



Delivery of sustainable supply of non-food biomass to support a
“resource-efficient” Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

D3.5 Formalized stepwise approach for implementing logistical concepts using BeWhere and LocaGIStics

18 November 2016



About S2Biom project

The S2Biom project - Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe - supports the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a “computerized and easy to use” toolset (and respective databases) with updated harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

Project coordinator



Fachagentur Nachwachsende Rohstoffe e.V.

Scientific coordinator



Project partners



About this document

This report corresponds to D3.5 of S2Biom. It has been prepared by:

Due date of deliverable:	31 October 2016 (Month 38)
Actual submission date:	18 November 2016 (Month 39)
Start date of project:	2013-01-09
Duration:	36 months

Work package	WP3
Task	3.3
Lead contractor for this deliverable	DLO
Editor	E. Annevelink
Authors	E. Annevelink, B. Elbersen, S. Leduc & I. Staritsky
Quality reviewer	R. van Ree

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services):	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Version	Date	Author(s)	Reason for modification	Status
0.1	21/10/2016	E. Annevelink	Draft which can be reviewed by co-authors	Done
0.2	04/11/2016	S. Leduc	Review of first draft	Done
0.3	09/11/2016	E. Annevelink	Second draft for review	Done
1.0	17/11/2016	E. Annevelink, B. Elbersen, S. Leduc & I. Staritsky	Final report	Done

This project entitled S2Biom (Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe) is co-funded by the European Union within the 7th Framework Programme – Grant Agreement n°608622 The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein.

Executive summary

This deliverable describes a formalized stepwise approach for implementing optimal logistical concepts in the practical design of national and regional biomass delivery chains and for assessing their economic and GHG performance using the tools BeWhere and LocaGISrics. It describes the functionality of and the relation between these two logistical assessment tools. BeWhere and LocaGISrics are closely interlinked so that LocaGISrics can further refine and detail the outcomes of the BeWhere model and that the BeWhere model can use the outcome of the LocaGISrics model to modify their calculations if needed.

The BeWhere model supports the development of EU-wide and national strategies to develop an optimal network of biomass delivery chains. The basis of this tool is a techno-economic spatial model that enables the optimal design and allocation of biomass delivery chains (at national level) based on the minimization of the cost and emissions of the full supply chain taking account economies of scale, in order to meet certain demand.

LocaGISrics is a regional assessment tool for biomass delivery chains. This tool can support the user to design optimal biomass delivery chains and networks at regional level and analyze in a comparative way (for different biomass delivery chains) the spatial implications and the environmental and economic performance. It will take account of the biomass cost-supply, the conversion and pre-treatment technology options and novel logistical concepts.

Table of contents

About S2Biom project.....	2
About this document.....	3
Executive summary.....	4
1. Introduction	7
1.1. Formalized stepwise approach	7
1.2. Contents of this report.....	7
2. Two assessment methods used in stepwise approach	8
2.1. Introduction	8
2.2. BeWhere	9
2.3. LocaGIStics.....	10
2.4. General comparison of the two tools.....	11
3. Overview of BeWhere.....	13
3.1. BeWhere general description.....	13
3.2. Data requirements BeWhere.....	13
4. Type of results from BeWhere	16
5. Overview of LocaGIStics	18
5.1. General description of the functionality of LocaGIStics	18
5.2. Data requirements for LocaGIStics	20
5.3. Calculation method of LocaGIStics: 'Simple sheet'	22
5.4. Data exchange between BeWhere and LocaGIStics	23
6. User interface of LocaGIStics	24
6.1. Getting started with a new variant.....	24
6.2. Biomass types.....	26
6.3. Biomass conversion plants	27
6.4. Intermediate collection points.....	28
6.5. Results	28
7. How to perform runs with LocaGIStics	30
7.1. Define experiments with LocaGIStics.....	30
7.2. Prepare dedicated simple sheet.....	31
7.3. Specify input of variant.....	31

7.4. Get results.....	32
8. Final remarks	33
References	34
Annex A. ‘Simple sheet’ LocaGIStics	36

1. Introduction

1.1. Formalized stepwise approach

The original title of this deliverable D3.5 in the DOW was ‘Formalized stepwise approach for implementing optimal logistical concepts (logistical roadmap)’. This referred to a formalized stepwise approach for implementing optimal logistical concepts (logistical roadmap) in the practical design of national and regional biomass delivery chains and for assessing their economic and GHG performance. This logistical stepwise approach was intended to be used as basis for the development of the tool to be further developed in WP4 (Task 4.5).

In the actual project the development of the assessment tool LocaGIStics was an iterative process, where the stepwise approach was improved and refined all the time during the process. Therefore, this deliverable is mainly a description of the functionality of LocaGIStics in relation to the BeWhere tool that already existed. So the final integrated tool is a reflection of the stepwise approach.

1.2. Contents of this report

This report will first briefly describe the two assessment methods that were used in the stepwise approach in Chapter 2. Then a more detailed overview will be given of the BeWhere tool in Chapter 3, followed by some examples of the type of output generated by BeWhere. In Chapter 5 an overview is given of the newly developed tool LocaGIStics and the user-interface of LocaGIStics is described in Chapter 6. Then Chapter 7 indicates how to perform runs with LocaGIStics and some final remarks are made in Chapter 8.

2. Two assessment methods used in stepwise approach

2.1. Introduction

Two logistical assessment methods have already been briefly described in Deliverable D3.2 'Logistical concepts' (Annevelink et al., 2015):

- BeWhere for the European & national level;
- LocaGIStics for the Burgundy and Spanish case on the regional level.

BeWhere and LocaGIStics are closely interlinked so that LocaGIStics can further refine and detail the outcomes of the BeWhere model and that the BeWhere model can use the outcome of the LocaGIStics model to modify their calculations if needed. The relationship between BeWhere and LocaGIStics in the S2Biom project is given in Figure 1.

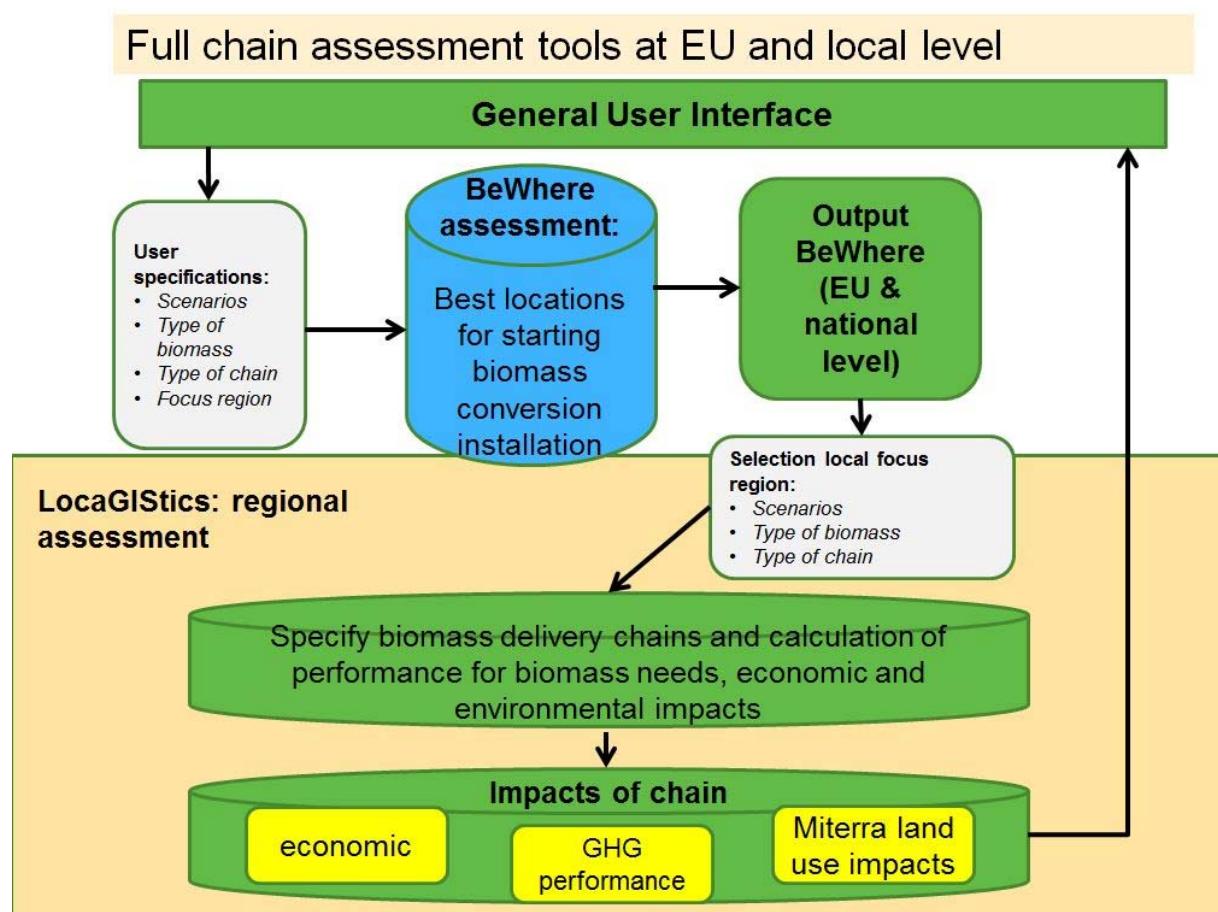


Figure 1. Relation between BeWhere and LocaGIStics.

