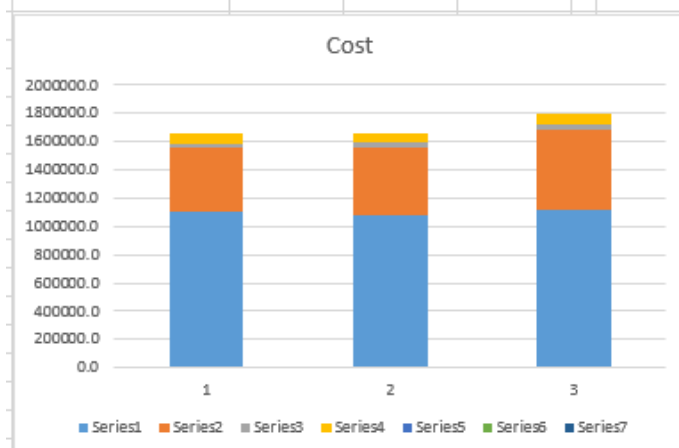


Figure 4.4 Breakdown of calculated results, also in graphs, within LocaGISTICS “playsheet”

## 5. Adoption of BioloCo tool

### 5.1 Introduction

The tool BioloCo (Biomass logistics computer optimization) was first developed around the beginning of this century (Erbrink, 2000) and was updated several times during the following years adding new functionalities like e.g. a goal programming option (Diekema et al., 2005). Originally, BioloCo was developed for the optimization of biomass value chains specifically aimed at the production of bioenergy (electricity & heat version). Several studies have been performed with this electricity & heat version of the BioloCo tool (Annevelink & de Mol, 2007; Geijzendorffer et al., 2008; Velazquez-Marti & Annevelink, 2009; Annevelink & de Mol, 2014). After ten years, more and more attention was given to biomass value chains linked to biorefineries, that also delivery of different types of products, like biofuels, biomaterials and bioproducts besides bioenergy. Therefore, in 2010 a first so-called biorefinery version of BioloCo was developed in the context of the European project EU-AGRO-BIOGAS (de Mol et al., 2010). However, this first biorefinery version was only still a draft that needed to be further improved to be fully operational. Therefore, this biorefinery version of BioloCo has been further developed and updated in the BECOOL project. Furthermore, also some major Windows 10 migration problems for both the electricity & heat version and the biorefinery version of BioloCo had to be solved. And finally, the standard data were extended through a literature search in the BECOOL project.

### 5.2 Brief description of BioloCo

BioloCo (both versions) calculates the optimal biomass value chain (within certain constraints) such as biomass types, transport types, storage facilities, pre-treatment methods and conversion techniques. The optimization is based on a single chosen optimization criterion (either financial, energetic or emission) or on a combination of these single optimization criteria (goal programming). BioloCo is a combination of i) a specially designed Access database to specify the data, ii) a graphical user module (programmed in Delphi 5) to design the current network and iii) Xpress to optimize the biomass value chain. The opening screen and the main menu screen of the Access database are shown in Figure 5.1.

