S2Biom Project Grant Agreement n°608622

D2.1
A method for standardized biomass characterization and minimal biomass quality requirements for each biomass conversion technology

30 April 2015

About S2Biom project

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

Project coordinator

FNR
Fachagentur Nachwachsende Rohstoffe e.V.

Scientific coordinator

Imperial College
London

Project partners

About this document

This report corresponds to D2.1 A method for standardized biomass characterization and minimal biomass quality requirement for each biomass conversion technology of S2Biom. It has been prepared by:

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Authors	Martijn Vis (BTG), Rik te Raa (BTG) Douwe van den Berg (BTG), Harrie Knoef (BTG), Eija Alakangas (VTT), Janne Karki (VTT) Ayla Uslu (ECN) Paulien Harmsen (DLO), Wolter Elbersen (DLO)
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Table of contents

ANNEX I Description and selection of conversion technologies

ANNEX II Classification of biomass properties - Draft instructions

ANNEX III Instructions on the database of conversion technologies

List of Figures

1. Summary of activities

1.1 Objectives and relation to other S2BIOM activities

The overall objective of WP 2 is:

- To identify and extensively characterise existing and future non-food biomass conversion technologies for energy and biobased products.
- To develop a standardized methodology according to which the different biomass categories identified and quantified in WP1 need to be characterised.
- To assess the optimal match of biomass categories of different quality with the existing and future non-food biomass conversion technologies.

This D2.1 report summarises the activities that have been performed in order to develop a *method for standardized biomass characterisation and minimal biomass quality requirement for each biomass conversion technology*. The main idea of D2.1 is to describe the desired biomass input specifications of the various conversion technologies for lignocellulosic biomass. In order to do so first relevant conversion technologies have been described and selected, followed by setting up a proper template for describing the relevant biomass input specifications. The biomass specifications and technology descriptions have been used to develop two databases to collect data from a wide range of technologies and biomass types. These databases provide the relevant data for the selection method to match biomass types with the best conversion technologies (Deliverable D2.2). This selection method will be further elaborated into a matching tool (part of WP4) for optimisation of biomass use from a technical perspective, with linkages to pretreatment and logistical parameters as developed in WP3. Figure 1 shows the linkages between WP1-4.

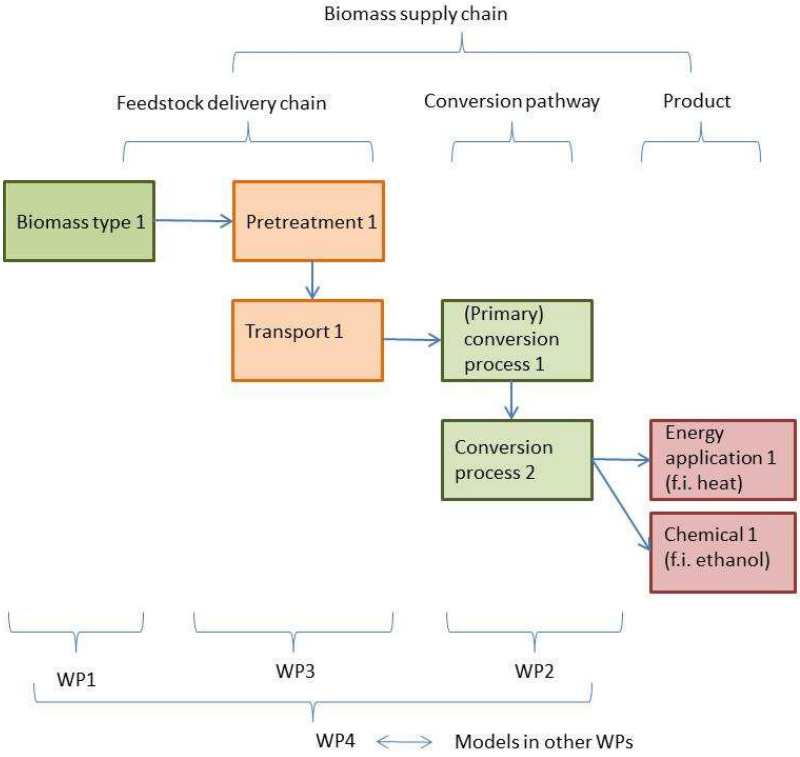

Figure 1 Structure of WP2 in WP1-4 of S2BIOM project

- The following linkages with other WPs have been established.
    - WP1: technologies cover the biomass sources assessed in WP1.
    - WP3: close cooperation with WP3 logistics
    - The database structure for conversion technologies have been developed in close cooperation with WP 4.
    - Coordination on information needed in the The RESolve model in WP7
    - All information will be available though the viewing tool in WP4, also for use in other WP2 (theme 2 and 3).

1.2 Activities performed

In this section the main flow of activities is summarised. The detailed results are written down in three Annex reports.

- ANNEX I Description and selection of conversion technologies.
- ANNEX II Classification of biomass properties - Draft instructions
- ANNEX III Instructions on the database for conversion technologies

The task was carried out in various steps:

- First an overview has been made of relevant existing and future technologies relevant for conversion of lignocellulosic biomass in combination with applications like heat, power, transport fuels, biochemicals in the period until 2030. From long list a selection has been made of conversion technologies that are relevant today, and that are expected to contribute significantly to renewable energy and the biobased economy in 2020 and 2030. In the selection and description of conversion technologies the following general considerations have been taken into account:
    - The S2BIOM project focusses on lignocellulosic conversion technologies. Therefore, the classification should be relevant for this category of biomass. For instance technologies using sugar, starch or oil crops are not considered.
    - The DOW makes a distinction between “existing” and “future” conversion technologies. This distinction has been replaced by an indication of the Technology Readiness Levels (TRL) to describe the state of the technology. The EC uses TRL in its Horizon 2020 programme. See Annex A. TRL 7-8 can be regarded as “existing”; TRL 1-6 as “future”.
    - The technology descriptions consider - when appropriate - changes in time for conversion efficiency and investment costs for 2020 and 2030. This is especially relevant for the future conversion technologies. For other data items a single value will be provided. Uncertainty and variations within one technology are at present day already large, which makes estimation of future variations not useful.
    - Conversion technologies have been described that produce heat, power, heat & power, fuels, chemicals and products. In the technology description, all outputs will be indicated and described.

  - Each technology has its own particular input specifications. However, three main classes of technologies can be distinguished for which similar parameters are relevant, whereas the values can differ. These classes are thermal, chemical and biochemical conversion technologies
  - A number of conversion technologies has been divided into sub-categories (especially combustion, gasification, anaerobic digestion) related to their technical properties, biomass input and capacity range.
  - The focus will be on conversion technologies that can be applied in Europe and meet European environmental standards and requirements of BAT.
  - 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. need of electricity, natural gas, chemicals) will be described in the mass and energy balance. Complete calculation of GHG performance or GHG factors are case specific and will not be described. Emissions for construction of the conversion technologies have not been described in WP2.
  - Carbonization is not included in the list of technologies. In Europe charcoal is mainly used for barbeque, an application that provides heat & smoke but does not add to the renewable energy targets of the EU.
  - In order to avoid long descriptions of technologies, in the database reference will be made to relevant literature and actual data from running plants/demo's/projects.

  For more details see the report "ANNEX I D2.1 Description and selection of conversion technologies".

- During an iterative process that started on October 2013 until March 2014, the relevant biomass input parameters were determined. Where possible, use has been made of existing biomass classification schemes, in particular relevant ISO standards like EN ISO 17225-1. An overview of these standards is presented in "ANNEX II Classification of biomass properties - Draft instructions".
- The final method for standardized biomass characterisation and minimal biomass requirements is reflected in "ANNEX III Instructions on the database for conversion technologies" that was released together with the database of conversion technologies on March 2014.
- The months thereafter until March 2015 were used to fill the database with the actual biomass input requirements for tech technology, thereby meeting Milestone MS3. The final database will be delivered in Month 30 (Deliverable D2.3).