2.2. BeWhere

The BeWhere model (www.iiasa.ac.at/bewhere) supports the development of EU-wide and national strategies to develop an optimal network of biomass delivery chains (Leduc, 2009; Leduc, 2012; Wetterlund, 2013; Natarajan, 2011). The basis of this tool is a techno-economic spatial model that enables the optimal design and allocation of biomass delivery chains (at national level) based on the minimization of the cost and emissions of the full supply chain and taking into account economies of scale, in order to meet certain demand. For doing this it considers the input on biomass cost-supply from WP1, the conversion technology specifications of WP2 and the logistical and pre-treatment technologies from WP3 and the demand categories as assessed in WP7 with the ReSolve model (for different scenarios). ReSolve also takes into account the already existing production plants and local energy demand (provided the information is included in the tool). BeWhere provides as output a network of existing and suggestions for new biomass conversion and pre-treatment chains according to optimal selection of technology, their location and capacity, the costs of each segment of the supply chain, the total bio-energy and biomaterial demand (depending on which technologies can be feasibly included in the tool), avoided emissions at different geographical levels (regional, national and European level). The spatial resolution in BeWhere is different between the case studies, ranging e.g., from 10 km grid resolution for Burgundy to 40 km grid resolution for Europe. Figure 2 presents a typical output from the BeWhere model with the locations of the bioenergy production plants (black circles). The selected production plants collect the biomass from the closest locations (Figure 2, left side, where one color represents the biomass collected for the production plant the area of the same color). The bioenergy production plants produce both heat and power. Heat is assumed to be distributed a district heating network, and therefore cannot be shipped for distances longer than 30 km. The right side of Figure 2 present the location of the plants and at the same time the location of the heat demand in Burgundy. One can notice that the plants are located where the heat demand is the highest.

Overall it is clear that the BeWhere tool can support the development of strategies for establishing biomass delivery chains to reach specific national bio-energy and wider bioeconomy targets. However, before enabling reliable support it is necessary to fill the tool with data as accurate as possible on many aspects including biomass cost-supply, existing biomass installations, topography, road and railway network data, heat and power demand as well as the associated costs/prices. Output of BeWhere can be used as input for further analysis and more precise chain design and evaluation in the LocaGIStics tool. BeWhere will provide to LocaGIStics the locations of the selected production plants, their capacity and technology chosen.

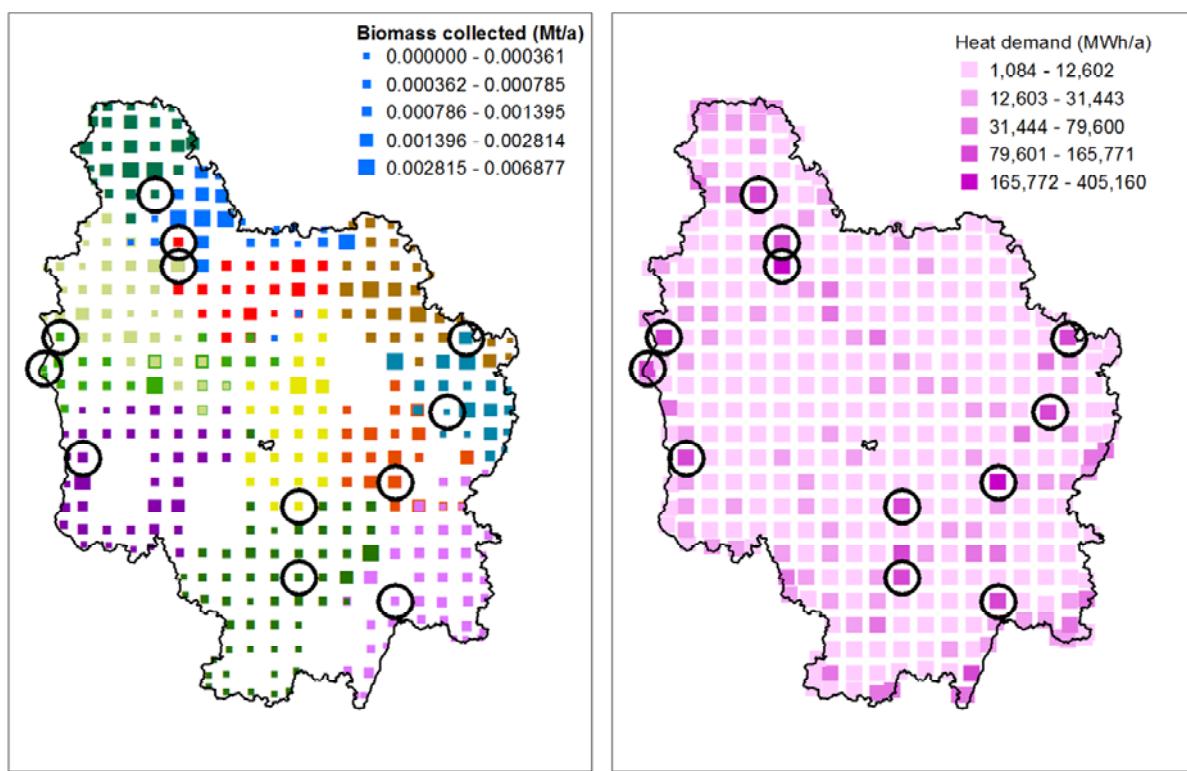


Figure 2. Example of output of BeWhere for Burgundy.

2.3. LocaGIStics

LocaGIStics is a regional assessment tool for biomass delivery chains. This tool can support the user to design optimal biomass delivery chains and networks at regional level and analyze in a comparative way (for different biomass delivery chains) the spatial implications and the environmental and economic performance. It will take account of the biomass cost-supply from WP1, the conversion and pre-treatment technology options from WP2 and WP3 and the novel logistical concepts of biomass hubs and yards from WP3. In relation to environmental impacts it takes account of the indicators and guidelines to be developed in WP5 for assessing the overall sustainability performance for bioeconomy value chains developed in WP5.

This tool provides support to regional and local stakeholders in making strategies for best ways to develop their bio-based economy and making use of sustainable local biomass resources potentially available to them. The scale of assessment is to be as detailed as data allows in the case studies for which the tool is developed. The tool was developed and validated in two case study regions.

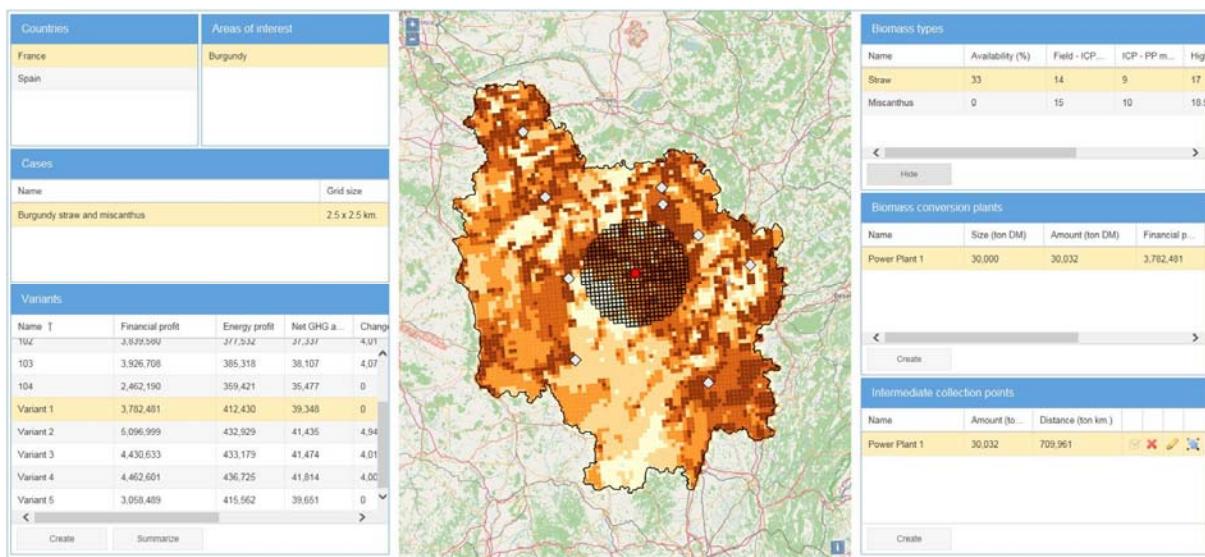


Figure 3. Example of the interface of LocaGIStics for Burgundy.

The first version of this tool was developed for the Burgundy case study using input from the LogistEC project (Figure 3). It enables the users to further design and evaluate in more detail the solutions for additional biomass delivery chains that were proposed by the BeWhere model for Burgundy. These solutions are translated in several biomass delivery designs using the variation in logistical concepts identified in WP3 (D3.2) covering of transport, pre-treatment and conversion options. The feasibility of every chain design can then be analyzed in a comparative way (for different biomass delivery chains) in relation to environmental (GHG emissions and mitigation including land use change emissions, soil C and an economic minimum acceptable return analysis). It will take account of high resolution cost-supply information available at 2,500 m resolution grid. Guidelines have been made for the collection of data for the case studies.

2.4. General comparison of the two tools

As mentioned BeWhere and LocaGIStics are two logistical models that complement each other (see Figure 1). The first one, an optimization model, optimizes the plant location, and the latter one, a simulation model, simulates the collection points for a given plant provided by the BeWhere model. Table 1 highlights the main differences between BeWhere and LocaGIStics.

Table 1. Comparison between functionality of BeWhere and LocaGIStics.

BeWhere	LocaGIStics
<ul style="list-style-type: none"> • supply chain optimization • national level • policy maker • rough grid • determine the optimal geographic location of production plants 	<ul style="list-style-type: none"> • supply chain simulation • regional level • project developer • finer grid • use one of the plant locations optimized from BeWhere & refine it

3. Overview of BeWhere

3.1. BeWhere general description

The BeWhere model follows the steps described in Figure 4. All geographic explicit data and other socio economic data are read from Matlab to be processed and transformed into text files that can easily be read in GAMS. The results from the model are further read and interpreted in Matlab and will further be plotted and read into an excel table. This structure of the model allows the user to create diverse scenarios with varying locations of e.g. plants, feedstock, or value of input parameters without varying the core of the model.

