S2Biom

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

S2Biom Project Grant Agreement n°608622

D3.1
Review of the main logistical components

26 August 2014

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, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

Project coordinator

Scientific coordinator

Project partners

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1. Introduction

This deliverable D3.1 was written within the S2Biom project for Task 3.1 'Identify and characterize the main logistical components as storage, pre-treatment and transportation technologies'. Work in this task will build on:

i. many different studies already performed to characterize existing state-of-the-art logistical components;
ii. the available knowledge and views from science and industrial stakeholders on the most recent technological developments to be applied in new future logistical components within the next 30 years.

Steps that need to be followed to collect the required information involve:

- literature review;
- review of European and national project results;
- market inventory on technological aspects, economics, state-of-the-art of current and new logistical components;
- consultation with scientific and industrial stakeholders as organized in WP8 and WP9 but prepared and summarized here.

Steps to store the information in an accessible way, so that it can be used in WP4 are:

- develop a database structure together with Task 4.7 to be populated here with data on the main technical, economic and GHG efficiency characteristics of the logistical components;
- collect and fill the database with data characterizing extensively the wide range of logistical components that are already or will be feasible over the next 30 years.

Task 3.1 was led by Wageningen UR Food & Biobased products (DLO-FBR). Other participating partners in the task were: Imperial College London (Imperial), Finnish Forest Research Institute (METLA), Biomass Technology Group (BTG), French National Institute for Agricultural Research (INRA), Spanish National Renewable Energy Centre (CENER), Research Centre for Energy Resources and Consumption (CIRCE) and Slovenian Forestry Institute (SFI/GIS).

2. Method

2.1 General considerations

The S2Biom project focusses on logistical components for lignocellulosic biomass. Therefore, the classification should be relevant for this category of biomass. For instance logistical components for sugar, starch or oil crops are not considered. The project covers agriculture & forestry, residuals, wastes and cropped biomass. So the appropriate considerations per type of lignocellulosic biomass will be taken into account within the logistical components and differentiation will be made where appropriate and feasible (due to modelling and/ or data availability constraints).

A **logistical component** is one of the links in the biomass value chain from biomass to (final) conversion. Examples are pre-treatment, storage and transport technologies that are needed to deliver biomass feedstock of a specified quality at the correct moment to a processing technology.

A selection of the most relevant logistical components is an important part of the work. A number of logistical components will be divided into sub-categories related to their technical properties, biomass input requirements and capacity range. The focus will be on logistical components that can be applied in Europe and meet European standards.

There will be a data category ‘status of the technology’ that will be classified according to the Technology Readiness Level (TRL) as described in Appendix A. The EC uses TRL in its Horizon 2020 program.

To avoid long descriptions of technologies, we will refer to relevant literature and actual data from existing logistical components or we will add the description in Annexes.

For the main pathways (that are considered in the modelling in other WPs) cost data will be gathered and calculated and estimated both on specific investment costs as well as operation and maintenance costs.

Inputs that are relevant for the greenhouse gas performance (e.g. energy demand) will be described. Complete calculation of GHG performance or GHG factors are case specific and will not be described. Emissions related to the construction of the logistical components will not be described in WP3 (but in other WPs of S2Biom).

The selection of logistical components will be matched with requirements from other WPs (Figure 1). This needed to be performed in advance because WP3 will have only limited possibilities to deliver tailor made data sets during the course of the project.

- Logistical components should collect the **biomass sources** assessed in WP1. So the supplied transfer data between WP1 and WP3 should be specified in close cooperation. Communication is needed with WP1-leader ALU-FR.
- Logistical components should deliver biomass to **conversion technologies** in WP2. So the required transfer of data between WP3 and WP2 should be specified in close cooperation. Communication is needed with WP2-leader BTG.
- The **database structure** for storing the description of the logistical components will be developed in close cooperation with WP4. Communication is needed with WP4-leader DLO-Alterra.
- The **RESolve model** in WP7 requires information on several types of logistical components from WP3. Communication is needed with WP7-leader ECN.

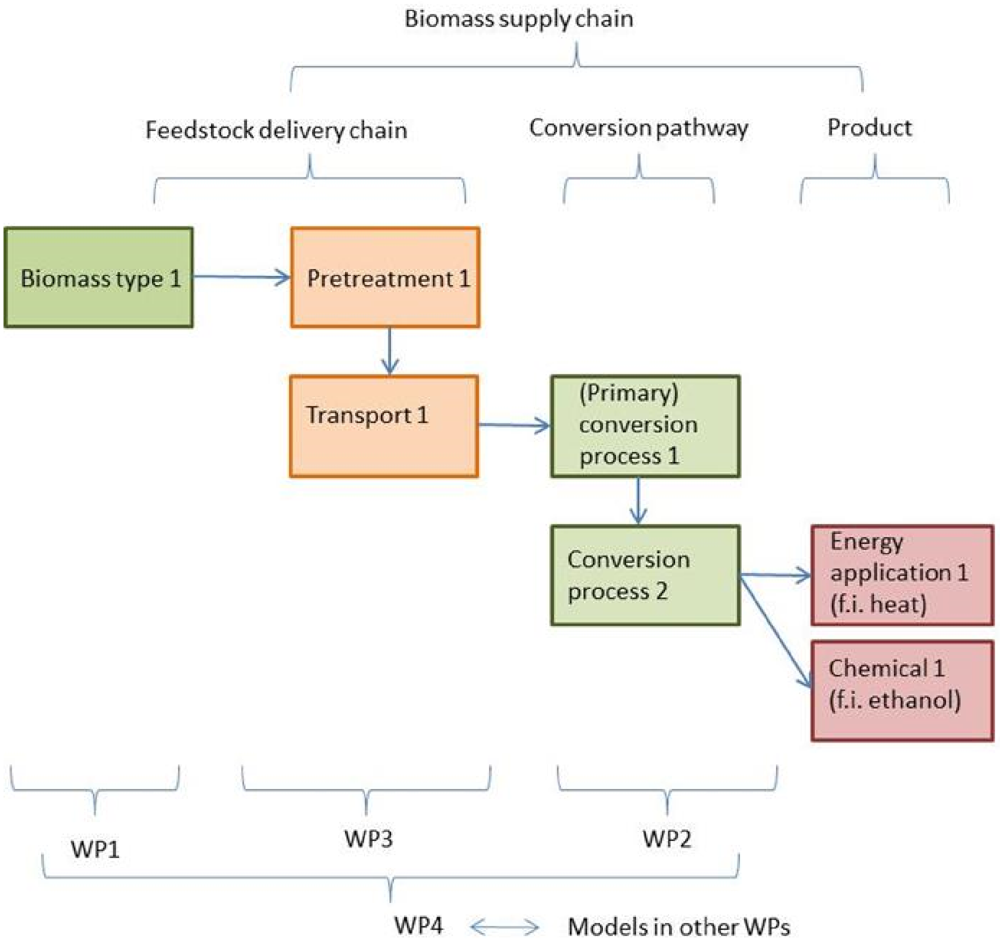

Figure 1 Structure of WP1 – WP4 in the S2Biom project.

2.2 Information sources

2.2.1 Literature review

A literature review was performed by several partners to obtain information about logistical components.

2.2.2 European and national project results

Both European and national research and development projects were a valuable source of information for the identification of logistical components (Appendix B). The reports of these identified projects were studied to extract data on logistical components.

2.2.3 Market inventory

A web search was performed to produce a long list of machine manufacturers of logistical components. This web search was combined with information in the global suppliers directory of Bioenergy International (2014 & 2013). The long list of manufacturers is given in Appendix C. For each company a compilation was made of (most of) the individual machines that they supply (identified by a product number). If available a reference was given for each logistical component to a web page that contains more information about the component. In the next step only a selection of the machines (short list) was entered in the database.

2.2.4 Consultation with scientific and industrial stakeholders

The consultation with scientific and industrial stakeholders was foreseen to be organized in WP8 and WP9 and prepared and summarized here. However this consultation was organised directly by WP3, because the stakeholder groups were not defined yet in year one of the project. Scientific and industrial stakeholders were contacted on the topic of logistical components during conferences, trade fairs and through direct email contact (Appendix D).

2.2.5 Some important data sources consulted

Within the Dutch project ‘An integrated framework to assess spatial and related implications of increased implementation of biomass delivery chains - ME4’ data were collected on logistical components (Oever & Annevelink, 2010a and 2010b) that were updated and added to the database.

The Bioboost project has recently finished a logistical study that contained valuable data about logistical components (Rotter & Rohrhofer, 2014).

Partner SFI filled in more than 130 machines, mostly chippers which data were given in BiomassTradeCentres project (BiomassTradeCentres, 2009a & 2009b; Krajnc, 2011). Furthermore they contacted some Slovenian forestry manufacturers (for wood fuel processor, forestry cable crane, chipper) and also those data were entered in the database. Useful information was also found in existing machine databases e.g. the forest machine database of the Austrian Research Centre for Forests (FZW, 2014).

A recent sensitivity assessment by ICL of the main techno-economic factors concerning the integration of biomass into urban energy systems for heat and power (Pantaleo, 2014) also led to data on several logistical components. Furthermore a study of Petrolia et al. (2008) on the economics of harvesting and transporting corn stover for conversion to fuel ethanol contained valuable data. Webster (2005, 2007 & 2008) gave data on large and small scale chippers based on several field experiments.

In Spain a relevant source of information has been the studies on performance of logistical components for forestry wood procurement carried out by Tolosana and co-workers (Tolosana, 2009; Tolosana et al., 2009).

The Woodfuel Handbook (2009) was an important source of information.

There are some interesting research projects on logistics of forestry biomass carried out by the research group of forest mechanization and biomass harvest of CNR-IVALSA in Italy (IVALSA, 2014). One of these projects (biomassaforestale.org) reports a software tool that returns the productivity of chippers and provides an estimate of chipping cost under user-specified working conditions, and another software that estimates the cost of thinning operations performed with a forestry-equipped skid-steer-loader. Guidelines for a development of a supply chain model for forestry biomass, including techno-economic parameters of different chipper technologies are also provided in GAL (2014).

2.3 Database development

A first prototype of the WP3 logistical components database was developed in WP4 in January - May 2014 by DLO-Alterra in co-operation with DLO-FBR. The work was done in close harmony with the definition and development of the WP2 database on conversion processes.

The database is located on a project dedicated website (www.biomass-tools.eu). For more details see Appendix E.

3. Properties of a logistical component

This Chapter specifies what data attributes were considered for each logistical component that will be stored in the data base (WP4).

A distinction is made between:

- general properties;
- technical properties;
- biomass input/output specifications;
- financial and economic properties;
- other properties.

The specific units to be used are indicated between brackets after each attribute in the next sections.

For biomass quantities it was suggested to use the unit fresh tonnes (t) combined with an indication of the moisture content (wet basis) as much as possible. This is in line with what has been agreed upon in the INFRES, LogistEC and EuroPruning FP7 projects. Fresh tonnes can then be converted to tonnes dry matter if needed. If really needed, biomass can also be specified in m^3.

For each record of a logistical component at least one and preferably more data sources need to be provided. For existing logistical components values based on practical experience will be used. Where appropriate: data ranges and typical values, future changes after 2020 and 2030 will be given.

3.1 General properties

- Commercial name (text)
    - use a unique name; this is the only field that cannot be changed later on by editing

- Main category (text)
    - e.g. communition (size reduction) (see Section 4.1 for all the different main categories)

- Sub-category (text)
    - e.g. chipping, chunking, crushing, grinding, etc. (see Sections 4.2 – 4.9 for all the different sub-categories)

- Image url (text)
    - e.g. www.producer.com/example_machine.jpg

- Most common/suitable applications (text)

- Main operating principle (text)
    - in this box may include any information about the operating principle of the logistical component, but also about relevant information that you cannot enter in the other data fields

- Level of commercial application (text)
    - describe the general status

- Year of first introduction in practice (text)
    - year of the first pilot/demo introduction of the logistical component

- Estimated number of systems in operation since introduction (number)

- Current Technology Readiness Level in 2014 (level number)
    - = state of the art; see Appendix 1 for description of levels

- Expected Technology Readiness Level in 2030 (level number)
    - = expected developments; see Appendix 1 for description of levels

- References (text)
    - Link to information sources e.g. article, report, web address, personal communication, etc.
    - commercial: www.producer.com/description_machine_type
    - scientific: author name(s), year (the full references of scientific papers will be stored in external reference word doc)
    - other: websites, magazines, etc.

