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

S2Biom Project Grant Agreement n°608622

D3.4 + D3.6: Annex 1
Results logistical case study Burgundy

22 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

Scientific coordinator

Project partners

About this document

This report corresponds to D3.4+D3.6 of S2Biom. It has been prepared by:

Due date of deliverable:	31 October 2016 (Month 38)
Actual submission date:	22 November 2016 (Month 38)
Start date of project:	2013-01-09
Duration:	36 months

Work package	WP3
Task	3.3
Lead contractor for this deliverable	DLO
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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	28/07/2016	E. Annevelink	First version contents sent to WP3 partners with request for additions & comments	Done
0.2	04/11/16	E. Annevelink	Draft sent to co-authors for comments	Done
0.3	10/11/2016	S. Leduc	Expanded on BeWhere results	Done
0.4	10/11/2016	E. Annevelink	Updated draft	Done
0.5	11/11/2016	E. Annevelink, S. Leduc, B. Elbersen	Updated draft sent for comments to INRA	Done
0.6	16/11/2016	E. Annevelink	Final draft sent to co-authors for review	Done
1.0	22/11/2016	All	Final report	Done

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 608622.

Executive summary

In the S2Biom project the logistical case study in Burgundy was the first that was performed. The data were based on the results of the LogistEC project, which had already performed a thorough assessment of the case. Therefore, the S2Biom case study was especially used to develop the new tool LocaGIStics, and to illustrate the possibilities of such a new logistical tool in combination with an existing tool, the BeWhere model. So the results of the case study were not primarily intended to further assess the real life case or to advise an actual company for taking decisions on their biomass supply chain yet.

The BeWhere model has been applied for the case study of Burgundy in order to identify the optimal locations of bioenergy production plants. It should be emphasized that the locations of the plants were highly driven by the location and amount of the demand of heat over the transport collection of the feedstock at least for this particular case study. The collection points of the biomass are nevertheless very well concentrated around the production plants. Anyhow to validate those results, LocaGIStics is a valuable tool for the simulation of the feedstock collection from the plants determined from BeWhere. The quality check controls the feedstock collection, capacity and therefore the validity of the chosen location.

The LocaGIStics model has especially been developed using the Burgundy case study. Several logistical concepts have been tested in the Burgundy case. These are: i) mixing different biomass types (straw as a biomass residue and Miscanthus as an energy crop), ii) applying pretreatment technology (pelletizing) to densify the material in order to lower the transportation costs and increase handling properties, iii) switching between different types of transport means (truck and walking floor vehicle) and iv) direct delivery to a power plant versus putting an intermediate collection point in the value chain. Due to the nature of this development case less value should be given to the exact results of the five variants that are described in this report. However, these variants are perfect examples of what effects can be achieved if the set-up of a lignocellulosic biomass value chain is changed, even if that change is only slightly. So the case was used successfully to build a first version of the locaGIStics tool. However, many improvements are still possible and could be achieved in future project cases.

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1. Introduction

1.1 Aim of logistical case study in Burgundy

In the S2Biom project the logistical case study in Burgundy was the first that was performed. The data were based on the results of the LogistEC project (Perrin et al., 2015; Gabrielle et al., 2015), which had already performed a thorough assessment of the case.

The LogistEC project aimed at developing new or improved technologies for all steps of the logistics chains for biomass supply from energy crops, and to assess their sustainability for small to large-scale bio-based projects. It encompassed all types of lignocellulosic crops: annual and pluri-annual crops, perennial grasses, and short-rotation coppice, and included pilot- to industrial-scale demonstrations. One of them involved the case-study based on the Bourgogne Pellets cooperative, which develops Miscanthus in Burgundy (eastern France), and which is being further evaluated here using some of the S2Biom tools, in particular LocaGIStics.

Therefore, the S2Biom case study was especially used to develop the new tool LocaGIStics, and to illustrate the possibilities of such a new logistical tool in combination with an existing tool, the BeWhere model. So the results of the case study were not primarily intended to further assess the real life case or to advise an actual company for taking decisions on their biomass supply chain yet. However, indirectly the company Burgundy Pellets (Figure 1) was kept in mind when designing test runs with LocaGIStics. That pellet production company was involved in the LogistEC project and its business goal is to develop biomass value chains that process Miscanthus to pellets for energy or animal bedding.

Bourgogne Pellets (BP) is a farmers' cooperative of about 350 members based in the municipality of Aiserey in the vicinity of Dijon, in the Burgundy region of France. It currently grows around 400 ha of Miscanthus, established on arable land in the vicinity of the cooperative's headquarters. The supply chain operated by BP is divided into 6 main stages, namely production, harvest, handling, transport, storage and processing. Each year, the importance of each stage varies in response to the biomass supply (Miscanthus yields) and the demand for the different products (chips, bales and pellets). The main markets for these end-products are gardening (mulching materials), bedding materials for horses and pets, and heat generation.

Figure 1. Burgundy Pellets company processing Miscanthus (Bjørkvoll, 2015).

1.2 Content of report

In this report the assessment methods for the logistical case study are described in Chapter 2. This is followed by the set-up of the Burgundy case study in Chapter 3. In Chapter 4 the type of data needed and in Chapter 5 the actual data used are described. Then the results are presented that were obtained by the BeWhere (Chapter 6) and by the LocaGIStics model (Chapter 7). Conclusions and recommendations are given in Chapter 8.

2. Assessment methods for logistical case studies

Various logistical assessment methods have already been described in Deliverable D3.2 ‘Logistical concepts’ (Annevelink et al., 2015). From these methods, the following three have been chosen for further assessments in the logistical case studies for the S2Biom project viz.:

- BeWhere for the European & national level;
- LocaGIStics for the Burgundy and Aragón case study at the regional level;
- Witness simulation model for the Finnish case.

BeWhere and LocaGIStics have been closely interlinked so that LocaGIStics can further refine and detail the outcomes of the BeWhere model and 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 2. These tools are described in further detail in D3.5 ‘Formalized stepwise approach for implementing logistical concepts (using BeWhere and LocaGIStics) so please consult that deliverable to understand the tools. The Witness simulation model was not used for the Burgundy case.

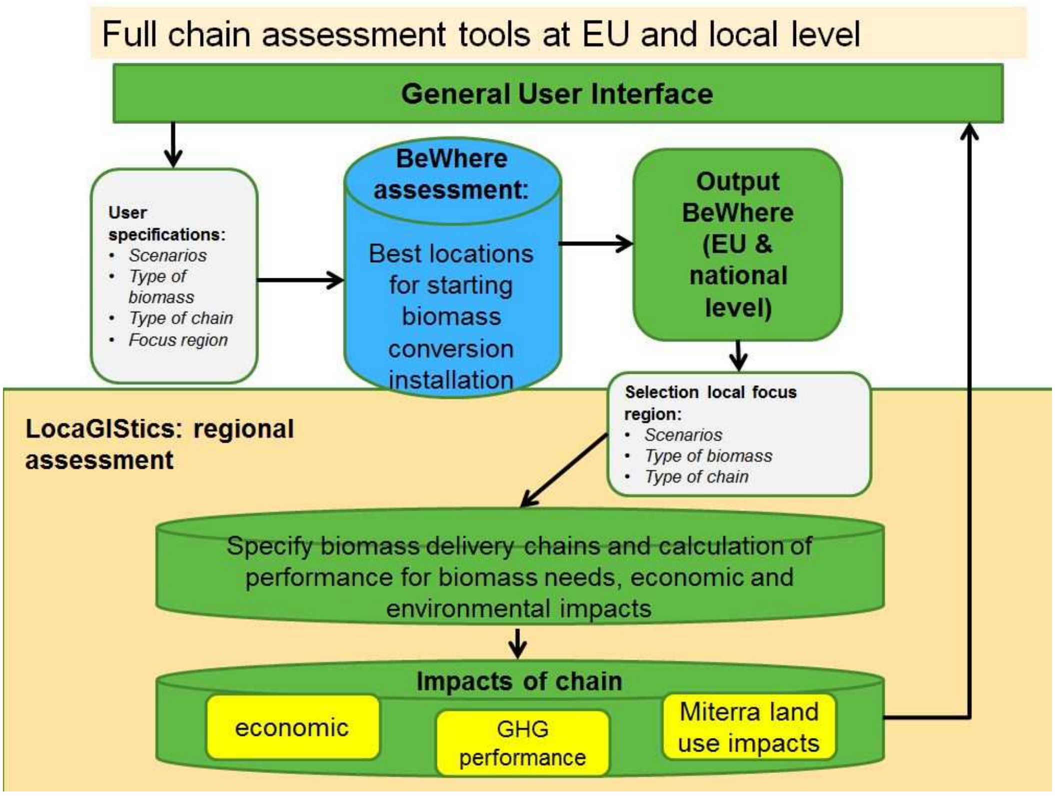

Figure 2. Relation between BeWhere and LocaGIStics.

3. Set-up of the case study

3.1 Introduction

The focus of the Burgundy case study is on Miscanthus and straw. For these types of feedstock the BeWhere model will tell us where there is a possibility to locate the (new) biomass conversion factory specifying the type of technology and size (in this case small scale combustion power plants). The case for BeWhere is to determine best solutions for satisfying the energy demand in Bourgogne in terms of cost and GHG efficiency based on overall energy (electricity demand) and local biomass availability in different scenarios. In order to make this assessment in BeWhere there is a need for detailed biomass potentials and electricity and heat demand.

LocaGIStics will then take the information on the size and type of technology and assess how the organisation of the biomass delivery chain should look like in terms of logistical concepts, specifying e.g. alternative user defined locations for a conversion plant, and for intermediate storage and pre-treatment alternatives given different types and amounts of Burgundy biomass use, etc.

Finally LocaGIStics will deliver:

- a basic chain design and alternative designs of the biomass chain
- full costs and returns of the proposed and alternative biomass chains
- full GHG emissions and GHG mitigation from the full chain (and alternative chains), including land use change emissions as compared to baseline (= no cultivation)
- N-balance

3.2 General characteristics of the Burgundy case

The Burgundy case that was described in the LogistEC project (Gabrielle et al., 2015) focuses on the biomass crop Miscanthus. The case is about the small scale local production of Miscanthus pellets and the logistics are pretty simple: feedstock Miscanthus - harvesting as bales or chips - bales stored at the farm - and then transported to the pellet plant - where they are chipped and pelletized. The LogistEC case does not include the further use of the pellets (yet) e.g. in a bioenergy power plant or in other applications. So it is only about producing intermediate products (pellets). Miscanthus pellets or chips may also be used for other purposes like animal bedding. Another application could be directly (without the pelletizing step) transporting the bales to a power plant with boilers that can burn bales directly.

The current S2Biom logistical case study will also take into account the further (long distance) transport of the pellets from the pellet factory to a power plant. LocaGIStics will look at the local/regional level and BeWhere will look at a higher level and make a suggestion for the location of a power plant.