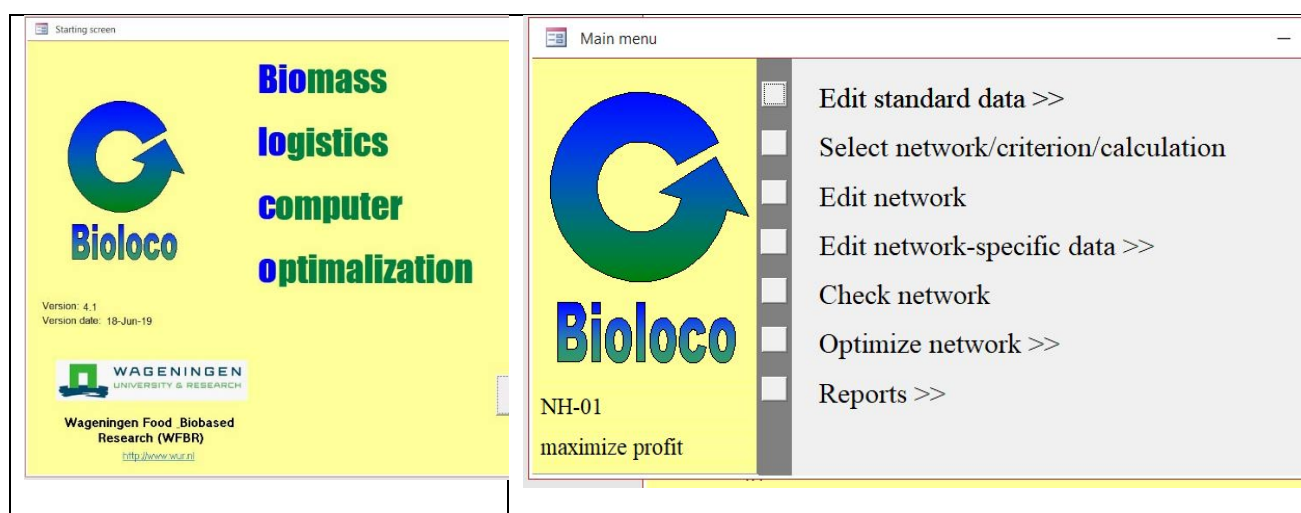


Figure 5.1 Opening screen and main menu screen of BioloCo.



Biolooco gives insight into the costs, energy consumption and greenhouse gas emission of the biomass value chain. Biolooco considers effects that are typical for biomass such as:

- seasonal fluctuations in supply and demand of biomass;
- losses of water due to drying (positive effects) and losses of dry matter due to heating (negative effects).

Biolooco contains a set of standard data that can be used and supplemented by the user, when defining his specific network. Examples of a Biolooco data entry form for biomass types, transport means, conversion technology and pre-treatments are given in Figure 5.2-5.5.

**Biomass types**

**name** BC Giant Reed

**description** Giant Reed

**bulk density** 155

**manifestation** chips

**heating** 0,015

**minimum heating content** 0,25

**ash-softening point** 900

**volatility** 79

**net heating value** 17

**own use source** diesel

	minimum	setting value	maximum
<b>particle size</b>	0	0	0
<b>ash contents</b>	0,00%	0,00%	0,00%
<b>initial moisture content</b>	0,00%	50%	0,00%
<b>source costs</b>	€ 0,00	€ 10,00	€ 0,00
<b>energy use source</b>	0,2	0,2	0,2

**reference** BECOOL

Record: 14 3 of 47 No Filter Search

Figure 5.2 Example of data entry form for biomass types in Biolooco: Giant Reed (imaginary data)

**Transport means**

**name** BC truck with trailer

**description** truck with trailer

**maximum volume** 120

**maximum weight** 50

**costs per km** €1.50

**costs per ton** €0.00

**costs per load** €0.00

**transport energy** 2.24

**own use transport** diesel

**reference** BECOOL

Record: 14 2 of 20 No Filter Search

Figure 5.3 Example of data entry form for transport means in Biolooco.

**Conversion techniques**

**name** gasifier, fluidised bed 24M

**description** fluidised bed gasifier 24MWe

**electrical power** 24 **thermal power** 60

**own use plant** electricity

**manifestation** solid

**volatility** 0

	minimum	maximum		
<b>moisture content</b>	0,00%	35,00%		
<b>particle size</b>	0,5	50		
<b>net heating value</b>	4	100		
<b>ash contents</b>		20,00%		
<b>net energy returns heat+electricity</b>	0,85	<b>electricity</b> 0,35		
<b>evaporation energy moisture</b>	2,4			
<b>capacity input</b>	15000			
<b>working hours</b>	625			
<b>fixed costs</b>	€ 8.413.000,00	<b>variable</b> €9,50		
<b>energy use</b>	0,2			
<b>ash-softening point</b>	900			
<b>temperature</b>	0	<b>pressure</b> 0		
<b>net produced steam</b>	7500			
<b>specific flue gass volume</b>	0			
	<b>CO2</b>	<b>NOx</b>	<b>SO2</b>	<b>dust</b>
<b>emission</b>	0	50	100	
<b>reference</b>	test cases			

Record: 11 of 14

Figure 5.4 Example of data entry form conversion technology in Biolooco: fluidised bed gasifier.

**Pretreatments**

**name** BC chipping Giant Reed

**description** chipping Giant Reed

**biomass input** BC Giant Reed

**biomass output** BC Giant Reed

**own use for pretreatment** diesel

**drying** ☐

**size reduction** ☒

	minimum	maximum
<b>particle size input</b>	0	300
<b>moisture content input</b>	0,00%	0,00%
<b>particle size output</b>	0	0
<b>moisture loss</b>	0,00%	
<b>moisture content output</b>	0,00%	
<b>dm loss</b>	0,00%	
<b>pretreatment costs</b>	€ 1,59	
<b>pretreatment energy</b>	1	
<b>drying costs</b>	€ 0,00	
<b>drying energy</b>	0	
<b>reference</b>	BECOL	

Record: 2 of 37

Figure 5.5 Example of data entry form for pre-treatments in Biolooco: chipping Giant Reed (imaginary data).

