S2BIOM SURVEY OF LOGISTICAL CONCEPTS

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ABSTRACT: A survey of various logistical biomass value chains in various European projects was made. A biomass value chain connects the available biomass types with the final conversion process through various logistical components. Based on the survey of biomass value chains the most important logistical concepts were identified. A logistical concept is broader and more general than a specific biomass value chain. A chosen logistical concept always still needs to be further specified and translated in order to obtain a specific biomass value chain (specify all the components). Often several possible biomass value chains fit within that general logistical concept. A qualitative assessment of each logistical concept was made.
Keywords: logistics, supply chain, transport, pretreatment, biocommodity.

1 INTRODUCTION

A survey of various logistical biomass value chains in various European projects was made [1]. The general set-up of a biomass value chain will be described in Section 2. A biomass value chain connects the available biomass types with the final conversion process through various logistical components. Based on the survey of biomass value chains in Section 3 the most important logistical concepts were identified in Section 4. A logistical concept is broader and more general than a specific biomass value chain. A chosen logistical concept always still needs to be further specified and translated in order to obtain a specific biomass value chain (specify all the components). Often several possible biomass value chains fit within that general logistical concept.

The defined logistical concepts were only assessed qualitatively for a generic situation (so not placed in a specific region/country yet) with an advantage-disadvantage analysis looking at average values for the most important parameters such as type of biomass, transportation distance, conversion method, etc. More detailed assessments will be made in the final year of the s2Biom project using several case studies.

2 BIOMASS SUPPLY CHAINS

2.1 Introduction

The logistics of a biomass supply chain (Figure 1) may include several logistical components such as feedstock handling, pre-treatment, storage and transport. Pre-treatment technologies like comminution (size reduction), compaction/densification and drying are needed in the biomass supply chain to convert the biomass ‘as received’ at the roadside (an amount in t, with certain costs €/t at roadside) to an intermediate biomass feedstock with the required quality at the gate of the biomass conversion facility (an amount in t, with certain costs €/t at factory gate). Storage bridges gaps in time between supply and demand and finally transport is needed to get the biomass from a large number of different sites of origin to one specific location ‘at the gate’ of a certain conversion technology.

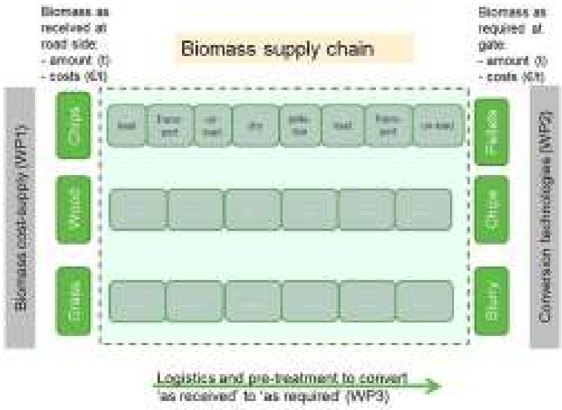

Figure 1: Role of logistics in matching biomass supply at the roadside with biomass demand at the gate of the conversion technology.

In the S2Biom project a biomass value chain is split up into three separate parts:

- the biomass including harvesting;
- the logistical chain with several logistical components and;
- the conversion process.

2.2 Biomass types

Many different types of lignocellulosic biomass can be available at the source in five sectors: 1. forestry, 2. agriculture on arable land & grass land, 3. other land use, 4. production based on lignocellulosic biomass and 5. post-consumer biomass (tertiary residues). Each sector was then further divided in categories, e.g. forestry was split into three level-1 categories: 1.1 primary production, 1.2 primary residues and 1.3 harvests from traditional coppice forests without focus on stem wood production. The project even further divided these subcategories, but this is less relevant for describing the logistical concepts.