ANNEX I Description and selection of conversion technologies.
ANNEX II Classification of biomass properties - Draft instructions
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Delivery of sustainable supply of non-food biomass to support a
“resource-efficient” Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

ANNEX I of D2.1

Description and selection of conversion technologies

30 April 2015

About S2Biom project

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

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Table of contents

List of Figures

List of Tables

1. Introduction

In this document an overview of conversion technologies is presented that are potentially relevant for the production of energy and materials in the period up till 2030. Based on this overview, a selection is made of conversion processes that are relevant today, and that are expected to contribute significantly to renewable energy and the biobased economy in 2020 and 2030. This selection is described in further detail in a database that will feed several models used in the S2BIOM project. The following main classification of conversion technologies has been used:

I. Thermal conversion technologies

1.	Direct combustion of solid biomass	VTT
2.	Gasification technologies	VTT
3.	Fast pyrolysis	BTG
4.	Torrefaction	ECN
5.	Syngas platform	ECN
6.	Treatment in subcritical water	BTG
7.	Treatment in supercritical water	BTG

II . Chemical and biochemical conversion technologies

8.	Anaerobic digestion	DLO
9.	Techniques from pulp and paper industry	VTT
10.	Chemical pretreatment	DLO
11.	Explosion processes	DLO
12.	Biochemical hydrolysis & Fermentation	DLO

2. Thermal conversion processes

2.1 Direct combustion of solid biomass (VTT)

2.1.1 Processes

Primary conversion technologies:

- Domestic wood-burning appliances
    - Residential batch-fired wood-burning appliances
        - Wood stoves
        - Fireplace inserts and zero clearance fireplaces
        - Heat storing stoves
        - Wood log boilers
    - Pellet appliances and burners
        - Pellet stoves
        - Pellet boilers (CV system)
    - Wood chips appliances
        - Pre-ovens
        - Under-fire boilers
        - Stoker burners
- Combustion technologies for industrial and district heating systems
    - Fixed bed combustion
        - Grate furnaces
        - Underfeed stokers
    - Fluidized bed combustion
        - Bubbling
        - Circulating
    - Pulverised fuel combustion

2.1.2 Applications

- Power generation (in combination with fixed/fluidized bed combustion)
    - Steam turbines
    - Organic Rancine Cycle (ORC)
    - Closed thermal cycles for power production
    - Steam piston engines
    - Steam screw engines
    - Closed gas turbines
    - Stirling engines
- Co-combustion (for power production)
    - Direct co-firing
    - Indirect co-firing
- Heat generation (heat only and CHP)

2.1.3 Selection for description in database

Selection of solid biomass combustion technologies that will be described in database

- Domestic residential batch fired stoves for heat (relevant in future only for emergency and stand by heat source during unusual coldness and power/gas supply blackout, continuous use limited by emission problems/regulations
- Domestic pellet burners for heat (stove/hot water boiler) use is possible in the future too, efficiency and emissions on acceptable level
- Fixed bed combustion for heat (hot water boilers), small scale installation are often batch operating, difficulties to fulfil emissions standards in the future, development needed
- Fixed bed combustion for CHP (steam cycle) and condensing electricity, stand on market and use, even performance is difficult or impossible to develop
- Fluidised bed combustion for CHP (steam cycle) and condensing electricity, dominant technology in the future; all above described problems can be avoided
- Direct co-combustion in coal fired power plants, share can be higher in future when CFB-technology more commonly in use
- Waste incinerators with energy recovery. Low power generation efficiency, very conservative market segment, lot of development needed to save resources.

2.2 Gasification technologies (VTT)

2.2.1 Processes

Primary conversion technologies:

- Fixed bed
    - Updraft
    - Downdraft
        - Open core
        - Multi-stage
    - Crossdraft
- Fluidized bed
    - Bubbling (BFB)
    - Circulating (CFB)
        - Atmospheric
        - Pressurised
- Entrained flow
    - Slagging
    - Non-slagging
- Twin-bed
    - Double fluidized bed

- Oxygen blown gasification

+ gas cleaning

2.2.2 Applications

- Gas/diesel engine
- IGCC
- Secondary conversion syngas (described elsewhere)
- Direct combustion in boiler & kiln

2.2.3 Selection for description in database

Most relevant commercial and industrially demonstrated gasification technologies and applications are selected to database. Small scale gasification technologies (under 5 MW fuel) for CHP application has countless number of different version and those are not taken to the database. Most common fixed bed technologies (downdraft and updraft) are described in the database.

Fluidized bed gasifiers cover bubbling and circulating, atmospheric and pressurized, air and oxygen/steam blown technologies and their different applications. Gasification gas cleaning is described in different applications. Syngas production application is limited to raw syngas production (gasification, hot gas filtration, catalytic reforming). Shift reaction, AGR and synthesis are described elsewhere.

- **Fixed bed – downdraft**
    - CHP (gas engine)
- **Fixed bed – updraft**
    - Direct combustion
- **Bubbling fluidized bed**
    - CHP (gas engine)
    - IGCC
    - syngas production
    - direct combustion
- **Circulating Fluidized bed**
    - CHP (gas engine)
    - IGCC
    - Direct combustion
    - syngas production
- **Entrained flow for syngas production**
- **Dual Fluidized bed**
    - CHP (gas engine)
    - syngas production

Selection of technologies that will be described in database:

- Fixed bed – downdraft (as far as relevant for Europe)
- Fixed bed – updraft (as far as relevant for Europe)
- Bubbling fluidized bed for CHP (gas engine)
- Circulating Fluidized bed for CHP (gas engine)
- Entrained flow for syngas production.

2.3 Fast pyrolysis (BTG)

2.3.1 Processes

Fast pyrolysis is a pathway in which biomass is converted to pyrolysis oil and other products. This technology can play a role in a biorefinery concept for the production of energy or other products which represents a higher value.

Several technologies are developed in which fast pyrolysis takes place. Currently, a number of pilot plants are in use worldwide. This technology is now ready for further up scaling. Fortum (Finland) and BTG (The Netherlands) are constructing a large scale pyrolysis plant.

An overview of fast pyrolysis technologies and plants is given in the table below.

Table 1: Worldwide biomass pyrolysis units in 2012[1]

Host Organisation	Country	Technology	Capacity kg feed/h	Applications	Status
ABRITech/ Advanced biorefinery Inc., Forespect	Canada	Auger	70-700 2000	Fuel	Operational Commissioning
Agri-Therm/ University of Western Ontario	Canada	Fluid bed	420	Fuel	Upgrade
Biomass Engineering Ltd.	UK	Fluid bed	250	Fuel and products	Construction
BTG BTG-BTL EMPYRO	Netherlands	Rotating cone	200 5000	Fuel	Operational Construction
Ensyn Several	Canada & USA	Circulating fluidised bed	3-3100	Fuel and chemicals	Operational
Fraunhofer UMSICHT	Germany	Ablative	250	Fuel	Commissioning
Fortum	Finland	Fluidised bed	10,000	Fuel	Commissioning
Genting	Malaysia	Rotating cone	2000	Fuel	Dormant
GTI	USA	Hydropyrolysis	50	Transportation fuels	Commissioning
KIT	Germany	Twin Auger	1000	Transportation fuel	Operational
Metso	Finland	Fluid bed	300	Fuel	Operational

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[1] Jani Lehto et al, Review of fuel oil quality and combustion of fast pyrolysis bio-oils from lignocellulosic biomass, Applied Energy 116 (2014) 178-190.