LocaGIStics could calculate e.g. with two scenarios like 300 ha Miscanthus that is already planted and available compared with 600 ha where 300 new ha would need to be planned on a hypothetical map. The question could be if the logistics still hold in this growth scenario. Also a larger pellet factory that needs more biomass could be an alternative case.

The location of the existing pellet factory is already chosen. Unfortunately there are few Miscanthus fields located directly beside the pellet factory.

3.3 Biomass value chains

Miscanthus and cereal straw are the two biomass types that are part of the biomass chains in this case study. The biomass value chain for Miscanthus is given in Figure 3. The value chain for straw is similar to that, but always with bales.

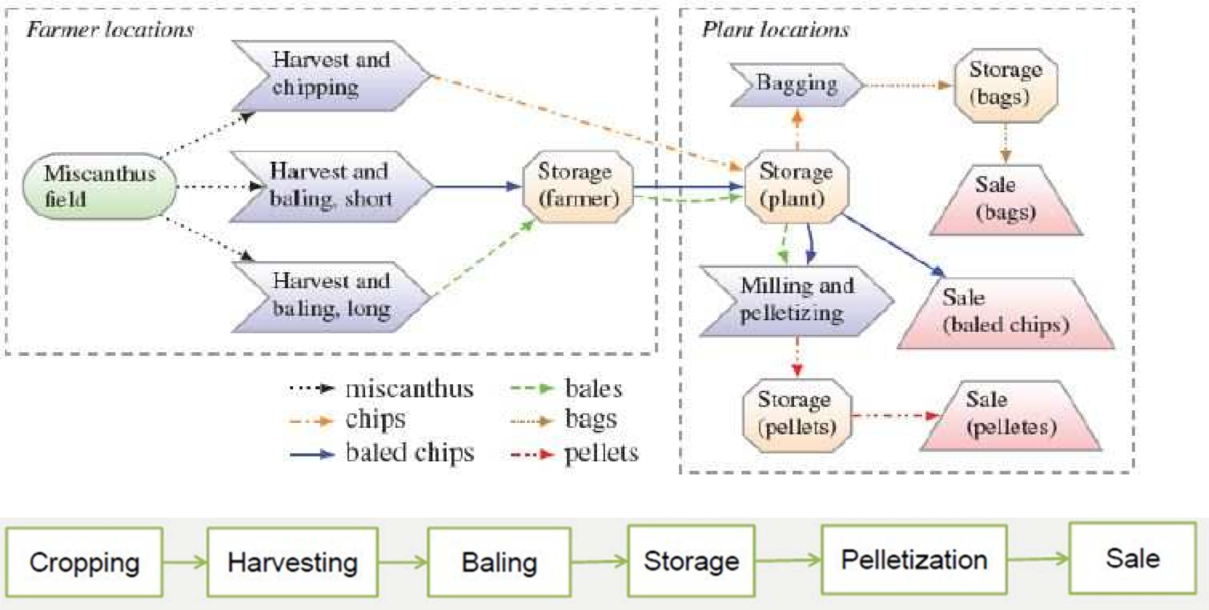

Figure 3. **Schematic biomass value chain for Miscanthus (Kaut et al., 2015).**

4. Type of data requirements for the case studies

4.1 Introduction

The type of data that are needed to run the BeWhere model and the model LocaGIStics model is described below.

4.2 BeWhere

The input data required in BeWhere has a lot on common with the one from LocaGIStics, but still does cover the following as expressed in Table 1. Each information in the table below should be provided for each country and at the level of each grid point.

Table 1. 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)
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.

4.2 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 Table 2 and 3).

Table 2. 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 3. 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. Actual data used for case study

5.1 Biomass data

The case study is based on the possible yields of Miscanthus as a new biomass crop in Burgundy (Table 4). These were assessed and evaluated in much detail in the LogistEC project (Perrin et al., 2015). Only a limited number of ha of Miscanthus are available at the moment. Three scenarios were developed to increase this amount of available Miscanthus in the near future.

Table 4. Current amounts of available Miscanthus and three future scenarios for increasing this amount (Perrin et al., 2015).

		2008	2009	2010	2011
Area	Total Miscanthus	3.5	104.2	309	385.8
	Mean/plot	1.75	1.47	1.93	1.95
No plots		2	71	160	198
No farmers		1	33	61	80

	Feedstock (t)	Miscanthus surface (ha)
Baseline	6,000	400
Scenario 1: +25%	8,000	500
Scenario 2: +100%	12,000	760
Scenario 3: maximum	30,000	1,900

There is an Access database with data of the Burgundy region that shows the availability of biomass. Available data on productivity and environmental impacts of energy crops and residues result from the simulation of crop growth with an agro-ecosystem model (CERES-EGC), as will be explained in Section 5.4.

Land-use (LU) allocation and calculation: two sources of LU were used to construct the data base: Corine Land Cover (2006) and the French agricultural census of 2010.-2011. They result in different estimates of utilizable area for cropland and grassland, due to the different methodologies employed, but it is recommended to use the CLC data for a better consistency with the simulation contours. Thus, in a given polygon, the area under fallow is calculated as the product of the *POURC_JACH* column (% under fallow, as reported by the 2010-2011 census) times the arable column (arable area in hectares), divided by 100.

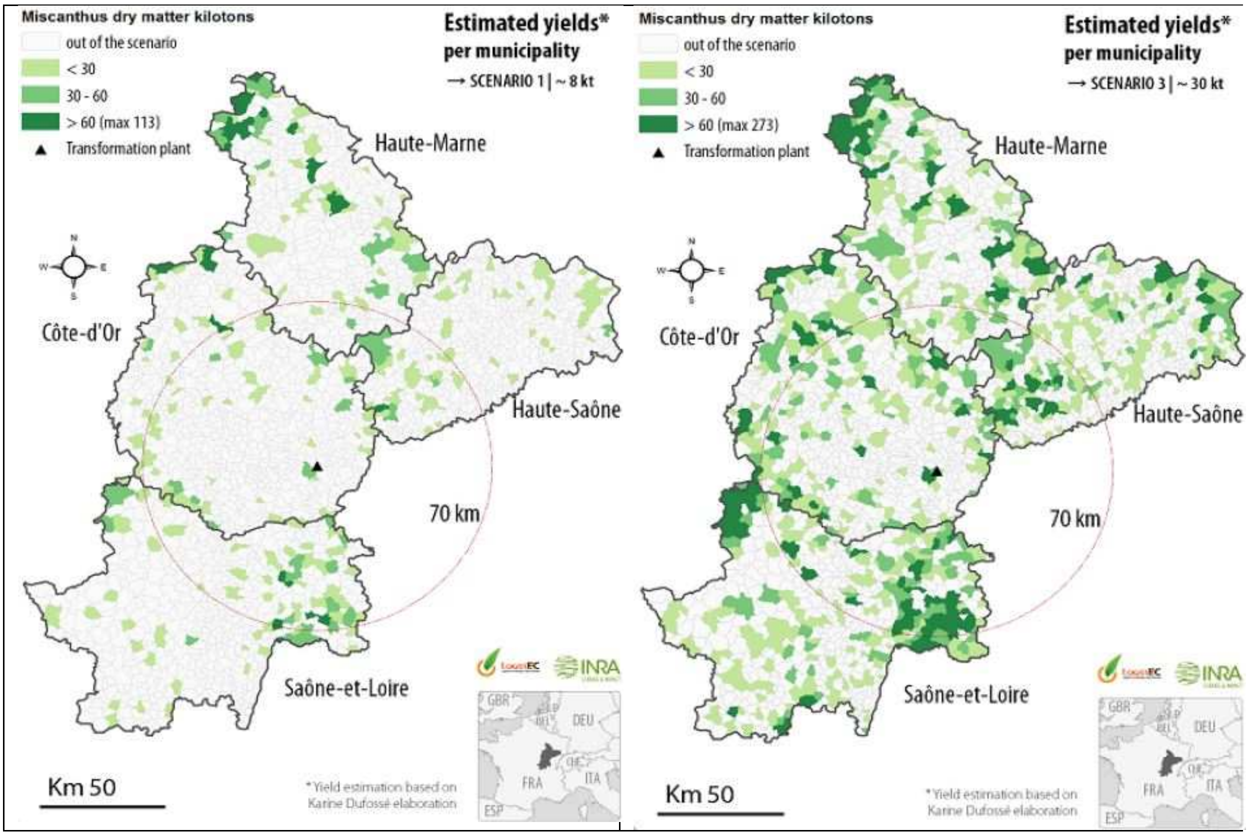

Figure 4. Estimated Miscanthus yields per municipality for two different scenarios from the LogistEC project (Gabrielle et al., 2015). The triangle sign indicates the position of the Burgundy Pellets plant.

Straw production may be allocated to the areas under wheat (and possibly barley) – noting that the dry matter yields already accounts for the fact that straw is harvested once every 3 years for agronomic reasons and soil C maintenance.

Dedicated crops may be allocated to the fallow land. Establishing the perennial crop (Miscanthus) on temporary grassland is also an option (using the *'PRAI_TEM'* column).

There are also maps with the possible locations of Miscanthus (Figure 4). For the case study these biomass potentials maps of Miscanthus were translated to grid cells of 2.5 x 2.5 km (Figure 5). The same was done for data on the available straw biomass (Figure 6). Reference grids were used for LocaGIStics (and if possible also for the BeWhere cases). LocaGIStics uses a 2.5 x 2.5 grid cell (more than 5,000 grid cells for Burgundy). However, this is far too detailed for BeWhere, therefore for this model all information was allocated to larger grids of 10 x 10 km cells (377 grid cells for Burgundy).

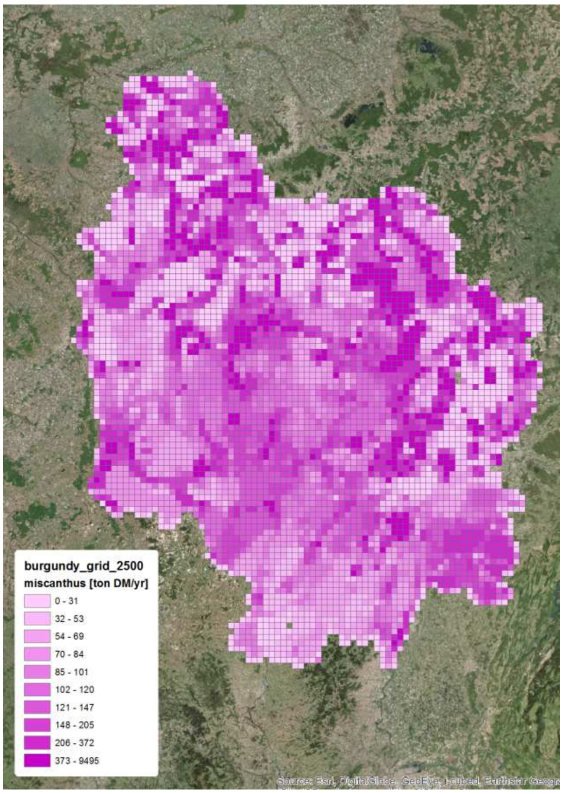

Figure 5. Translated Miscanthus yields per 2.5 x 2.5 km grid cell.