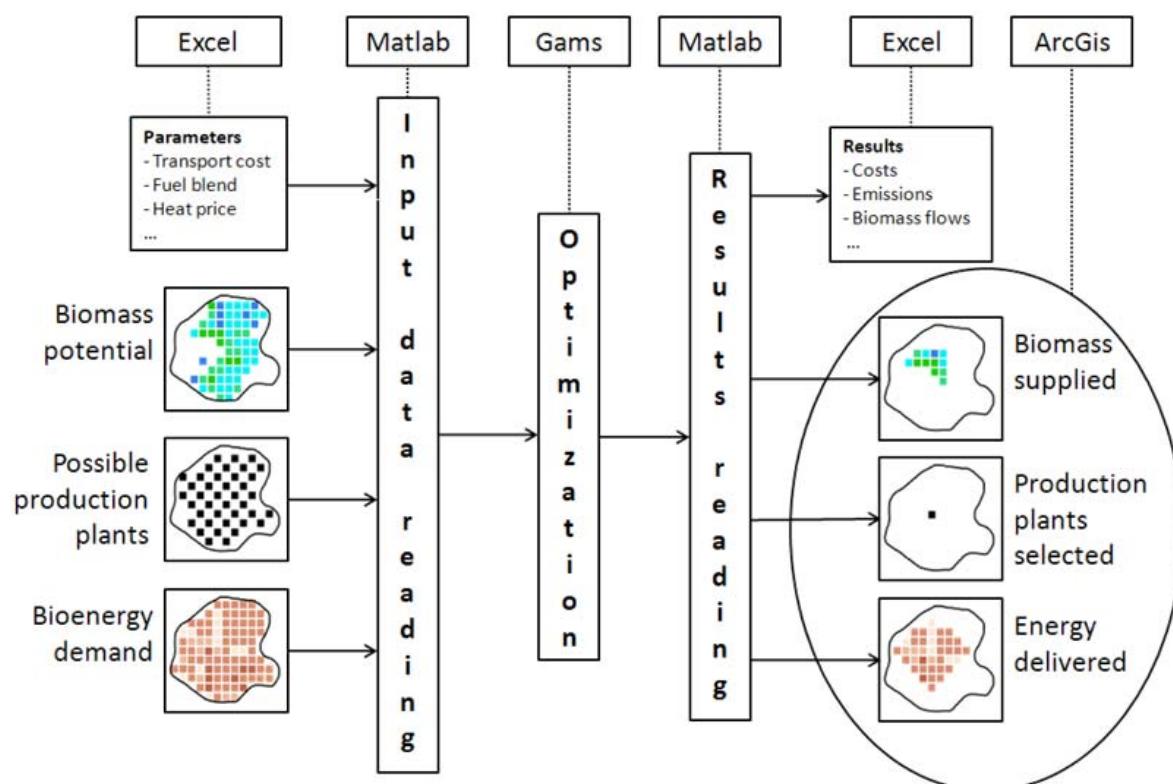


Figure 4. Overview of the modeling steps of the BeWhere model.

3.2. Data requirements BeWhere

The input data required in BeWhere has a lot in common with the one from LocaGIStics, but still does cover the following as expressed in Table 2. Each information in the Table below should be provided for each country and at the level of each grid point.

Table 2. Required data for BeWhere.

Category	Attribute description (unit)
Biomass characteristics	Biomass type(s) available (name) Higher heating value per biomass type (GJ/ton dm)
Biomass availability	Amount of biomass available per source location/grid cell (ton dm/year) at the grid level. Costs at roadside per biomass type (€/ton dm) Energy used for biomass production (GJ/ton dm) GHG emission used for biomass production (ton CO ₂ -eq/ton dm)
Logistics	Type of available transport means for each part of the chain (name) Detailed road/rail/ship network (could be taken from open street maps) Maximum volume capacity per transport type (m ³) Maximum weight capacity per transport type (ton) Costs variable per transport type (€/km) Costs fixed per transport type (€/load) Energy used per transport type (MJ/km) GHG emission per transport type (ton CO ₂ -eq/ton dm)
Conversion	Technology type per conversion plant (name) Net energy returns electricity (usable GJ/GJ input *100%) Net energy returns heat (usable GJ/GJ input *100%) Capacity input (PJ _{biomass} /year) Working hours (hours/year) Costs conversion plant fixed (M€/year) Costs conversion variable (M€/PJ _{biomass}) Energy use for conversion (GJ/m ³) Emissions CO ₂ equivalent (mg/Nm ³) Economical characteristics of each country (taxes, labour cost, ...)
Revenues	Price electricity (€/GJ) Price heat (€/GJ) Price other type(s) of (intermediate) products (€/ton)
Distribution	Cost of transport of the end-use product (electricity, heat or biofuel) Location of the demand point for heat, electricity or transport fuel Amount of demand of energy products
Policy instruments	Carbon cost, cost of competing product (fossil fuel based), subsidies Emissions factors for each energy product per country
Imports	Locations of different import location ports (overseas or inland) Quantities of biomass or transport fuel that can be imported at each specific import point.

As an example of input data for the technologies, Figure 5 presents the operation and maintenance and the investment costs of the technologies that run under woody biomass for the production of heat and power.

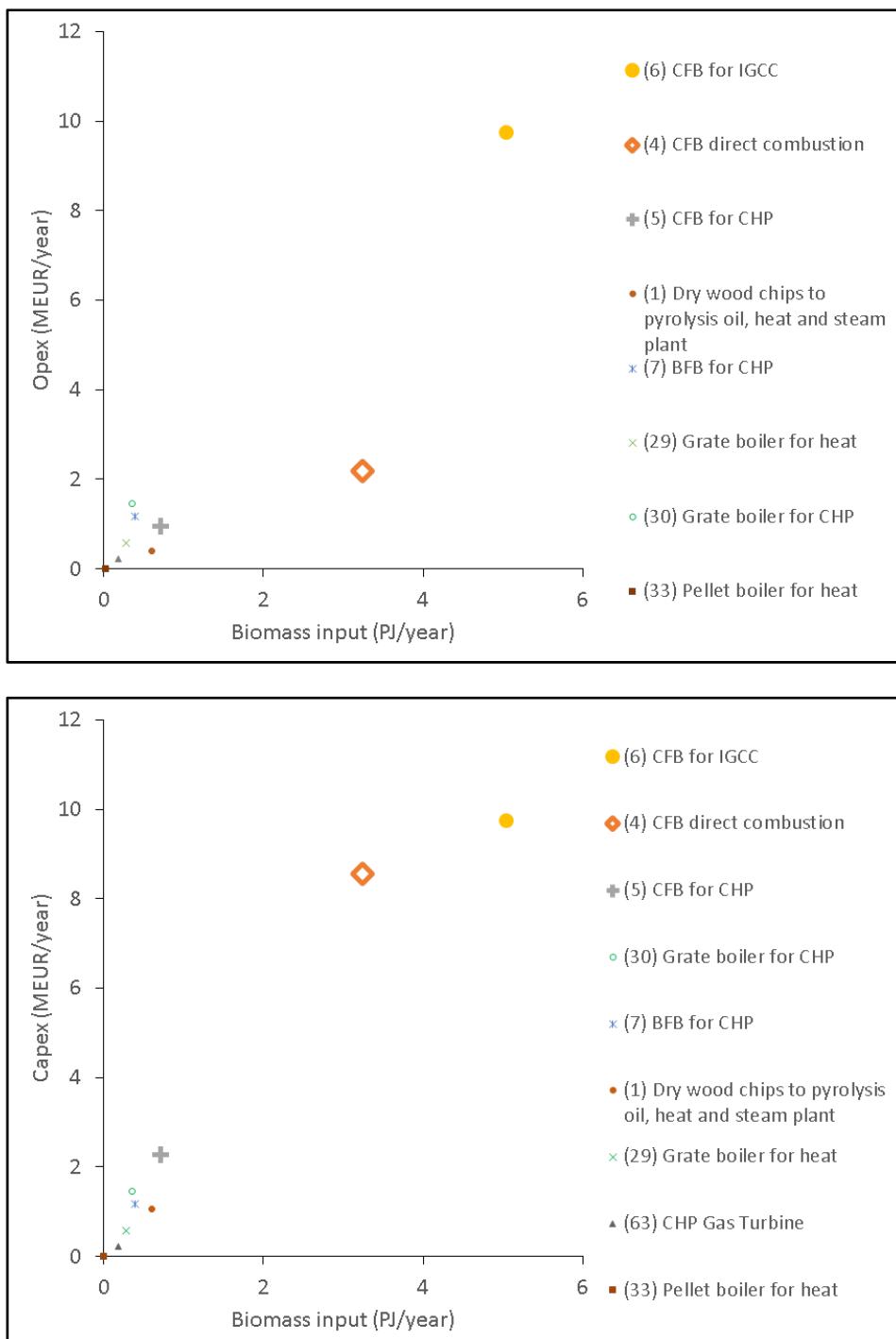


Figure 5. Operation and maintenance (top) and investment (bottom) costs depending of the plant capacity expressed in biomass input for the technologies developed under the WP2.

4. Type of results from BeWhere

The BeWhere model cannot be run online due to long computation time at the European level. Nevertheless the results can be uploaded on a user friendly platform so that the user can have a quick overview of the consequences on the results when varying key parameters such as cost of fossil fuel, or carbon in the system. The following Tables and Figures presents some examples of the outcome from the BeWhere model. Table 3 presents the selected plants from the BeWhere model for the case study of Burgundy together with the amount of feedstock required and the final energy output. The model keeps also track of all costs and emissions of the supply chain.

Table 3. Overview of the bioenergy plant locations, biomass collection and energy carrier generation.

No	Longitude deg	Latitude deg	Max collection distance (km)	Straw (kt/a)	Miscanthus (kt/a)	Power (TJ/a)	Heat (TJ/a)
1	3.59	47.78	146	17	13	128	306
2	4.87	47.03	121	13	17	128	306
3	4.35	46.92	146	12	18	128	306
4	2.90	47.35	143	6	15	89	214
5	2.97	47.47	158	11	18	126	302
6	5.13	47.31	70	18	12	128	306
7	5.20	47.58	114	20	10	128	306
8	3.15	47.03	109	14	14	122	293
9	3.42	48.04	79	18	12	128	306
10	4.91	46.58	103	16	14	128	306
11	4.38	46.65	108	10	17	115	276
12	3.58	47.86	108	16	14	128	306

At the European scale, the results provide information on the locations of the plants, flows of biomass between the different countries as well as the distribution of the technologies. At such a scale, the results have more interest when aggregated at the country or the European level. Figure 6 presents how the technologies developed under the WP2 of the project can be selected for the production of power and heat in Europe under different policy scenarios. As an indication, those technologies are presented in Figure 6 at the top. The figure at the top present the development of technologies with increasing carbon cost, and the second one at the bottom presents the development of technologies with increasing fossil fuel cost (here the fossil fuel factor represents the factor applied to the 2013 fossil fuel cost the limiting factor

being the biomass availability, the feedstock is distributed between small, medium and large scale industries.