Biomass supply chains can be modelled in BioloCo by means of a network structure (see Figure 5.6), where ‘nodes’ correspond with source locations, collection sites, or conversion sites and where ‘arcs’ correspond with transportation routes. Pre-treatments are performed at the beginning or the end of an arc. The network is drawn and edited in the BioloCoEdit interface (of BioloCo) that is activated from the Access database.

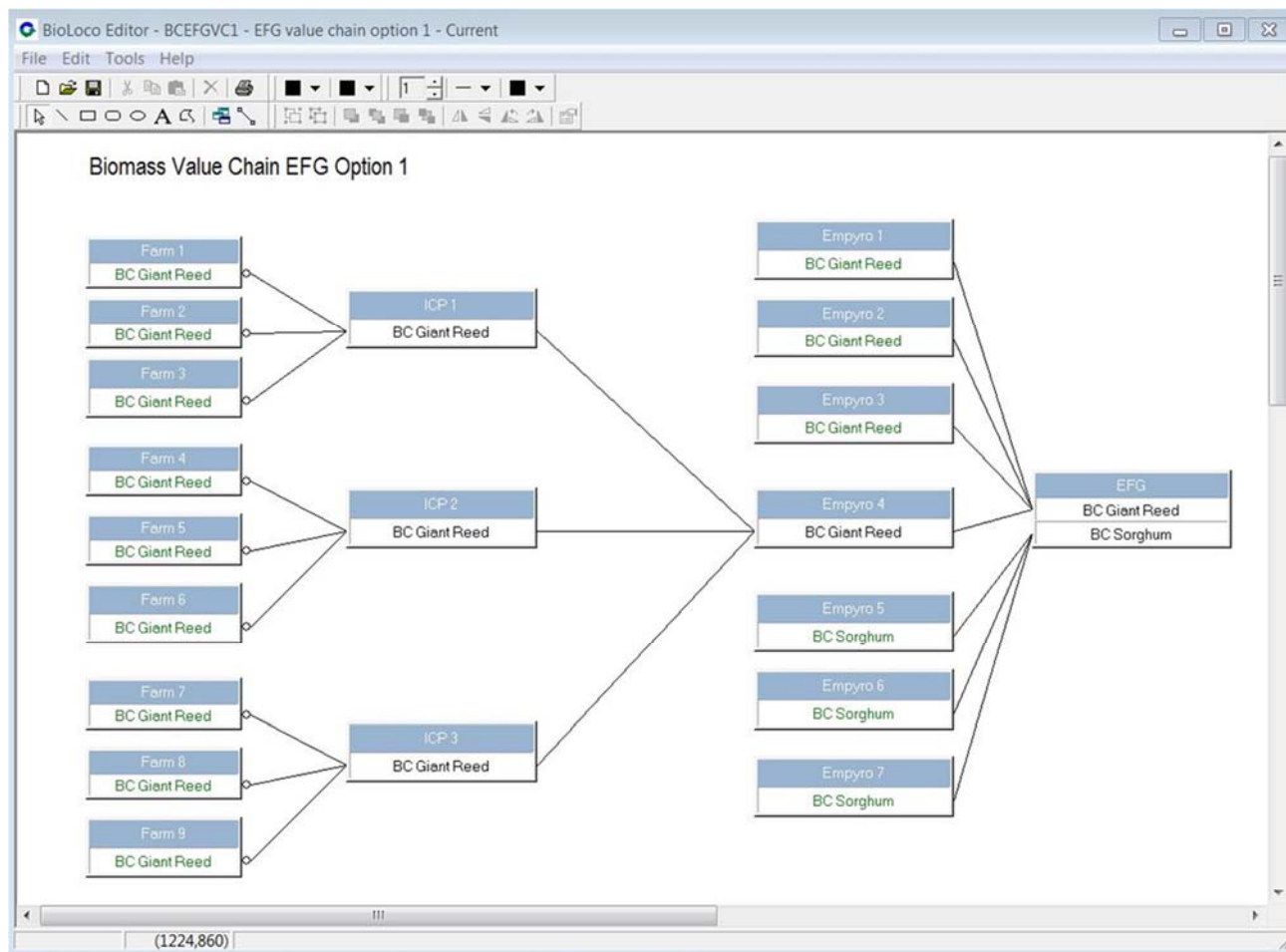


Figure 5.6 Example of a network structure for a value chain with Giant Reed in the BioloCoEdit interface.