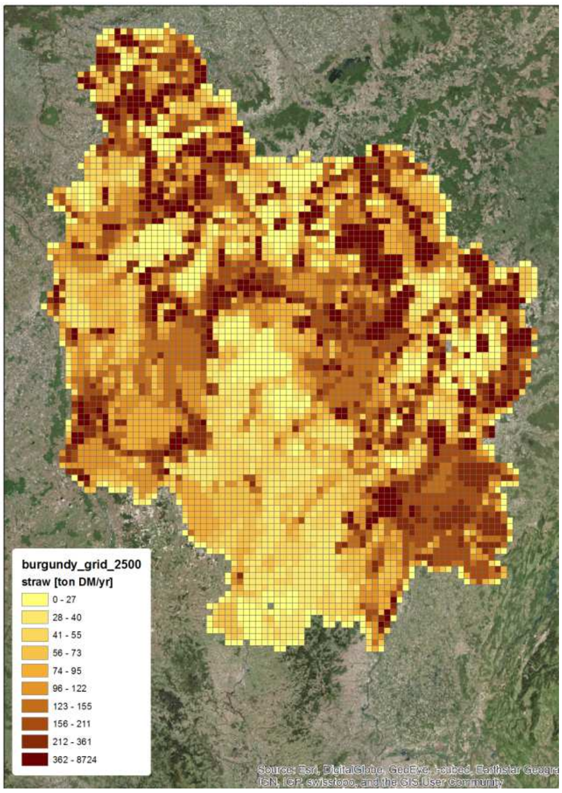

Figure 6. Translated straw yields per 2.5 x 2.5 km grid cell.

A shapefile was made with the availabilities of straw and Miscanthus on a 2.5 km grid. The grid cells have received a unique id, ‘grid-id’. The availabilities of straw and Miscanthus are in tons DM per year in a 2.5 km grid cell. The assumptions are:

- Straw is allocated on *CEREALS* fraction of UAA
- Miscanthus is allocated on *FALLOW* and 10% of *TEMPORARY_GRASSLAND* of UAA

Total yearly (average) production in whole region is then 967,154 ton dry matter for straw and 978,630 ton dry matter for Miscanthus.

5.2 Correction for ecological zones

A correction on the possible locations of the bioenergy power plants and on the possible yields of Miscanthus should be made for zones with high nature conservation value. Some Natura 2000 shapefiles were used to delineate the nature conservation value areas (http://inpn.mnhn.fr/telechargement/cartes-et-information-geographique/nat_/natura). In addition to the Natura 2000 areas also another high nature conservation area category was added called 'Natural Areas of Ecological Fauna and Flora Interest (ZNIEFF)'. These areas include areas that are identified for their strong biological capabilities and a good state of conservation’.

There are two ZNIEFF types:

- ZNIEFF type I: areas of great biological or ecological interest;
- ZNIEFF type II: large, rich and slightly modified natural landscapes, providing significant biological potential."

So ZNIEFF type II zones are larger in area than type I. None of the zones entail particular consequences for bioenergy plants, developers should only exert some caution and monitor some rare species for instance typical of the zone.

See Figure 7 for the protected areas in Burgundy that were used in the S2Biom case.

Two issues are related to the protected areas:

- No bioenergy plants are allowed in Natura 2000 areas (by law), but we leave open the possibility for ZNIEFF type II zones because they are less critical than ZNIEFF type I or Natura 2000 in terms of biodiversity. These power plants are not forbidden by law in ZNIEFF type I and II zones anyhow.
- Regarding the collection of the biomass: only a minor fraction (10%) of the available fallow land was considered utilizable for energy crops, to prioritize biodiversity preservation. This amounted to extracting less biomass from protected areas. Regarding straw extraction, protection zones would not affect

the extraction rates since those already allow the maintenance of soil C stocks.

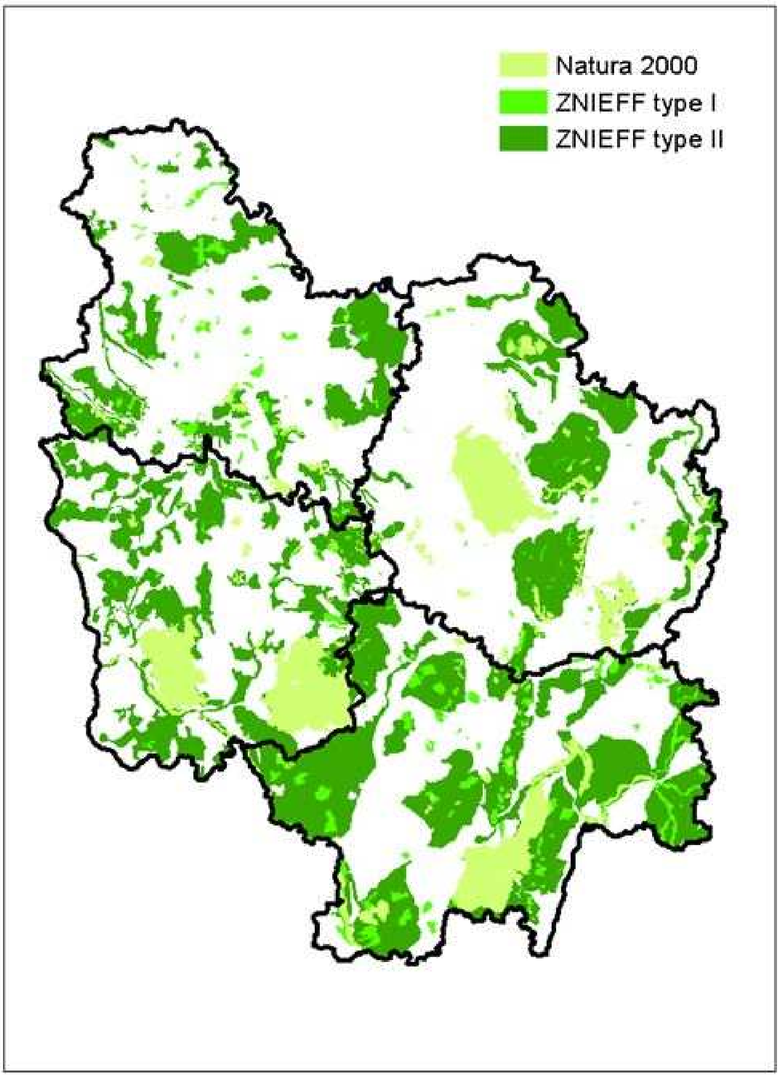

Figure 7. Protected areas in Burgundy.

5.3 Other data used in BeWhere

The BeWhere model uses a 10km grid size for the case study of Burgundy. Each location of potential new production sites are allocated to the center of the grid cell. The Figure 8 and 9 present the principal geographic explicit input data used in the BeWhere model. Figure 8 presents the complexity of a complete road network that has been simplified considering only the roads that may be dedicated for feedstock transportation. The same input data as from LocaGIStics is used but aggregated from a 2.5 km to a 10 km grid size level such as biomass availability (Figure 9 left).

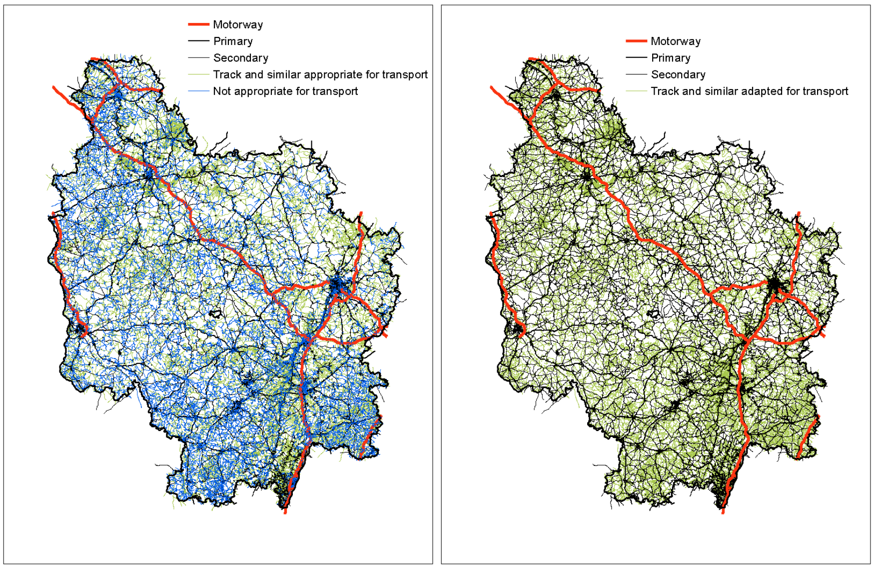

Figure 8. Transport road network simplified from a complete network (left) to a network adapted for biomass transport (right).

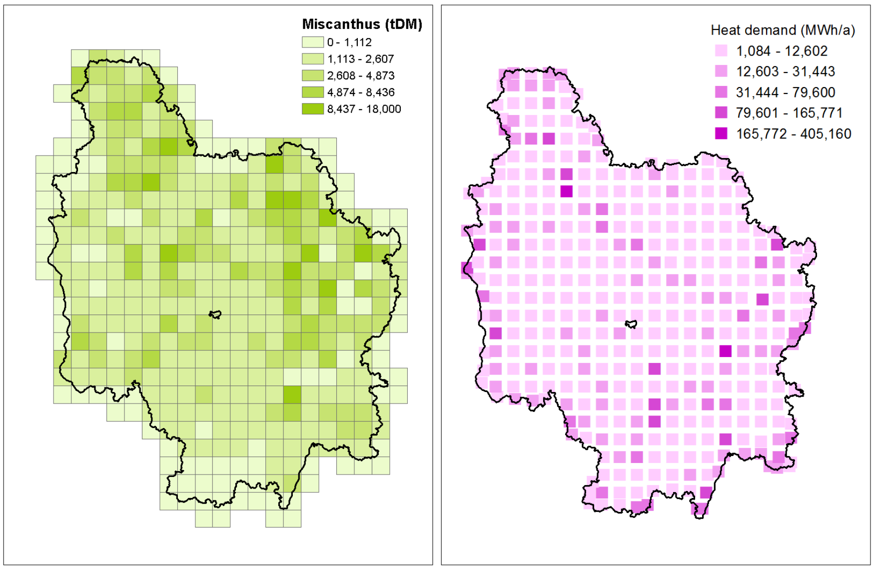

Figure 9. Aggregated input data used in the BeWhere model. Left: Miscanthus potential in t dm, right: Heat demand in MWh per year.

The technologies that the model has to choose from are presented in Table 5 below. Those technologies vary in terms of capacity, costs and conversion efficiencies, and the model will identify the optimal technology that best answers the problem.

Table 5. Overview of the technologies considered in the Burgundy case study together with the key parameters used in BeWhere (source: S2Biom WP2).