3.2 Technical properties

- Energy demand (MJ/t or MJ/m^3)
- Type of energy needed (text)
  - e.g. diesel, fuel, heat, power, other:
- Other input demand (text)
  - e.g. materials, chemicals, enzymes, etc.
- Pre-treatment efficiency (output/input)
  - e.g. t output/t input or m^3 output/m^3 input
- Input processing capacity (t/hour or m^3/hour)
- Storage capacity for input (t or m^3)
- Storage capacity for output (t or m^3)
  - e.g. a bunker or container connected to the logistical component
- Number of full load hours per year (hours)
- Maximum load volume of transport system (m^3)
- Maximum load weight of transport system (t)
- Typical lifetime of equipment (years)
- Labour requirements pre-treatment (hours/t input or hours/m^3 input)
- Labour requirements storage (hours/t input or hours/m^3 input)
- Labour requirements transport (hours/t input or hours/m^3 input)
- Transportability (text)
  - e.g. mobile, semi-mobile, static, other:

3.3 Biomass input specifications

This section describes the detailed information on the **input** requirements of biomass supplied to the logistical component.

- Acceptable biomass input groups (text)
    - five different acceptable biomass input groups can be specified
    - all different biomass types that are mentioned in the long list of WP1 are aggregated in WP3 in the following groups:
    - all types, crop, crop: annual, crop: grass, crop: other residues (not straw), crop: perennial, crop: straw, wood, wood: forestry, wood: industry residues, wood: landscape management, wood: orchard residues, wood: SRC and other:

- received (intermediate) biomass type (text)
    - e.g. bark, branches, bundle (e.g. logging residue bundles), chunks, construction and demolition wood, crown, fellings, fruit seeds/olive residues, logwood/firewood, roots, round bales, saw dust, shavings, slurry, square bales, stemwood/roundwood, straw, thinnings, whole tree, wood chip and other:
    - sometimes this is not relevant because it remains unchanged by the logistical component

- Particle size input (length, width/diameter, height in mm) Minimum & Maximum

- Moisture content input (%, wet basis) Minimum & Maximum

- Bulk density input (kg/m^3, wet base) Minimum & Maximum

- Maximum input level of contamination with exogenous material (%, dry base)
    - exogenous material can be e.g. metals, soil particles, dust, gravel, stones, etc.

- Maximum ash content input (%, dry basis)

3.4 Biomass output specifications

This section describes the detailed information on the **output** requirements of biomass that has to be supplied to the next step in the biomass chain e.g. to a processing factory.

- Indication of follow-up processes (text)
    - five different indications of follow-up processes can be specified
    - see WP2 for all different processes; however also other logistic components from WP3 could be the follow-up
    - e.g. all types, anaerobic digestion, chemical pre-treatment, combustion, enzymatic hydrolysis, explosion processes, fermentation, forwarding, gasification, Hydro Thermal Upgrading (HTU), pyrolysis, simultaneous saccharification & fermentation (SSF), storage, supercritical gasification, techniques from pulp and paper industry, torrefaction, transport and other:

- Delivered (intermediate) biomass type (text)
    - see Table 1 with traded forms that is also used in WP2
    - e.g. bark, briquettes, bundle (e.g. logging residue bundles), chopped straw or energy grass, fruit seeds/olive residues, logwood/firewood, other (black liquor, BMW, PO etc.), pellets, round bales, saw dust, shavings, square bales, stemwood/roundwood, whole tree, wood chips
    - sometimes this is not relevant because it remains unchanged by the logistical component

- Dimensions (text)
    - see Table 1
    - the dimensions vary depending on the specified delivered (intermediate) biomass type
    - the specifications should be in line with international standards such as the ISO (2014) standard.

- Moisture content output (%, wet basis) Minimum & Maximum

- Bulk density output (kg/m^3, wet base) Minimum & Maximum

- Maximum output level of contamination with exogenous material (%, dry base)

- Maximum ash content output (%, dry basis)

Table 1 Overview of dimensions of different traded forms of biomass.

Traded form	Dimensions (in mm)	Fine fraction
whole tree	Length x diameter	
stemwood/roundwood	Length x diameter	
log wood, firewood	Length x diameter	
bundle (e.g. logging residue bundles)	Length x diameter	
wood chips	P16S – P300 (see below)	F05-F30+ (see below)

Dimensions (mm) ISO 17827-1

Main fraction [b] (minimum 60 w-%), mm		Coarse fraction, w-% (length of particle, mm)	Max. length of particles [c], mm	Max. cross sectional area of the coarse fraction [d], cm²
P16S	3,15 mm < P ≤ 16 mm	≤ 6 % > 31,5 mm	≤ 45 mm	≤ 2 cm²
P16	3,15 mm < P ≤ 16 mm	≤ 6 % > 31,5 mm	≤ 150 mm	
P31S	3,15 mm < P ≤ 31,5 mm	≤ 6 % > 45 mm	≤ 150 mm	≤ 4 cm²
P31	3,15 mm < P ≤ 31,5 mm	≤ 6 % > 45 mm	≤ 200 mm	
P45S	3,15 mm < P ≤ 45 mm	≤ 10 % > 63 mm	≤ 200 mm	≤ 6 cm²
P45	3,15 mm < P ≤ 45 mm	≤ 10 % > 63 mm	≤ 350 mm	
P63	3,15 mm < P ≤ 63 mm	≤ 10 % > 100 mm	≤ 350 mm	
P100	3,15 mm < P ≤ 100 mm	≤ 10 % > 150mm	≤ 350 mm	
P200	3,15 mm < P ≤ 200 mm	≤ 10 % > 250mm	≤ 400 mm	
P300	3,15 mm < P ≤ 300 mm	to be specified	to be specified	

Fine fraction, F (< 3,15 mm w-%), ISO 17827-1

F05	≤ 5 %
F10	≤ 10 %
F15	≤ 15 %
F20	≤ 20 %
F25	≤ 25 %
F30	≤ 30 %
F30+	> 30 (maximum value to be stated)

Traded form	Dimensions (in mm)	Fine fraction
briquettes	Length x diameter	
pellets	D06-D25 (see below)	F1.0 - F6.0+ (see below)

Dimensions (mm) ISO 17829

Diameter (*D*) and **Length** (*L*) [a]

D06	6 mm ± 1,0 mm and 3,15 mm < L ≤ 40 mm
D08	8 mm ± 1,0 mm and 3,15 mm < L ≤ 40 mm
D10	10 mm ± 1,0 mm and 3,15 mm < L ≤ 40 mm
D12	12 mm ± 1,0 mm and 3,15 mm < L ≤ 50 mm
D25	25 mm ± 1,0 mm, and 10 mm < L ≤ 50 mm

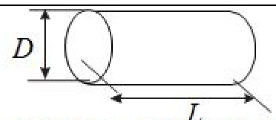

Figure 3 — Dimensions (mm)

Amount of fines, F (w-%, < 3,15 mm) after production when loaded or packed, ISO 18846

F1.0	≤ 1,0 %
F2.0	≤ 2,0 %
F3.0	≤ 3,0 %
F4.0	≤ 4,0 %
F5.0	≤ 5,0 %
F6.0	≤ 6,0 %
F6.0+	> 6,0 % (maximum value to be stated)

Traded form	Dimensions (in mm)	Fine fraction
shavings	not applicable	
sawdust	not applicable	

Table 1 (continued): Overview of dimensions of different traded forms of biomass.

bark		

Dimensions (mm) ISO 17827-1

	Nominal top size, mm [a]	Coarse fraction, max. length of a particle, mm < 5 w-%
P16	P ≤ 16 mm	> 45 mm, all < 100 mm
P45	P ≤ 45 mm	> 63 mm
P63	P ≤ 63 mm	> 100 mm
P100	P ≤ 100 mm	> 150 mm
P200	P ≤ 200 mm	> 350 mm

chopped straw or energy grass	Length	
round bales	Length x diameter	
square bales	Length x width x height	
fruit seeds, olive residues	D03-D10+ (see below)	F1.0-F1.0+ (see below)

Dimensions (mm) ISO 17827-1, ISO 17827-1, ISO 17827-2

Diameter (*D*) (5 w-% may have diameter over the class)	
D 03	1 mm ≤ *D* ≤ 3,15 mm
D 05	1 mm ≤ *D* ≤ 5 mm
D 10	1 mm ≤ *D* ≤ 10 mm
D 10+	*D* > 10 mm (maximum value to be stated)

Amount of fines, F (w-%, < 1 mm) ISO 17827-1

F1.0	≤ 1,0 %
F1.0+	> 1.0 %

3.5 Financial and economic properties

- Specific investment costs of equipment, included auxiliaries (€)

- Operation and maintenance costs (€/t or €/m^3)
- Calculation method (text)
    - description of calculation method for operation and maintenance costs
    - e.g. effective operation time, including idle time (maintenance time, time break for workers, etc.), etc.

- Storage costs (€/t or €/m^3)

- Loading costs (€/t or €/m^3)
- Unloading costs (€/t or €/m^3)

- Transport costs per kilometre (€/km)
- Transport costs per tonne (€/t)
- Transport costs per load (€)
- Transport costs fixed (€)

3.6 Other properties

- infrastructures needed (text)
    - in the region of application e.g. connection to rail network, connection to road network, connection to the grid, connection to water supply, none, other:

4. Overview of categories of logistical components

4.1 Introduction

The purpose of this Chapter is to provide a long list with names of categories and subcategories of logistical components. Not all of these (sub)categories will be added to the database. A selection will be made based on the data that are needed for the case studies and based on specific biomass valorisation chains that will be chosen together with the other WP's.

The following main categories of logistical components were distinguished:

- comminution (size reduction);
- compaction/densification;
- drying;
- feedstock handling;
- harvesting/collection;
- other pre-treatments that influence feedstock quality;
- storage;
- transportation technologies.

The general description of the categories in the next paragraphs is based on several literature sources.

4.2 Comminution (size reduction)

Comminution (size reduction) diminishes the volume of the biomass material and thus increases the bulk density. Follow-up processes like handling and transport will be facilitated by size reduction. Furthermore the physical properties of the biomass will be adjusted, e.g. the particle size distribution will be modified. A method often used to reduce the size of biomass is chipping. Many different types of chippers are being used (disk, drum and screw chippers), and each will have a specific influence on the quality of the produced biomass chips. If fresh chips need to be stored for a longer period they will need to be dried (see Section 4.4). An alternative way is to chunk the biomass, which will produce larger particles that are easier to dry and that can therefore be stored longer.

Different subcategories of logistical components for comminution (size reduction) are:

• chipping o disk chippers o drum chippers o screw chippers • chunking • crushing • debarking • grinding o hammer mill o horizontal grinder o tub grinder	• milling • screening o disk screen o drum screen o flip-flow screen o star screen • shredding

4.3 Compaction/densification

Compaction/densification can be used to produce a uniform material with favourable physical and mechanical properties. Densification methods are briquetting, centrifugation (for wet biomass materials) and pelletizing. Under high pressure the biomass is densified into briquettes (diameter 50-100 mm, length 60-150 mm) or pellets (6-12 mm). Sometimes this requires a binding agent (other than the lignin already present in the biomass). The economy of pelletizing strongly depends on the volume and the costs of the raw feedstock material. An advantage of pellets is that they are dry, clean and mechanically stable. Furthermore pellets can flow more easily, which facilitates loading and unloading and wood pellets e.g. are standardized in Europe (EN 14961-2). So far pellets are meant for the bioenergy markets: both industrial (co-firing in coal fed power plants) and household markets (stoves). Pellets have a lower energy content per volume unit than coal. Consequently more storage space at a power plant is needed for pellets than for coal.

Different subcategories of logistical components for compaction are:

• briquetting • centrifugation • pelletizing • bundling

4.4 Drying

Biomass can be dried to reduce the moisture content. This influences energy i) efficiency of conversion processes, ii) storage options and iii) transport costs.