BioloCo has four types of global results (see Figure 5.7):

- total throughput;
- costs and revenues (and profit);
- energy revenues and energy consumption;
- greenhouse gas emissions and greenhouse gas emissions avoided.

Furthermore, many detailed reports can be generated, based on results per source/depot/arc (e.g. supply & remainders per source, storage per depot, supply per arc and number of transports per arc) and on results per plant (e.g. production of electricity and heat, throughput dry matter per plant, supply volume per plant).



Output Biolooco classic: global results			
calculation	69 woensdag 15 september 2010 11:46:17		
network	NH-01		
criterion	3 maximize profit		
model	1 Biolooco classic		
<b>Total throughput:</b>			
[ton dm]:		from sources	63960
		to plants	63012
<b>Costs and revenues:</b>			
purchase costs	€ 607.761	low-valued heat revenues	€ 0
storage costs	€ 125.536	high-valued heat revenues	€ 1.099.648
transport costs	€ 1.277.911	electricity revenues	€ 13.761.588
loading/unloading costs	€ 1.004.613	total revenues	€ 14.861.235
pretreatment costs	€ 768.521		
conversion costs	€ 10.151.588		
total costs	€ 13.935.930	profit	€ 925.305
<b>Energy use and returns:</b>			
[GJ]:			
energy used for purchase	19.576	low-valued heat returns	0
energy used for storage	0	high-valued heat returns	346.892
energy used for transport	15.011	electricity returns	256.700
energy used for loading/unloading	0	total energy returns	603.592
energy used for pretreatment	394		
energy used for conversion	15.358		
total energy use	50.339	energy profit	553.253
<b>Greenhouse gas emissions and avoided emissions:</b>			
[ton CO <sub>2</sub> -equivalents]:			
emissions purchase	1.460	low-valued heat avoided emissions	0
emissions storage	0	high-valued heat avoided emissions	32.755
emissions transport	1.119	electricity avoided emissions	24.239
emissions loading/unloading	0	total avoided emissions	56.994
emissions pretreatment	29		
emissions conversion	1.573		
total emissions	4.181	net avoided emissions	52.813

Figure 5.7 Example of the global results page of Biolooco.

### 5.3 Main changes of the Biolooco electricity & heat version

The main changes to the existing Biolooco electricity & heat version are described below in this section.

*Migration of Biolooco electricity & heat version to Windows 10.* During the past years several small modifications had to be made to Biolooco, so that it could still function when a new Windows release appeared. However, this recent conversion from Windows 7 to Windows 10 constituted some specific problems. E.g. access violations in the Access database and problems with the ODBC driver needed to be solved. An autoincrement problem had to be solved by introducing external text files with the highest ID's of several tables, that are updated after each change in the network.

*Reinstalling Delphi 5.* The BioloocoEdit program was originally designed and compiled using the software development tool Delphi 5. This old version needed to be recovered from a colleague at WR and reinstalled under Windows 10 to be able to make the required changes to the user interface. Unfortunately, it is not possible to migrate to more recent versions of Delphi or its successors, because then it will not be possible anymore to use the specific graphical library that is now used.

*Installation manual Delphi 5.* A new internal manual in Dutch has been written for BioloCo developers on how to install the available recovered Delphi 5 version, and how to use it for compiling new versions of BioloCoEdit.

*Adding replaced energy carrier value.* This value is now added automatically to the conversion record in the BioloCoEdit user interface, while it had to be changed manually in the database in the previous version. This makes the use of BioloCo easier because it avoids making mistakes when running the model.

*Translation of the complete BioloCoEdit interface.* The old version of this user interface was still programmed in Dutch. The interface has now been completely translated to English.

*Updating the installation manual of BioloCo.* The installation manual for new users of BioloCo has been completely revised. This contains information on installing the optimization tool Xpress, installing BioloCo, setting up the ODBC link between the Access database and Xpress, and finally about operating BioloCo, BioloCoEdit & Xpress.

#### 5.4 Main changes of the BioloCo biorefinery version

The main changes to the existing BioloCo biorefinery version are described below in this section.

*Migration of BioloCo biorefinery version to Windows 10.* The biorefinery version was also migrated using the same approach that was developed for the electricity & heat version.

*Adding biorefinery specific functionality to BioloCoEdit.* The draft BioloCo biorefinery version that existed before the recent updates did not have the opportunity to use the BioloCoEdit interface, because that could not be changed until now. However, since the Delphi 5 version was reinstalled and operational it was now possible to add the required functionality to BioloCoEdit. This includes e.g. specifying various additives and non-electrical/heat products that are connected to pre-treatments or conversion processes. So far this could only be done in the Access database, but now this is also possible in the BioloCoEdit user interface (Figure 5.8). This makes it much easier to rapidly describe new networks that need to be optimized in BioloCo.