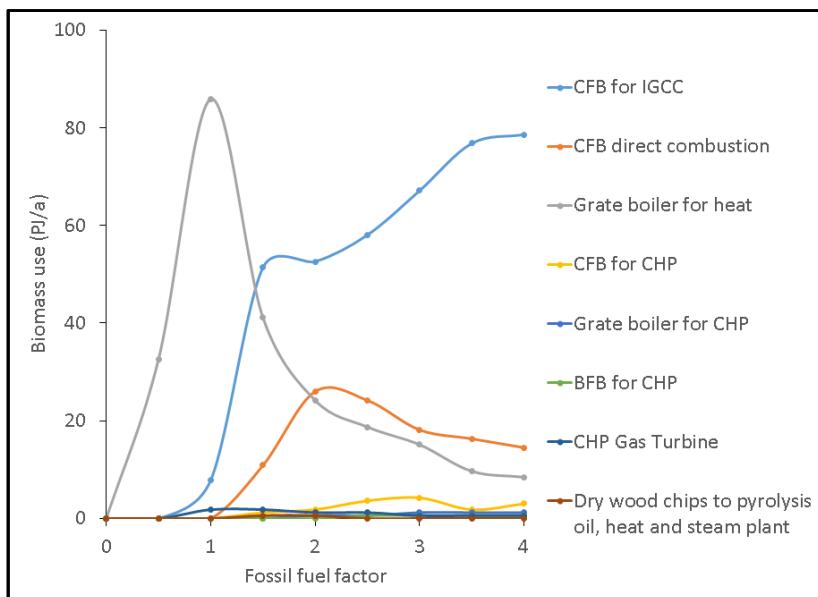
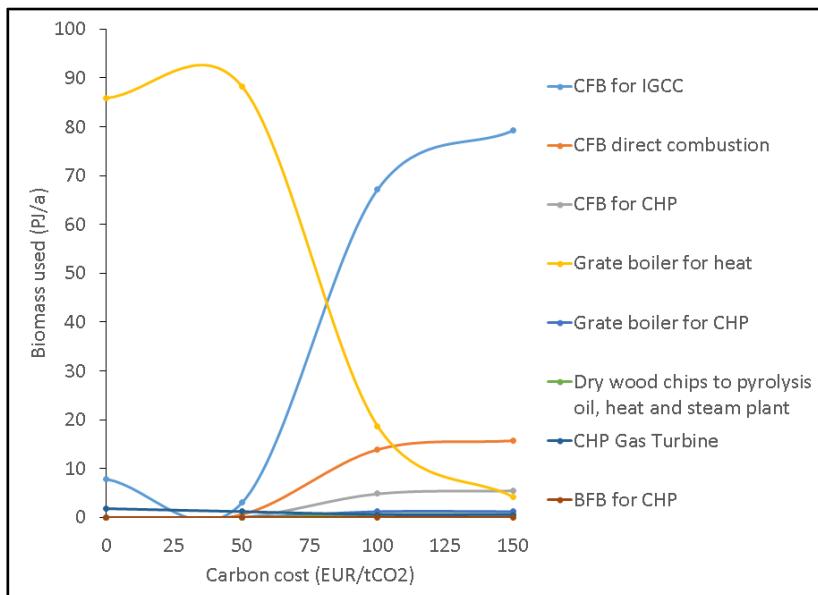


Figure 6. Technology development for the combined heat and power plants with varying carbon cost at fossil fuel equals to the 2013 levels (top), and varying fossil fuel cost at carbon cost equals to zero (bottom).

Small-scale industries are mainly of high interest at low fossil fuel cost or carbon cost, and large-scale industries are becoming of interest at increasing carbon cost due to the high potential of emission substitution effect of those plant. They are also interesting when the fossil fuel cost is increasing, which can be interpreted as a subsidy effect. As the competing product is getting more expensive, the high investment of those plants is getting as well interesting. Nevertheless the ratio of expansion of a technology is much steeper in a carbon scenario, whereas a fossil fuel change increases much slowly the expansion of the same technology.

5. Overview of LocaGIStics

5.1. General description of the functionality of LocaGIStics

At the start of the development of the LocaGIStics tool the functional requirements were determined in several iterations. This has led to a first general set-up of LocaGIStics (Figure 7) that was then used by the software developers to build the simulation tool.

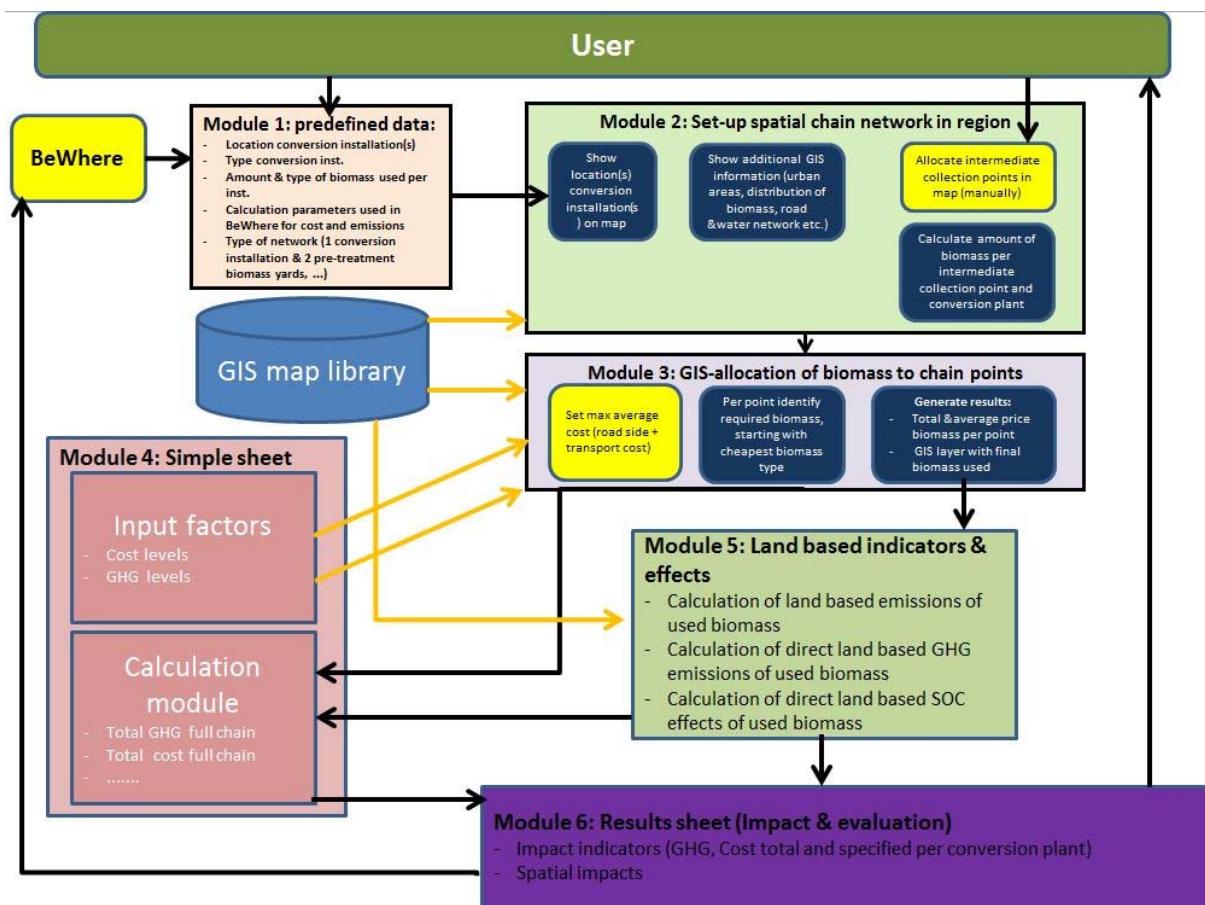


Figure 7. Set-up of LocaGIStics.

During this iterative design process of LocaGIStics it was decided that this new tool should include the following functionality:

Transfer from BeWhere

- select country;
- select region case study;
- select pre-calculated BeWhere case that needs to be analyzed in more detail;

- get grid coordinates of BeWhere and the box (10x10 km, 50x50 km) of identified conversion installation location(s) for which BeWhere identified room;
- get additional data from BeWhere like
 - location, type of conversion technology, scale, costs and GHG effects of the calculated power plants;
 - used amount of biomass per power plant on map.

LocaGIStics

- determine unique number for this analysis, e.g. case name in combination with run number;
- choose biomass types that need to be included on the map (this can be more than one);
- represent locations of each biomass type with separate color on the map (within certain boundaries to be specified, e.g. 50x50 km);
- check if amount of biomass in selected area (e.g. 50x50km) is sufficient;
- specify import amounts and distances and transport type (costs);
- choose size of grid network that LocaGIStics wants to impose on the map (e.g. 2.5x2.5 km, 5x5 km, 10x10 km) to be able to calculate biomass totals per grid cell;
- choose the number of power plants to be included in analysis;
- enable the user to change the pre-specified location for each conversion site (can be more than one) on the map; initially the user can specify manually the locations for the intermediate collection points; for this supportive layers like spatial distribution of biomass potentials, infrastructure and location of urban areas will be provided;
- specify the number of intermediate collection points and possibly allocate them to a specific power plant;
- let the user allocate a location on the map for an intermediate collection site (can be more than one);
- choose starting parameters of the run;
- start ‘peeling mechanism’; the peeling mechanism can be based on pre-calculated distances or on the as the bird flies distances;
- determine preliminary results:
 - calculate total transport distance of biomass supply per arc (possibly with different transport type);
 - represent biomass actually used on map.