Technology	Operating hours hours/year	Investment cost MEUR	Heat MWth	Electricity MWe	Heat Efficiency (PJ_{heat}/ $PJ_{biomass}$)	Electricity Efficiency ($PJ_{electricity}$/ $PJ_{biomass}$)
Fixed bed for CHP	7,200	0.2	0.1	0.05	0.5	0.23
Pyrolysis combustion engine (compression-ignition)	7,500	0.7	0.25	0.25	0.4	0.4
Fixed bed, direct combustion	8,500	2.5	5	-	0.88	-
BFB for CHP	8,500	18	8	5	0.52	0.3
Grate boiler for CHP	8,500	25	10	5	0.6	0.25

5.4 Inclusion of environmental impacts in LocaGIStics

The land based environmental impacts in LocaGIStics cover the whole chain including the land based GHG emissions and other impacts on nitrogen and phosphate balances and soil organic carbon (SOC). In the Burgundy case this is particularly relevant given the biomass chains based on dedicated cropping with Miscanthus. For the land based emissions spatially specific emission factors for a range of maximum land use changes scenarios were included in the model. Depending on the final biomass consumption the emissions and other environmental impacts are then generated by the LocaGIStics for the specific chain covering only the land use changes caused by the specific chain. The environmental impact indicators given maximum biomass cultivation and/or harvesting are thus included at the level of the 2,5 x 2.5 km grid. If only part of the biomass in the location is to be included in the chain (e.g. 50 %), only the emissions and environmental impacts related to the specific biomass quantity used is allocated to the chain.

The initial environmental impacts for GHG, nitrogen and phosphate balances and SOC were generated as part of the LOGISTEC project work using an agro-ecosystem model (CERES-EGC) (see Dufossé et al., 2016). The model simulates crop growth for a 20 year period predicting biomass yields for all simulation units (in t DM ha^{-1} yr^{-1}) and direct emissions of N_2O, NO_3, NH_3 and NO_x (kg N ha^{-1} yr^{-1}) in the fields as well as the average increase of carbon stocks in soil (t C ha^{-1} yr^{-1}) between the first year and the last year of crop growth.

The model uses gridded weather data combined with soil data to generate emissions on various GHG emission trajectories for the 2010-2030 time slice. The simulation is done in spatial entities (polygons) which are an intersection of soil and weather data and cover the whole of Burgundy (see Figure 10). The methodology is described in

(Dufossé et al., 2016). The simulations assume that Miscanthus can grow in all places where there is currently fallow land or temporary grass. Straw is extracted from cereal fields (wheat and barley). For further details on land use see Section 5.2.

Before the results on the crop yield and environmental impacts from the simulation model could be entered in the LocaGIStics database the data had first be allocated from the polygons to the 2.5 x 2.5 km grid.

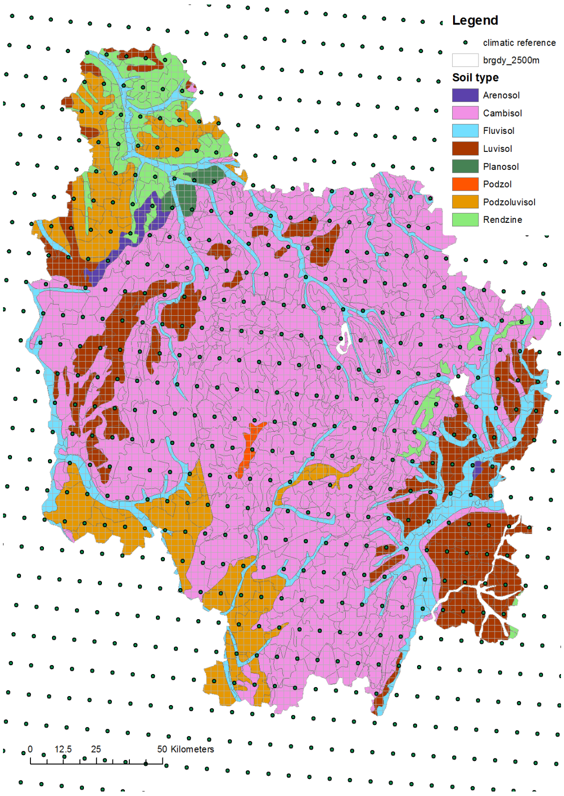

Figure 10. Spatial units for which CERES-EGC model calculated the environmental impacts.

5.5 Other data used in LocaGIStics

The basic data are given in Annex A. The machines in the LogistEC project case database have also been entered into the WP3 database.

6. Results BeWhere for Burgundy case study

The locations of the bioenergy production plants have been proceeded in three steps. First the location of the first production plant has been determined, then the model is run to determine the optimal distribution and capacities of the plants, and finally a test run has been accomplished with increased biomass availability.

The model has first been set to identify the optimal position and capacity of the first production plant that would be setup in Burgundy. Figure 11 presents the location of such a plant. As expected, the feedstock is collected within a circle around the plant, and this area corresponds to one of the most biomass rich in Burgundy, at the same time the heat demand is one of the largest in Burgundy.

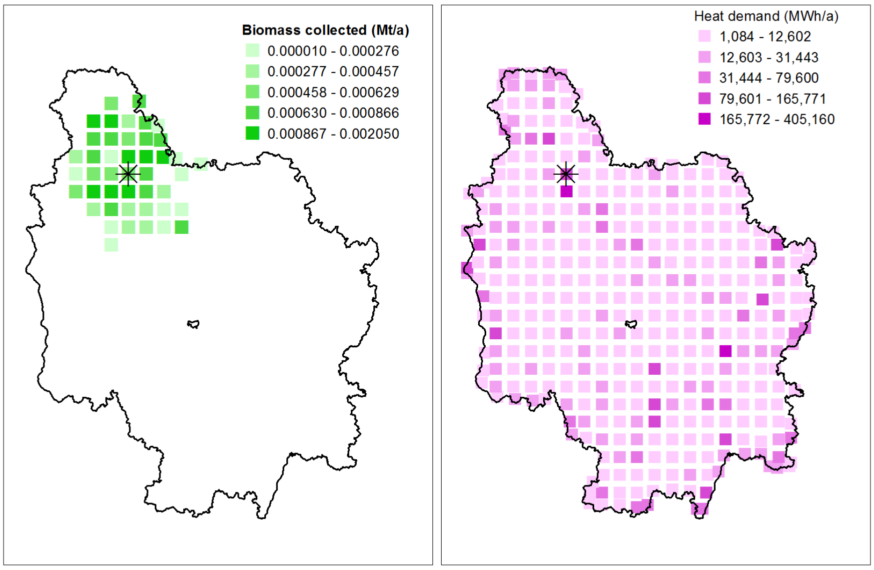

Figure 11. Location of the first plant on top of the biomass collected (left) and the heat demand (right).

The plant identified is a grate boiler for CHP, with a capacity of 10 MW_{th}, and it collects 30 kt of Miscanthus within a radius of 65 km around the plant.

When it comes to optimize the number of plants for the whole region, where the only constraints are the biomass availability and the heat demand, the final solution looks like as presented in Figure 12. The first plant identified in the first run remains, and now the plants are mainly located where the heat demand is the highest (Figure 12, right). The technology chosen remains the same for all plants as well which is a grate boiler for CHP, with a capacity of 10 MW_{th}.

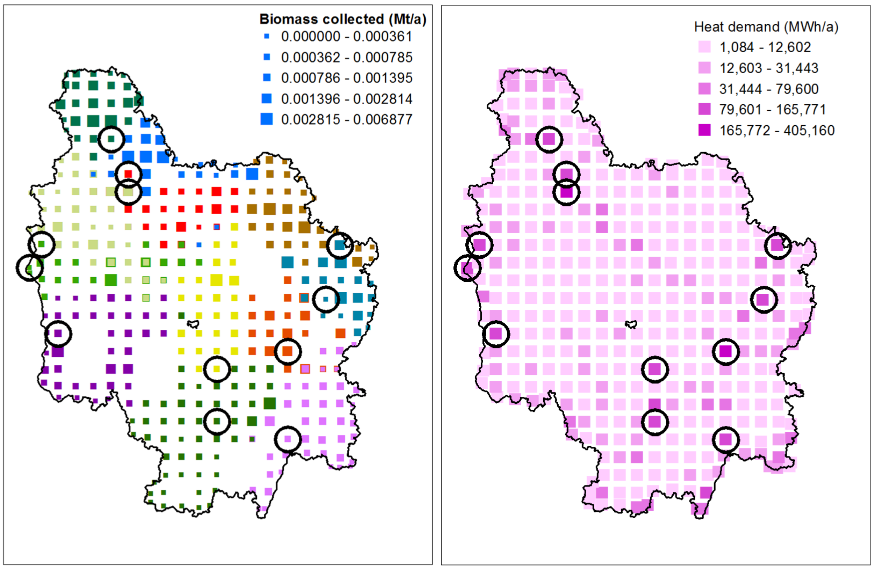

Figure 12. Location of the production plants on top of their respective collection points (left) and the heat demand (right). A same color of the biomass location means that the biomass is collected to the same plant which usually is located within the corresponding colored area.

As can be noticed from Figure 12 above, the location of the feedstock collected is no longer within a circle around the plant, but some optimal distribution around the plant balancing transport cost, availability and collection cost. This means that heat demand has a greater impact on the location of the plant than the biomass, which now is collected within distances ranging from 70 to 158 km.

Table 6. 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

The model allows some flexibility in the production and may not operate at full capacity, explaining the differences in power and heat generation (see Table 6).

An increase of the biomass availability by 25% will leave some place for lower capacity plants as presented in Figure 13. Increasing the biomass availability by 25% would allow space for an additional plant of 10MWth, instead the model choses the identification of multiple smaller scale power plants distributed all over the region. In that respect, the heat generated will not be wasted, as the plants will be able to deliver the heat produced.

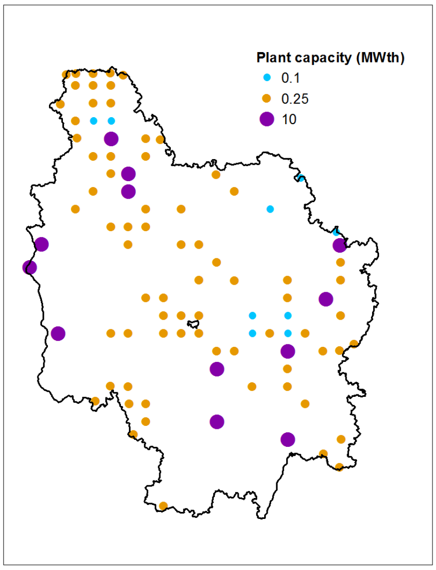

Figure 13. Location of the plants when the biomass available increases by 25%.

7. Results LocaGIStics for Burgundy case study

7.1 Five variants of a biomass supply chain

The BeWhere model calculated that there was a possibility to build 10 small-scale power plants with a capacity of 30,000 ton dm in the Burgundy region (Figure 14).