Mississippi State University	USA	Auger	200	Fuel	Construction
National Renewable Energy Laboratory	USA	Fluid bed	12	Fuels and chemicals	Operational
Pytec	Germany	Ablative	250	Fuel	Commissioning
Red arrow	USA	Circulating	125-1250	Food products and fuel	Operational
Ensyn Several		Fluidised bed			
Renewable oil International LLC	USA	Auger/ moving bed	105	Fuel	Operational
RTI International	USA	Catalytic fast pyrolysis	40	Transportation fuel	Construction
UDT	Chile	Fluid bed	120	Fuel	Operational
UOP	USA	Circulating fluidised bed	40	Transportation fuel	Operational
University of Science and Technology of China, Hefei	China	Fluid bed	120	Fuel	Operational
Virginia Tech	USA	Fluid bed	250	Fuel	Operational
VTT	Finland	Fluidised bed	20	Fuel	Operational

The major players in the field of pyrolysis technology are Ensyn, Fortum and BTG. A brief overview of these companies and their technologies are given.

Ensyn[2]

Ensyn's RTP technology is a processing system that uses heat to thermally crack carbon-based feedstocks such as wood biomass (cellulose, lignin) into high yields of pyrolysis oil product. The core RTP process does not employ high temperatures or excessive operating pressure. The RTP pyrolysis process is based on the application of a hot "transported" bed (typically sand) that is circulating between two key vessels. Feedstock, such as wood residues, are subjected to fast, intimate contact with the hot sand for under a few seconds, resulting in the thermal cracking of the feedstock to gases and vapours. Product vapours are rapidly quenched, or cooled, and recovered as a light liquid product.

Fortum[3]

Fortum invests in the commercialisation of the new fast pyrolysis technology by building a pyrolysis-oil plant connected to the Joensuu power plant in Finland. The integrated bio-oil plant, based on fast pyrolysis technology, is one of the first of its kind in the world on an industrial scale.

The pyrolysis plant, which will be integrated with the combined heat and power production plant (CHP) in Joensuu, will produce electricity and district heat and 50,000 tonnes of bio-oil per year. The bio-oil raw materials will include forest residues and other wood based biomass.

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[2] http://www.ensyn.com/technology/overview/

[3] http://www.fortum.com/en/mediaroom/pages/fortum-invests-eur-20-million-to-build-the-worlds-first-industrial-scale-integrated-bio-oil-plant.aspx

BTG[4]

BTG's fast pyrolysis process is based on the rotating cone reactor developed by the University of Twente. Biomass particles at room temperature and hot sand particles are introduced near the bottom of the cone where the solids are mixed and transported upwards by the rotating action of the cone. In this type of reactor, rapid heating and a short gas phase residence time can be realized.

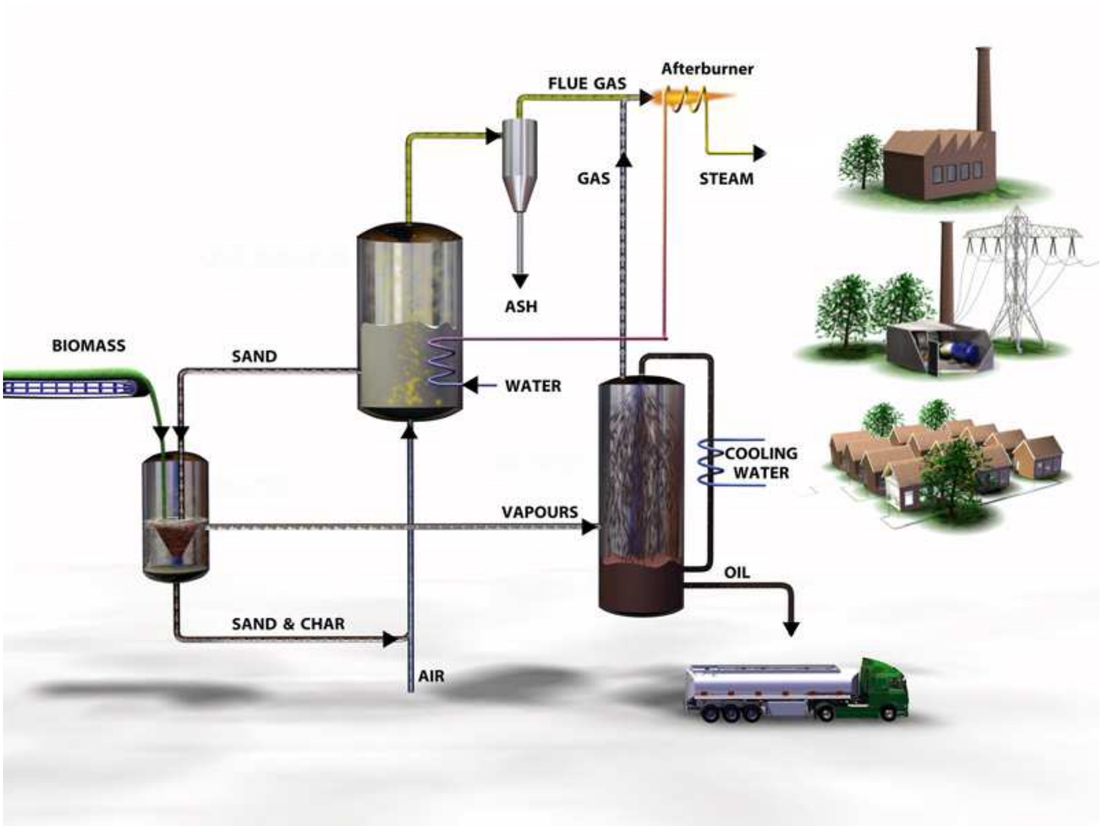

Figure 1: Process flow diagram fast pyrolysis[5].

Biomass particles are fed near the bottom of the pyrolysis reactor together with an excess flow of hot heat carrier material such as sand, where it is being pyrolysed. The produced vapours pass through several cyclones before entering the condenser, in which the vapours are quenched by re-circulated oil. The pyrolysis reactor is integrated in a circulating sand system composed of a riser, a fluidized bed char combustor, the pyrolysis reactor, and a down-comer. In this concept, char is burned with air to provide the heat required for the pyrolysis process. Oil is the main product; non-condensable pyrolysis gases are combusted and can be used e.g. to generate additional steam. Excess heat can be used for drying the feedstock.

Two test facilities are available in BTG's lab. A small unit (2- 3 kg/hr) to enable rapid screening of potential feedstocks, and a 100 - 200 kg/hr pilot plant. The latter one provides reliable and representative data for a full scale plant. The pilot plant has processed in total over 70 tonnes of oil for a number of clients. In Hengelo (the Netherlands) a 5 tonnes/hr pyrolysis plant is under

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[4] http://www.btgworld.com/nl/rtd/technologies/fast-pyrolysis

[5] Ref: BTG Biomass Technology Group. www.btgworld.com

construction. This unit will convert wood into pyrolysis oil, process steam and electricity. For further details see the project website of the EMPYRO plant[6].

2.3.2 Applications

Pyrolysis oil is used as a platform material and has several applications. Direct applications are for instance combustion. Pyrolysis oils can also be used as input for secondary processes such as hydrogenation, fractionation and gasification. For secondary applications, more (upgrading) processes are required.

Direct applications:

- Combustion
    - In small heating plant
    - In large gas/oil fired heating plant
    - Direct combustion in diesel engine

In Borculo (The Netherlands), a large combustion plant of 25 MW_{th} is under construction for process heat in an industrial complex. This is a dual fuel boiler and run on a mixture of pyrolysis oil and natural gas or biogas.