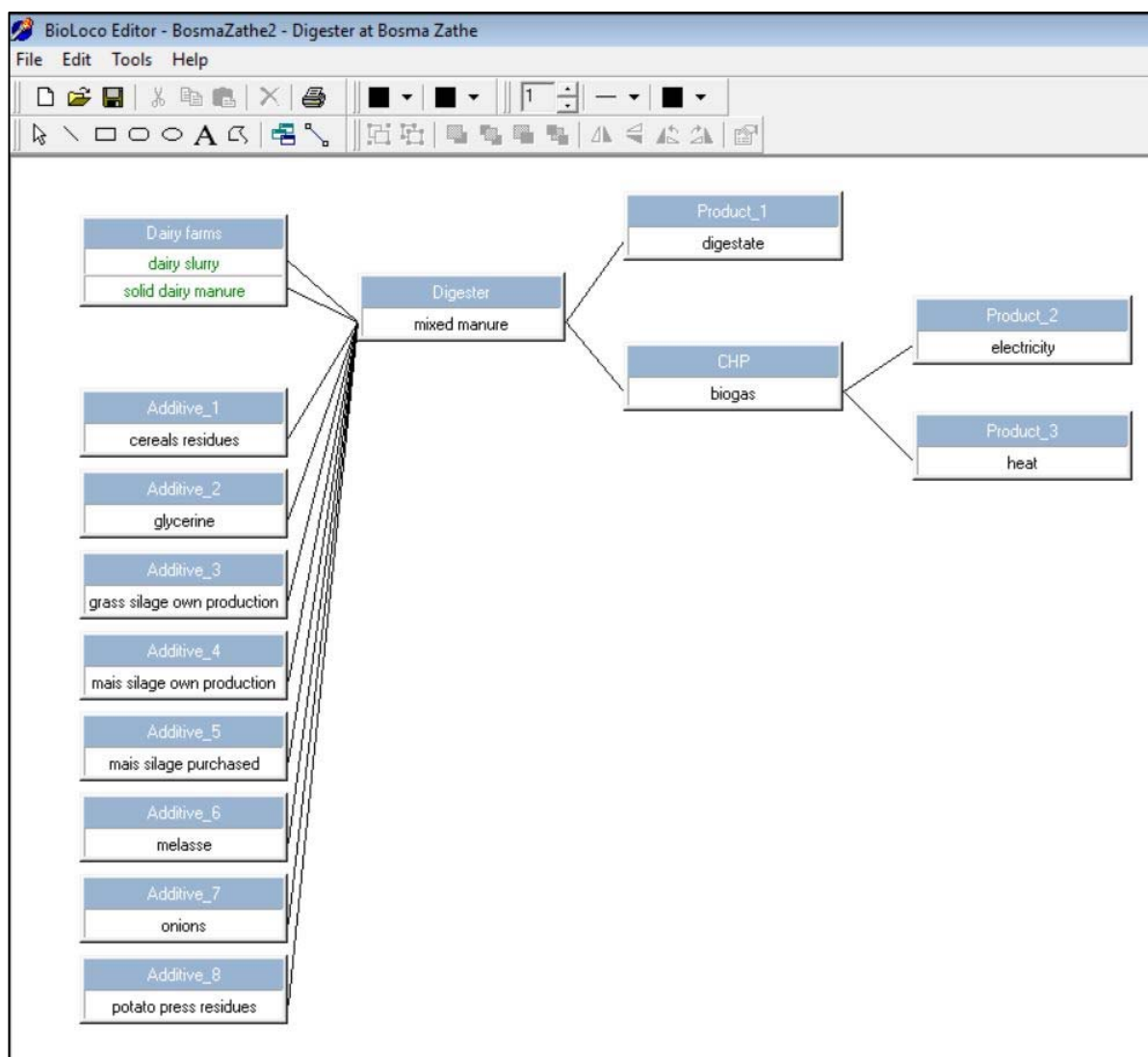


Figure 5.8 Network with additives and various products in the BioloCo biorefinery version of BioloCoEdit.

### 5.5 Expanding the set of standard data

The database feeding the three logistics tools (LocaGIStics2.0, BioloCo and BeWhere) has been redesigned, and is being filled with data that were collected from literature.