For thermal conversion processes like combustion or gasification dry biomass is needed. That way less of the energy content is lost due to evaporation. Moreover, different thermal conversion processes demand different moisture contents. Typical gasification processes require biomass with a moisture content in the range of 10-15%. Combustion can also deal with higher moisture contents depending on the design of the boiler. In some case it is also possible to combust freshly harvested biomass, e.g. wood chips, with a moisture content of 40-50%. In most cases drying is not necessary for anaerobic digestion processes. Other processes like Hydro Thermal Upgrading (HTU) specially require relatively wet biomass.

Biomass that is too wet (more than 20% of moisture content; see Table 2) it is perishable. By drying wet biomass it will be easier to store the material for a longer time without danger of heating, composting, ignition or moulds. Furthermore, transport of dried biomass can be more efficient because relatively less water needs to be moved.

Table 2 Bulk density and moisture content of different biomass fuels (Alakangas & Virkkunen, 2007; Woodfuel Handbook, 2009; Woodenergy, 2014).

Name	Manifestation	Bulk density fresh (kg/loose m^3)	Moisture content fresh (wt.%)
Whole tree	chips	250-350	45-55
Stem wood	chips	250-350	40-55
Stump	chips	200-300	30-50
Logging residue	chips	250-400	50-60
Log wood (oven-ready)	logs	240-320	20-25
Wood residue	chips	150-300	10-50
Wood	pellets	550-650	7-8
Plywood	chips	200-300	5-15
Sawmill residue	dust	250-350	45-60
Cutter	chips	80-120	5-15
Grinding residue	dust	100-150	5-15
Straw	chopped	80	12-20
Straw	pellets	550-650	8-10
Miscanthus	chopped	110-140	8-20

Several methods are available for drying biomass. The cheapest alternative is to dry passively in the open air. This could be done in several configurations e.g. in covered piles on bearers (see more storage methods in Section 4.8). Usually outdoor drying can lead to a reduction of moisture content to about 20-30%. Factors that influence drying biomass are: initial moisture content, shape and size of the biomass particles, bulk density during storage, method of storage, weather conditions (wind , temperature, rainfall and relative humidity). When passive drying does not lead to the required results one can move to active/forced drying. However, this demands energy input and additional costs for a drying installation. Sometimes it is possible to use heat surplus from other processes.

Different subcategories of logistical components for drying are:

• Active/forced drying (artificial) o belt dryer o dryer equipment o heating with residual heat o rotary drum dryer o ventilation with fans or blowers	• passive drying (natural) o inside in barn o outside covered o outside in open air and sun

4.5 Feedstock handling

Feedstock handling is needed throughout the biomass value chain to move the biomass between different components e.g. loading biomass from storage to a means of transportation. Another use for feedstock handling is to move biomass from one position to another, where the transport distance is relatively low.

Different subcategories of logistical components for feedstock handling are:

• bucket grab • conveyor o belt o bucket o chain o screw • crane o wood crane • front loader • gravity feed • intake system • loading/unloading system o ship o train o truck	• pneumatic blower • pumped flow • screw type auger feed • shovel • squeeze loader • stacker • telehandler • tipping platform (raising front of trailer)

4.6 Harvesting/collection

Integrated methods have been developed for harvesting biomass in agriculture and forestry (both for main product and for residues). A restrictive factor is the fact that grown biomass and primary agricultural and forestry residues always are released de-centrally/regionally. Therefore, the biomass still needs to be transported to a more central location. Furthermore, biomass often can only be harvested in a certain period, which requires building buffers through storage. The total amount of biomass that can be removed from an agricultural field or forest plot is limited by various reasons, like preventing erosion, maintaining soil fertility, ecological reasons, etc. Moreover, the agricultural residues often present alternative uses (i.e. zootechnical applications in case of straw) that can limit the potential for energy conversion. In other cases, such as for forestry residues, the resource accessibility and the high harvesting and transport costs can be a major drawback for the full deployment of the theoretically available resources. During harvesting or collecting biomass pollution (e.g. with soil or stones) needs to be prevented. Secondary and tertiary residues need to be collected on the location where they originate. These residues can be released both centrally (e.g. at a food processing industry) or de-centrally (e.g. at demolition activities).

Different subcategories of logistical components for harvesting or collection are specified in the next sub-paragraphs. A distinction was made between agriculture, forestry and landscape management:

Agriculture • bale wrapper • baling o round bales o square bales • bio flail mulcher • chopping • cutter • forage harvester • in field hauling • loading • mower • mower conditioner • raking • SRC harvester o chips o whole stem • sugar cane harvester	*Forestry* • baling • cable yarding • chipping • forwarding • harvesting • road transport • skidding • stump extraction	*Landscape management* • pruning • whole tree harvesting

Three running FP7 projects are each dealing with harvesting and/or collecting specific biomass types: LogistEC with harvesting energy crops, INFRES with harvesting forestry residues and finally EuroPruning with the collection of prunings.

4.7 Other pre-treatments that influence feedstock quality

This category covers a broad collection of other pre-treatments that might occur within the biomass supply chain. Different subcategories of logistical components for other pre-treatments are:

• biological pre-treatments (fungi) • blending • conservation (e.g. silage) • de-watering • separation (e.g. S/L)	• sieving • sorting out metal with a magnet • ultrasonic pre-treatment • washing

Torrefaction and hydrothermal upgrading (HTU) could also be seen as pre-treatment technologies. However, in S2Biom they are described as conversion processes in WP2. On the other hand some of the pre-treatments that could also be considered as a part of (mostly biobased) conversion processes (such as washing, separation, ultrasonic pre-treatment and biological pre-treatment) are not described in WP2 but are dealt with here as a logistical component in WP3.

4.8 Storage

Storage is important in relation to buffering biomass either over a longer period somewhere in the supply chain (e.g. to compensate for seasonal effects of biomass supply from forests and nature area, where it is impossible to harvest year-round) or on the short term just before delivering to the final conversion process. Both relatively dry biomass (e.g. wood) and wet biomass (e.g. grass) can be stored.

During storage, since biomass is an organic material, whenever its moisture content is higher than 20%, fermentation will occur and this process will lead to heat development. This natural process on the one hand helps to reduce the moisture content but on the other hand it can also have a negative effect generating energy loss, ignition risks and health problems for the operators (related to microorganism growth).

When choosing a storage method it is also important to take into account handling: how can biomass be received efficiently and how can it easily and safely be taken out of the storage facility again in order to supply it to the next link in the value chain. A problem that might occur during handling in a storage facility is so-called bridge formation (Farnish, 2006). This is caused by irregular, large or flaky particle forms of the biomass. Natural heating could also lead to formation of lumps that cause blockage. When breaking them, dust clouds might cause problems like dust explosions and inhalation of dust by personnel (the latter is considered as an important long-term health problem because of spores inhalation).

Storage problems can be reduced through: i) minimizing storage duration, ii) correct management and control of the storage iii) the use of flexible storage facilities that can handle a wide range of materials and iv) investing in adjustments that match the characteristics of the specific biomass to be stored.

A bigger storage capacity at the end user can lead to less frequent supply visits, lower biomass costs (e.g. due to discounts) and a bigger reserve (with less danger of a shutdown of the conversion process). However, a bigger storage is more difficult to be controlled and optimised, so it is more likely to suffer from the problems mentioned above.

The subcategories for storage mentioned below are a result of the combination of several characteristics:

- indoors versus outdoors
- covered versus uncovered
- base type: asphalt, bare soil, bearers or concrete floor
- permanent storage structure type: bunker, container, silo or tank
- temporary bulk form type: big bag, ensiled, pile or stack

The resulting subcategories of logistical components for storage are:

- indoors bunker
- indoors container
- indoors silo
- indoors tank

- outdoors bunker - covered
- outdoors bunker - uncovered
- outdoors container - covered
- outdoors container - uncovered

- outdoors on asphalt - big bag
- outdoors on asphalt - ensiled
- outdoors on asphalt - pile - covered
- outdoors on asphalt - pile - uncovered
- outdoors on asphalt - stack - covered
- outdoors on asphalt - stack - uncovered

- outdoors on bare soil - big bag
- outdoors on bare soil - ensiled
- outdoors on bare soil - pile - covered
- outdoors on bare soil - pile - uncovered
- outdoors on bare soil - stack - uncovered
- outdoors on bare soil - stack - covered

- outdoors on bearers - big bag
- outdoors on bearers - ensiled
- outdoors on bearers - pile - covered
- outdoors on bearers - pile - uncovered
- outdoors on bearers - stack - covered
- outdoors on bearers - stack - uncovered

- outdoors on concrete floor - big bag
- outdoors on concrete floor - ensiled
- outdoors on concrete floor - pile - covered
- outdoors on concrete floor - pile - uncovered
- outdoors on concrete floor - stack - covered
- outdoors on concrete floor - stack - uncovered

- outdoors silo
- outdoors tank

Storage can also be needed used in case of excessive quantities of feedstock in timber yard (e.g. natural disturbances). The large and sudden supply of raw material that subsequently becomes available may by far exceed the conversion and sales capabilities of the sawmilling industry (Stodafor, 2004). Eventually, a large proportion of the wood could be lost due to rot and insect infestation. Solutions, such as storage of logs on site or in special storage yards, aid to maintain the feedstock quality and the economic value of timber (Triplat et al., 2013). That kind of solutions are several different methods of storage of timber, used throughout Europe, to avoid especially fungi attack. The moisture content of timber may play the most important role in determining the extent and diversity of fungal colonisation. Methods, that maintain the moisture content of timber assortments as high as possible are: sprinkling logs with water, ponding or immersion of logs in fresh water, logs covered with plastic sheets, storage in snow, logs covered with a mineral suspension composed of calcareous dust and water. The opposite methods, which are lowering the natural wood moisture content as fast as possible are: log pre-drying in covered cross-pile, rapid log pre-drying in open cross-pile. There are also other, supplementary conservation methods that reduce the risk of attack from wood-boring insects or fungal discoloration and prevent decay of green timber such as chemical, biological and physical protection of wood.

4.9 Transportation technologies

Biomass can be transported locally, regionally and globally. However, it is difficult to specify the exact distance boundaries between these subareas, because this depends on factors like bulk density, means of transportation, density of the infrastructure (road, rail and water), etc. Roughly speaking locally could be 0 – 30/50 km, regionally 30/50 – 250 km and globally > 250 km.

It might not be necessary to pre-treat the biomass yet for local transport (< 30 km) to a first depot (biomass yard). However, for transport over longer distances (> 250 km) biomass will usually need to be pre-treated (e.g. comminute, dry and/or densify) at a biomass yard near the origin of the biomass to improve bulk density and to make it storable. Pellets are one type of biocommodity that is already transported worldwide in bulk carriers (Sanders et al., 2009), but there are also new ones like e.g. pyrolysis oil that need other types of vessels.

Transport on short and medium distance will most likely be performed on the road. Many transport means are available for this like farm trailers, bulk vans, removable cargo container lorries, tipper trailers and walking floor trailers. For long (and sometimes medium) distances other transport options like rail, inland waterways and sea might also be possible. Transport means are closed or open train wagons, wagons with the WoodTainer system, several types of barges and bulk carriers.

Multimodal logistical networks make use of a combinations of transport means, e.g. bulk carriers to transport pellets to a large port (like Rotterdam) and dry bulk cargo barges to further transport the pellets to an inland power plant (Kisslinger, 2005). Another example is a combination of road transport to a railway yard and then railway transport to a large biomass power plant in Sweden (Ljungblom, 2011).

The resulting subcategories of logistical components for transport are:

• Inland waterway o deck barge o dry bulk cargo barge o hopper barge o tug-boat • Maritime o handymax bulk carrier o handysize bulk carrier o Panamax bulk carrier • Rail o closed bulk wagon o closed wagon with rolling roof o open bulk wagon o open wagon o wagon suitable for 3 TEU containers o wagon suitable for WoodTainersystem	• Road o bulk van/chip van o farm trailer o flatbed trailer o log trailer o open-end bulk van o removable cargo container lorry/trailer o tanker, grain or animal feed vehicle o timber haulage wagon o tipper trailer or truck o walking floor trailer/self-unloading floor/live floor

4.10 Other factors that influence the logistical chain

Factors mentioned in this section cannot really be called logistical components, although they do influence the logistical chain. So these factors will **not** be stored in the database. However, they will be taken into account when describing the logistical concepts in Task 3.2.