Secondary conversion processes:

- Hydrogenation of pyrolysis oil is necessary for upgrading to stable pyrolysis oil or even further to fuel quality.
- Fractionation and extraction of pyrolysis oil to valuable materials
- Gasification of pyrolysis oil to syngas. This syngas is used as platform for input material in the chemical industry.

Pyrolysis oil has the following secondary applications:

- Diesel: by hydrogenation of pyrolysis oils, fuels such as diesel, petrol and jet fuel is produced. This hydrogenation process consists of several processes where hydrogen is added, oxygen removed and fuels are produced.
- Co-refinery: pyrolysis oils can be added in the refinery process of crude oil to fuels. Before this is possible, the pyrolysis oil needs to be stabilized by a hydrogenation step. A fraction of pyrolysis oil is added in the crude oil and refined to fuels such as diesel, jet fuel and petrol.
- Pyrolysis oils consist of three fractions: the watery, sugar and lignin fractions. Pyrolysis oil is separated in these three fractions by extraction and shifting. The lignin fractions have applications in bitumen, a source for asphalt and roof materials. Sugar fraction is a platform chemical as source for the chemical industry. The water fraction contains valuable materials such as acids.

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[6] http://www.empyroproject.eu/

2.3.3 Selection for description in database

The following conversion chains have been selected for description in the database:

- Pyrolysis and application pyrolysis oil in a boiler for heat and steam generation
- Pyrolysis and application pyrolysis oil in diesel engine for electricity and heat generation
- Pyrolysis and upgrading (hydrogenation) for advanced biofuel production.

The 5 tonne/hour Empyro plant using BTGs rotating cone pyrolysis technology has been selected for description in the database, as it is representative for the current state-of-art of pyrolysis technology.

The most robust application of pyrolysis oil is heat and steam generation in a boiler. Another very promising application that could become commercially available within the next years is the use of pyrolysis oil in a diesel engine for electricity and heat production. Given the relevance of low ILUC advanced biofuels for the automotive sector, hydrogenated pyrolysis oil for advanced biofuels production is selected as well.

2.4 Torrefaction (ECN)

2.4.1 Processes

Torrefaction is a mild thermal treatment of biomass under low-oxygen conditions. Torrefaction results in a homogeneous fuel, with a much improved grinding quality, a higher energy density and containing fewer impurities. The torrefied biomass is hydrophobic, preventing it from absorbing water during storage and making it resistant to rot and fermentation. When the torrefied biomass is densified through pelletisation it results in a more energy-dense product. A typical mass and energy balance for woody biomass torrefaction is that 70% of the mass is retained as a solid product, containing 90% of the initial energy content. The other 30% of the mass is converted into torrefaction gas, which contains only 10% of the energy of the biomass. Several torrefaction technologies are developed. An overview of reactor technologies that are applied for torrefaction is presented in Table 2. Several torrefaction technology providers in Europe claim to have reached commercial production.

Table 2 Overview of reactor technologies[7]:

Reactor technologies	Companies involved
Rotating drum	CDS (UK), Torr-Coal (NL), BIO3D (FR), EBES AG (AT), 4Energy Invest (BE), BioEndev/ ETPC (SWE), Atmosclear S.A. (CH), Andritz, EarthCare Products (USA)
Screw reactor	BTG (NL), Biolake (NL), FoxCoal (NL), Agri-tech Producers (US)
Herreshoff oven/ Multiple Hearth Furnace	CMI-NESA (BE), Wyssmont (USA)
Torbed reactor	Topell (NL)

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[7] J. Koppejan et al, Status overview of torrefaction technology, IEA Bioenergy task 32 report, December 2012

Microwave reactor	Rotawave (UK)
Compact moving bed	Andritz/ ECN (NL), Thermya (FR), Buhler (D)
Belt dryer	Stramproy (NL), Agri-tech producers (USA)
Fixed bed	NewEarth Eco Technology (USA)

Example processes

Topell Energy’s fluid bed technology has reached commercial scale operation. Topell Energy applies a TORBED reactor designed for effective gas/solid contact in various industrial applications. The core of the Topell torrefaction System consists of several TORBED reactors, which have a short retention time and high heat transfer efficiency. During the torrefaction process volatiles are produced (“torgas”). The thermal energy needed for the pre-drying and the torrefaction process is provided by a dual fuel combustor, which burns the torgas and natural gas as a support fuel. The exiting gas from the combustor (the “flue gas”) is cooled with several heat exchangers before it is sent to the pre-dryer and torrefaction reactors. The heat exchangers are chosen in such a way that a range of operating conditions (flow and temperature) in the reactors can be chosen. Transport of the various gas streams is done by fans (SECTOR, D3.2, 2014).

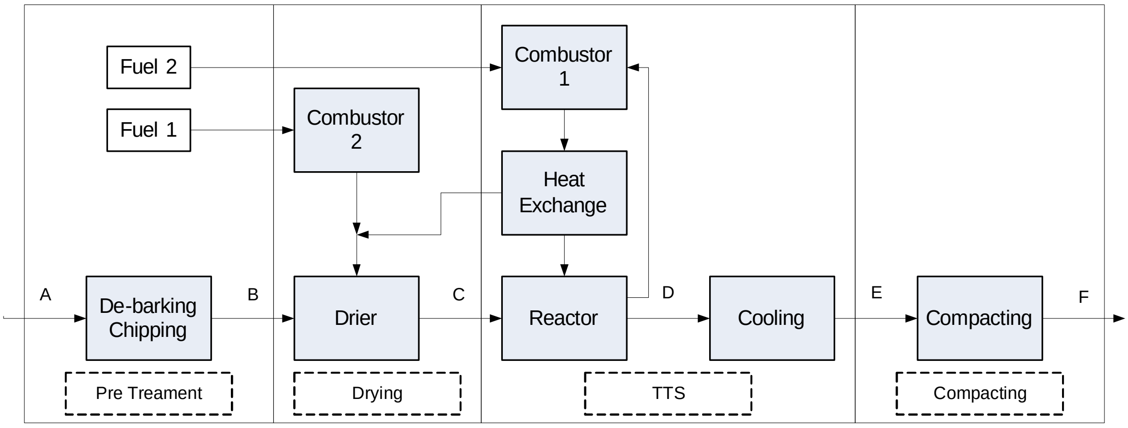
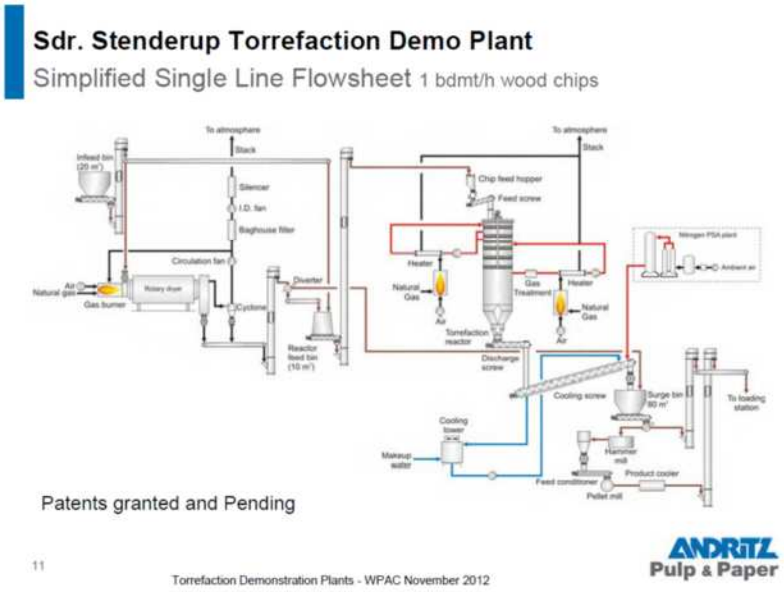


Figure 2 Process diagram of TORBED torrefaction plant

The moving bed technology developed by ECN is in demonstration phase at the Andritz demo plant in Denmark. The process is a pressurised, directly heated co-current moving bed reactor utilising conventional drying and pelletisation. The pilot plant incorporates biomass receiving, drying, torrefaction, and pelletising in an integrated system. The torrefaction process blends ECN and ANDRITZ technologies and has been patented. The production capacity of the demonstration plant amounts approximately 1 ton per hour, while focus for commercial plants is on plants with a capacity in excess of 250 000 tons per year (SECTOR D3.2, 2014).