Additional standard data on logistical components were collected from literature especially for BioloCo (although they can also be of use for LocaGIStics2.0 and BeWhere). The four types of logistical components that were added are forced drying, pelletization, handling and storage. The detailed data tables can be found in Annex A. The references that were used for this are mentioned in the tables in the Annex A and they can be found in the Reference section.

For forced drying, information was collected on the biomass type that was dried, initial moisture content, final moisture content, the difference in moisture content, flow rate, energy demand, CO<sub>2</sub>-emission and costs. For pelletization, some of the same data types were collected and supplemented with data on bulk density (in and out) and dimensions of the pellets. For handling, the form and volume were additional data

types which were also added in the new version. And finally, for storage, the size of the storage was important (length, width and height).

## 6. Conclusions

The models have been developed as far as possible as was described in the former sections. Next steps taken will focus completely in running the tools in the specific case study regions and countries selected for testing best chain solutions for the advanced biofuels. These take in account of all biomass supply options, logistical concepts and conversion technology requirements developed in WP1, WP2, WP3 and WP4 in the BECOOL project. These are extensively described in Deliverable 2.3.

Application of the three logistical tools will focus on three case study regions: Emilia Romagna (Italy), Soria (Spain) and Mecklenburg Vorpommern (Germany). The LocaGISTICS and BioloCo tools will be run for these regions finding the best solutions for chain design for the BECOOL advanced biomass chains. The BeWhere model will be further operationalised to identify best locations for new advanced biomass-fuels value chains at the level of the three countries in which the regional case studies are located, Italy, Spain and Germany.

BeWhere will need to deliver the supplycosts (including logistics and conversion) from the BECOOL value chains to GLOBIOM in WP5. GLOBIOM needs EU wide results to assess BECOOL chain potentials and large-scale impacts. It was decided that BeWhere can be run for the 3 countries in which the case studies are located (Germany, Italy and Spain). Therefore, an extrapolation algorithm is needed for expanding BeWhere results in terms of the cost-supply data and collection distances to all other EU countries. This extrapolation is expected to be based on spatial density of biomass, infrastructure density and econometrics for adapting the unitary costs for capital, labor and fuels used in the supply chains to all the EU countries. .

Consistency in the assessments with the three logistical models and with the GLOBIOM model is ensured in two ways:

- 1) All data on the generic value chains defined in the BECOOL project are compiled in one data collection sheet which is used as central input in all tools, models and the LCA assessments in WP2 and WP5;
- 2) Consistency is created in all data inputs between the three logistical models and GLOBIOM (e.g. biomass potential yields).

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## Annex A. Standard data collected for Biolooco

### A1. Collected data on forced drying

Forced drying	Biomass	initial MC	final MC	ΔMC	Flow rate	Energy demand	Energy demand	CO2 emission	Costs	Country	Year of publ.	Author
		(%)	(%)	(%)	(ton/h dry)	(GJ/ton H2O)	(GJ/ton dry)	(kg/ton dry)	(€/ton dry)			
Band drying	sawdust, wood chips	55.0%	12.5%	42.5%	8.5	4.5	4.86	272	-	Northern Europe	2010	Fagernas
Rotary drying	sawdust, wood chips, bark	55.0%	12.5%	42.5%	6.5	4.5	4.86	272	-	Northern Europe	2010	Fagernas
Steam rotary drying	sawdust wood processing	55.0%	12.5%	42.5%	5.5	3.5	3.78	212	-	Northern Europe	2010	Fagernas
Drying with renewable energy sources	sawdust (80%), shavings (20%)	47%	10%	37.4%	5	-	5.58	3.9	53.3	Italy	2010	Sikkema, Faaij
Drying with renewable energy sources	sawdust (95%), shavings (5%)	55%	8%	46.9%	10	-	2.96	1.5	45.7	Sweden	2010	Sikkema, Faaij
Drying with renewable energy sources	sawdust (49%), shavings (51%)	36%	6%	29.7%	20	-	4.50	15.6	12.6	Netherlands	2010	Sikkema, Faaij
Drying with natural gas (methane)	sawdust and shavings	-	6%	-	-	-	-	178	-	Netherlands	2010	Sikkema, Faaij
Drying (hot air, unspecified)	wood logs, chips	-	-	-	-	3.5	-	-	-	Italy	2009	Aebiom
Rotary drum drying	sawdust	40%	10%	30.0%	6		-	-	10.3	US/Canada	2006	Mani, Sokhansanj
Belt dryer Dorset / Amandus Kahl	wood chips	-	-	-	-	-	4.5	-	1.0	NL	2014	S2Biom Excel-file
Rotary drum drying	wood chips	-	-	-	-	-	4.5	-	1.0	NL	2015	S2Biom Excel-file