- Types of intermediate (storage) locations
    - Satellite Storage Locations (Cundiff, 2009)
    - Local Biomass Processing Depot (Campbell, 2011)
    - Biomass yard (Schweinle, 2012)
    - Bulk terminal
    - Biomass hub
    - Harbour

- Quality monitoring
    - Monitor moisture content
    - Monitor temperature
    - Monitor contamination
    - Monitor health protection issues
    - Weighing bridge
    - Ash content measuring

Quality monitoring is interesting because the quality of the biomass input is a key theme in the suitability of biomass sources for conversion technologies in WP2 and therefore monitoring is also important in the logistical chain of WP3. Quality monitoring is also important to determine harvesting windows, and also to check quality of storage. In Logist'EC an ERP (Entreprise Resource Planning) system to monitor stacks of biomass (remotely) with a GIS capacity is being tested. An ERP system could be an (integrative) component. EuroPruning is developing a centralised system for facilitating the organisation of local markets (place orders, check conformity), organisation of logistics (decision support to transport companies, e.g.) and follow-up of delivery. This system will integrate quality components and a traceability labelling.

Quality control also influences costs. However, it was not included as a ‘real’ logistical component. It is more a part of the overall costs of logistics. For example the organization of logistics is also a part of the logistics costs, but is certainly not a logistic component.

Some aspects that influence all categories of logistical components are:

- mobile versus stationary;
- large scale versus small scale;
- de-central versus central.

Centralized and decentralized is especially related to the location (and also the scale) of the conversion plant. This also relates to the choice of specific logistical components in a certain biomass value chain. E.g. small-scale could have a direct supply to the conversion site (e.g. a local power plant) without the need of storage at a biomass yard (with certain logistical components like a large scale-chipper and storage space), while large-scale does need such a biomass yard in the value chain. In Task 3.2 of the project these biomass value chains (logistical concepts) will be defined and then the logistical components from the database will be used to construct such logistical concepts.

5. Results

In the period of May – July 2014 logistical components were entered by the partners (Appendix F) in the first prototype of the WP3 database. Data entry will remain an ongoing process in the project. It will be continued during the further duration of the project. Furthermore, an updated version of the WP3 database will be constructed in year 2 of the S2Biom project based on the experiences of the partners (see discussion in Chapter 6) during this first data entry round. This Chapter summarizes the status of the WP3 database content on the reference date 14th of July 2014.

The total number of logistical components that were (partially) entered is 198 (see Appendix G). These records are divided over the main and subcategories as indicated in Table 3.

So the vast majority of records can be found in the main category comminution (size reduction), followed by transportation and harvesting/collecting. The other main categories feedstock handling, storage and compaction are only little represented. The main categories drying and other are even completely absent.

So when this list in Table 3 is compared with the possible subcategories of the logistical components (Section 4.2 - 4.9) it can clearly be seen that not all subcategories are covered yet. From the beginning of the task this already was considered not to be really necessary, because only subcategories that are relevant for the case studies were needed. However, since the case studies are not completely specified yet, it might turn out that some logistical components are still missing. In that case they will have to be added to the WP3 database at a later stage.

Unfortunately most logistical component records were not completely filled yet. Most data categories were only filled for a limited number of records. A distinction can be made here between data categories i) where all records were completed for that category ii) where a substantial number of records were completed, iii) where very little records were completed and finally iv) where no records were completed for the specific data category.

In the case where all records were completed for a certain data category they sometimes all received the same value. So then unfortunately no distinction can be made yet between the logistical components by looking these data categories.

Table 3 Division of logistical components according to the main categories and subcategories.

Main Category	Subcategory	Number in subcategory	Total number in main category
Comminution	chipping	8	148
	chipping - disk	61	
	chipping - drum	59	
	chipping - screw	4	
	chunking	4	
	grinding - hammermill	1	
	shredding	12	
Compaction	pelletizing	3	3
Drying	-	0	0
Feedstock handling	crane	1	8
	crane - wood	3	
	front loader	1	
	telehandler	3	
Harvesting/collection	agriculture: baling round	2	15
	agriculture: baling square	2	
	agriculture: in field hauling	2	
	agriculture: mower conditioner	1	
	agriculture: raking	1	
	forestry: forwarding	2	
	forestry: harvesting	2	
	forestry: skidding	1	
	forestry: stump extraction	1	
	landscape: whole tree harvesting	1	
Other	-	0	0
Storage	indoors bunker	2	4
	outdoors bare soil - pile - covered	1	
	outdoors bare soil - pile - covered	1	
Transportation	inland water: dry bulk cargo barge	6	20
	maritime: handymax bulk carrier	1	
	rail: closed wagon with rolling roof	1	
	road: farm trailer	3	
	road: flatbed trailer	1	
	road: log trailer	1	
	road: removable cargo container	3	
	road: timber haulage wagon	1	
	road: tipper trailer or truck	1	
	road: walking floor trailer	2	
		Total	198

Examples of data categories were all records received an input value are:

General properties

- all records were marked having ‘Technology Readiness Level 9’ (System ready for full scale deployment)

Technical properties

- none of the logistical components had an ‘other input demand’
- mostly filled in for transportability was ‘mobile’ (196); ‘static’ and ‘semi-mobile’ were both only entered once

Biomass input specifications

- acceptable biomass input groups was always specified (198) with wood being the most important type (see Table 4); sometimes a second type (14) and third type (9) was specified
- also the received (intermediate) biomass type was always specified, with logwood/firewood (70) and fellings (56) as most important ones (see Table 5); in 22 cases it was specified that this is not important because the type remains unchanged

Biomass output specifications

- an indication of follow up processes was always given (see Table 6); this was mostly transport (155); sometimes more than one follow up process was specified
- the delivered (intermediate) biomass type was always specified (Table 7), being mostly wood chips (144); in 26 cases it was specified that this is not important because the type remains unchanged
- the dimensions of the wood chips (144) are given in Table 8

Financial and economic properties

- infrastructure need was always specified, being none (143), connection to rail (1), connection to waterways (6) and connection to road (48)

Table 4 Acceptable biomass input groups specified in the database.

Biomass type	Number of occurrences
wood forestry	16
wood	145
crop: straw	14
crop: other residues (not straw)	1
crop: grass	1
crop: annual	2
crop	4
all types	14
none	1
total	198

Table 5 Received (intermediate) biomass types specified in the database.

Received (intermediate) biomass type	Number of occurrences
bark	1
branches	12
bundle	2
fellings	56
logwood/firewood	70
not relevant: unchanged	22
roots	1
round bales	1
square bales	9
stemwood/roundwood	1
straw	4
thinnings	7
whole tree	9
wood chips	3
total	198

Table 6 Indication of follow up processes specified in the database.

Follow up process	Number of occurrences
all types	25
combustion	3
forwarding	3
storage	12
transport	155
total	198

Table 7 Delivered (intermediate) biomass type specified in the database.

Biomass type	Number of occurrences
chopped straw	1
logwood/firewood	3
not relevant: unchanged	26
pellets	3
round bales	3
square bales	11
stemwood/roundwood	4
whole tree	3
wood chips	144
total	198

Table 8 Dimensions of wood chips specified in the database.

Dimension	Number of occurrences
P16S	7
P16	25
P31	12
P45	49
P63	22
P100	16
P200	8
P300	5
total	144

It must be kept in mind that one uniform database was built for all types of logistical components. That means that not all of the data fields are always relevant for each type of logistical component. E.g. maximum load volume, maximum load weight and transport costs only apply to transportation components. This means that some data fields will remain empty for certain types of components anyhow.

However, there still was a group of data categories where a substantial number of records did receive a value. In sequence of the input screens (see Appendix E) these data categories were (with number of records between brackets):

Technical properties

- energy demand (40)
- input processing capacity was specified 124 times (109 times in m^3/h and 15 times in t/h)
- number of full load hours per year (165)
- maximum load volume of transport system (103); only 20 transport systems have been specified so this has also been filled in for other main categories, most of them chipping
- maximum load weight of transport system (24); same remark
- typical life time (156)

Biomass input specifications

- maximum particle size input: length (7), width/diameter (149) and height (3); so most of the time the maximum diameter was specified

Biomass output specifications

- none

Financial and economic properties

- specific investment costs of equipment (146)
- operation and maintenance costs (34) where the calculation method is always set to ‘effective operation time’
- transport costs per kilometre (18)

Also some data category fields were almost never filled. This could have several reasons like: i) they were thought to be less relevant, ii) no data were available at this point in time (due to ongoing projects), iii) the data category was unclear, iv) the data values vary too much depending on operational conditions, v) the data value depends to a large extent on other than machine properties and vi) some data fields are not relevant for the specific type of logistical component (see also Chapter 6 for a further discussion of the results).

In sequence of the input screens (see Appendix E) these data categories were (with number of records between brackets):

General properties

- year of first implementation in practice (9)
- estimated number of systems in operation since introduction (4)

Technical properties

- pre-treatment efficiency (8)
- storage capacity for input (1)
- storage capacity for output (3)
- labour requirements pre-treatment (5)

Biomass input specifications

- minimum particle size input: length (9), width/diameter (13) and height (5)
- moisture content input min (5) and max (7)
- bulk density input min (4) and max (5)
- maximum input level of contamination (1)

Biomass output specifications

- moisture content output min (3) and max (7)
- bulk density output min (3) and max (5)
- maximum output level of contamination (1)
- maximum ash content output (3)

Financial and economic properties

- storage costs (3)
- loading costs (1)
- unloading costs (2)
- transport costs per tonne (2)
- transport costs fixed (1)

Finally some data categories where never filled in:

- labour requirements storage (0)
- labour requirements transport (0)
- maximum ash content input (0)

6. Discussion

This Chapter describes the problems that were encountered by the partners during the filling process of the logistical components database.

Lack of information

It is often difficult to find all the required information, certainly from literature only. So if the information could not be found yet, then these fields were left open. Data that are more or less essential are costs, energy consumption and capacity. However, even for these data it is not always possible to find everything yet for each logistical component. The problem of missing data will have to be discussed during the project meeting in Helsinki in September 2014.

Level of detail

The main problem when designing a database like this is the level of detail that one wants (and can) include in it. It was now chosen to give general/ aggregated/ average data for performance, costs etc. And of course there are always underlying data and a specific calculation method that are used to determine these general/ aggregated/ average data. And these might be different for some logistical components.

It was tried to enter all types of data that could be found (and this can differ depending on the fact if it originates from catalogue, detailed time studies, experience from a manufacturer or literature). To keep track of the type/background of the data type a remark could be made about the background in the free format text box ‘Main operating principle’ (e.g. ‘... Found in catalogue ...’, ‘... field experiments ...’ or ‘... expert judgement of manufacturer ...’).

When the operation of filling the first draft of the logistical components database was completed the content of the database was carefully analysed. During the project meeting in September in Finland it will be discussed with the WP3 team what improvements need to be made in version two of the database.

Manual felling not included

Manual felling is not included yet as a logistical component. However, it is good to think of a way to include this when describing a biomass value chain later on in Task 3.2.

Type of data source influencing performance data

Data coming from a catalogue (technical sheet) just serve to know brand, size and power. Even in catalogues one sometimes does not find basic information: e.g. particle size output of a chipper. Only by talking with a machinery builder or seller it is possible to produce somehow reliable records. Moreover, some machines can be operated in a range of input-output products, with variable efficiencies on the basis of the specific operating conditions.

Three data sources could be used for the performance:

- if the data comes from a *catalogue*, it may refer to the operation of machinery without stops during a well-planned test: maximum performance (usually given in catalogues). It does not take into account time for feeding, or other stops. This means maximum work unaffected by the operation conditions.
- if the data comes from *literature*, then the data refers to a specific operational environment, usually in real situation (e.g. a field where it is not so easy to drive, etc.). then:
    1. performance given may refer to the whole time of operation in an experience (including motion time, technical stops, etc.).
    2. performance given may refer to the whole operational time (including stops, turns, etc.)
- if the data is given by an experienced *machinery builder/seller (or operator)*, one gets data on general performance (an average). Less affected than a literature study in terms of the operational conditions. The expert refers to a usual value expected.