2.3 Logistical components

Logistical components are used to solve mismatch problems in the biomass value chain from the original biomass source to the final conversion. The quality of the biomass is changed in the value chain so that in the end the biomass is more suitable for the conversion process. Logistical challenges that are related to the biomass feedstock quality can take different forms:

- too large or too irregularly shaped (inhomogeneous quality) → comminution (size reduction);
- too low a density → compaction/densification;
- too wet (relatively high moisture content) → drying;
- not in place at the correct logistical component or process → feedstock handling;
- contaminated with soil etc. → sieving, washing (other pre-treatments);
- not available in each period of the year (seasonal supply patterns) → storage;
- not on the correct location (small quantities scattered over many sources locations) → transport.

A logistical components database was developed within the S2Biom project to store relevant data, such as general properties, technical properties, biomass input / output specifications and financial & economic properties.

2.4 Conversion technologies

Biomass conversion technologies form the essential link between the different available lignocellulosic biomass sources including their wide range of properties and the different end uses and markets. Conversion technologies (including bio-refineries) and end-use applications (both bio-energy and bio-based products) are the essential elements of each pathway, and are being identified and characterized in detail in the S2Biom project. For each conversion technology the input specifications were gathered in a database. That database can then be used to define which logistical tools are needed to link the road-side characteristics of a certain type of biomass to the input specifications of a certain type of conversion technology, so that the whole value chain can be defined.

3 EXAMPLES OF BIOMASS SUPPLY CHAINS STUDIED IN EU PROJECTS

3.1 Introduction

The purpose of this section is to describe some examples of biomass value chains, including the logistical concepts that are applied. These examples are then used in the next section to deduce general logistical concepts that can be applied to optimize the design of sustainable non-food biomass feedstock delivery chains. The examples of biomass value chains were all described in a standard format (see Table I). The examples could supply an advice for projects that want to set-up a new regional biomass value chain. A biomass value chain can be represented by a sequence of specific individual records in the logistical components database.

Several EU-projects have been screened for examples of biomass value chains. In this paper the results are shown of:

- Bioboost (2012-2015);
- Biocore (2010-2014);
- BiomassTradeCentres I and II (2007-2014);
- EuroPruning (2013-2016);
- Infres (2012-2015);
- LogistEC (2012-2016).

3.2 Bioboost

The pathways studied in the FP7-project ‘Biomass based energy intermediates boosting biofuel production’ (BioBoost) included the concentration of bioenergy in decentral plants and transport of energy carriers to large, central plants for upgrading to transportation fuel as usable bioenergy commodity. In focus was the decentral conversion to bioenergy carriers and the heuristic optimization of the logistic network, plant size and plant location [2].

Table I: An general theoretical example of a biomass value chain in the standard description format.

What?	How?	Where?
felling and bunching of thinning wood	with harvester	in forest
forwarding of stems	with forwarder	from forest to roadside
storage & drying of stems	in piles on ground	at roadside
chipping	with mobile chipper	at roadside
loading of chips in walking floor vehicle	by blowing	at roadside
transport	with walking floor vehicle	from roadside to biomass yard
unloading chips from walking floor vehicle	by dumping	at biomass yard
storage & drying of chips	in piles on concrete floor	at biomass yard
loading of chips in container vehicle	by shovel	at biomass yard
transport	with container vehicle	from biomass yard to conversion site
unloading chips from container vehicle	by tipping	at conversion site
storage of chips	in bunker	at conversion site
on-site conveying of chips to combustion installation	by conveyor belt	at conversion site
bioenergy production	by combustion	at conversion site

The main logistical concepts that appear in the Bioboost project are:

- application of most efficient equipment;
- combination of different forest residues in one procurement chain;
- optional use of intermediate depots;
- decentral biomass conversion to energy carriers to improve transport properties;
- economic upgrading to marketable bioenergy products (e.g. transportation fuel) in large central plants (due to unit of scale effect and/or synergies).