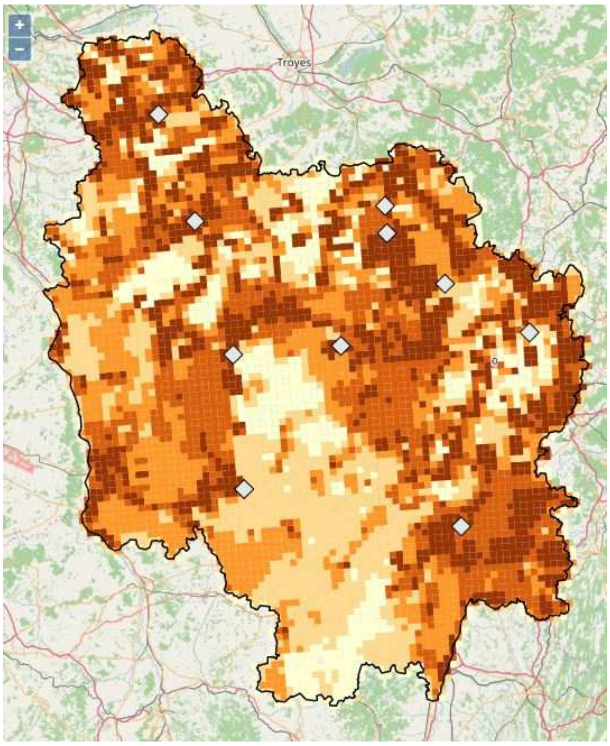

Figure 14. Possible locations of small-scale power plants (white diamond shapes) suggested by the BeWhere tool.

The LocaGIStics tool was then used to further detail the biomass value chain of one of these possible locations. Five variants were calculated for one specific power plant location:

1. Power plant & no biomass yard; only straw;
2. Power plant & no biomass yard; straw & Miscanthus;
3. Power plant & one biomass yard; straw & Miscanthus;
4. Power plant & two biomass yards; straw & Miscanthus;
5. Power plant & two biomass yards; only straw.

As mentioned already in Section 1.1 the exact calculation results were of less importance in the Burgundy case than the testing process during the development of the new LocaGIStics tool. However, in the next section the results are shown to give an impression of the effects of the choices in the different variants.

The results of the five variants are summarized for:

- financial profit, energy profit and net GHG avoided (Table 7);
- crop production effects of different variants (Table 8);
- logistical results of different variants (Table 9).

These results for each variant will be discussed and compared to other variants in more detail in Section 7.2.

Table 7. Main results of the five variants.

Variant no.	Financial profit (€)	Energy profit (GJ)	Net GHG avoided (ton CO_2-eq)
1	1,863,492	356,738	35,208
2	3,173,480	377,106	37,285
3	2,939,348	377,532	37,337
4	3,008,029	385,318	38,107
5	1,553,969	359,421	35,477

Table 8. Crop production effects of different variants (only in the case of Miscanthus).

Variant no.	Change in organic matter content (kg CO_2-eq)	Direct N_2O emission (kg CO_2-eq)	Indirect N_2O emission (kg CO_2-eq)
1	-	-	-
2	4,945,974	157,380	126,353
3	4,019,948	77,310	148,446
4	4,073,814	88,637	141,965
5	-	-	-

Table 9. Logistical results of different variants (ICP = intermediate collection point and BCP = biomass conversion plant).

Variant no.	Distance ICP to BCP (km)	Distance ICP to BCP (ton km)	Distance field to ICP (km)	Distance field to ICP (ton km)
1	0	0	22,013	709,961
2	0	0	2,757	298,544
3	2,672	1,011,452	597	166,402
4	2,132	1,166,305	235	121,373
5	18,893	1,198,140	6,183	342,875

7.2 Results of the five variants

<u>Variant 1 – Power plant & no biomass yard; only straw (33%)</u>

Characteristics variant 1 - Only 33% of the overall straw production, and no Miscanthus (0%) is available as feedstock. There is no intermediate collection point (biomass yard), so all biomass is transported by truck straight to the site of the power plant. Therefore, the biomass is only loaded and unloaded once. At the site of the power plant the raw biomass is first stored in open air during an average of 4.5 months, then pelletized, and then the pellets are again stored under a cover for an average of 4.5 Months. Before the pellets can be fed to the power plant they need to be grinded. The demand of the power plant is 30,000 t dm per year.

Results variant 1 – The main results are shown in Table 10. The map with the collection area of the straw is shown in Figure 15. The demand of the power plant is completely met. The maximum collection distance is 32.5 km and the transport amount is 709,961 ton.km. Looking at the purchase costs it should be noticed that they are higher in comparison to the other variants because the purchase costs of straw (45 €/t dm) are much higher than those of Miscanthus (8.82 €/t dm) and in this variant only straw is available. The storage costs of 60,815 € are relatively low compared to the variants 3 until 5, because there is only open air storage. The transport costs are relatively high compared to variant 2, because of a larger collection area in variant 1. Loading and unloading cost the same as in variant 2, but lower than in variant 3-5, because they only occur once in variant 1 and 2. The pre-treatment costs are more or less the same for all variants. The variable conversion costs are more or less the same for all variants and the fixed conversion costs are exactly the same for all variants. The revenues in variant 1 with only straw (and also in variant 5) are lower than in the variants 2 until 4 that also contain Miscanthus. This is caused by the lower energy content of straw (HHV 17 GJ/t dm) compared to Miscanthus (HHV 18.5 GJ/t dm). So less electricity and heat can be sold if the 30,000 t dm only consists of straw. The overall financial profit of variant 1 is one of the lowest, because of the relatively higher costs and lower revenues. Only variant 5 has an even lower financial profit.

Remarks - The size of the collection circle can be influenced by assuming a higher or lower biomass availability percentage for a certain biomass type, but also by adding more biomass types. To see this effect Miscanthus was included as a second feedstock type in Variant 2.

Table 10. Main results Variant 1.

Variable	Straw	Miscanthus	Total
Logistics			
Maximum collection distance (km)	32.5	0	32.5
Collected biomass (ton dm)	30,032	0	30,032
Transport amount (ton·km)	709,961	0	709,961
Costs			
Purchase costs (€)	1,351,441	0	1,351,441
Storage costs (€)	60,815	0	60,815
Transport costs (€)	87,010	0	87,010
Loading/Unloading costs (€)	39,042	0	39,042
Pre-treatment costs (€)	2,792,546	0	2,792,546
Variable conversion costs (€)	900,961	0	900,961
Fixed conversion costs (€)	-	-	625,000
		Total	5,856,815
Revenues			
Electricity (€)	-	-	6,760,849
Heat (€)	-	-	959,458
		Total	7,720,307
Profit			
Financial profit (€)	-	-	1,863,492
Energy profit (GJ)	-	-	356,738
Net GHG avoided (ton CO_2-eq)	-	-	35,208

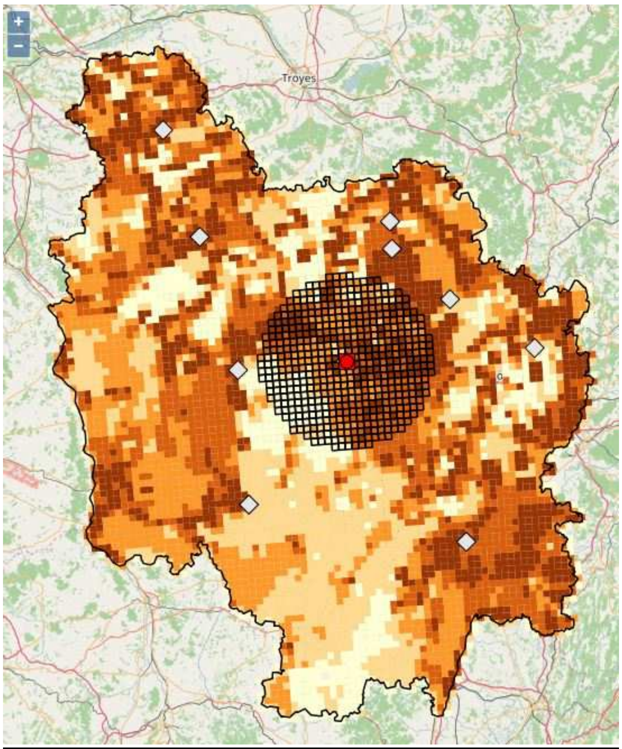

Figure 15. Map straw for Variant 1.

<u>Variant 2 – Power plant & no biomass yard; straw (33%) and Miscanthus (100%)</u>

Characteristics variant 2 - Again 33% of the overall straw production, but now also 100% of the grown Miscanthus is available as feedstock. Again there is no intermediate collection point (biomass yard), so all raw biomass is transported by truck straight to the site of the power plant. Therefore, the biomass is only loaded and unloaded once in this variant. At the site of the power plant the raw biomass is first stored in open air during an average of 4.5 months, then pelletized, and then the pellets are again stored under a cover for an average of 4.5 Months. Before the pellets can be fed to the power plant they need to be grinded. The demand of the power plant is 30,000 t dm per year.

Results variant 2 – The main results are shown in Table 11. The map with the collection area of the Miscanthus is shown in Figure 16. The demand of the power plant is completely met. The maximum collection distance is 17.5 km which is 15 km lower than the collection distance in variant 1. Variant 2 has a smaller supply area, because more biomass (Miscanthus) is now available at a closer distance. The transport amount is 298,544 ton.km which is about 2.4 times smaller than the 709,961 ton.km in variant 1 due to the smaller collection area. The purchase costs of variant 2 are much lower than in variant 1 because more than 2/3 of the sourced biomass is now Miscanthus with a much lower price (8.82 €/t dm). The storage costs are again relatively low 60,815 € compared to the variants 3 until 5, because there is only open air storage. The transport costs are relatively low compared to variant 1, because of the smaller collection area in variant 2. Loading and unloading cost the same as in variant 1, but lower than in variant 3-5, because they only occur once in variant 1 and 2. The pre-treatment costs are more or less the same for all variants. The variable conversion costs are more or less the same for all variants and the fixed conversion costs are exactly the same for all variants. The revenues in variant 2 with both straw and Miscanthus are higher than in the variants 1 and 5 with only straw. This is caused by the higher energy content of Miscanthus (HHV 18.5 GJ/t dm) compared to straw (HHV 17 GJ/t dm). So more electricity and heat can be sold if the 30,000 t dm only consists of more Miscanthus and less straw. The overall financial profit of variant 2 is the best of the five, because of the relatively lower costs and higher revenues.

Remarks - The size of the collection circle can also be influenced by placing intermediate collection points in the middle of densely occupied biomass areas. To see this effect one intermediate collection point was included in Variant 3.

Table 11. Main results Variant 2.