Furthermore, there are several classifications of working time and performance like the methodology from IUFRO (Forest work study nomenclature) or the ASAE S495 DEC99 (Uniform technology for agricultural machinery management). So even performance data with the same title may have a different meaning.

So performance data are indeed very tricky. So it was suggested to make a specific note in the box about the ‘background’ of the data.

The consequence of not yet completely standardizing the data at this moment yet is that the S2Biom project team has to be very careful and check the background of the data when it starts building biomass chains based on the collected logistical components in year two of the project. Then the data might also need to be improved in some cases.

Non-machine factors influencing performance data

Input processing capacity also depends on a number of factors other than the machine type, e.g. tree size (see an example Figure 2 below), field shape and area, removal per hectare, tree species, terrain trafficability, logging method and operator skills. In forestry processing capacity can hardly be considered as a property of a machine. An average value can be given, but the variation is really huge as can be seen in the example Figure 2.

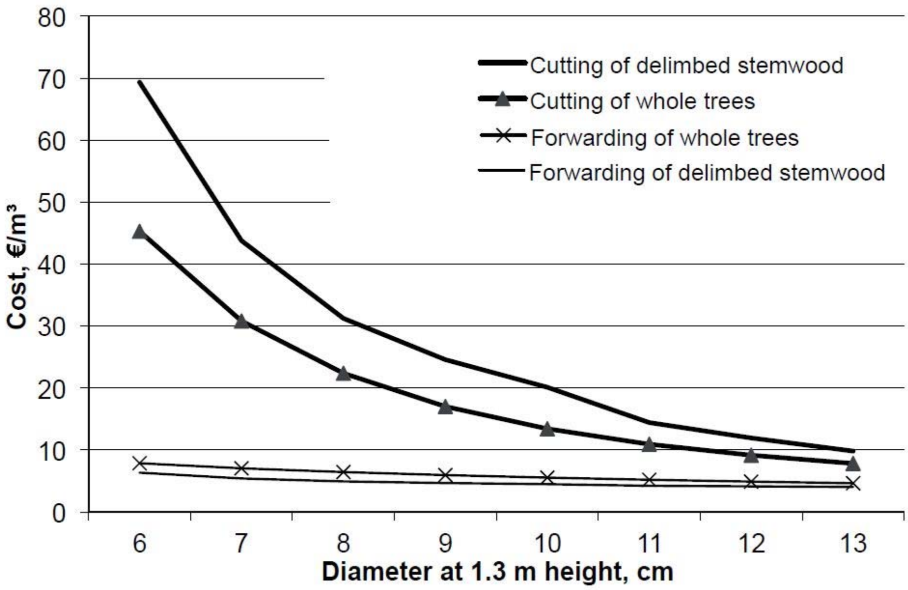

Figure 2 The cutting and forwarding costs of delimbed pine stemwood and pine whole trees (Laitila et al., 2010).

Type of data source influencing particle size

A list of possible particle size outputs for chippers was proposed (Section 3.4). However, a chipper can produce different sizes, which depends on the mesh size. So, a single chipper may be able to produce P16, P60, etc. The particle size ranges as output of chippers should be a range.

There are also differences depending on the data source:

- if data comes from *catalogue*, it refers to the capabilities of the machine;
- if data comes from a *singular experience*, then they may report they produce P60, but they could have done P100 as well according to machinery performance; so each record with data coming from a single experience must be completed with catalogue data
- if data comes from the side of an *expert*, then the data shows the ranges (capabilities), price, life time, consumption, etc. but 'in general, not related to any of the particle size produced.

An idea could be to make selectable ranges of particle size. Also a 'tick field' could be included in data sources to indicate if the data came from catalogue, single study/test, or from wide experienced user/seller. This idea was put on the discussion list for the second version of the database. For the time being it was suggested to fill in the smallest/finest category that the chipper can produce, so for example P60 instead of P100, because the finest quality would be the limiting factor when applying the machine.

Prices/investments

Data should refer to the pure purchasing price of the machinery, so not to the purchasing price including all sorts of extras like additional warranties, or extended support service.

Year of cost estimation

A suggestion was made to have an additional field per instance of logistical component, indicating the year of cost estimations. This would allow us to input harmonised cost values on a temporal scale.

Operation and maintenance costs calculated in WP1

The operation and maintenance costs are actually what METLA is trying to calculate in WP1. So far they have estimated the hourly costs for some machines (€/h). Input data like the possibility to utilise low-tax fuel and labour cost are still missing for some countries. In addition more machines will be added in the calculation. The next task is to estimate the productivity (or input processing capacity, m^3/h) of the operations in different conditions. For this METLA needs data from the EFI (e.g. mean diameter of harvested trees and removal per hectare) covering the whole Europe. Only after that they will be able to give an estimate of the operation costs (€/m^3 or €/t).

Machine Cost Calculation Model

A 'Machine Cost Calculation Model' has been produced by an international group of experts, operating within the framework of COST Action FP0902. The new calculation model is specifically designed for cost calculations within biomass harvesting operations, but they are fit for general use and can be applied to many other fields where costing models are needed. The calculation sheet can be found on the website of Forestry.org (2014).

Labour cost

The labour cost to operate these logistic processes should be also taken in account, and this cost is influenced by a number of factors such as geographical area (not uniform work costs at EU level), typology of supply chain organization (i.e. private or public operated), seasonality of work (that could increase costs).

Organisation of biomass chain

The logistic costs are highly influenced by the organization of the biomass supply chain. In particular if the biomass producer (in case of energy crops) or the operator in charge of harvest-transport (in case of agricultural and forestry residues) is also involved into the biomass upgrade-storage-densification and the final energy conversion, this reduces costs.

Database user category

As shown from this first database version, too many fields remain blank. Having the problem of data collection in mind, when structuring the future version of the database, the WP3-team should probably think about the main target audience, e.g. the people who will be more likely to use it: farmers, investors, politicians, scientists? This will help the team in tailoring the data fields and level of detail to fill in the database. In fact, maybe some fields in the database might not be relevant for some stakeholders' categories.

7. Conclusions

A comprehensive list of properties of logistical components was drawn up based on the expert knowledge and experience of the partners in WP3. These properties were divided in the following groups: general, technical, biomass input specifications, biomass output specifications, financial and economic and other.

Then an overview was given of different main categories of logistical components. For each of these main categories further subcategories were given. This way a standardised methods was developed that could be used to store information about logistical components that were found in literature, in European and national projects, through a market inventory and through consultation with scientific and industrial stakeholders.

After a first round of entering logistical components in the database, a total of 198 data records were present. The vast majority of records can be found in the main category comminution (size reduction), followed by transportation and harvesting/collecting. The other main categories feedstock handling, storage and compaction are only little represented. The main categories drying and other are even completely absent.

Some data categories were always filled. Unfortunately most logistical component records were not completely filled yet. Most data categories were only filled for a limited number of records. A distinction can be made here between data categories i) where all records were completed for that category ii) where a substantial number of records were completed, iii) where very little records were completed and finally iv) where no records were completed for the specific data category.

When data category fields were not filled this could have several reasons like: i) they were thought to be less relevant, ii) no data were available at this point in time (due to ongoing projects), iii) the data category was unclear, iv) the data values vary too much depending on operational conditions, v) the data value depends to a large extent on other than machine properties and vi) some data fields are not relevant for the specific type of logistical component

So it was often difficult to find all the required information, certainly from literature only. Data that are more or less essential are costs, energy consumption and capacity. However, even for these data it is not always possible to find everything yet for each logistical component. The problem of missing data will have to be discussed during the project meeting in Helsinki in September 2014.

Some other issues were identified that need clarification in the next version of the WP3 database:

- What level of detail is needed?
- How to include manual felling as a logistical component?
- How does the type of data source influence performance data?
- How do non-machine factors influence performance data?
- How does the type of data source influence particle size?
- Which prices/investments should be used?
- Include year of cost estimation
- Consultation with WP1 about operation and maintenance costs calculations
- The guidelines for populating the database (and for calculating economic data, e.g. costs) needs to be extended

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Appendix A. Technology Readiness Level (TRL)

The TRL scale is a metric for describing the maturity of a technology. The acronym stands for Technology Readiness Level. The scale consists of 9 levels. Each level characterises the progress in the development of a technology, from the idea (level 1) to the full deployment of the product in the marketplace (level 9).

This scale was developed by NASA in the 70s to assess the maturity of a technology prior to integrating this technology into a system. It contained 7 levels at that time. Nowadays, 9 levels compose the scale. These levels are detailed below.

Level 1 - Basic Research: basic principles are observed and reported

Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include fundamental investigations and paper studies.

Level 2 – Applied Research: technology concept and/or application formulated

Once basic principles are observed, practical applications can be formulated. Examples are limited to analytic studies and experimentation.

Level 3 – Critical function, proof of concept established

Active research and development is initiated. Laboratory studies aim to validate analytical predictions of separate components of the technology. Examples include components that are not yet integrated or representative.

Level 4 – Laboratory testing of prototype component or process

Design, development and lab testing of technological components are performed. Here, basic technological components are integrated to establish that they will work together. This is a relatively “low fidelity” prototype in comparison with the eventual system.

Level 5 – Laboratory testing of integrated system

The basic technological components are integrated together with realistic supporting elements to be tested in a simulated environment. This is a “high fidelity” prototype compared to the eventual system.

Level 6 – Prototype system verified

The prototype, which is well beyond that of level 5, is tested in a relevant environment. The system or process demonstration is carried out in an operational environment.

Level 7 – Integrated pilot system demonstrated

Prototype is near, or at, planned operational system level. The final design is virtually complete. The goal of this stage is to remove engineering and manufacturing risk.

Level 8 – System incorporated in commercial design

Technology has been proven to work in its final form under the expected conditions. In most of the cases, this level represents the end of true system development.

Level 9 – System ready for full scale deployment

Here, the technology in its final form is ready for commercial deployment.

Appendix B. European and national projects

The following EU projects were identified that explicitly studied biomass logistics (often in a separate work package):

- Agriforenergy II (www.agriforenergy.com)
- Bioboost (www.bioboost.eu)
- Biocore (www.biocore-europe.org)
- BiomassTradeCentres II (www.biomasstradecentre2.eu)
- Eurobioref (www.eurobioref.org)
- Europruning (www.europruning.eu)
- INFRES (www.infres.eu)
- LogistEC (www.logistecproject.eu)
- NewFor (www.newfor.net)
- Proforbiomed (www.proforbiomed.eu)
- SmartLogChain
- Suprabio (www.suprabio.eu)
- RENESENG (www.reneseng.com)
- WoodApps (www.woodapps.eu)

National projects that were studied to find information on logistical components were:

- An integrated framework to assess spatial and related implications of increased implementation of biomass delivery chains - ME4 (The Netherlands)
- Miajadas case (Spain)
- PERLES – Wood potentials for perspective wood production chains in Slovenia (Slovenia)
- Research group on forest mechanization and biomass harvest (Spain) http://www.biomassaforestale.org/ivalsa/inglese/inizio_ing.htm

Appendix C. Long list manufacturers of logistical components

Several categories

Bruks - www.bruks.com
Claas - http://claas.co.uk
Mowi - www.mowi.se

Comminution (size reduction)

AHWI (Prinoth) - http://en.prinoth.com
Albach - www.albach-maschinenbau.de
Backers - www.backers.de
Bandit Industries, Inc. - www.banditchippers.com
Berkili - www.berkili-maschinen.de
Berti Macchine Agricole S.p.A. - www.bertima.it
Continental Biomass Industries (CBI) - www.cbi-inc.com
Diamond Z - www.diamondz.com
Doppstadt - www.doppstadt.com
Dutch Dragon - www.dutchdragon.nl
Ecolog - www.eco-log.se
Erjo - www.erjo-osw.se
Eschlböck - www.eschlboeck.at
Euroklip - www.euroklip.at
Haas - www.haas-recycling.de
Hama - www.hama-schechen.de
Heizomat - www.heizomat.de
Hekotek - www.hekotek.com
Jensen - www.holzhackmaschinen.com
Jenz - www.jenz.de
Kesla - www.kesla.fi
Kirchmayr Umwelttechnik GmbH - no website
Komptech - www.komptech.com/en/home.htm
Laimet - http://en.laimet.kummeli.fi
LHM Hakkuri - www.lhmhakkuri.com
Lindana - www.tp.dk