3.3 Biocore

The Biocore project focused on the quantification of the availability of biomass for a 150 kt/y CIMV Organosolv process from 2015 and 2025. Residual feedstock, made available after harvesting the main crops, was identified as primary resource to sustain the biomass supply chain, because of the widely spread cultivation of food crops in the area (wheat in particular). Wheat straw availability, though, was conditioned by several competitive uses increasing over time. Thus, an increasing share of the feedstock supplied to the biorefinery was represented by Miscanthus grown in marginal lands [3].

The main logistical concepts that appear in the Biocore project are:

- combination of different biomass feedstock types and quality in one value chain (i.e. residual biomass, energy crops, loose/chipped/ pelletized woody biomass);
- tradeoff between the use of residual feedstock and energy crops;
- transportation straight to the biorefinery versus transportation from the farm (after storage) to the biorefinery;
- integrated biomass preprocessing (e.g. wood chipping and pelletization) at industrial facilities already operating in the territory;
- effect of moisture content on the logistics (e.g. seasoning, transport cost) as well as on biomass processing efficiency at the biorefinery;
- combination of different transport modes (e.g. trucks/rail/barges).

3.4 BiomassTradeCentres I and II

The so-called ‘Biomass Yard’ concept was developed in the BiomassTradeCentre I project (2009-2011) [4]. A biomass yard is a regional ‘fuel station’ for solid biofuels with a high quality, run by a group of farmers. The project aimed at the sustainable supply of woody biomass through centralized marketing of larger bundled quantities of high quality biomass. The follow-up BiomassTradeCentre II project aimed at the development and implementation of new ‘Biomass logistic and trade centres (BLTCs)’ in nine countries (Austria, Croatia, Germany, Greece, Ireland, Italy, Romania, Slovenia and Spain) [5].

The main logistical concept that appears in these two projects is:

- Biomass logistic centre - biomass yards.

3.5 EuroPruning

EuroPruning carries out a demonstration of value chains for woody biomass from prunings in three EU countries: Germany, France and Spain. These demonstrations aim to reproduce several logistics chains at pilot scale. They are designed to prove two newly built pruning harvesters and a central system for supporting traceability and the organization of the logistics by traders [6].

The main logistical concepts that appear in biomass value chains from agricultural prunings are:

- collecting prunings in bales that will be chipped later on in the value chain versus chipping immediately at the source location;
- producing separate modular units (big-bags or bales) versus bulk material (hog wood);
- biomass size reduction: chipping versus shredding;
- front mounted shredding versus rear towed chipping / baling units (the former avoids tractor to drive over the prunings);
- combination of different transportation types;
- a biomass yard is part of the biomass value chain;
- transport of bulk and packed biomass (big-bags or bales) in moving floor trucks.

The main logistical concepts that appear in biomass value chains from wood from up-rooted fruit trees are:

- mechanized felling of fruit trees versus mechanized cut with a shear;
- shear mounted in front of a tractor versus mounted in the arm of a walking excavator;
- on field chipping of trees with mobile train (tractor – chipper – trailer) along the row of felled trees;
- on field utilization regular agricultural trailers with relevant volumetric capacity 30 m^3);
- manual preparation of trees before chipping.

3.6 Infres

The Infres project (Innovative and effective technology and logistics for forest residual biomass supply in the EU) is dealing especially with biomass from the forestry sector. Five main biomass supply chains have been demonstrated in practice together with the associated IT-systems for fleet and storage management [7].

The main logistical concepts that appear in the Infres project:

- integrated harvesting;
- coupled vs. de-coupled logistics for wood chip production;
- terminal logistics;
- logistics optimization;
- multi-tree handling;
- two-stage grinding.

3.7 LogistEC

The Burgundy case in the LogistEC project is about the energy crop Miscanthus. The case is about small scale local production of Miscanthus pellets and the logistics are pretty simple. The current project does not include the further use of the pellets (yet) e.g. in a bioenergy power plant or in other applications (like animal bedding) [8].