Sdr. Stenderup Torrefaction Demo Plant

Simplified Single Line Flowsheet 1 bdmt/h wood chips

Patents granted and Pending

11

Torrefaction Demonstration Plants - WPAC November 2012

Figure 3 ECN/Andritz torrefaction demo plant in Stenderup, Denmark

2.4.2 Applications

Torrefied biomass has several applications. The main application is for co-firing and combustion. The applications are discussed below:

- Co-firing torrefied biomass in large scale power production plants. The market potential of this application is very high. Another option is co-firing in gasification, but this market potential is limited.
- Combustion in industrial, district or residential heating is another application. Boilers, also used for wood pellets or chips burning are available for this application. The market potential is high.
- Gasification to produce syngas/biofuels (there are a number of initiatives on this, i.e. than EU NER300 funded the first commercial large scale demonstration plant to produce syngas).

2.4.3 Selection for description in database

A stand-alone Torrefaction and Pelletisation Plant (TOP) with a capacity of about 72800 t/a, foreseen as a typical European commercial plant, is selected for description in the database. Since most of data to be presented in the database are identical for both technologies introduced above (the mass and the energy balances of the two technologies included in SECTOR project are practically almost the same and there are no detailed comparable cost figures per technology) a more generic torrefaction concept is described in the database.

The chains to be considered are cofiring torrefied biomass in large power plants, combusting in industrial, district or residential heating and gasification to produce syngas/biofuels.

Application

- co-firing in large scale power production plants
- Combustion of torrefied biomass for industrial or residential heating.

2.5 Syngas platform (ECN)

2.5.1 Processes

Syngas platform is based on gasification + gas cleaning + fuel synthesis.

- Gasification + upgrading
    - Fischer Tropsch synthesis, FT-diesel
    - Natural gas production
    - Alcohol (methanol, ethanol, and higher alcohols synthesis).

2.5.2 Applications

- Diesel, kerosene, petrol production
- Heat and power production
- Gasification

2.5.3 Selection for description in database

The following conversion chains have been selected for description in the database:

- Fluidised bed gasification for methanol production
- Fluidised-bed gasification for FT-fuels production
- Indirect gasification for SNG production

2.6 Treatment in subcritical water (BTG)

2.6.1 Processes

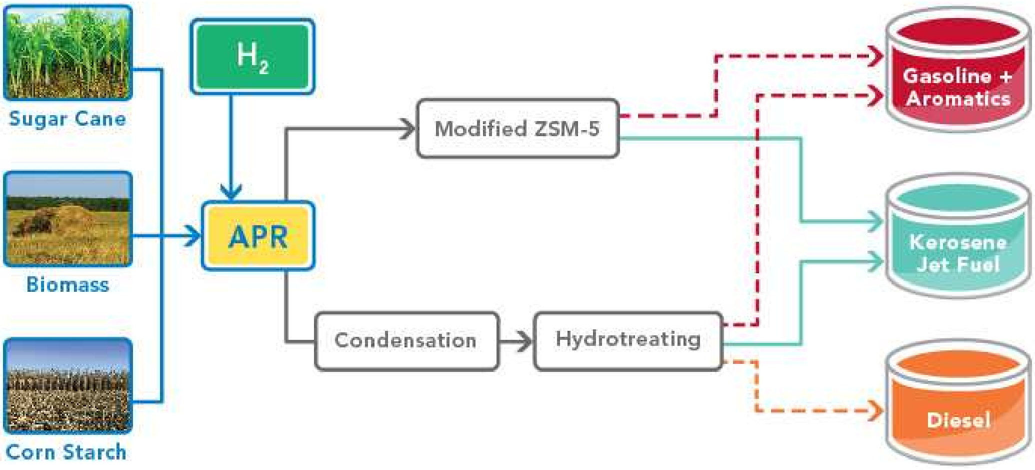
Biomass can be converted in energy carriers in subcritical water. Water reaches its supercritical point at 374 °C and 218 bar. Two relevant processes in subcritical water are:

- Aqueous Phase Reforming
- Hydro Thermal Upgrading (HTU).

These two processes are further described below.

Aqueous Phase Reforming (APR)

Virent BioForming® technology features catalytic chemistry, which converts plant-based sugars into a full range of hydrocarbon products such as gasoline, diesel, jet fuel, and chemicals for plastics and fibers. The technology is feedstock flexible from conventional sugars as well as a wide variety of cellulosic biomass from non-food sources.



This technology is based on a combination of Aqueous Phase Reforming (APR) technology with catalytic processing. The APR technology was discovered at the University of Wisconsin in 2001 by Virent’s co-founder and chief technology officer, Dr. Randy Cortright.

The soluble carbohydrate streams consist of a wide range of molecules and are processed through the aqueous phase reforming step. The aqueous phase reforming step utilizes heterogeneous catalysts at moderate temperatures and pressures to reduce the oxygen content of the carbohydrate feedstock. Some of the reactions in the APR step include:

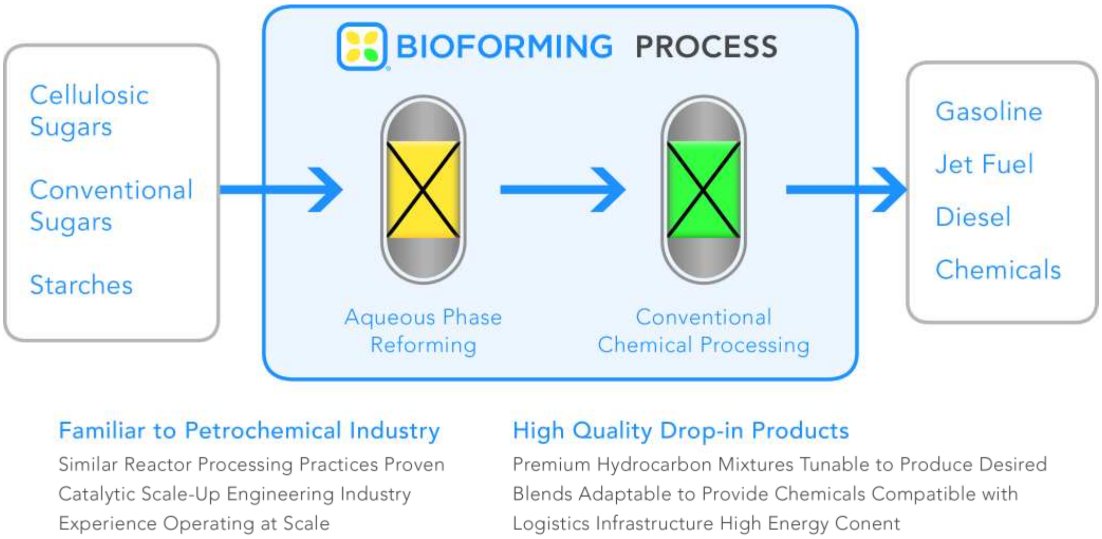
1. reforming to generate hydrogen
2. dehydrogenation of alcohols/hydrogenation of carbonyls
3. deoxygenation reactions
4. hydrogenolysis
5. and cyclization.