Simple sheet (calculation method)

- transfer data to simple sheet: e.g. cumulative transport distance;
- run simple sheet;
- transfer data back to web application.

LocaGIStics

- represent final results for the case on i) cost effects, ii) GHG effects and iii) energy effects.

Transfer to BeWhere

- send suggestions to BeWhere for updating their analysis based on results LocaGIStics run.

5.2. Data requirements for LocaGIStics

There is some overlap with the required data for the BeWhere model. However, in general LocaGIStics will need more detailed data than the BeWhere model. Data for a required logistical component could already be present in the S2Biom logistical component database (WP3). However, several deviations might occur, which require changes to the records in the database:

- if available but incomplete, then please add the missing data of that specific logistical component;
- if available but containing other numbers than expected (e.g. costs), then please copy the original logistical component and make changes in the copied version to adjust it to the required numbers;
- if not available at all then several options are available: i) copy a similar existing component and make changes in the copied version to adjust it to the required numbers or ii) make a completely new logistical component.

Data for the conversion technology could already be present in the database (WP2).

The required data are given in Table 4 and 5.

Table 4. Description of the set-up of the biomass value chain.

Category	Attribute description (unit)
Biomass value chain	General description of the set-up of the biomass value chain, including variants and specific questions (e.g. intermediate collection points included or not) that could be addressed by the LocaGIStics tool in the case study (text)
	Number of biomass yards (number)
	Coordinates of possible locations for intermediate collection points (plus map-projection)
	Number of conversion plants (number)
	Coordinates of possible locations for conversion plants (plus map-projection)
	Locations where conversion plants or intermediate collection points should not be placed (e.g. Natura 2000 regions)

Table 5. Required data for LocaGIStics.

Category	Attribute description (unit)
Biomass characteristics	Biomass type(s) available (name)
	Bulk density per biomass type (kg dm/m ³)
	Higher heating value per biomass type (GJ/ton dm)
	Moisture content at roadside per biomass type (kg moisture/ kg total)
Biomass availability	Amount of biomass available per source location/grid cell (ton dm/year) (this should be as detailed as possible, e.g. Nuts4 or Nuts5 or even at parcel level, please add GIS file (shapefile) with locations)
	Description of form/shape (name) e.g. bales or chips
	Costs at roadside per biomass type (€/ton dm)
	Energy used for biomass production (GJ/ton dm)
	GHG emission used for biomass production (ton CO ₂ -eq/ton dm)
Storage	Type of storage per specific location (name)
	Capacity per storage type per location (m ³)
	Costs per storage type per location (€/m ³ .month)
	Energy used per storage type per location (MJ/ m ³ .month)
	GHG emission per storage type (ton CO ₂ -eq/ton dm)
Logistics	Type of available transport means for each part of the chain (name)
	Detailed road/rail network (could be taken from open street maps)
	Maximum volume capacity per transport type (m ³)
	Maximum weight capacity per transport type (ton)
	Costs variable per transport type (€/km)
	Costs fixed per transport type (€/load)
	Energy used per transport type (MJ/km)
	GHG emission per transport type (ton CO ₂ -eq/ton dm)
Handling	Type of available handling equipment per specific location (name) e.g. for loading and unloading
	Costs handling equipment per type (€/m ³)
	Energy used per handling equipment type (MJ/m ³)
	GHG emission per handling equipment type (ton CO ₂ -eq/ton dm)
Pre-treatment	Type of pre-treatment needed per specific location (name)
	Description of output form/shape (name) e.g. chips, pellets
	Costs of pre-treatment per type (€/m ³)
	Energy input of pre-treatment per type (MJ/m ³)
	GHG emission per pre-treatment type (ton CO ₂ -eq/ton dm)
Conversion	Technology type per conversion plant (name)
	Net energy returns electricity (usable GJ/GJ input *100%)
	Net energy returns heat (usable GJ/GJ input *100%)
	Capacity input (ton dm/year or ton dm/month)
	Working hours (hours/month)
	Costs conversion plant fixed (€/year)

	Costs conversion variable (€/ton dm input)
	Energy use for conversion (GJ/m ³)
	Emissions CO ₂ (mg/Nm ³)
	Emissions NO _x (mg/Nm ³)
	Emissions SO ₂ (mg/Nm ³)
Revenues	Price electricity (€/GJ)
	Price heat (€/GJ)
	Price other type(s) of (intermediate) products (€/ton)

5.3. Calculation method of LocaGISrics: 'Simple sheet'

'Simple sheet' is an excel-file that perform a simple calculation of the economic, energy and GHG effects of a biomass value chain specially designed in the LocaGISrics tool. In Annex A. the content of these excel-sheets and the formula behind the calculations are specified. This excel-file itself contains part of the data that are needed for the calculations (see sheet 'Input basic'). Another part of the required basic data is transferred from the LocaGISrics tool to the sheet 'Input basic' (biomass data and data on the first transport means). The set-up of the network (see sheet 'Input chain') is generated based on the actual design in the LocaGISrics tool: the chosen biomass types are always delivered at an intermediate collection point (biomass yards), however, this can be the same location as the conversion site; the biomass is pre-treated at the biomass yard and then shipped on demand to a biomass conversion site.

The sheets in the 'simple sheet' excel-file are aimed at:

Input:

- input basic (content partly standard, partly generated from LocaGISrics)
- input chain (content generated from LocaGISrics)

Calculation of results:

- calculate costs
- calculate energy
- calculate GHG

Output:

- global results (summary of calculation results)

5.4. Data exchange between BeWhere and LocaGIStics

The first step in the data exchange is transferring data about the results from BeWhere to LocaGIStics. The second step is sending results from LocaGIStics back to BeWhere (Figure 8). So designing new biomass chains is an iterative process of running the two tools.

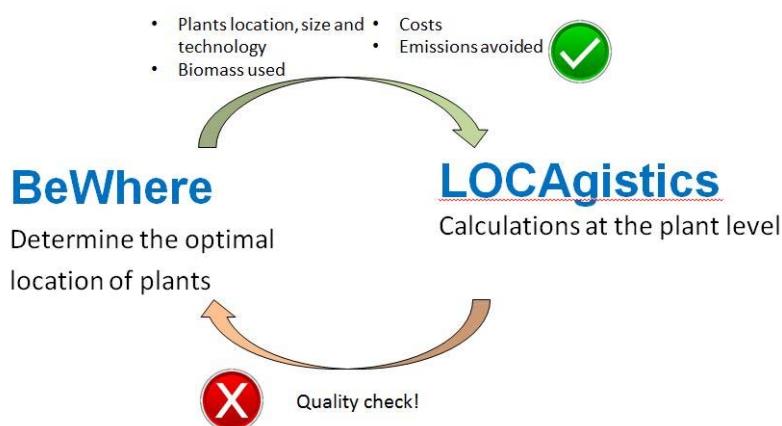


Figure 8. The relation and data exchange between BeWhere and LocaGIStics.

The BeWhere model first optimizes the locations of the bioenergy production plants under a specific scenario. For a quality control of the results, the following results are provided to the LocaGIStics model:

- suggested/selected plant data;
- coordinates of suggested locations;
- general data of technology such as name, type;
- technical data of technology such as size, total biomass demand, hours per year;
- economic data of technology such as fixed costs per year, operation cost.

Providing an exact match of the input parameters described in the tables above, the LocaGIStics model will then simulate the collection of the feedstock for each production plant determined from the BeWhere model. If the results from the simulations are not satisfactory, which means if the plants cannot get enough biomass for the capacity determined by the BeWhere model at a specific position, to a competitive cost and emission reduction, a new run has to be completed by the BeWhere model. In which case, the locations of the plants can be omitted in case the locations are not technically feasible, or the capacity may be decreased. This process of exchange of information between the two models will go on until the results from the BeWhere model are proven satisfactory by LocaGIStics in terms of costs and emission reduction. This process of quality control improve the quality of the results considerably.

6. User interface of LocaGIStics

6.1. Getting started with a new variant

The starting screen of LocaGIStics (Figure 9) shows a map of the selected country and area of interest (Burgundy in this example) and several data entry panes on the left and the right side of this map. The user is able to design new biomass delivery chains e.g. by choosing the size and location of the power plant while designing the chain with or without intermediate collection points. To operate the LocaGIStics tool one starts specifying the choices in the top left hand pane ‘Countries’, going down to the ‘Areas of interest’, ‘Cases’ and ‘Variants’ pane on the left side. Then the user has to move to the top right panes specifying ‘Biomass types’, ‘Biomass conversion plants’ and finally the ‘Intermediate collection points’.

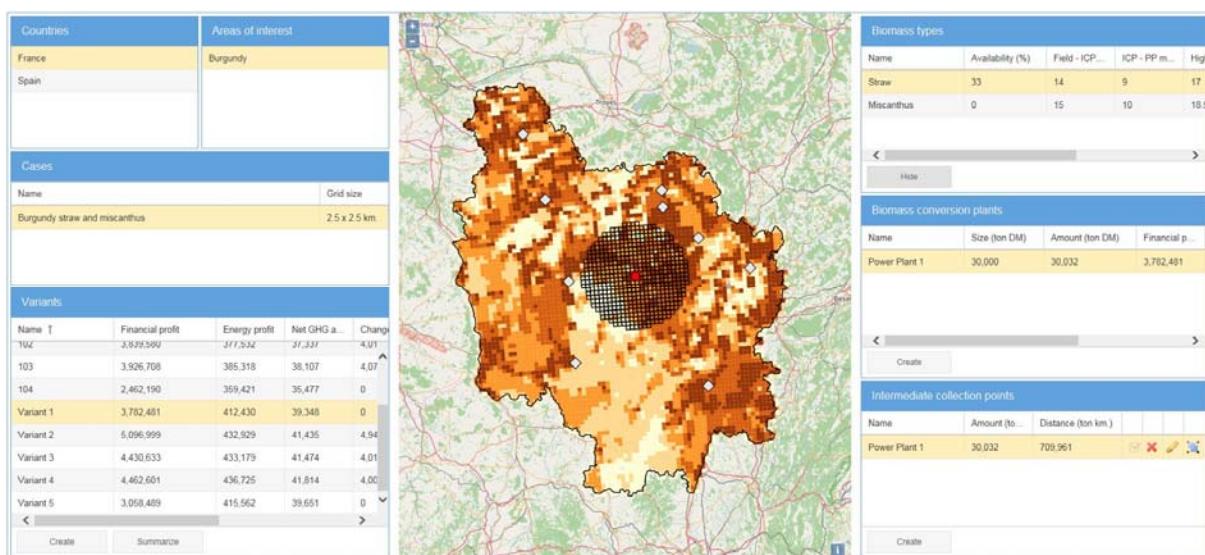


Figure 9. Starting screen of LocaGIStics.