The main logistical concept that appear in this Burgundy case is:

- direct chipping at the roadside versus chipping bales at conversion site.

4 GENERAL LOGISTICAL CONCEPTS

4.1 Introduction

A logistical concept is broader and more general than a specific biomass value chain. A chosen logistical concept always still needs to be further specified and translated in order to obtain a specific biomass value chain (specify all the components). Often several possible biomass value chains fit within that general logistical concept. The general logistical concepts that were deduced from the analysis of the studied European projects are mention in Table II.

Table II: General logistical concepts.

Variant 1	Variant 2
pre-treatment integrated with harvesting/collecting	stand-alone pre-treatment later on in the biomass chain
indirect supply through biomass yards to the final conversion location	direct supply from the road-side to the final conversion location
multi-modal transportation (combination of different types)	only one transport modality (road, water or rail)
standardized biocommodities (e.g. wood pellets, ethanol, pyrolysis oil)	'raw' biomass (e.g. wood chips, bales)
many small-scale conversion plants	one large-scale conversion plant

4.2 Pre-treatment integrated with harvesting/collecting

In the agricultural sector there is already a long tradition of integrating several operations during the harvesting process. A good example is the development of the combine harvester, where cutting the stem with the grain and threshing it to separate the grain from the straw are combined in one machine. Sometimes this is even combined with baling the straw.

In case of biomass harvest from prunings, the integrated collection concept differs from annual crops. Pruning and fruit/olive/grape harvesting is done in two different moments of the crop cycle, and so, the integration of main product harvesting with the harvest of the residue is not possible. Pruning is carried out usually manually with shears or with mechanically assisted tools (electric shears or chainsaws, e.g.), even though there is a trend to execute non-selective mechanized pre-pruning operations. The pre-pruning takes away important parts of the shoots and branches, in order to reduce the manual work to be carried out later on by workers. Pruning collection can be integrated in next ways:

- Mechanized pre-pruning: by building new machinery able to convey the shredded pieces of wood into a collecting system (instead the default spread of wood pieces on the soil).
- Pick-up and treatment: the current pruning biomass harvest consists in machinery with a pick-up system feeding the branches into the shredder, chipper or baling system. Harvest requires in many cases a previous windrowing operation. Therefore integration can be improved by including windrowers with the harvester, or by adapting the manual pruning work so that the pruning is placed in the center of rows.

Also in the forestry sector integration of chipping with felling is possible in easy terrain, if the soil bearing capacity is good and yarding distances short. In Finland and Sweden chipping in the forest is no more practised due to logistical challenges and high costs.

For new non-food biomass feedstocks value chains integration of certain pre-treatments with harvesting or collecting might be advantageous as well. This can already be seen in the three recent EU-projects (EuroPruning [6], Infres [7] & LogistEC [8]) dealing with new concepts to optimize biomass logistics.

Table III: Advantages and disadvantages of the logistical concept pre-treatment integrated with harvesting/ collecting.

Advantages	Disadvantages
• Save one or more extra rides with a machine on the field • Lower overall costs per tonne for the combination of operations • Save extra biomass handling • Better biomass quality (less contaminated with soil) • Possibility of direct loading in transport vehicle	• More expensive machine for initial investment • More complex machinery including system with multiple purposes • Heavier machine which needs to be compensated (with larger tires) to avoid soil compaction • Slower harvesting rate • Failure in the biomass system may abort the harvest of the main product

4.3 Biomass yards

A biomass yard is a logistical concept. Several types of biomass supplied by different sectors (e.g. agriculture, forestry, nature management) are collected efficiently on a central location (biomass yard) in a region. There the biomass can be pre-treated into a standardized intermediate product (biocommodity) for further processing by industry. In some cases the biomass is also directly converted into an end-product at the biomass yard. The goal of a biomass yard is to produce a homogeneous output stream with the required specifications based on different inhomogeneous input streams that can be traded as a biocommodity [9]. A biomass yard is a spider in the web of collecting biomass. A biomass yard has two main types of tasks: i) technical-operational tasks and ii) management & trade tasks.