Lindner - www.l-rt.com/en/
Morbark - www.morbark.com
Mus Max - www.mus-max.at
Neuenhauser - www.neuenhauser-umwelttechnik.de/en
Neuson Ecotec - www.neuson-ecotec.com
Peterson - www.petersoncorp.com
Pezzolato - www.pezzolato.it
Powerscreen - www.powerscreen.com
Rotochopper - www.rotochopper.com
Schutte Buffalo Hammermill - www.hammermills.com
Starchl - www.starchl.at
Stark - www.stark-maschinenbau.ch
Terra Select - www.terra-select.de
Vandaele - www.vandaele.biz
Vermeer - www.vermeer-benelux.com/en
Willibald - www.willibald-gmbh.de

Compaction/densification

Amandus Kahl - www.akahl.de
Andriz - www.andritz.com
CPM - www.cpmeurope.com
Dieffenbacher - www.dieffenbacher.com
DIPIU - www.di-piu.com
Instalmec - www.instalmec.it
Jiangsu Five Continents Machinery Co., Ltd - www.fcm-cn.com
Jining Tiannong Machine Co., Ltd - www.orient-biofuel.com
La Meccanica - www.lamec-pellets.com
Muench - www.muench-gmbh.net
Muyang - www.muyang.com
Prodesa - www.prodesa.net
Promill Stoltz - www.promill.fr
RUF - www.briquetting.com
Salmatec - www.salmatec-gmbh.de
Yongli - www.yongli-machine.com

Drying technology

Recalor, S.A. - www.recalor.com
Stela - www.stela.de
Swedish Exergy AB - www.swedishexergy.com
Swiss combi - www.swisscombi.ch
Vadeb - www.vadeb.com

Feedstock handling

Ahlmann Mecalac - www.ahlmann.nl/english
Lachenmeier Monsun - www.www.lachenmeier-monsun.com
Moheda - www.mohedasystem.se
Telestack - www.telestack.com
Vigan Engineering S.A. - www.vigan.com

Harvesting/collection

Anderson - www.grpanderson.com
Bracke Forest - www.brackeforest.com
Bühler - www.buhlerindustries.com
Hesston - www.hesston.com
John Deere - www.deere.co.ukLog Max - www.logmax.com
Logset - www.logset.com
Ponsse - www.ponsse.com
Silvatec - www.silvatec.com

Other

No companies were added yet to the long list for other pre-treatments, storage and transportation technologies.

Appendix D. Scientific and industrial stakeholders consulted

The contacts with industrial stakeholders included among others:

- Doppstadt (Germany) - T. Authmann
- Dutch Dragon/Wellink Caesar (The Netherlands) - P. Koeman
- Jenz (Germany) - M. Horstmeier-Griese
- MYCSA (Spain) – J.A. Luna
- Tajfun Planina d.o.o. (Slovenia) - J. Obrez
- Tekoma (Slovenia) - F. Marguč
- CAPAX – Environmental Services - Bart Tambuyser (not contacted yet, but could give useful insights for the development of the database)

The contacts with scientific stakeholders included among others:

- Danish Technological Institute (DTI, Denmark) - J. Hinge
- Lappeenranta University of Technology (LUT, Finland) - Prof. T. Ranta
- Swedish University of Agricultural Sciences (SLU, Sweden) - Prof. G. Gebresenbet

Appendix E. Practicalities of data entry of the logistical components

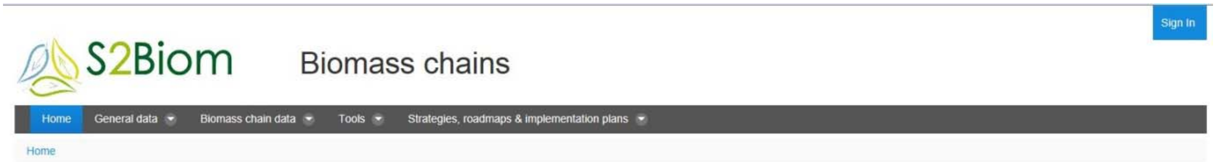
E.1 Login

The database is set up and maintained by DLO and can be found on the following website: www.biomass-tools.eu

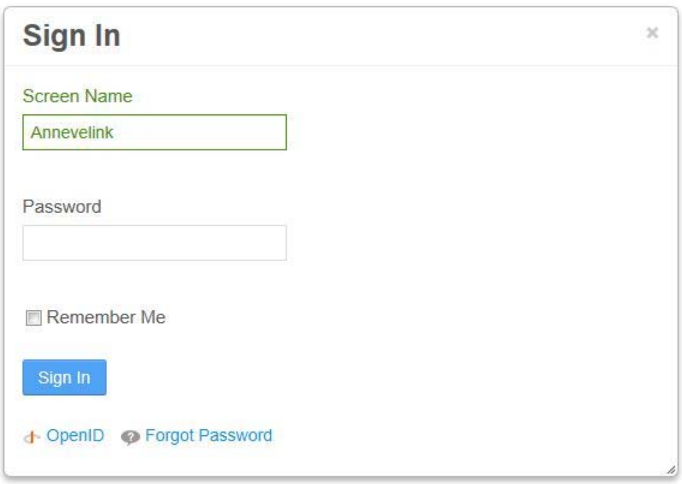
All WP3 partners have received a user name and password, which gives them access to the database.

E.2 Using the database

After going to the website you will see the user screen:

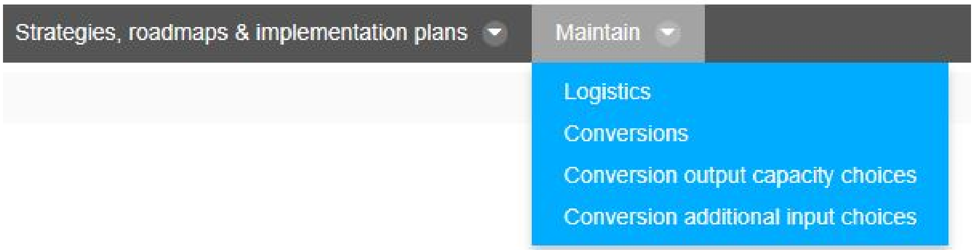


In order to maintain the database you have to enter the protected area by pushing the blue ‘Sign In’ button at the right-hand top of the screen. Then the sign in screen will appear:

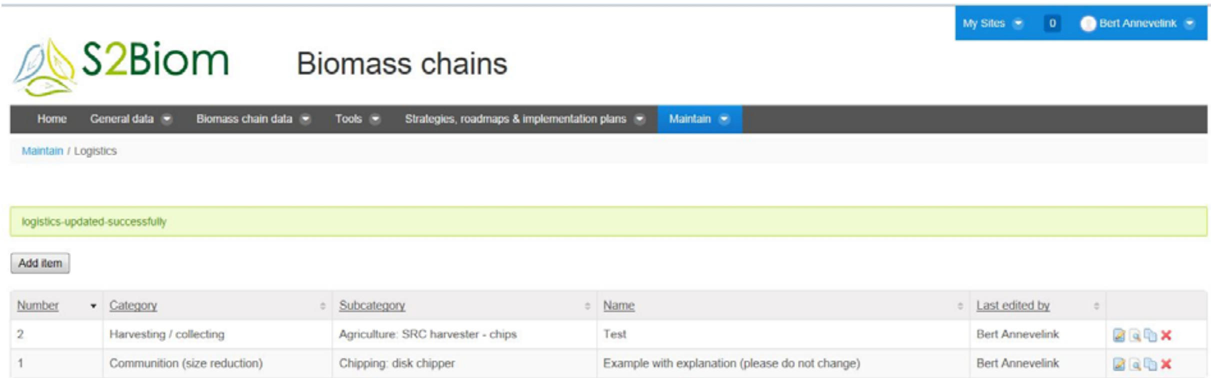


You have to fill in your username and password. Once you are signed in, your name will appear in the blue button:

Also an extra option will appear in the black line at the top of the user screen with the option ‘Maintain’:



Within ‘Maintain’ you have to choose the option ‘Logistics’ and then the list with current logistical components will appear:



To **add** a description of a new logistical component, click the ‘add item’ button at the top left above the number column. Now you can fill in the details of the new logistical component on two input screens that are given on the next pages of this chapter.

The values of a data field either need to be typed in free format by hand (text or numbers as specified per data-field), or they can be chosen from standard values in a drop-down list. See Chapter 3 for the properties of the data items in the drop-down lists. You can enter the given value by pressing the tab button on your key-board (not the return button!) and then the pointer will jump to the next data-field to be entered. You can also select an arbitrary data-field that you want to enter somewhere on the input screen with your mouse.

Sometimes you might not be able to enter all the necessary data immediately during your first run (e.g. because you still have to find some additional data). In that case please do not enter any value in the data field. This way it will remain empty so that you will be able to recognize that you will still have to fill in the **missing data** of this specific data field later on. So please only enter the number zero when the value of a specific data field is really zero!

The second input screen is reached by clicking ‘save and proceed’ at the bottom of the first page. The logistical component is completely stored when the ‘save button’ at the bottom of the second screen is pushed. Your username will also be added to the record of the logistical component so that it will be clear that the record was last edited by you.

You can **cancel** entries and changes by pushing the ‘cancel’ button both in input screen 1 and 2. Then the list with logistical components appears again and you can restart the procedure mentioned above.

If you would like to **edit** a logistical component that was already described, please find the logistical component in the list and click the edit button in the utmost right column. This is the icon with a pen at the far left:

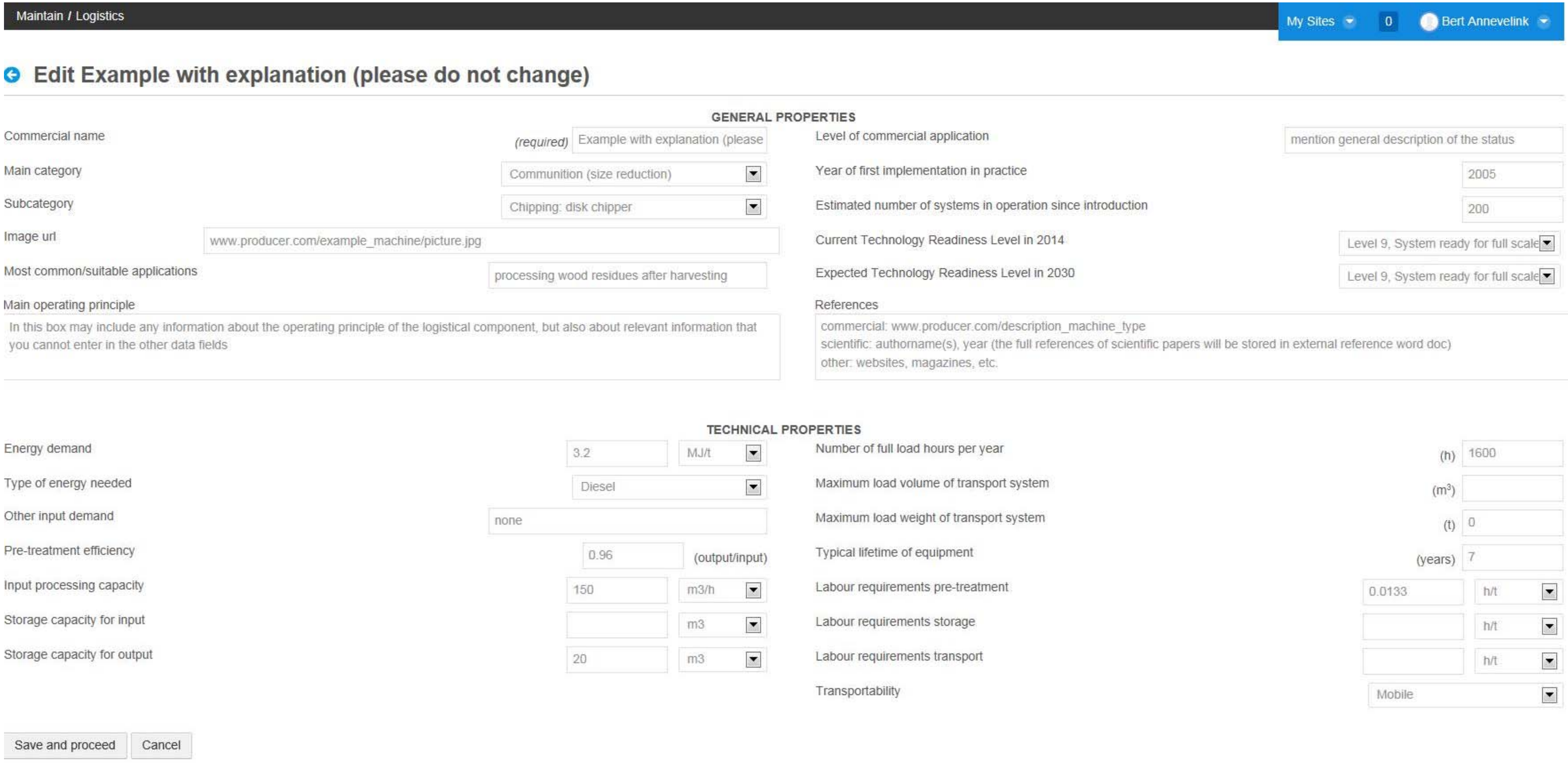
You can also **only have a look** at a record (without being able to change it by accident) by clicking the second icon (magnifying glass).