After the choice of the ‘Countries’ (France or Spain are implemented sofar), ‘Area of interest’ (Burgundy or Aragon) and ‘Cases’ (Burgundy straw and Miscanthus or Aragon) (Figure 10) the user continues with the ‘Variants’ pane (Figure 11). In Figure 11 the variant pane and its columns are enlarged compared to the picture in Figure 9. This can be achieved by choosing the border of the map pane with the mouse and pulling it to the right. In this variants pane a new variant can be defined after pressing the ‘create’ button and a name for the variant of the chain one is going to design (e.g. ‘Variant 1 only straw’ or ‘Variant 2 mixed straw and Miscanthus’) has to be chosen. The variant that has been created is highlighted with a yellow bar. If needed the name of the variant can be changed. On the right hand side of the line of a variant there are four icons that enable the user to copy, delete, edit and (re)calculate the variant. Editing can be done in a pop-up screen (Figure 12).

Countries	Areas of interest
France	Burgundy
Spain	
Cases	
Name	Grid size
Burgundy straw and miscanthus	2.5 x 2.5 km.

Figure 10. Countries, areas of interest and case panes.

Variants							
Name ↑	Financial profit	Energy profit	Net GHG a...	Change in...	Direct N2O...	Indirect N2...	
102	3,839,580	377,532	37,337	4,019,948	77,310	148,446	
103	3,926,708	385,318	38,107	4,073,814	88,637	141,965	
104	2,462,190	359,421	35,477	0	0	0	
Variant 1	3,782,481	412,430	39,348	0	0	0	
Variant 2	5,096,999	432,929	41,435	4,945,974	157,380	126,353	
Variant 3	4,430,633	433,179	41,474	4,019,948	77,310	148,446	
Variant 4	4,462,601	436,725	41,814	4,009,354	87,322	139,631	
Variant 5	3,058,489	415,562	39,651	0	0	0	

Figure 11. Variants pane.

✖
Edit variant

Name:	<input type="text" value="Variant 1"/>
Distance calculation method:	<input type="text" value="Bird flight"/> ▼
Peeling mechanism:	<input type="text" value="Distance"/> ▼
Bulk density (kg dm/m3):	<input type="text" value="400"/>
Maximum volume (m3):	<input type="text" value="80"/>
Maximum weight (ton):	<input type="text" value="26.6"/>
Variable vehicle costs per driven km (euro/km):	<input type="text" value="3.26"/>

Figure 12. Edit variant pop-up screen.

6.2. Biomass types

The biomass types pane (Figure 13) shows the available biomass types (in the Burgundy case these are straw and Miscanthus). One can choose the actual amount of biomass (availability percentage) one wants to include in the analysis (this could be lower than the maximum). The choice could be e.g. to use only straw, so then one needs to put the amount of the other biomass types (now only Miscanthus is included) on '0'. The biomass availability and related properties (field moisture %, moisture content after intermediate collection/pre-treatment, higher heating value, costs and energy use at roadside) can be edited. All biomass properties have a default setting (in this case 33% straw and 0% Miscanthus), but can be changed by the user. The map shows the biomass availability in a grid pattern (e.g. 2.5 x 2.5 km). Deep colored grids have higher biomass availability than light colored grids. The 'active' biomass type (highlighted with the yellow bar), for which a biomass conversion plant is selected is shown on the map. In the Burgundy case straw is yellow and Miscanthus is purple. One can also hide the biomass map in order to see the topographical map of the area containing roads, cities, etc. (Figure 14).

Biomass types						
Name	Availability (%)	Field - ICP moistu...	ICP - PP moistur...	Higher heating value...	Biomass costs...	Energy use biomass at roadside...
Straw	33	14	9	17	45	0.5
Miscanthus	0	15	10	18.5	8.82	0.84

<
>

Hide

Figure 13. Biomass pane.

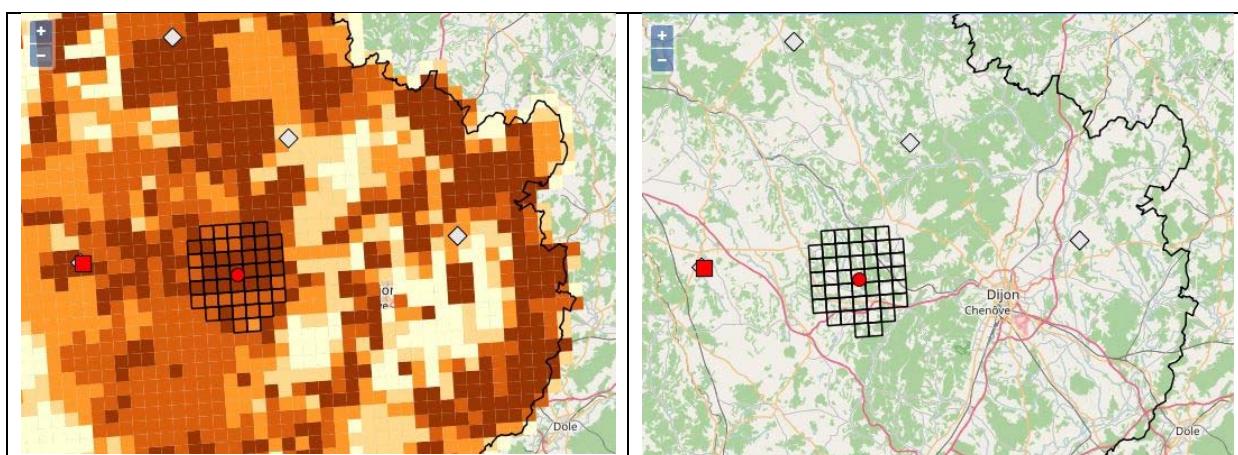


Figure 14. Part of the biomass map and regular map (after hide).

6.3. Biomass conversion plants

In this pane (Figure 15) one can define the power plant location and demand size (in this example the size is chosen to be 30,000 ton dry matter of biomass, and only small size deviations of about 10% can be made). By clicking the 'Create' button one can add a new power plant and specify its name and size in terms of amount of biomass (in ton dry matter) processed on a yearly basis. After clicking 'Submit' a power plant is located on the map (red square) in the center of the region. Then one can move the red square to the location on the map where one wants to locate the plant (Figure 16). The suggested locations by the BeWhere optimization model (grey diamonds in the map) can be used as a reference point, and the biomass density shown on the map (brown grids) is also meant to be a guidance.

Biomass conversion plants						
Name	Size (ton DM)	Amount (ton DM)	Financial profit	Energy profit	Net GHG avoided	
Power Plant 1	30,000	30,032	3,782,481	412,430	39,348	  

[Create](#)

Figure 15. Biomass conversion plants pane.

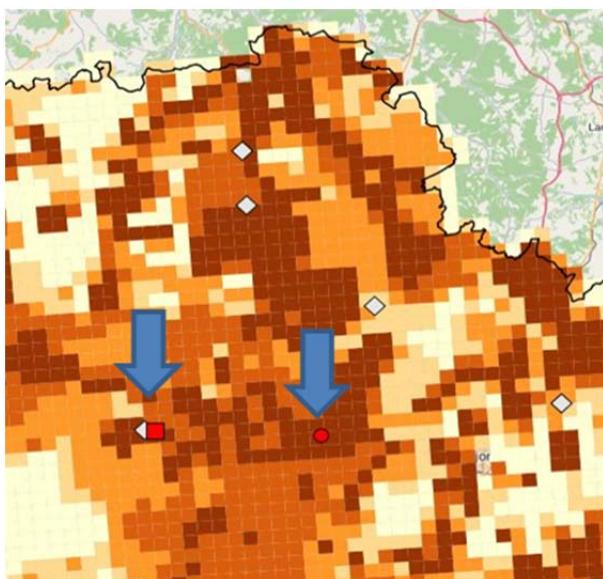


Figure 16. Positioning the conversion plant and the intermediate collection point on the map pane.

6.4. Intermediate collection points

In this pane the intermediate collection points supplying to the biomass conversion plant that was just designed in the former pane can be defined. The first step is to click on 'Create' and then assign a name. Then click on 'Submit'. One will see a red circle on the map indicating the location of the intermediate collection point (Figure 17). The user can now click on this red circle and drag it to the position where he wants the intermediate collection to be located. Most likely the place selected should be where the biomass is most concentrated spatially so that you obtain short transport distances to the intermediate collection point. If the user wants to let the intermediate collection coincide with the power plant itself he can click on the most right icon in the 'Intermediate collection point' pane. This definition of intermediate collection points can be repeated for a second intermediate collection point.

Intermediate collection points						
Name	Amount (to...)	Distance (ton km.)				
Power Plant 1	30,032	709,961	<input checked="" type="checkbox"/>			
<hr/>						
< > Create						

Figure 17. Intermediate collection points pane.

6.5. Results

The results will be available on the screen and also in the 'Simple sheet' excel-file. In the 'variants pane' (Figure 18) the financial profit, energy profit and the net GHG avoided is specified as assessed for the defined biomass delivery chain. In the 'Intermediate collection points pane' (Figure 19) the amount of biomass and the total transport kilometers in every intermediate collection point are shown.