The product from the APR step is a mixture of chemical intermediates including alcohols, ketones, acids, furans, paraffins and other oxygenated hydrocarbons. Once these intermediate compounds are formed they can undergo further catalytic processing to generate a cost-effective mixture of nonoxygenated hydrocarbons.

The chemical intermediates from the APR step can be reacted over a Virent modified ZSM-5 catalyst to produce a high-octane gasoline blendstock that has a high aromatic content similar to a petroleum-derived reformate stream. Virent has trademarked this product BioFormate™.

The chemical intermediates from the APR step can also be converted into distillate range hydrocarbon components through a condensation step followed by conventional hydrotreating.

All of Virent’s hydrocarbon products from the BioForming processes are “drop-ins” for petroleum fuels and petrochemicals.



HTU

Hydro Thermal Upgrading (HTU) is a process to convert biomass into a biocrude. This process takes place at high pressure and temperature. This biocrude is a liquid hydrocarbon and is not directing applicable. Further upgrading is necessary to get end products such as biofuel (diesel) or heat and power. The process flows are given below.

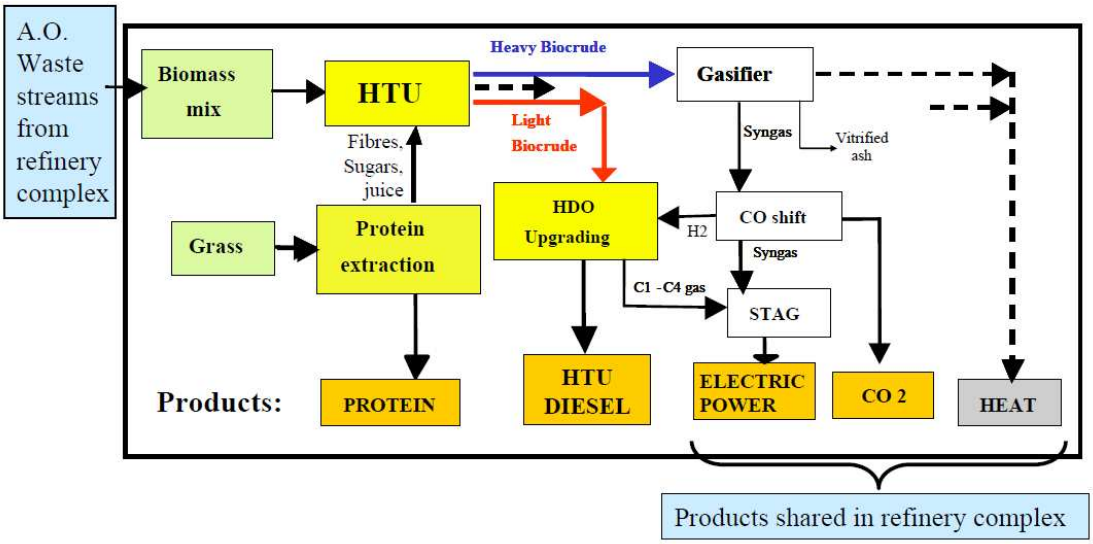


Figure 4: Process flow diagram Hydro Thermal Upgrading[8].

Processes

The HTU process is a thermal process which takes place under the following circumstances:

- Pressure 120-180 bar
- Temperature: 300-350 °C
- Moisture content: optimum 25-30 %

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[8] Presentation: HTU Diesel from wet waste streams, F. Goudrian, J.E, Naber, Symposium New Biofuels, Berlin, May 2008.

- Reaction time: 5-20 minutes.

As feedstock is required all types of biomass, domestic, agricultural and industrial residues, wood. Also wet feedstock, no drying is required.

The HTU process produces these products (%w on feedstock, dry ash free basis)

- 45% Biocrude
- 25% Gas (> 90% CO_2, remainder CO)
- 20% H_2O
- 10% Dissolved organics (e.g., acetic acid, ethanol)

Biocrude has the following characteristics:

- Heavy organic liquid, solidifies at 80 °C
- Not miscible with water
- Oxygen content 10 - 18 %w, H/C = 1.1
- Heating Value (LHV) 30 - 35 MJ/kg
- Separation into light and heavy fractions by fasting or extraction

Applications

Biocrude has these applications:

- Upgrading with hydrogenation to biofuel such as diesel, jet fuel, etc.
- Gasification for syngas. With the water gas shift reaction, hydrogen and carbon dioxide are produced. Besides this, syngas can be used for power and heat generation.

2.6.2 Selection for description in database

- Aqueous Phase Reforming is a proven technology to convert clean sugars into biofuels. When lignocellulosic material is used, the sugars have to be extracted first. This technology is selected for description in the database.
- HTU: At this moment, no demonstration or large scale plants are in use or planned for construction. The technology readiness level is not so far at this moment and it not expected that this technology has impact before 2030. From this perspective, this technology is not selected for the database.

2.7 Treatment in supercritical water (BTG)

2.7.1 Processes

Biomass can be converted in energy carriers (methane, hydrogen, etc.) via a thermal process in supercritical water. Water reaches its supercritical point at 374 °C and 218 bar. Under these conditions, biomass converts into other energy carriers.

Several research institutes and companies are doing research to this technology. Four known institutes/ companies are:

- KIT Verona
- Paul Scherrer Institute (PSI)
- Sparqle
- Gensos
- BTG

Paul Scherrer Institute (PSI)[9] has the approach of hydrothermal gasification, developed in the Catalytic Process Engineering (CPE) group, wet biomass, including purpose-grown algae, can be processed efficiently to synthetic natural gas (SNG). The scale-up of this technology is well on the way to be realized in the spin-off company Hydromethan AG together with industrial partners, although many scientific questions still remain to be answered. Due to the extremely tight boundary conditions for an economically feasible energy production process based on biomass, the co-generation of energy and chemicals seems to be a highly attractive pathway, which will be further developed in the laboratory in the next years.

BTG has the RSW (Reforming in Supercritical Water) process and consists of a number of unit operation as feed pumping & pressurizing, heat exchanging, reactor, gas-liquid separators and if desired product upgrading. The reactor operating temperature is typically between 600 and 650 °C; the operating pressure is around 300 bar. A residence time of up to 2 minutes is required to achieve complete carbon conversion, depending on the feedstock. Heat exchange between the inlet and outlet streams from the reactor is essential for the process to achieve high thermal efficiency. The two-phase product stream is separated in a high-pressure gas-liquid separator (T = 25 - 300 °C), in which a significant part of the CO_2 remains dissolved in the water phase.