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## A2. Collected data on pelletization

Pelletization	Biomass	Bulk density IN (kg/m3)	Bulk density OUT (kg/m3)	Flow rate (ton/h dry)	Dimension, d*I (mm)	Energy consumption (GJ/ton dry)	CO2 emission (kg/ton dry)	Costs (€/ton dry)	Country	Year of publ.	Author
Bliss Pioneer B35A-75 Pelletizer	Corn stover	112	695	1	6.25*75	0.34	49.0	-	US	2015	Crawford
	Poplar	117	650	1	6.25*56	0.42	60.9	-	US	2015	Crawford
	Switch grass	128	610	1	6.25*63	0.57	81.8	-	US	2015	Crawford
	Miscanthus	144	658	1	6.25*75	1.16	167.8	-	US	2015	Crawford
30 HP CPM Master Model Series 1000 Pelletizer	Corn stover	122	639	0.1	6.25*L	0.49	71.1	-	US	2014	Wilson
	Sorghum stalks	161	500	0.12	6.25*L	0.38	55.5	-	US	2014	Wilson
	Wheat straw	105	591	0.11	6.25*L	0.56	80.9	-	US	2014	Wilson
	Big Bluestem (grass)	118	630	0.1	6.25*L	0.58	83.8	-	US	2014	Wilson
Pelletization	Coniferous sawdust	-	-	3	-	0.36	37.3	4.59	Argentina	2011	Uasuf
Pelletization + cooling	Corn stover	160	650	6	-	0.93	135.0	9.81	US	2010	Sokhansanj
Pelletization	Sawdust + Shavings	-	-	-	-	0.45	34.0	11.38	Netherlands	2010	Sikkema, Faaij
Pelletization	Sawdust + Shavings	-	-	-	-	0.24	2.53	13.37	Sweden	2010	Sikkema, Faaij
Pelletization	Sawdust + Shavings	-	-	-	-	0.30	53.50	25.89	Italy	2010	Sikkema, Faaij
Pelletization	Woody biomass	-	600	2	-	-	-	28.3	Spain (Majorca)	2015	Sanchez, Fernandez
Micro pellet processing line	Miscanthus	-	-	0.15	-	0.93	118.2	-	Ireland	2013	Murphy
200 HP Sprout Waldrin pellet mill	Switchgrass	-	609	2	6.25*L	0.29	14.3	-	Canada	2001	Jannasch
Own calculation of pelletizing costs								11.43			See calculation below
Small Pelletizer	Wood chips			0.4				68	NL	2014	S2Biom Excel-file
Medium Pelletizer	Wood chips			1.4				57	NL	2014	S2Biom Excel-file
Large Pelletizer	Wood chips			4.5				50	NL	2014	S2Biom Excel-file

## A3. Collected data on handling

Handling	Biomass	Form	Volume	Energy source	Energy demand	CO2 emission	Costs	Country	Year of publ.	Author
			(ton/h)		(MJ/ton)	(kg/ton)	(€/ton)			
Front loader 3,7 m	Wood	Chips					3.72	NL	2014	S2Biom Excel-file
Front loader 3,7 m	Straw	Bale					1.89	NL	2014	S2Biom Excel-file
Front loader 3,7 m	Straw	Bale	22	Diesel	32.3	2.21	2.03	NL	2014	Bioboost D4.1
Front loader 3,7 m	Wood	Pellet	97	Diesel	7.4	0.51	0.46	NL	2014	Bioboost D4.1
Telehandler 8.6 m	Wood	Chips					1.13	NL	2014	S2Biom Excel-file
Telehandler 8.6 m	Straw	Bale					0.68	NL	2014	S2Biom Excel-file
Telehandler 8.6 m	Straw	Bale	38	Diesel	7.0	0.48	0.87	NL	2014	Bioboost D4.1
Telehandler 8.6 m	Wood	Pellet	168	Diesel	1.6	0.11	0.20	NL	2014	Bioboost D4.1
Gantry Crane 8 m	Wood	Chips					2.91	NL	2014	S2Biom Excel-file
Gantry Crane 8 m	Straw	Bale					0.65	NL	2014	S2Biom Excel-file
Gantry Crane 8 m	Wood	Pellet	168	Power	0.41	0.04	0.19	NL	2014	Bioboost D4.1
Loading (at ICP)	Biomass	Chips	-	-	-	-	1	Spain (Majorca)	2015	Sanchez et al.
Front loader	Corn stover	Chopped	-	-	-	-	1.28	US	2010	Sokhansanj
Stacking (while unloading)	Corn stover	Bale	-	-	-	-	2.00	US	2010	Sokhansanj
Stacking (on wagon in field)	Corn stover	Bale	-	-	124	10.8	7.11	US	2010	Sokhansanj