Variants												
Task ↓	Financial pr...	Energy profit	Net GHG a...	Ton fresh	Ton dry ma...	Change in...	Direct N2O...	Indirect N2...	Distance i...	Distance i...	Distance fi...	Distance fe...
▶ <input type="checkbox"/> Variant 5	3,050,469	415,562	39,651	35,202	30,274	0	0	0	10,893	1,190,140	6,103	342,875
▶ <input type="checkbox"/> Variant 4	4,462,601	436,725	41,814	35,500	30,255	4,009,364	87,322	139,631	2,143	1,158,546	236	119,111
▶ <input type="checkbox"/> Variant 3	4,430,633	433,179	41,474	35,210	30,008	4,019,948	77,310	148,446	2,672	1,011,452	597	166,402
▶ <input type="checkbox"/> Variant 2	6,096,999	432,929	41,435	35,295	30,103	4,945,974	157,380	126,353	0	0	2,757	298,544
▶ <input type="checkbox"/> Variant 1	3,782,481	412,430	39,348	34,921	30,032	0	0	0	0	22,013	709,961	

Figure 18. Example of the summary of the results that can be reached through the variants pane of LocaGIStics.

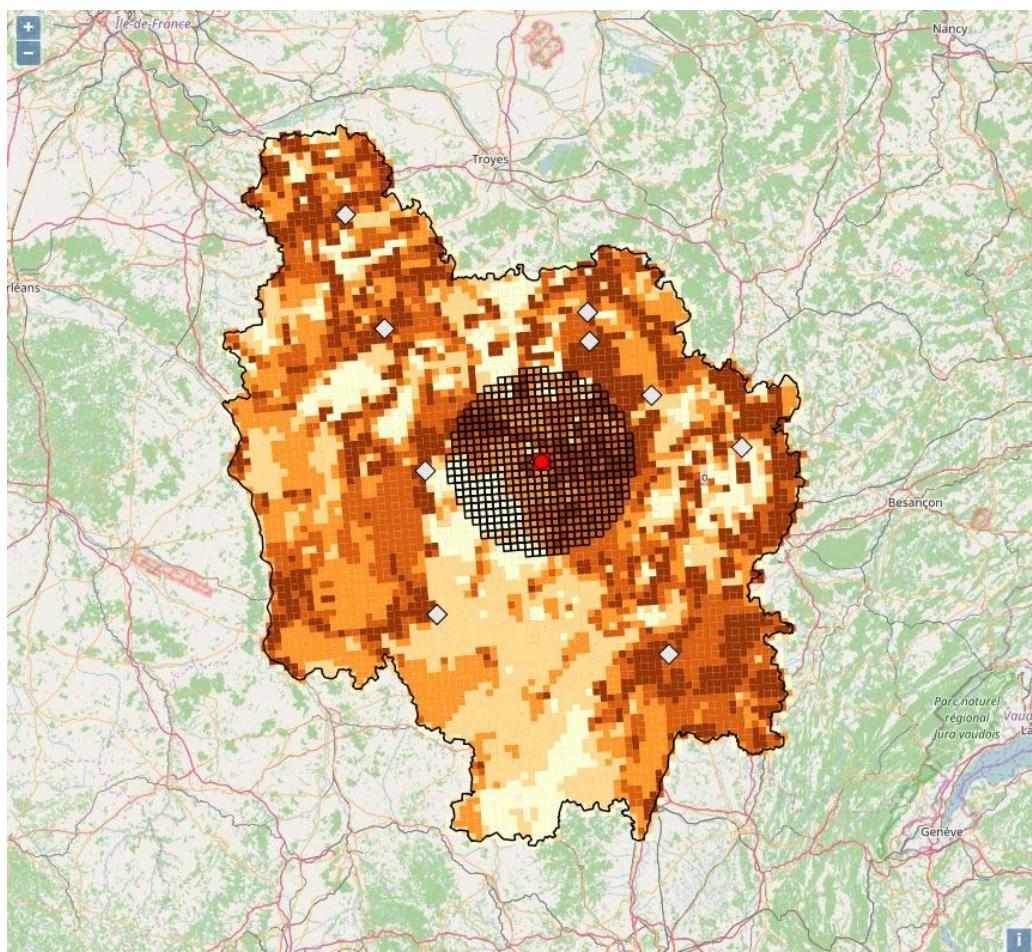


Figure 19. Example of the collection area of Variant 1 shown in the map pane.

7. How to perform runs with LocaGIStics

7.1. Define experiments with LocaGIStics

The case studies can be varied on a number of different aspects, e.g.:

- A choice of different biomass types that are taken into account as a possible supply source.
- The used availability percentage of the biomass types. It is expected that this will influence the radius of the supply circle and thus the transport costs. When less biomass is available due to a lower percentage the biomass will have to be collected at further distance.
- Inclusion of a biomass yard or not, so two-stage transport or direct transport to the production plant. And if included what are the chosen positions for the biomass yards (e.g. in a biomass supply area).
- Different types of pre-treatment and the location of these pre-treatments e.g. chipping at the biomass source, at an intermediate biomass yard or at the production plant.
- Different types of transport (even multi-modal).
- The chosen position for the production plants (e.g. near the main demand).
- The capacity of the production plant could be slightly increased (within the boundaries of the possibilities, e.g. 5-10%) without a change of the fixed costs.

Furthermore there will be a connection with BeWhere:

- The suggested results of BeWhere need to be transferred to LocaGIStics.
- A choice has to be made which of the suggested production plants will be the first to be further refined in LocaGIStics.
- After the calculations of one production plant possibly more of the surrounding production plants that were suggested by BeWhere could also be calculated to see if there is competition for the biomass (e.g. irregularly shaped supply circles).
- In theory this could continue for all of the suggested production plants. However, that is not really the main goal of using LocaGIStics, that is meant for further refining the decision for establishing one specific production plant.

There are of course limitations to LocaGIStics:

- This is a simulation tool that will not find an optimal solution, and only calculate the effects of a pre-specified supply chain.
- The results depend largely on the choices that are made by the user. LocaGIStics just calculates the effects of these decisions.
- The results also depend on the chosen ‘peeling mechanism’, which contains the rules for choosing which biomass is collected first (e.g. closest first, cheapest first, etc.). Depending on a specific regional situation certain rules might yield better results than others.

7.2. Prepare dedicated simple sheet

The following steps should be taken (for the moment this can unfortunately only be done by the developers of the tool):

- Prepare specific simple sheet with the correct data for the case and rename the sheet in the first sheet with case specific code.
- Make this the standard simple sheet that is recognized by LocaGIStics in the directory /Network/scomp1172.wur.nl/s2biom\$/xls/template.
- Check for each run if it is made with the correct simple sheet.

7.3. Specify input of variant

The following steps should be taken:

- Choose country and region
- Create new variant & change data if needed:
 - change name of variant (use a numbered code: 001, 002, etc. with short description)
 - add peeling mechanism because this field is empty
 - change data about bulk density if needed (applies only for the first biomass type)
 - change data about the first vehicle used: maximum volume, maximum weight & variable transport costs
 - (if applicable the second vehicle needs to be changed in the simple sheet)

- Choose biomass types & change data if needed:
 - specify availability percentage
 - correct the moisture content at source and at gate
 - change HHV
 - correct biomass costs at roadside
 - change energy
- Create Power Plant & change data if needed:
 - change name
 - specify biomass demand
 - allocate on correct position
- Create Intermediate Collection Point
 - change name (only if located at other position than power plant)
 - specify position; if needed make this the same as power plant by ticking the box (repeat this in case of a copied variant)
- Press calculate

7.4. Get results

The following steps should be taken:

- make dedicated subdirectory for the variant with data and code 001, 002, etc.
- make screenshots of input parameters:
 - variant
 - biomass types
- make screenshots of results:
 - summary screen
 - amount biomass supplied to collection points / power plants
 - maps of sourcing per power plant and per biomass type
- insert the screenshots in a standard report format
- save the simple sheets per power plant
- copy the input data and the cost results in the standard report format

8. Final remarks

Besides BeWhere and LocaGIStics there has also been a third logistical assessment method that was used especially for the Finnish regional case study. This third tool is based on the Witness simulation model and is described in full detail in D3.4+D3.6, Annex 3 (Väätäinen et al., 2016). The Witness tool performs an even more detailed analysis than LocaGIStics. However, for the time being it has not been integrated yet with BeWhere and LocaGIStics and therefore it was not further described in this deliverable.

References

- Annevelink, E., I. Staritsky, B. Vanmeulebrouk, B. Elbersen & B. Gabrielle, 2016. LocaGIStics: design & evaluation of regional biomass delivery chains. In: Proceedings of the 24th European Biomass Conference and Exhibition, 6-9 June 2016, Amsterdam, 174-175.
- Annevelink, E. I. Staritsky, N. Krajnc, T. Lammens, D. Sanchez Gonzalez, K. Lenz, S. Kühner, P. Anttila, R. Prinz, S. Leduc, S. Giarola, N. Shah, B. Gabrielle & D. García Galindo, 2016. S2biom survey of logistical concepts. In: Proceedings of the 24th European Biomass Conference and Exhibition, 6-9 June 2016, Amsterdam, 108-113.
- Annevelink., E., H. de Groot, N. Shah, S. Giarola, M. Pantaleo, P. Anttila, M. Vis, R. te Raa, D. van den Berg, B. Gabrielle, D. Sanchez Gonzalez, D. García Galindo, Š. Ščap & N. Krajnc, 2015. S2Biom database with logistical components of the biomass value chain. In: Proceedings of the 23rd European Biomass Conference and Exhibition, 1-4 June 2015, Vienna, Austria, 339-343.
- Annevelink, E., H. de Groot, N. Shah, S. Giarola, M. Pantaleo, P. Anttila, M. Vis, R. te Raa, D. van den Berg, B. Gabrielle, D. Sanchez Gonzalez, D. García Galindo, E. López Hernandez, Š. Ščap, N. Krajnc, 2014a. Review of the main logistical components. S2Biom project, Deliverable D3.1, 65 pp.
- Annevelink, E., , I. Staritsky, N. Krajnc, T. Lammens, D. Sanchez Gonzalez, K. Lenz, S. Kühner, P. Anttila, R. Prinz, S. Leduc, S. Giarola, N. Shah, B. Gabrielle & D. García Galindo, 2015. Logistical concepts. S2BIOM project, Deliverable D3.2, 83 pp.
- Annevelink, E. & R.M. de Mol, 2014. The logistics of new biomass chains on a regional scale in The Netherlands. In: Proceedings of the 22nd European Biomass Conference and Exhibition, 23-26 June 2014, Hamburg, Germany, 59-63.
- Annevelink, E., B.S. Elbersen, H.W. Elbersen & J. Sanders (editors), 2012. An integrated framework to assess spatial and related implications of biomass delivery chains. Klimaat voor Ruimte, Report, 048/12, 68 pp.
- Elbersen, B.S., E. Annevelink, J. Roos Klein-Lankhorst, J.P. Lesschen, I. Staritsky, J.W.A. Langeveld, H.W. Elbersen & J.P.M. Sanders, 2014. A framework with an integrated computer support tool to assess regional biomass delivery chains. Regional Environmental Change, DOI 10.1007/s10113-014-0584-1, 14 pp.
- Leduc, S., 2009. Development of an optimization model for the location of biofuel production plants. Doctoral thesis, Luleå University of Technology, Sweden, 71 pp + 6 Annexes.
- Leduc, S., E. Wetterlund, E. Dotzauer & G. Kindermann, 2012. CHP or biofuel production in Europe? Energy Procedia, 20:40-49.