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[9] http://www.psi.ch/lbk/about-lbk

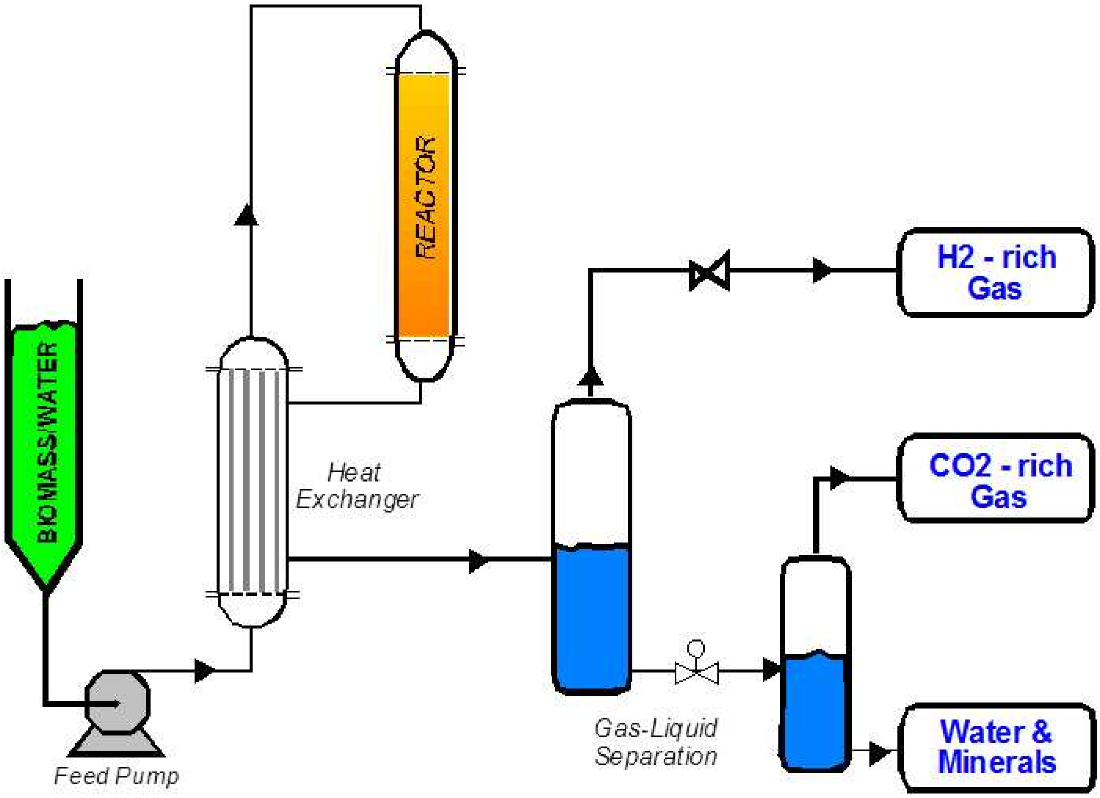

Figure 5: Schematic overview reforming in superctrical water[10].

Reforming in supercritical water
Possible contaminants like H_2S, NH_3 and HCl are likely captured in the water phase due to their higher solubility, and thus in-situ gas cleaning is obtained. The gas from the HP separator contains mainly the H_2, CO and CH_4 and part of the CO_2. In a low pressure separator a second gas stream is produced containing relative large amounts of CO_2, but also some combustibles. This gas can e.g. be used for process heating purposes.

2.7.2 Applications

- Hydrogen production
- Synthesis gas production
- Substitute natural gas production
- Methanol production

2.7.3 Selection for description in database

Currently, this technology is under development. Several research institutes and companies have pilot plants running. The technology readiness level is low. It is not expected that this technology will be market ready within the coming decade. **Therefore, this technology is not taken for description in the database.**

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[10] Reference: www.btgworld.com

3. Chemical and biochemical conversion processes

3.1 Anaerobic digestion (DLO) of high ligno-cellulose biomass

3.1.1 Processes

A very wide range of anaerobic digestion systems exist. Here we focus on systems that can typically be used for digestion of high lignocellulose containing biomass types with or without addition of co-products such as manure. We focus on the typical systems used in Europe now and in the (near) future.

Introduction to the anaerobic digestion process:

Formulas

$$C_6H_{12}O_6 \rightarrow 3CH_4 + 3CO_2$$

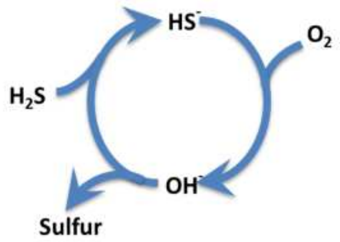
Methanogenesis, etc

Yield of biogas (Provisional data)

Component (kg)	Biogas (m3 per kg)	Methane %
Protein	0,60 – 0,70	70-75%
Fat/oil	1,00 – 1,25	68-73%
Fibre	0,70 – 0,80	50-55%
Carbohydrate	0,70 – 0,80	50-55%

Inhibiting aspects

Biogas treatment: H2S removal and biogas upgrading



Introduction to typical systems / classification

Anaerobic digestion technologies:

- Complete mix digester
    - One stage
    - Two stage

- Plug flow digester
    - Peddle wheel digester
    - ?
- Dry Digestion
    - Batch
    - Plug flow “Compogas”

All these systems can be operated at ambient (Mesophilic) temperature typically 30–40 °C or Thermophilic typically 53–58 °C.

3.1.2 Applications

Applications of biogas produced:

- CHP (gas engine) producing electricity and heat
- Upgrading biogas to biomethane
    - Biomethane for grid injection
    - Biomethane for car transport (CNG)
    - Biomethane for trucks (LNG)
- Using biogas in a dedicated biogas grid

3.1.3 Selection for description in database

- Complete mix digester
- Plug flow digester
- Dry Digestion

3.2 Techniques from pulp and paper industry (VTT)

3.2.1 Processes

Conversion process:

- Pulping in paper industry
    - Kraft pulping based processes
        - Kraft (existing)
        - Kraft with LignoBoost process, (TRL 9)
    - Sulphite pulping (existing)
    - Soda, soda-oxygen, soda-AQ pulping (existing)
- Pulping in dissolving pulp production
    - Prehydryolysis Kraft processes:
        - autohydrolysis stage done by pre-steaming (existing)
        - autohydrolysis done in water phase (hot water pretreatment) (existing)
    - Sulphite pulping processes (existing)
- Organosolv pulping
    - Organic acid processes
        - Formic acid based Formico (TRL 9) and CIMV (TRL 9)
        - Acetic acid based Acetocell (TRL 7-8)
    - Ethanol based Alcell (TRL 9) and its further developed process Lignol
- Ionic liquid-aided fractionation (TRL 3)

3.2.2 Applications

- Main products: different pulp products: paper grade pulp, dissolving pulp, NFC, CMC etc.
- Main side products in existing processes:
    - energy
    - tall oil and turpentine
    - lignosulphonates (Sulphite)
    - vanillin, furfural, xylose etc. (Sulphite)
- Possible side product in the future:
    - lignin (LignoBoost, organosolv processes)
    - hemicelluloses as polymers, monomers, hydroxy acids from (Kraft, sulphite, prehydrolysis Kraft and Organosolv processes)

3.2.3 Selection for description in database

- Kraft process with LignoBoost process (TRL 9)
  - In near future LignoBoost process will be built to reduce the CO_2 emissions of the pulp mill by replacing a significant amount of natural gas with dried lignin fired in the lime kilns
  - Separation of the lignin from black liquor for lignin product
- Prehydrolysis Kraft process in water phase (existing)
  - In future there will be possibility to separate hemicelluloses for the valuable intermediate products and chemicals (TRL 4-5).

3.3 Pretreatment, hydrolysis and fermentation processes (DLO) [11]

3.3.1 Chemical pretreatment processes

To this group belong the pretreatments that are initiated by chemical reactions for disruption of the biomass structure

- Liquid hot water (TRL 9)

  Liquid hot water (LHW) processes are biomass pretreatments with water at high temperature and pressure. Other terms are hydrothermolysis, autohydrolysis, hydrothermal pretreatment, aqueous fractionation, solvolysis or aquasolv. Hot compressed water is in contact with biomass for up to 15 min at temperatures of 200–230 °C. Between 40% and 60% of the total biomass is dissolved in the process, with 4–22% of the cellulose, 35–60% of the lignin and all of the hemicellulose being removed.