Variable	Straw	Miscanthus	Total
Logistics			
Maximum collection distance (km)	17.5	17.5	17.5
Collected biomass (ton dm)	8,782	21,321	30,103
Transport amount (ton·km)	86,847	211,697	298,544
Costs			
Purchase costs (€)	395,186	188,051	583,237
Storage costs (€)	17,783	43,175	60,958
Transport costs (€)	10,644	25,945	36,588
Loading/Unloading costs (€)	11,416	27,717	39,134
Pre-treatment costs (€)	816,592	1,982,545	2,799,137
Variable conversion costs (€)	263,457	639,630	903,087
Fixed conversion costs (€)	-	-	625,000
		Total	5,047,141
Revenues			
Electricity (€)	-	-	7,198,985
Heat (€)	-	-	1,021,635
		Total	8,220,621
Profit			
Financial profit (€)	-	-	3,173,480
Energy profit (GJ)	-	-	377,106
Net GHG avoided (ton CO_2-eq)	-	-	37,285

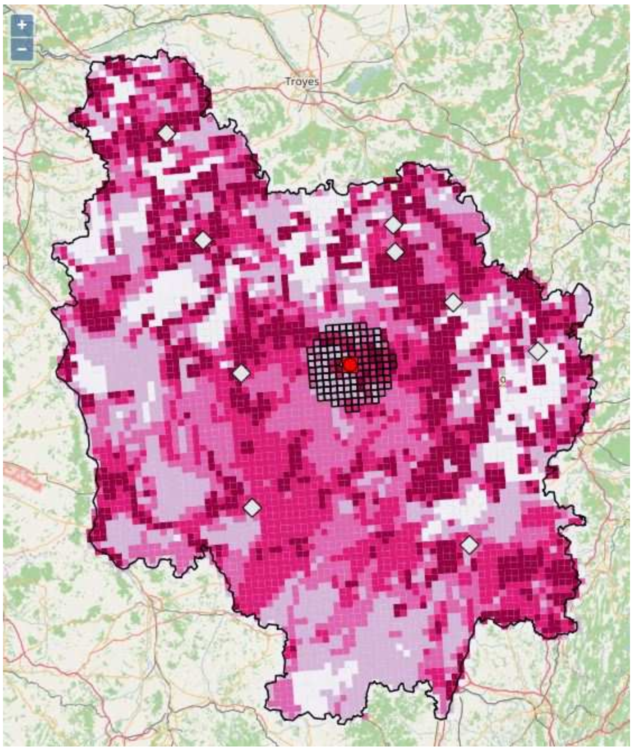

Figure 16. Map Miscanthus for Variant 2.

Variant 3 – Power plant & one biomass yard; straw (33%) and Miscanthus (100%)

Characteristics variant 3 - Again 33% of the overall straw production, and 100% of the grown Miscanthus is available as feedstock. Now there is one intermediate collection point (biomass yard indicated by a red circle in Figure 17), so all raw biomass is first transported by truck to the intermediate collection point. The intermediate collection point is located near to an area with a high biomass availability, while the power plant is located near to area with a high energy demand (specified by the BeWhere model). Later on the pelletized biomass is transported with a walking floor vehicle from the intermediate collection point to the separate site of the power plant. Therefore, the biomass is loaded and unloaded twice in this variant. At the intermediate collection point the raw biomass is first stored in open air during an average of 4.5 months and then pelletized. At the site of the power plant the received pellets are stored under a cover for again an average of 4.5 Months. Before the pellets can be fed to the power plant they need to be grinded. The demand of the power plant is 30,000 t dm per year.

Results variant 3 – The main results are shown in Table 12. The map with the collection area of the Miscanthus is shown in Figure 17. The demand of the power plant is completely met. The maximum collection distance is 10.0 km which is 15 km lower than the collection distance in variant 1 and 22.5 km lower than variant 2. So introducing an intermediate collection point near higher biomass availability can indeed decrease the size of the collection area. However, in this variant the total transport amount (a combination of the first and second stage transport) is 1,177,854 ton.km which is about 1.7 times larger than the 709,961 ton.km in variant 1. This is caused by the longer distance from the intermediate collection point to the site of the power plant. So perhaps the intermediate collection point should be placed closer to the power plant. This requires further study. The purchase costs of variant 3 are much lower than in variant 1 and also a bit lower than in variant 2 because even more (about 3/4) of the sourced biomass is now Miscanthus with a much lower price (8.82 €/t dm). The storage costs are much higher now 271,328 € compared to the variants 1 and 2, because there is both open air storage at the first stage and more expensive covered storage at the second stage. The transport costs of variant 3 (132,376 €) are 1.5 times higher compared to variant 1 (87,010 €), because of the long transportation distances between the intermediate collection point and the site of the power plant. Loading and unloading cost of variant 3 (67,492 €) are 1.7 times higher than in variant 1 (39,042 €), because they occur twice in variant 3. They are not double because the density of the loaded material differs between stage 1 and stage 2. The pre-treatment costs are more or less the same for all variants. The variable conversion costs are more or less the same for all variants and the fixed conversion costs are exactly the same for all variants. The revenues in variant 3 with both straw and Miscanthus are higher than in the variants 1 and 5 with only straw. This is caused by the higher energy content of Miscanthus (HHV 18.5 GJ/t dm) compared to straw (HHV 17 GJ/t dm). So more electricity and heat can be sold if the

30,000 t dm only consists of more Miscanthus and less straw. The overall financial profit of variant 3 is lower than variant 2 because of the slightly higher costs and almost the same revenues.

Remarks – Although one collection point already showed to be less profitable, still the idea needed to be tested that two intermediate collection points, situated even better in the middle of densely occupied biomass areas, could further decrease the collection areas. This effect was tested in Variant 4.

Table 12. Main results Variant 3.

Variable	Straw	Miscanthus	Total
Logistics			
Maximum collection distance (km)	10.0	10.0	10.0
Collected biomass (ton dm)	6,811	23,197	
Transport amount (ton·km) a) field to ICP b) ICP to PP	38,202 227,495	128,200 783,957 Total:	166,402 1,011,452 1,177,854
Costs			
Purchase costs (€)	306,481	204,598	511,079
Storage costs (€) a) field to ICP b) ICP to PP	13,792 47,790	46,974 162,772 Total:	- - 271,328
Transport costs (€) a) field to ICP b) ICP to PP	4,682 25,187	15,712 86,795 Total:	- - 132,376
Loading/Unloading costs (€) a) field to ICP b) ICP to PP	8,854 6,464	30,156 22,018 Total:	- - 67,492
Pre-treatment costs (€) a) field to ICP b) ICP to PP	521,189 112,434	1,775,153 382,948 Total:	- - 2,791,724
Variable conversion costs (€)	204,321	695,911	900,232
Fixed conversion costs (€)	-	-	625,000
		Total	5,299,231
Revenues			
Electricity (€)	-	-	7,214,712
Heat (€)	-	-	1,023,867
		Total	8,238,579
Profit			
Financial profit (€)	-	-	2,939,348
Energy profit (GJ)	-	-	377,532
Net GHG avoided (ton CO_2-eq)	-	-	37,337

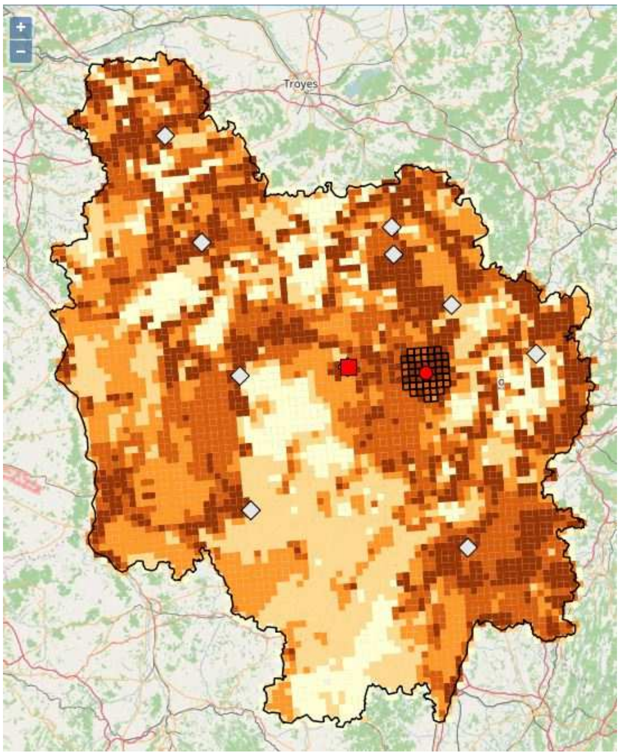

Figure 17. Map straw for Variant 3.

<u>Variant 4 – Power plant & two biomass yards; straw (33%) and Miscanthus (100%)</u>

Characteristics variant 4 - Again 33% of the overall straw production, and 100% of the grown Miscanthus is available as feedstock. Now there are two intermediate collection points (biomass yards indicated by two red circles in Figure 18), so all raw biomass is first transported by truck to the intermediate collection points. The intermediate collection points are located near to an area with high biomass availability, while the power plant is located near to area with a high energy demand (specified by the BeWhere model). Later on the pelletized biomass is transported with a walking floor vehicle from the intermediate collection points to the separate site of the power plant. Therefore, the biomass is loaded and unloaded twice in this variant. At the intermediate collection points the raw biomass is first stored in open air during an average of 4.5 months and then pelletized. At the site of the power plant the received pellets are stored under a cover for again an average of 4.5 Months. Before the pellets can be fed to the power plant they need to be grinded. The demand of the power plant is 30,000 t dm per year.

Results variant 4 – The main results are shown in Table 13. The map with the collection area of the Miscanthus is shown in Figure 18. The demand of the power plant is completely met. The maximum collection distance is 6.5 km which is 26 km lower than the collection distance in variant 1 and 3.5 km lower than variant 3. So introducing a second intermediate collection point near higher biomass availability can indeed even further decrease the size of the collection area. However, in this variant the total transport amount (a combination of the first and second stage transport) is even higher viz. 1,287,677 (compared to 1,177,854 ton.km in variant 3) which is about 1.8 times larger than the 709,961 ton.km in variant 1. This is caused by the longer distance from the two intermediate collection points to the site of the power plant. The purchase costs of variant 4 are comparable to variant 3. The storage costs (276,888 €) are again much higher now compared to the variants 1 and 2, because there is both open air storage at the first stage and more expensive covered storage at the second stage. The transport costs of variant 4 (144,002 €) are 1.6 times higher compared to variant 1 (87,010 €), because of the long transportation distances between the intermediate collection point and the site of the power plant. Loading and unloading cost of variant 4 (68,875 €) are 1.8 times higher than in variant 1 (39,042 €), because they occur twice in variant 4. They are not double because the density of the loaded material differs between stage 1 and stage 2. The pre-treatment costs are more or less the same for all variants. The variable conversion costs are more or less the same for all variants and the fixed conversion costs are exactly the same for all variants. The revenues in variant 4 with both straw and Miscanthus are higher than in the variants 1 and 5 with only straw. The overall financial profit of variant 4 is a bit higher than variant 3 because of the slightly higher revenues.