Concepts that resemble a biomass yard are mentioned in several European countries like: Austria, Germany, Sweden and Finland. The concept is also mentioned in the US and Canada.

A biomass yard can play a role in the process of guaranteeing the year-round availability of biomass. The biomass will be stored at the biomass yard until the exact moment when it is needed. The pre-treatment of biomass has to lead to a standardized intermediate product (biocommodity) that can be traded more easily.

Table IV: Advantages and disadvantages of the logistical concept biomass yards

Advantages	Disadvantages
• Production of biocommodities with a guaranteed quality to supply different conversion processes • Different types of biomass can be combined (e.g. woody and wet biomass)	• Inserting a biomass yard in a logistical biomass chain requires extra investment costs • The biomass yard concept still has to prove itself (partially)

4.4 Multi-modal transportation

The traditional method for transporting biomass is road transport. However, alternatives could be transport by rail or by waterway. The choice for a certain type of transport is determined by:

- transport distance;
- accessibility.

The feasibility of multi-modal transportation increases in combination with the use of a biomass yard and/or with pretreatment.

Table V: Advantages and disadvantages of the logistical concept multi-modal transportation.

Advantages	Disadvantages
• Enables optimal choice of transport type for each section of the transport route • For longer transport distances cheaper transport modes (ship or train) can be chosen	• More handling during transhipments • Higher loading & unloading costs • Not all locations can be reached by alternative transport modalities

4.5 Biocommodities

A biocommodity can be seen as a standardised form of biomass. The need for the development of biocommodities was described by [9]. The main reasons for developing biocommodities are:

- security of supply;
- need for quality standards and quality control and;
- facilitation of trade.

Possible examples of biocommodities that will be further developed are pyrolysis oil, torrefaction pellets, wood pellets and biosyngas. It is not completely clear yet which biocommodities will arise and this will certainly be a stepwise introduction. However, biocommodities will certainly have a number of properties that include:

- transportability;
- stability;
- sufficient market volume;
- year-round availability;
- competitive costs;
- easily standardized in uniform quality characteristics for specific applications;
- easy and quick quality measurements possible.

Biocommodities could be produced e.g. at biomass yards and they will greatly influence the set-up of a biomass value chain. They will enable transportation of the biomass over a much longer distance, thus facilitating international trade.

Table VI: Advantages and disadvantages of the logistical concept 'Biocommodities'.

Advantages	Disadvantages
• standardization • easier to trade (inter)nationally • better transportability • increased storability through stability • better quality that can be measured	• sufficient market volume is needed • higher pre-treatment costs need to be compensated

4.6 Small-scale versus large-scale conversion

The choice for the scale of the conversion leads to either shorter transport distances or longer transport distances.

The scale is also important for plant operation: e.g. in a small plant the wood chip feeding is done by a telehandler and one driver, in a larger plan by a wheel loader and one driver. On the other side a large plant needs more biomass than a small one, which increases the transport efforts.

The optimum between transport efforts and production costs depends on the relative importance of the two cost items transport and conversion. If the conversion technology is sophisticated and expensive as for example entrained flow gasification for synfuel production, the high processing costs outrun the wood chip transport costs and the lowest overall costs are at a large plant. In contrast, the processing costs of a pellet mill are relatively low and the wood chip transport has a higher contribution to the overall costs compared to a synfuel plant. So the most economic size of a pellet mill is smaller than that of a synfuel plant.

Table VII: Advantages and disadvantages of the logistical concept small-scale conversion.

Advantages	Disadvantages
• Short transport distance	• Higher conversion costs per unit

5 CONCLUSION

In the S2Biom project several logistical concept were identified based on a survey of current European projects focusing on the design of biomass value chains. A general, qualitative assessment of these logistical concepts was made.

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