Natarajan, K., S. Leduc, P. Pelkonen, E. Tomppo & E. Dotzauer, 2011. Optimal locations for methanol and CHP production in Eastern Finland. Bioenergy Research, 5 (2):412-423.

Väätäinen, K., P. Anttila & E. Annevelink, 2016. Logistical case study in Finland. S2BIOM project, Deliverable D3.4 + D3.6 : Annex 3, 22 pp.

Wetterlund, E., S. Leduc, E. Dotzauer & G. Kindermann, 2013. Optimal use of forest residues in Europe under different policies - second generation biofuels versus combined heat and power. Biomass Conversion and Biorefinery, 3 (1):3-16.

Annex A. 'Simple sheet' LocaGIStics

A1. Input Basic

Biomass basic

name
Higher Heating value [GJ/ton dm]
initial moisture content [kg moisture/kg total]
biomass costs at roadside [euro/ton dm]
energy use biomass at roadside [GJ/ton dm]

Form basic

description form	
bulk density [kg dm/m3]	
specific volume [m3/ton dm]	1,000/bulk density

Storage basic

name
costs [euro/m3.month]
energy use [MJ/m3.month]

Transport basic

name	
maximum volume [m3]	
maximum weight [ton]	
variable vehicle costs per driven km [euro/km]	
fixed vehicle costs per load [euro]	
transport energy [MJ/km]	double costs related to transport back and forth
	double energy related to transport back and forth

Loading/unloading basic

transport type being (un)loaded
loading costs [euro/m3]
unloading costs [euro/m3]
loading energy [MJ/m3]
unloading energy [MJ/m3]

Pretreatment

name
output form
pretreatment costs [euro/m3]
pretreatment energy [MJ/m3]
drying costs [euro/ton moisture]
drying energy [MJ/ton moisture]

Conversion

name
net energy returns electricity [usable GJ/GJ input]
net energy returns heat [usable GJ/GJ input]
evaporation energy moisture [GJ/ton moisture]
capacity input [ton dm/month]
working hours [per month]
fixed costs plant + conversion [euro /year]
variable costs conversion [euro/ton dm input]

energy use [GJ/m3]
emission CO2 [mg/Nm3]
emission NOx [mg/Nm3]
emission SO2 [mg/Nm3]
emission dust [mg/Nm3]

Revenues

price electricity [euro/GJ]
price heat [euro/GJ]

A2. Input Chain

Chain	Formula
case description	
calculation number	
biomass chain name	
Biomass	
biomass type	fixed
origin location	fixed
destination location	fixed
description form	taken from Input basic
bulk density [kg dm/m3]	taken from Input basic
specific volume [m3/ton dm]	1000/bulk density
biomass shipped fresh [ton fresh]	biomass dry matter / (100 - initial moisture content) * 100
moisture content [kg moisture/kg total]	transfer from LocaGIStics
biomass shipped dry [ton dm]	
Storage	
name	taken from Input basic
costs [euro/m3.month]	taken from Input basic
energy use [MJ/m3.month]	taken from Input basic
average storage time [month]	default that can be changed
Transport basic	
name	taken from Input basic
maximum volume [m3]	taken from Input basic
maximum weight [ton]	taken from Input basic
variable vehicle costs per driven km [euro/km]	taken from Input basic
fixed vehicle costs per load [euro]	taken from Input basic
transport energy [MJ/ton.km]	taken from Input basic
total transport [ton.km]	transfer from LocaGIStics
transported weight per trip (if volume limited) [ton]	IF (max volume/specific volume) < maximum weight THEN = (max volume/specific volume) ELSE = Maximum weight
Loading/unloading basic	
transport type being (un)loaded	taken from Input basic
loading costs [euro/m3]	taken from Input basic
unloading costs [euro/m3]	taken from Input basic
loading energy [MJ/m3]	taken from Input basic
unloading energy [MJ/m3]	taken from Input basic

Pretreatment

name	taken from Input basic
biomass output	taken from Input basic
pretreatment costs [euro/m3]	taken from Input basic
pretreatment energy [MJ/m3]	taken from Input basic
drying costs [euro/ton moisture]	taken from Input basic
drying energy [MJ/ton moisture]	taken from Input basic

A3. Calculate costs & revenues

Costs	Formula
purchase costs [euro]	biomass shipped dry [ton dm] * biomass costs at roadside [euro/ton dm]
storage costs [euro]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * storage costs [euro/m3.month] * average storage time [month]
transport costs [euro]	(total transport [ton.km] * variable vehicle costs per driven km [euro/km]) / transported weight per trip (if volume limited) [ton]
number of transports	biomass shipped dry [ton dm] / max volume <u>or</u> year consumed biomass / transported weight (in case of volume limited)
loading/ unloading costs [euro]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * (loading costs [euro/m3] + unloading costs [euro/m3])
pretreatment costs [euro]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * pretreatment costs [euro/m3]
drying costs [euro]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * drying costs [euro/ton moisture]
variable conversion costs [euro]	biomass shipped dry [ton dm] * variable costs conversion [euro/ton dm input]
fixed conversion costs [euro]	fixed costs plant + conversion [euro /year] ONLY ONCE!
total conversion costs [euro]	variable conversion costs + fixed conversion costs [euro]
Revenues	
electricity [euro]	electricity * payment electricity
heat [euro]	heat * payment heat

A4. Calculate energy

Returns	Formula
gross energy [GJ]	biomass shipped dry [ton dm] * Higher Heating value [GJ/ton dm]
evaporation energy [GJ]	biomass shipped dry [ton dm] * moisture content [kg moisture/kg total] * evaporation energy moisture [GJ/ton moisture]
electricity [GJ]	(gross energy - evaporation energy) * net energy returns electricity [usable GJ/GJ input]
heat [GJ]	(gross energy - evaporation energy) * net energy returns heat [usable GJ/GJ input]

Use	
purchase energy [GJ]	biomass shipped dry [ton dm] * energy use biomass at roadside [GJ/ton dm]
average storage energy [GJ]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * storage energy use [MJ/m3.month] * average storage time [month] /1000
transport energy [GJ]	(total transport [ton.km] * transport energy [MJ/ton.km])/ (transported weight per trip (if volume limited) [ton] * 1000)
loading/ unloading energy [GJ]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * (loading energy [MJ/m3] + unloading energy [MJ/m3])/1000
pretreatment energy [GJ]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * pretreatment energy [MJ/m3] / 1000
drying energy [GJ]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * drying energy [MJ/ton moisture] / 1000
energy used for conversion [GJ]	biomass shipped dry [ton dm] * specific volume [m3/ton dm] * conversion energy use [GJ/m3]

A5. Calculate GHG

Avoided (based on coal replacement)	Formula
electricity [CO2-equivalents]	electricity [GJ] * sum emission factors coal
heat [CO2-equivalents]	heat [GJ] * sum emission factors coal
Emission (based on diesel consumption)	
purchase GHG emission [CO2-equivalents]	purchase energy [GJ] * sum emission factors diesel
average storage GHG emission [CO2-equivalents]	average storage energy [GJ] * sum emission factors diesel
transport GHG emission [CO2-equivalents]	transport energy [GJ] * sum emission factors diesel
loading/ unloading GHG emission [CO2-equivalents]	loading/unloading energy [GJ] * sum emission factors diesel
pretreatment GHG emission [CO2-equivalents]	pretreatment energy [GJ] * sum emission factors diesel
drying GHG emission [CO2-equivalents]	drying energy [GJ] * sum emission factors diesel
conversion GHG emission [CO2-equivalents]	energy used for conversion [GJ] * sum emission factors diesel

A6. Global results (example Variant 3 Burgundy case)

Output simple chain calculation

Case description Case: Burgundy straw and Miscanthus, variant: 102
 Calculation number 803
 Biomass chain name bioenergy

Total throughput:

[ton dm]:

from sources 30,008

Revenues and costs:

[euro]

electricity revenues	7,214,712	total revenues	8,238,579
heat revenues	1,023,867		
purchase costs	511,079	total costs	5,299,231
	271,328		2,939,348
	132,376		
	67,492		
	2,791,724		
	0		
	1,525,232		

Energy returns and use:

GJ]

electricity returns	134,578	total energy returns	457,564
heat returns	322,987		
energy used for purchase	22,891	total energy use	80,032
	0		377,532
	162		
	775		
	56,195		
	0		
	10		

Green House Gas avoided and emission

[ton CO₂-equivalents]

electricity GHG avoided	12,731
heat GHG avoided	30,555

total GHG avoided	43,287
-------------------	--------

GHG emission for purchase	1,702
GHG emission for storage	0
GHG emission for transport	12
GHG emission for loading/unloading	58
GHG emission for pretreatment	4,178
GHG emission for drying	0
GHG emission for conversion	1

total GHG emission	5,950
net GHG avoided	37,337