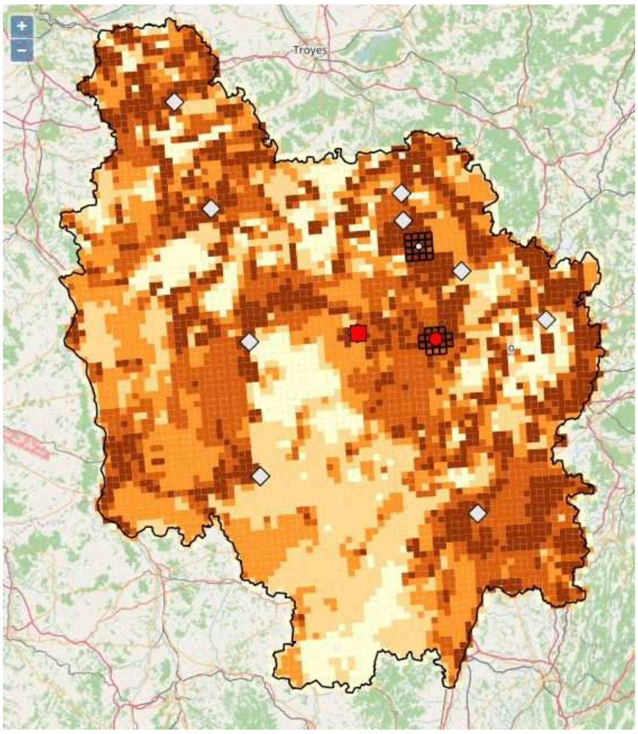

Figure 18. Map straw for Variant 4.

Table 13. Main results Variant 4.

Variable		Straw	Miscanthus	Total
Logistics				
Maximum collection distance (km)		6.5	6.5	6.5
Collected biomass (ton dm)	a) ICP1	4,324	15,315	19,639
	b) ICP2	2,549	8,435	10,984
			Total:	30,623
Transport amount (ton·km)	a) field to ICP1	15,432	55,022	70,454
	b) field to ICP2	11,685	39,233	50,918
	c) ICP1 to PP	144,429	517,577	662,006
	d) ICP2 to PP	115,980	388,319	504,299
			Total:	1,287,677
Costs				
Purchase costs (€)		309,276	209,474	518,749
Storage costs (€)	a) field to ICP1	8,756	31,013	-
	b) field to ICP2	5,162	17,081	-
	c) ICP1 to PP	30,340	107,464	-
	d) ICP2 to PP	17,886	59,187	-
			Total:	276,888
Transport costs (€)	a) field to ICP1	1,891	6,743	-
	b) field to ICP2	1,432	4,808	-
	c) ICP1 to PP	15,990	57,303	-
	d) ICP2 to PP	12,841	42,992	-
			Total:	144,002
Loading/Unloading costs (€)	a) field to ICP1	5,621	19,909	-
	b) field to ICP2	3,314	10,965	-
	c) ICP1 to PP	4,104	14,536	-
	d) ICP2 to PP	2,419	8,006	-
			Total:	68,875
Pre-treatment costs (€)	a) field to ICP1	330,885	1,171,976	-
	b) field to ICP2	195,055	645,482	-
	c) ICP1 to PP	71,381	252,826	-
	d) ICP2 to PP	42,078	139,248	-
			Total:	2,848,930
Variable conversion costs (€)		206,183	712,495	918,679
Fixed conversion costs (€)		-	-	625,000
			Total	5,401,123
Revenues				
Electricity (€)		-	-	7,364,086
Heat (€)		-	-	1,045,066
			Total	8,409,152
Profit				
Financial profit (€)		-	-	3,008,029
Energy profit (GJ)		-	-	385,318
Net GHG avoided (ton CO_2-eq)		-	-	38,107

Variant 5 – Power plant & two biomass yards; only straw (33%)

Characteristics variant 5 - Only 33% of the overall straw production, and 0% of the grown Miscanthus is available as feedstock. Now there are again two intermediate collection points (biomass yards indicated by two red circles in Figure 19), so all raw biomass is first transported by truck to the intermediate collection points. The intermediate collection points are located near to an area with high biomass availability, while the power plant is located near to area with a high energy demand (specified by the BeWhere model). Later on the pelletized biomass is transported with a walking floor vehicle from the intermediate collection points to the separate site of the power plant. Therefore, the biomass is loaded and unloaded twice in this variant. At the intermediate collection points the raw biomass is first stored in open air during an average of 4.5 months and then pelletized. At the site of the power plant the received pellets are stored under a cover for again an average of 4.5 Months. Before the pellets can be fed to the power plant they need to be grinded. The demand of the power plant is 30,000 t dm per year.

Results variant 5 – The main results are shown in Table 14. The map with the collection area of the Miscanthus is shown in Figure 19. The demand of the power plant is completely met. The maximum collection distance is 17.5 km which is 15 km lower than the collection distance in variant 1 but 11 km higher than variant 4 (also with two intermediate collection points). So introducing two intermediate collection points near higher biomass availability can indeed be more relevant when only straw is available as biomass type. However, in this variant the total transport amount (a combination of the first and second stage transport) is even higher viz. 1,541,015 (compared to 1,177,854 ton.km in variant 3 and 1,287,677 in variant 4) which is about 2.2 times larger than the 709,961 ton.km in variant 1. This is caused by the longer distance from the two intermediate collection points to the site of the power plant and the larger collection area. The purchase costs of variant 5 are comparable to variant 1 (also only straw). The storage costs (273,736 €) are again much higher now compared to the variants 1 and 2, because there is both open air storage at the first stage and more expensive covered storage at the second stage. The transport costs of variant 5 (174,773 €) are 2.0 times higher compared to variant 1 (87,010 €), because of the long transportation distances between the intermediate collection point and the site of the power plant. Loading and unloading cost of variant 5 (68,091 €) are 1.7 times higher than in variant 1 (39,042 €), because they occur twice in variant 5. They are not double because the density of the loaded material differs between stage 1 and stage 2. The pre-treatment costs are more or less the same for all variants. The variable conversion costs are more or less the same for all variants and the fixed conversion costs are exactly the same for all variants. The revenues in variant 5 with only straw are comparable with variants 1. The overall financial profit of variant 5 is the lowest of the five variants, because of the relatively higher costs and lower revenues.

Table 14. Main results Variant 5.

Variable		Straw	Miscanthus	Total
Logistics				
Maximum collection distance (km)		17.5	0	17.5
Collected biomass (ton dm)	a) ICP1	14,826	0	14,826
	b) ICP2	15,448	0	15,448
			Total:	30,274
Transport amount (ton·km)	a) field to ICP1	164,309	0	164,309
	b) field to ICP2	178,566	0	178,566
	c) ICP1 to PP	495,230	0	495,230
	d) ICP2 to PP	702,910	0	702,910
			Total:	1,541,015
Costs				
Purchase costs (€)		1,362,333	0	1,362,333
Storage costs (€)	a) field to ICP1	30,023	0	-
	b) field to ICP2	31,282	0	-
	c) ICP1 to PP	104,034	0	-
	d) ICP2 to PP	108,398	0	-
			Total:	273,736
Transport costs (€)	a) field to ICP1	20,137	0	-
	b) field to ICP2	21,884	0	-
	c) ICP1 to PP	54,829	0	-
	d) ICP2 to PP	77,822	0	-
			Total:	174,673
Loading/Unloading costs (€)	a) field to ICP1	19,274	0	-
	b) field to ICP2	20,082	0	-
	c) ICP1 to PP	14,072	0	-
	d) ICP2 to PP	14,662	0	-
			Total:	68,091
Pre-treatment costs (€)	a) field to ICP1	1,134,567	0	-
	b) field to ICP2	1,182,155	0	-
	c) ICP1 to PP	244,756	0	-
	d) ICP2 to PP	255,022	0	-
			Total:	2,816,501
Variable conversion costs (€)		908,222	0	908,222
Fixed conversion costs (€)		-	-	625,000
			Total	6,228,555
Revenues				
Electricity (€)		-	-	6,815,334
Heat (€)		-	-	967,190
			Total	7,782,524
Profit				
Financial profit (€)		-	-	1,553,969
Energy profit (GJ)		-	-	359,421
Net GHG avoided (ton CO_2-eq)		-	-	35,477

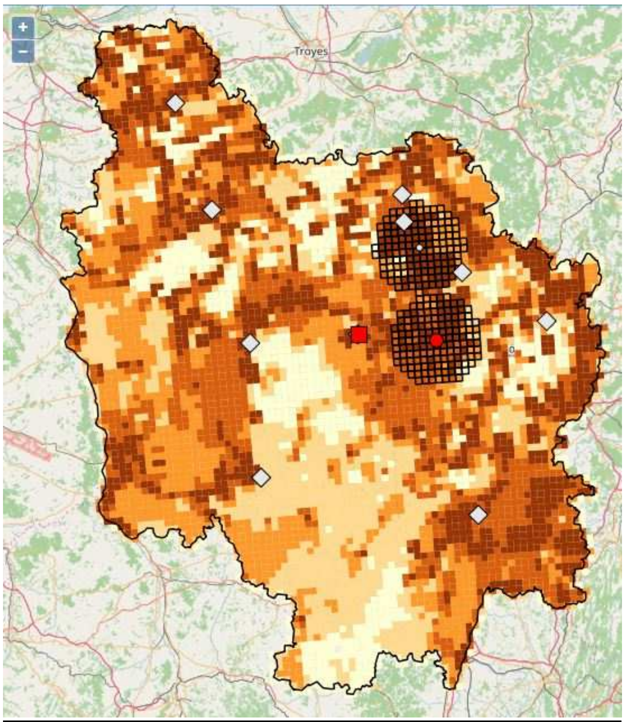

Figure 19. Map straw Variant 5.

8. Conclusions and recommendations

8.1 Conclusions

The BeWhere model has been applied for the case study of Burgundy in order to identify the optimal locations of bioenergy production plants. It should be emphasized that the locations of the plants were highly driven by the location and amount of the demand of heat over the transport collection of the feedstock at least for this particular case study. The collection points of the biomass are nevertheless very well concentrated around the production plants. Anyhow to validate those results, LocaGIStics is a valuable tool for the simulation of the feedstock collection from the plants determined from BeWhere. The quality check controls the feedstock collection, capacity and therefore the validity of the chosen location.

The LocaGIStics model has especially been developed using the Burgundy case study. Several logistical concepts have been tested in the Burgundy case. These are: i) mixing different biomass types (straw as a biomass residue and Miscanthus as an energy crop), ii) applying pretreatment technology (pelletizing) to densify the material in order to lower the transportation costs and increase handling properties, iii) switching between different types of transport means (truck and walking floor vehicle) and iv) direct delivery to a power plant versus putting an intermediate collection point in the value chain. Due to the nature of this development case less value should be given to the exact results of the five variants that are described in this report. However, these variants are perfect examples of what effects can be achieved if the set-up of a lignocellulosic biomass value chain is changed, even if that change is only slightly. So the case was used successfully to build a first version of the locaGIStics tool. However, many improvements are still possible and could be achieved in future project cases.

8.2 Recommendations

The BeWhere model has been applied for the case study of Burgundy, for which the locations of the plants are mainly driven by the demand of the heat for the technology potentially feasible. Anyhow the BeWhere model is a tool useful for policy planning, which indicates what technology should be used in which region providing a specific energy or emission target. The results of the model need further analysis from a LocaGIStics model that will conduct a very detailed analysis of the economic feasibility of setting up a new production plant in a particular region. For good energy planning for biomass based industries, both models are very much complementary and useful.