## BECool – Deliverable D2.2

Handling	Biomass	Form	Volume	Energy source	Energy demand	CO2 emission	Costs	Country	Year of publ.	Author
			(ton/h)		(MJ/ton)	(kg/ton)	(€/ton)			
Shovel 128 kW (2012)	Biomass	Pellet	105	Diesel	9.2	0.63	0.46	NL	2019	<a href="https://www.traktorpool.nl/de">https://www.traktorpool.nl/de</a>
Belt conveyor (Telescope, 14 m, Mobile)	Biomass	Chips	41	Power	0.55	0.06	0.15	NL	2018	<a href="https://transportbanden.info/s">https://transportbanden.info/s</a>
Belt conveyor (10 m, Horizontal, static)	Biomass	Chips	150	Power	0.04	0.006	0.003	UK	2018	<a href="http://www.conveyorsdirect.co">http://www.conveyorsdirect.co</a>
Sekup Screw auger (15 m, fixed, 0°)	Biomass	Grain	102	Power	0.53	0.05	0.012	NL	2018	<a href="https://www.sukup-eu.com/m">https://www.sukup-eu.com/m</a>
Sekup Screw auger (15 m, fixed, 15°)	Biomass	Grain	87	Power	0.62	0.06	0.014	NL	2018	<a href="https://www.sukup-eu.com/m">https://www.sukup-eu.com/m</a>
Sekup Screw auger (15 m, fixed, 35°)	Biomass	Grain	66	Power	0.82	0.08	0.019	NL	2018	<a href="https://www.sukup-eu.com/m">https://www.sukup-eu.com/m</a>
Sekup Screw auger (15 m, fixed, 45°)	Biomass	Grain	56	Power	0.96	0.10	0.022	NL	2018	<a href="https://www.sukup-eu.com/m">https://www.sukup-eu.com/m</a>
Sekup Screw auger (15.5 m, mobile, 15°)	Biomass	Grain	120	Power	0.56	0.06	0.015	NL	2018	<a href="https://www.sukup-eu.com/m">https://www.sukup-eu.com/m</a>
Sekup Screw auger (15.5 m, mobile, 40°)	Biomass	Grain	78	Power	0.85	0.09	0.022	NL	2018	<a href="https://www.sukup-eu.com/m">https://www.sukup-eu.com/m</a>

## A4. Collected data on storage

Storage	Length	Width	Height	Volume	Costs	Country	Year of publ.	Author	Investment costs	Depreciation period	Relative costs
	(m)	(m)	(m)	(m3)	(€/m3.a)				(€, ex VAT)	(years)	(€/m2.a)
Outdoor Soil	50	20	3.6	2,786	0.023	NL	2018	BeCool	627	1	0.063
Outdoor Soil	50	40	3.6	6,127	0.020	NL	2018	BeCool	627	1	0.063
Outdoor Soil + Plastic cover	50	15	3.6	1,951	0.15	NL	2018	BeCool		1	0.39
Outdoor Covered					0.38	NL	2014	S2Biom			
Outdoor Concrete floor	50	40	7.0	10,276	0.20	NL	2018	BeCool	41,464	20	1.04
Indoor steel (no floor)	50	30	3.85	5,775	0.73	NL	2018	BeCool	105,620	25	2.82
Indoor steel (with floor)	50	30	3.85	5,775	1.00	NL	2019	BeCool			
Indoors Bunker	31.7	18.3	3.7	2,146	6.03	NL	2019	BeCool	207,207	20	
Indoors Bunker					0.80	NL	2014	S2Biom			
Indoors Bunker					0.76	NL	2014	S2Biom			

## BECool – Deliverable D2.2

Storage	Length	Width	Height	Volume	Costs	Country	Year of publ.	Author	Investment costs	Depreciation period	Relative costs
	(m)	(m)	(m)	(m3)	(€/m3.a)				(€, ex VAT)	(years)	(€/m2.a)
Glass fibre-Polyester tank				52	21.63	NL	2018	BeCool	9,000	10	
RVS tank				50	44.88	NL	2018	BeCool	17,950	10	
RVS tank				105	38.04	NL	2018	BeCool	31,950	10	
RVS tank				181	34.36	NL	2018	BeCool	49,750	10	