Copying a record is done by the third icon (two sheets of paper).

And finally if you would like to **delete** a record of a logistical component that you have added yourself, please find the logistical component in the list and click the delete icon (red cross) at the utmost right column.

ATTENTION: Please don’t edit or delete logistical components that were added by other authors in this first phase/round of data entry. If you really do not agree with the some values of the logistical component please make your own copy and change the values in that copy. Then please notify the WP3-leader (Bert Annevelink) and the original author of the logistical component so that we can decide together what to decide on the specific issue.

Input screen 1



Maintain / Logistics

My Sites 0 Bert Annevelink

Edit Example with explanation (please do not change)

GENERAL PROPERTIES

Commercial name *(required)*	Example with explanation (please
Main category	Communition (size reduction)
Subcategory	Chipping: disk chipper
Image url	www.producer.com/example_machine/picture.jpg
Most common/suitable applications	processing wood residues after harvesting
Main operating principle	In this box may include any information about the operating principle of the logistical component, but also about relevant information that you cannot enter in the other data fields
Level of commercial application	mention general description of the status
Year of first implementation in practice	2005
Estimated number of systems in operation since introduction	200
Current Technology Readiness Level in 2014	Level 9, System ready for full scale
Expected Technology Readiness Level in 2030	Level 9, System ready for full scale
References	commercial: www.producer.com/description_machine_type scientific: authorname(s), year (the full references of scientific papers will be stored in external reference word doc) other: websites, magazines, etc.

TECHNICAL PROPERTIES

Energy demand	3.2	MJ/t
Type of energy needed	Diesel	
Other input demand	none	
Pre-treatment efficiency	0.96	(output/input)
Input processing capacity	150	m3/h
Storage capacity for input		m3
Storage capacity for output	20	m3
Number of full load hours per year	1600	(h)
Maximum load volume of transport system		(m^3)
Maximum load weight of transport system	0	(t)
Typical lifetime of equipment	7	(years)
Labour requirements pre-treatment	0.0133	h/t
Labour requirements storage		h/t
Labour requirements transport		h/t
Transportability	Mobile	

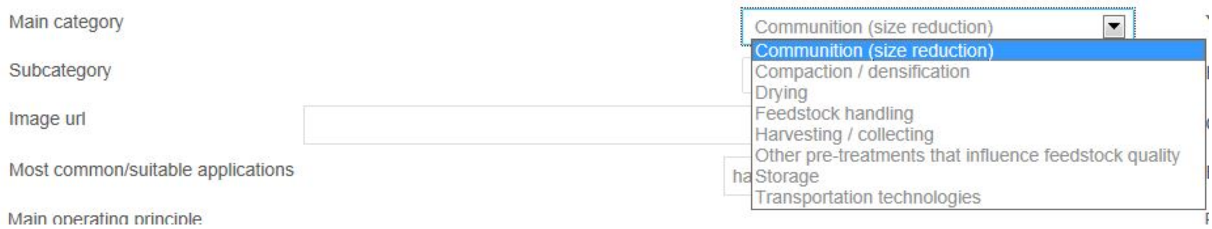
Save and proceed | Cancel

Input screen 2

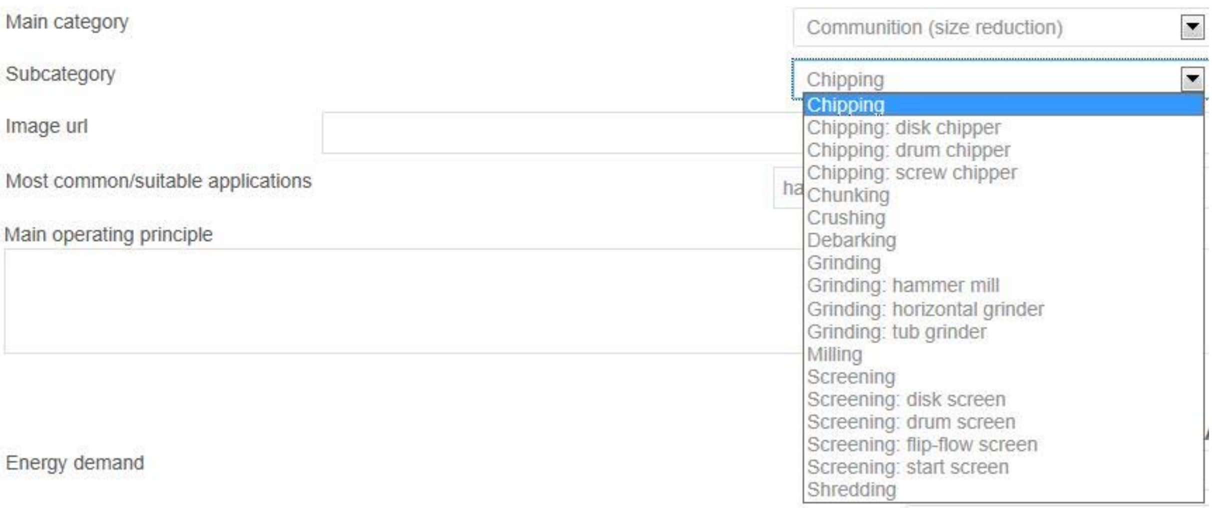
E.3 Drop down lists

Several fields have a drop down list with pre-defined choices. Examples are given below for the 'main category' and the subcategory 'communition (size reduction)'.

Main category:



Subcategories of communition (size reduction):



E.4 Contact persons

Contact person regarding technicalities of the database (database accessibility, login name, password, etc.): Hugo de Groot, hugo.degroot@wur.nl, +31 317 481 901

In case of other questions on the contents of the WP3 logistical components database please contact Bert Annevelink, bert.annevelink@wur.nl, +31 317 488 700

Appendix F. Division of information sources between partners

The following division of information sources has been made between partners:

Partner	Logistical components to be entered by the partner
Imperial	• All logistical components studied in the Biocore project
METLA	• Forestry components with emphasis on harvesting/collection, storage, compaction, comminution (size reduction) and transportation technologies • All logistical components studied in the Infres project
BTG	• Drying and feedstock handling components • All logistical components studied in the Suprabio project
INRA	• Agricultural components with emphasis on harvesting/collection, storage, compaction, comminution (size reduction) and transportation technologies • All logistical components studied in the LogistEC project / the France-Burgundy case study
CENER	• All logistical components studied in the Spain-Miajadas case study
CIRCE	• All logistical components studied in the Europruning project / the Spain-Zaragoza case study
SFI	• Forestry components with emphasis on harvesting/collection, storage, compaction, comminution (size reduction) and transportation technologies • All logistical components studied in the Biomass TradeCentre project
DLO	• All different categories complementary to input of the other partners • All logistical components studied in the Eurobioref project • All logistical components studied in the Bioboost project

Appendix G. Logistical components in WP database (14th July 2014)

1	maincat	subcat	lgname
2	Communition (size reduction)	Chipping	AHWI Eurochipper HM 950
3	Communition (size reduction)	Chipping	Chipper High Power
4	Communition (size reduction)	Chipping	Chipper Small Power
5	Communition (size reduction)	Chipping	Chipping Medium Power
6	Communition (size reduction)	Chipping	Kirchmayr Lignolupo 500
7	Communition (size reduction)	Chipping	Komptech Chippo 500
8	Communition (size reduction)	Chipping	Komptech Chippo 7000
9	Communition (size reduction)	Chipping	Picker/C 180 Berti
10	Communition (size reduction)	Chipping: disk chipper	Berkili B10D
11	Communition (size reduction)	Chipping: disk chipper	Berkili B10Z
12	Communition (size reduction)	Chipping: disk chipper	Berkili B12D
13	Communition (size reduction)	Chipping: disk chipper	Berkili B15D
14	Communition (size reduction)	Chipping: disk chipper	Berkili B15Z
15	Communition (size reduction)	Chipping: disk chipper	Berkili B20D
16	Communition (size reduction)	Chipping: disk chipper	Berkili B20Z
17	Communition (size reduction)	Chipping: disk chipper	Berkili B24D
18	Communition (size reduction)	Chipping: disk chipper	Berkili B24Z
19	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 2-14
20	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 2-14 Motor
21	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 3
22	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 3 Motor
23	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 5K
24	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 5K Motor
25	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 5KL
26	Communition (size reduction)	Chipping: disk chipper	Eschlböck Biber 5L
27	Communition (size reduction)	Chipping: disk chipper	Euroklip H 680/140
28	Communition (size reduction)	Chipping: disk chipper	Euroklip H 880/250
29	Communition (size reduction)	Chipping: disk chipper	Euroklip H 980/300
30	Communition (size reduction)	Chipping: disk chipper	Farmi CH 260
31	Communition (size reduction)	Chipping: disk chipper	Greenmech 19-28 Arborist
32	Communition (size reduction)	Chipping: disk chipper	Greenmech M220MT 55
33	Communition (size reduction)	Chipping: disk chipper	Husmann H4-Z
34	Communition (size reduction)	Chipping: disk chipper	Jensen A 141
35	Communition (size reduction)	Chipping: disk chipper	Jensen A 141 M
36	Communition (size reduction)	Chipping: disk chipper	Jensen A 141 XL M
37	Communition (size reduction)	Chipping: disk chipper	Jensen A 141 XL Z
38	Communition (size reduction)	Chipping: disk chipper	Jensen A 141 Z
39	Communition (size reduction)	Chipping: disk chipper	Jensen A 231
40	Communition (size reduction)	Chipping: disk chipper	Jensen A 231 M
41	Communition (size reduction)	Chipping: disk chipper	Jensen A 231 Z
42	Communition (size reduction)	Chipping: disk chipper	Jensen A 328
43	Communition (size reduction)	Chipping: disk chipper	Jensen A 328 M
44	Communition (size reduction)	Chipping: disk chipper	Jensen A 328 Z
45	Communition (size reduction)	Chipping: disk chipper	Jensen A 425
46	Communition (size reduction)	Chipping: disk chipper	Jensen A 425 M
47	Communition (size reduction)	Chipping: disk chipper	Jensen A 425 Z
48	Communition (size reduction)	Chipping: disk chipper	Jensen A 521 XL
49	Communition (size reduction)	Chipping: disk chipper	Jensen A 521 XL M
50	Communition (size reduction)	Chipping: disk chipper	Jensen A 521 XL Z