Now the Burgundy case was primarily used for developing the new LocaGIStics model. The variants that were presented in this report were especially aimed at creating different circumstances for the model to be tested. The LocaGIStics model was shown to potential users (agricultural advisors and the manager of BP) during a field visit last July, and they confirmed that the tool was relevant to address the design and optimization of their value-chains. However, for a ‘real’ logistical assessment of this case study further research will need to be performed. The LocaGIStics model can also still be further improved to make it more flexible so that it can deal with a variety of different biomass value chain set-ups.

References

Bjørkvoll, T., 2015. Sustainability assessment of biomass supply chains from energy crops in Europe. Power point LogistEC project, Workshop in Rome on the 19th of May 2015.

Dufossé, K., J.L. Drouet & B. Gabrielle, 2016. Agro-ecosystem modeling can aid in optimizing the environmental performance of biomass supply chains. Environment Modeling and Software, 85, 139-155.

Gabrielle, B., T. Flatberg, A. Perrin, J. Wohlfahrt, T. Bjørkwoll, I. E. Goni, R. van der Linden, C. Loyce, E. Pelzer, G. Ragaglini, I. Shield & N. Yates, 2015. Improving logistics for biomass supply from energy crops in Europe: main results from the Logist'EC project. Proc. 23rd EU Biomass Conference and Exhibit, 3 June 2105, Vienna, ETA, 2015, 1-6.

Kaut, M., R. Egging, T. Flatberg & K.T. Uggen, 2015. BLOMST – An Optimization Model for the Bioenergy Supply Chain. In "Handbook of Bioenergy - Bioenergy Supply Chain - Models and Applications ", Eds., Eksikoglu, S.D., Rebennack, S.D., Pardalos, P., Springer.

Perrin, A., J. Wohlfahrt, T. Flatberg, F. Morandi, C. De La Rua Lope, H. Østergard, T. Bjørkvoll & B. Gabrielle, 2015. Optimization of biomass supply-chain logistics and sustainability assessment. The case of Miscanthus at Bourgogne Pellets, France Proceedings of the Biomass and Energy Crops V conference, Brussels, 20-22 Oct. 2015, Association of Applied biologists, Warwick, UK.

Annex A. Example simple sheet Variant 3

Table A1. Basic input data of Variant 3.

	yellow = calculated	orange = transfered from LocaGIStics

Biomass basic	**B1**	**B2**
name	Straw	Miscanthus
Higher Heating value [GJ/ton dm]	17.00	18.50
initial moisture content [kg moisture/kg total]	14.00	15.00
biomass costs at roadside [euro/ton dm]	45.00	8.82
energy use biomass at roadside [GJ/ton dm]	0.50	0.84

Form basic	**F1**	**F2**	**F3**
description form	bales	pellets	powder
bulk density [kg dm/m3]	400	590	320
specific volume [m3/ton dm]	2.50	1.69	3.13

Storage basic	**S1**	**S2**
name	open air storage	covered storage
costs [euro/m3.month]	0.18	0.92
energy use [MJ/m3.month]	0.00	0.00

Transport basic	**FI to IC**	**IC to PP**
name	truck	walking floor
maximum volume [m3]	80	92.3
maximum weight [ton]	26.6	28
variable vehicle costs per driven km [euro/km]	3.26	3.10
fixed vehicle costs per load [euro]	0.00	0.00
transport energy [MJ/km]	0	4.48

Loading/unloading basic	**L1**	**L2**
transport type being (un)loaded	truck	walking floor
loading costs [euro/m3]	0.35	0.31
unloading costs [euro/m3]	0.17	0.25
loading energy [MJ/m3]	3.13	3.00
unloading energy [MJ/m3]	3.13	3.00

Pretreatment	**P1**	**P2**	**P3**
name	pelletising	grinding	briquetting
output form	pellets	powder	briquettes
pretreatment costs [euro/m3]	30.61	9.74	22.00
pretreatment energy [MJ/m3]	505.00	360.00	204.00
drying costs [euro/ton moisture]	0.00	0.00	0.00
drying energy [MJ/ton moisture]	0.00	0.00	0.00

Conversion	C1
name	combustion, grate boiler 5MWe, 10MWth
net energy returns electricity [usable GJ/GJ input]	25.00%
net energy returns heat [usable GJ/GJ input]	60.00%
evaporation energy moisture [GJ/ton moisture]	2.256
capacity input [ton dm/month]	2,500
working hours [per month]	583
fixed costs plant + conversion [euro /year]	625,000
variable costs conversion [euro/ton dm input]	30.00
energy use [GJ/m3]	0.0002
emission CO2 [mg/Nm3]	0
emission NOx [mg/Nm3]	472
emission SO2 [mg/Nm3]	0
emission dust [mg/Nm3]	3,000

Revenues	PP
price electricity [euro/GJ]	53.61
price heat [euro/GJ]	3.17

Legenda
Bx = biomass type;
Fx = form;
L = loading/unloading;
P = pretreatment;
C = conversion
IC = intermediate collection point;
PP = power plant;
FI = field.

Table A2. Set-up of the input chain in Variant 3 with one intermediate collection point (ICP1) and one power plant (PP1).

Chain				
case description	Case: Burgundy straw and miscanthus, variant: 102			
calculation number	803			
biomass chain name	bioenergy			
Chain design	**Straw to ICP1**	**Straw ICP1 to PP1**	**Miscanthus to ICP1**	**Miscanthus ICP1 to PP1**
Biomass				
biomass type	Straw	Straw	Miscanthus	Miscanthus
origin location	field	ICP 1	field	ICP1
destination location	ICP1	PP1	ICP1	PP1
description form	bales	pellets	bales	pellets
bulk density [kg dm/m3]	400	590	400	590
specific volume [m3/ton dm]	2.50	1.69	2.50	1.69
biomass shipped fresh [ton fresh]	7,919	7,484	27,291	25,774
moisture content [kg moisture/kg total]	14	9	15	10
biomass shipped dry [ton dm]	6,811	6,811	23,197	23,197

Storage

name	open air storage	covered storage	open air storage	covered storage
costs [euro/m3.month]	0.18	0.92	0.18	0.92
energy use [MJ/m3.month]	0	0	0	0
average storage time [month]	4.5	4.5	4.5	4.5

Transport basic

name	truck	walking floor	truck	walking floor
maximum volume [m3]	80	92.3	80	92.3
maximum weight [ton]	26.6	28	26.6	28
variable vehicle costs per driven km [euro/km]	3.26	3.1	3.26	3.1
fixed vehicle costs per load [euro]	0	0	0	0
transport energy [MJ/ton.km]	0	4.48	0	4.48
total transport [ton.km]	38,202	227,495	128,200	783,957
transported weigt per trip (if volume limited) [ton]	26.6	28	26.6	28

Loading/unloading basic

transport type being (un)loaded	truck	walking floor	truck	walking floor
loading costs [euro/m3]	0.35	0.31	0.35	0.31
unloading costs [euro/m3]	0.17	0.25	0.17	0.25
loading energy [MJ/m3]	3.13	3	3.13	3
unloading energy [MJ/m3]	3.13	3	3.13	3

Pretreatment

name	pelletising	grinding	pelletising	grinding
biomass output	pellets	powder	pellets	powder
pretreatment costs [euro/m3]	30.61	9.74	30.61	9.74
pretreatment energy [MJ/m3]	505	360	505	360
drying costs [euro/ton moisture]	0	0	0	0
drying energy [MJ/ton moisture]	0	0	0	0

Table A3. Costs and revenues value chain of Variant 3.

Costs	Sum	Straw to ICP 1	Straw (ICP 1) to Power Plant 1	Miscanthus to ICP 1	Miscanthus (ICP 1) to Power Plant 1
purchase costs [euro]	511,079	306,481	0	204,598	0
storage costs [euro]	271,328	13,792	47,790	46,974	162,772
transport costs [euro]	132,376	4,682	25,187	15,712	86,795
number of transports	2,200	256	243	872	828
loading/ unloading costs [euro]	67,492	8,854	6,464	30,156	22,018
pretreatment costs [euro]	2,791,724	521,189	112,434	1,775,153	382,948
drying costs [euro]	0	0	0	0	0
variable conversion costs [euro]	900,232	0	204,321	0	695,911
fixed conversion costs [euro]	625,000	0	0	0	0
total conversion costs [euro]	1,525,232				

Revenues		
electricity [euro]	7,214,712	7,214,712
heat [euro]	1,023,867	1,023,867

Table A4. Energy returns and use of Variant 3.

Returns	Sum	Straw to ICP 1	Straw (ICP 1) to Power Plant 1	Miscanthus to ICP 1	Miscanthus (ICP 1) to Power Plant 1
gross energy [GJ]	544,927	0	115,782	0	429,145
evaporation energy [GJ]	6,616	0	1,383	0	5,233
electricity [GJ]	134,578	0	28,600	0	105,978
heat [GJ]	322,987	0	68,639	0	254,347

Use					
purchase energy [GJ]	22,891	3,405	0	19,486	0
average storage energy [GJ]	0	0	0	0	0
transport energy [GJ]	162	0	36	0	125
loading/ unloading energy [GJ]	775	107	69	363	236
pretreatment energy [GJ]	56,195	8,599	4,156	29,286	14,154
drying energy [GJ]	0	0	0	0	0
energy used for conversion [GJ]	10	0	2	0	8

Table A5. GreenHouse Gas avoided and emission of Variant 3.

Avoided (based on coal replacement)

electricity [CO2-equivalents]	12,731
heat [CO2-equivalents]	30,555

Emission (based on diesel consumption)

purchase GHG emission [CO2-equivalents]	1,702
average storage GHG emission [CO2-equivalents]	0
transport GHG emission [CO2-equivalents]	12
loading/ unloading GHG emission [CO2-equivalents]	58
pretreatment GHG emission [CO2-equivalents]	4,178
drying GHG emission [CO2-equivalents]	0
conversion GHG emission [CO2-equivalents]	1

Table A6. Example of the global results of Variant 3.

Total throughput [ton dm]:

from sources	30,008		

Revenues and costs [euro]:

electricity revenues	7,214,712		
heat revenues	1,023,867	total revenues	8,238,579
purchase costs	511,079		
storage costs	271,328		
transport costs	132,376		
loading/unloading costs	67,492		
pretreatment costs	2,791,724		
drying costs	0		
conversion costs	1,525,232	total costs	5,299,231
		profit	2,939,348

Energy returns and use [GJ]:

electricity returns	134,578		
heat returns	322,987	total energy returns	457,564
energy used for purchase	22,891		
energy used for storage	0		
energy used for transport	162		
energy used for loading/unloading	775		
energy used for pretreatment	56,195		
energy used for drying	0		
energy used for conversion	10	total energy use	80,032
		energy profit	377,532

GreenHouse 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