	maincat	subcat	lgname
51	Communition (size reduction)	Chipping: disk chipper	Jensen A 530 Nova
52	Communition (size reduction)	Chipping: disk chipper	Jensen A240 PTO
53	Communition (size reduction)	Chipping: disk chipper	Schliesing 105 ZX
54	Communition (size reduction)	Chipping: disk chipper	Schliesing 200 MX
55	Communition (size reduction)	Chipping: disk chipper	Schliesing 220 MX
56	Communition (size reduction)	Chipping: disk chipper	Schliesing 220 ZX
57	Communition (size reduction)	Chipping: disk chipper	Schliesing 300 MX Raupe
58	Communition (size reduction)	Chipping: disk chipper	Schliesing 330 ZX
59	Communition (size reduction)	Chipping: disk chipper	Schliesing 350 EX
60	Communition (size reduction)	Chipping: disk chipper	Schliesing 400 ZX
61	Communition (size reduction)	Chipping: disk chipper	Schliesing 460 EX
62	Communition (size reduction)	Chipping: disk chipper	Schliesing 480 EX
63	Communition (size reduction)	Chipping: disk chipper	Schliesing 500 ZX
64	Communition (size reduction)	Chipping: disk chipper	Schliesing 550 MX
65	Communition (size reduction)	Chipping: disk chipper	Schliesing 550 ZX
66	Communition (size reduction)	Chipping: disk chipper	Silvatec 1700 CH-T
67	Communition (size reduction)	Chipping: disk chipper	Silvatec 878 CH
68	Communition (size reduction)	Chipping: disk chipper	TP 150
69	Communition (size reduction)	Chipping: disk chipper	TP 200
70	Communition (size reduction)	Chipping: drum chipper	ALBACH SILVATOR 2000
71	Communition (size reduction)	Chipping: drum chipper	Bruks-Klöckner 1300 CT
72	Communition (size reduction)	Chipping: drum chipper	Bruks-Klöckner 600 CT
73	Communition (size reduction)	Chipping: drum chipper	Bruks-Klöckner 604 CT
74	Communition (size reduction)	Chipping: drum chipper	Bruks-Klöckner 805 CT
75	Communition (size reduction)	Chipping: drum chipper	Doppstadt DH 910
76	Communition (size reduction)	Chipping: drum chipper	Doppstadt DH 910 K
77	Communition (size reduction)	Chipping: drum chipper	Dutch Dragon EC10075
78	Communition (size reduction)	Chipping: drum chipper	Dutch Dragon EC6060
79	Communition (size reduction)	Chipping: drum chipper	Dutch Dragon EC9045
80	Communition (size reduction)	Chipping: drum chipper	Eschlböck Biber 7
81	Communition (size reduction)	Chipping: drum chipper	Eschlböck Biber 7 plus Z and Biber 7 plus ZK
82	Communition (size reduction)	Chipping: drum chipper	Eschlböck Biber 70 S
83	Communition (size reduction)	Chipping: drum chipper	Eschlböck Biber 70 Z and Biber 70 ZK
84	Communition (size reduction)	Chipping: drum chipper	Eschlböck Biber 80 RBZ
85	Communition (size reduction)	Chipping: drum chipper	Eschlböck Biber 80 S
86	Communition (size reduction)	Chipping: drum chipper	Eschlböck Biber 80 Z and Biber ZK
87	Communition (size reduction)	Chipping: drum chipper	Euroklip THE 480
88	Communition (size reduction)	Chipping: drum chipper	Euroklip THE 90 S
89	Communition (size reduction)	Chipping: drum chipper	Euroklip THE 900
90	Communition (size reduction)	Chipping: drum chipper	Foresteri 4560C
91	Communition (size reduction)	Chipping: drum chipper	HAMA Profi-Hacker 40x42
92	Communition (size reduction)	Chipping: drum chipper	HAMA Profi-Hacker 55x82
93	Communition (size reduction)	Chipping: drum chipper	HAMA Profi-Hacker 67x104
94	Communition (size reduction)	Chipping: drum chipper	Heizohack HM 14-800
95	Communition (size reduction)	Chipping: drum chipper	Heizohack HM 5-400
96	Communition (size reduction)	Chipping: drum chipper	HRUST 92-45
97	Communition (size reduction)	Chipping: drum chipper	Jenz 450Z
98	Communition (size reduction)	Chipping: drum chipper	Jenz AZ 660 D
99	Communition (size reduction)	Chipping: drum chipper	Jenz HEM 1000 D-XL
100	Communition (size reduction)	Chipping: drum chipper	Jenz HEM 561 Z

	maincat	subcat	lgname
101	Communition (size reduction)	Chipping: drum chipper	Jenz HEM 581 Z
102	Communition (size reduction)	Chipping: drum chipper	Jenz HEM 700 D
103	Communition (size reduction)	Chipping: drum chipper	Jenz HEM583DQ & MB Arocs 3348 6x6
104	Communition (size reduction)	Chipping: drum chipper	KRONE BIG X 650 mit WOOD CUT 1500
105	Communition (size reduction)	Chipping: drum chipper	Musmax Terminator 8
106	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 10 XL DLB
107	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 10 XL DLK
108	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 10 XL Z
109	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 6 Z
110	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 7 Z
111	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 8 DH
112	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 8 XL Z
113	Communition (size reduction)	Chipping: drum chipper	MUS-MAX Wood-Terminator WT 9 XL Z
114	Communition (size reduction)	Chipping: drum chipper	Pezzolato PTH 900/1000
115	Communition (size reduction)	Chipping: drum chipper	Starchl Mk 102
116	Communition (size reduction)	Chipping: drum chipper	Starchl Mk 37
117	Communition (size reduction)	Chipping: drum chipper	Starchl Mk 50
118	Communition (size reduction)	Chipping: drum chipper	Starchl Mk 62
119	Communition (size reduction)	Chipping: drum chipper	Starchl Mk 74
120	Communition (size reduction)	Chipping: drum chipper	Starchl Mk 86
121	Communition (size reduction)	Chipping: drum chipper	Starchl Mk 98
122	Communition (size reduction)	Chipping: drum chipper	Starchl U-1200
123	Communition (size reduction)	Chipping: drum chipper	Starchl U-260
124	Communition (size reduction)	Chipping: drum chipper	Stark SH 4585-Z
125	Communition (size reduction)	Chipping: drum chipper	TP 100 VM
126	Communition (size reduction)	Chipping: drum chipper	Willibald ESU 4800
127	Communition (size reduction)	Chipping: drum chipper	Wüst BBHK
128	Communition (size reduction)	Chipping: drum chipper	Wüst BBHK-Z
129	Communition (size reduction)	Chipping: screw chipper	Laimet HP21
130	Communition (size reduction)	Chipping: screw chipper	Laimet HP-25
131	Communition (size reduction)	Chipping: screw chipper	Laimet HP-35
132	Communition (size reduction)	Chipping: screw chipper	Laimet HP-50
133	Communition (size reduction)	Chunking	Combined Wood Sawing-Splitting
134	Communition (size reduction)	Chunking	Wood Sawing
135	Communition (size reduction)	Chunking	Wood Splitting
136	Communition (size reduction)	Chunking	Woodfuel processor RCA400 JOY
137	Communition (size reduction)	Grinding: hammer mill	SAT-4
138	Communition (size reduction)	Shredding	Berkili Z65-D
139	Communition (size reduction)	Shredding	CBI Magnum Force 6400 Shredder
140	Communition (size reduction)	Shredding	Doppstadt DZ 750 Kombi
141	Communition (size reduction)	Shredding	Komptech Crambo 3400
142	Communition (size reduction)	Shredding	Komptech Crambo 5000
143	Communition (size reduction)	Shredding	Komptech Crambo 6000
144	Communition (size reduction)	Shredding	Rudnick+Enners RE-MGS 570/814
145	Communition (size reduction)	Shredding	Stark SUZ 1000 S
146	Communition (size reduction)	Shredding	Stark SUZ 400 S
147	Communition (size reduction)	Shredding	Willibald MZA 2400
148	Communition (size reduction)	Shredding	Willibald MZA 4300
149	Communition (size reduction)	Shredding	Willibald MZA 4800
150	Compaction / densification	Pelletizing	Large Pelletizer

	maincat	subcat	lgname
151	Compaction / densification	Pelletizing	Medium Pelletizer
152	Compaction / densification	Pelletizing	Small Pelletizer
153	Feedstock handling	Crane	Gantry crane (BioBoost)
154	Feedstock handling	Crane: wood crane	Cable Crane Light
155	Feedstock handling	Crane: wood crane	Mobile forestry cable crane MOZ 300
156	Feedstock handling	Crane: wood crane	Wood Crane Medium
157	Feedstock handling	Front loader	Front-end loader on farm tractor (Bioboost)
158	Feedstock handling	Telehandler	Forklift truck (BioBoost)
159	Feedstock handling	Telehandler	John Deere 3220 Telehandler
160	Feedstock handling	Telehandler	Telescopic handler (BioBoost)
161	Harvesting / collecting	Agriculture: Baling: round bales	John Deere 557 Round Baler
162	Harvesting / collecting	Agriculture: Baling: round bales	Lerda T110
163	Harvesting / collecting	Agriculture: Baling: square bales	CASE LBX 422
164	Harvesting / collecting	Agriculture: Baling: square bales	Hesston 4790 Rectangular Baler
165	Harvesting / collecting	Agriculture: In field hauling	Inland 2500 Bale Mover
166	Harvesting / collecting	Agriculture: In field hauling	Inland 4000 Bale Mover
167	Harvesting / collecting	Agriculture: Mower conditioner	KUHN
168	Harvesting / collecting	Agriculture: Raking	Straw rotary rake
169	Harvesting / collecting	Forestry: Forwarding	PONSSE Wisent 8w
170	Harvesting / collecting	Forestry: Forwarding	Wood Forwarder
171	Harvesting / collecting	Forestry: Harvesting	John Deere 1070E
172	Harvesting / collecting	Forestry: Harvesting	Wood Harvester
173	Harvesting / collecting	Forestry: Skidding	Wood Skidder
174	Harvesting / collecting	Forestry: Stump extraction	Volvo EC220DL & Väkevä Kantopilkkuri
175	Harvesting / collecting	Landscape management: Whole tree harvesting	Valmet 911
176	Storage	Indoors bunker	Induro
177	Storage	Indoors bunker	Intermediate depot - closed storage (BioBoos
178	Storage	Outdoors on bare soil - pile - covered	Piles at roadside landing (BioBoost)
179	Storage	Outdoors on bare soil - stack - covered	Outdoor Storage
180	Transportation technologies	Inland waterway: dry bulk cargo barge	Big Rhine ship (ME4)
181	Transportation technologies	Inland waterway: dry bulk cargo barge	Dortmund- Ems ship (ME4)
182	Transportation technologies	Inland waterway: dry bulk cargo barge	Inland waterway barge
183	Transportation technologies	Inland waterway: dry bulk cargo barge	Kempenaar ship (ME4)
184	Transportation technologies	Inland waterway: dry bulk cargo barge	Rhine-Herne-canal ship (ME4)
185	Transportation technologies	Inland waterway: dry bulk cargo barge	Spits ship (ME4)
186	Transportation technologies	Maritime: handymax bulk carrier	Timber Haulage by Ship
187	Transportation technologies	Rail: closed wagon with rolling roof	Rail
188	Transportation technologies	Road: farm trailer	Farm tractor and hook lift trailer for roll-off c
189	Transportation technologies	Road: farm trailer	Farm tractor with 2 tipper (BioBoost)
190	Transportation technologies	Road: farm trailer	Farm tractor with platform trailer (BioBoost)
191	Transportation technologies	Road: flatbed trailer	Trailer
192	Transportation technologies	Road: log trailer	Wood Trailer
193	Transportation technologies	Road: removable cargo container lorry/trailer	Truck
194	Transportation technologies	Road: removable cargo container lorry/trailer	Truck and drawbar/hook lift trailer for roll-off
195	Transportation technologies	Road: removable cargo container lorry/trailer	Truck with 2 Containers (ME4)
196	Transportation technologies	Road: timber haulage wagon	Timber truck (BioBoost)
197	Transportation technologies	Road: tipper trailer or truck	Truck with Tipper (ME4)
198	Transportation technologies	Road: walking floor trailer/self-unloading floor/live	Truck and drawbar trailer (BioBoost)
199	Transportation technologies	Road: walking floor trailer/self-unloading floor/live	Truck with Walking Floor Trailer (ME4)