  Inbicon in Denmark produces ethanol from straw by autohydrolysis on demonstration scale. Advantages of this process include the absence of chemicals and the low water use as they operate at high dry matter content (>30 wt%).
- Supercritical fluids (CO_2, water) (TRL 7)

  A supercritical fluid is any substance at a temperature and pressure above its critical point where distinct liquid and gas phases not exist. Supercritical fluid behaves like a liquid with the viscosity of a gas: it can diffuse through solids like a gas and dissolves material like a liquid.

  CO_2 and water are the most commonly used supercritical fluids being used for various food and non-food applications. CO_2 becomes supercritical above 31 °C and 73 bar, water above 374 °C and 218 bar.

  SC-CO_2 is widely used as an extraction solvent for various applications and is also being considered as possible pretreatment route for lignocellulosic material. SC-water can potentially be applied for decomposition of biomass. The company **Renmatix** is currently commercialising the Plantrose pretreatment technology.
- Dilute acid hydrolysis (TRL 9)

  Dilute or weak acid hydrolysis is one of the most effective pretreatment methods for lignocellulosic biomass. In general there are two types of dilute acid hydrolysis:

  1. High temperature and continuous flow process for low-solids loading (T> 160 °C, 5-10 wt% substrate concentration)
  2. Low temperature and batch process for high-solids loading (T≤160 °C, 10-40 wt% substrate concentration)

  Acid is added to the raw material and the mixture is held at elevated T for short period of time. Hydrolysis of hemicellulose to sugars occurs but also degradation products are formed (strong

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- [11] Harmsen PFH, Lips S, Bakker RRC, *Pretreatment of lignocellulose for biotechnological production of lactic acid; research review,* WUR-Food and Biobased Research (2013), Available from: http://edepot.wur.nl/293952.
- Harmsen PFH, Huijgen W, Bermudez L, *Literature review of physical and chemical pretreatment processes for lignocellulosic biomass,* WUR-Food and Biobased Research (2010), Available from: http://edepot.wur.nl/150289.

inhibitors to microbial fermentation). Furthermore, acids can be corrosive and neutralization is required (resulting in the formation of solid waste).

Several companies use dilute acid as pretreatment method for fractionation of lignocellulosic biomass. **Blue Sugars** in the US has a demonstration plant for the production of ethanol from sugarcane bagasse. **Cobalt Technologies**, in cooperation with Rhodia and Andritz, are building a demonstration plant in Brazil for the production of butanol from sugarcane bagasse. **POET-DSM** is building at the moment a commercial cellulosic ethanol plant in the US. In Europe the Swedish company **Sekab** is producing ethanol on demonstration scale from softwood, straw and sugarcane bagasse.

- Concentrated acid hydrolysis (TRL 7)

  Concentrated acids such as H_2SO_4 and HCl have been widely used for treating lignocellulosic materials because they are powerful agents for cellulose hydrolysis and no enzymes are needed for the production of sugars. Advantages of concentrated acid hydrolysis are the flexibility in terms of feedstock choice, low concentration of inhibitors, high monomeric sugar yield as well as mild temperature conditions that are needed (cooling might be needed). Drawbacks of using concentrated acids are corrosive nature of the reaction and the need to recycle acids in order to lower cost. For recovery of acid used it is essential that the biomass has a high dry matter content, otherwise the biomass stream is too much diluted.

  To date, several companies are in the process of commercialising strong acid hydrolysis of lignocellulosic biomass. **Blue Fire Renewables** (US) acquired the rights from Arkenol for the production of sugars and ethanol from biomass. **Virdia** produces sugars from lignocellulosic biomass by using concentrated HCl. Their CASE™ process is demonstrated at pilot scale at the moment and samples of cellulosic sugars and lignin are being produced for commercial application testing. In Europe the Norwegian company **Weyland** is producing sugars and lignin on pilot scale since 2010. They mainly use wood and agricultural residues as biomass source.

- Alkaline hydrolysis (TRL 7)

  The major effect of alkaline pretreatment is the removal of lignin from biomass, thereby improving the reactivity of the remaining polysaccharides and decrystallisation of cellulose. As opposed to the acid-catalysed methods, the general principle behind alkaline pretreatment methods is the removal of lignin whereas cellulose and part of the hemicelluloses remain in the solid fraction. The solid fraction is submitted to enzymatic hydrolysis for the production of C6- and C5 sugars and this pretreatment method is especially suitable in combination with fermentation routes in which both C6- and C5-sugars can be converted to products. For alkaline hydrolysis calcium hydroxide, sodium hydroxide or ammonia can be used.

  On industrial scale **DuPont Danisco** applies alkaline conditions for their biomass pretreatment. The pilot plant in the US produces ethanol from lignocellulosic biomass (switchgrass, corn cobs, corn stover) by dilute ammonia hydrolysis followed by enzymatic hydrolysis to produce the fermentable sugars. They have plans for production on commercial scale in 2014.

- Organosolv (TRL 7-8)

  Organosolv processes use an organic solvent or mixtures of organic solvents with water for removal of mainly lignin. Common solvents for the process include ethanol, methanol, acetone, ethylene glycol, formic acid and acetic acid. Temperatures used for the process can be as high as 200 °C, but lower temperatures can be sufficient depending on e.g. the type of biomass and the use of a catalyst. Removal and recovery of the solvent is required for reducing costs and environmental impact.

Organosolv originates from the pulp and paper industry where it was developed as an alternative for kraft pulping. To date several companies use the organosolv technology for the fractionation of biomass. **Chempolis** in Finland uses a mixture of formic acid and acetic acid in water as pulping liquid. The Formico Biorefinery Technology processes non-wood biomass on demonstration scale. From the cellulose fraction ethanol and paper pulp is obtained, from the hemicellulose fraction ethanol, furfural, acetic acid and formic acid, and the lignin is used to generate power and steam.

Also **CIMV** in France uses formic acid and acetic acid for their organosolv process. The pilot plant is running since 2006 and processes wheat straw into a variety of intermediar products: paper pulp and glucose from cellulose, C5-sugars from hemicellulose, and lignin for the chemical industry (not as fuel).

Lignol in Canada uses ethanol as solvent in their Alcell process. Ethanol has a big advantage over other organic solvents as it has a low boiling point and can easily be recovered by distillation. The cellulose and hemicellulose fractions are hydrolysed by enzymes for the production of ethanol and other biochemicals. The high purity lignin is considered as a new class of valuable-added renewable aromatic chemicals. Lignol has a running pilot plant since 2010.

- Oxidative delignification (TRL 8)

  Delignification of lignocellulose can be achieved by treatment with an oxidizing agent such as hydrogen peroxide, ozone, oxygen or air. The effectiveness in delignification can be attributed to the high reactivity of oxidizing chemicals with the aromatic ring. However, oxidation might not be very selective, leading to high chemical use and high processing costs.

  Wet oxidation operates with oxygen or air in combination with water at elevated temperature and pressure. It was presented as an alternative to steam explosion which had become the most widely used pretreatment method. Industrially, wet air oxidation processes have been used for the treatment of wastes with a high organic matter by oxidation of soluble or suspended materials by using oxygen in aqueous phase at high temperatures (150-350 °C) and high pressure (5-20 MPa) [45]. However, high pressure equipment is expensive and continuous operation is difficult.

  BioGasol in Denmark combines wet oxidation with steam explosion for the production of ethanol from agricultural residues. The process is called ‘wet explosion’ and the use of oxygen and pressure release at high temperature (170-200 °C) are combined. All by-products are further converted to energy carriers (e.g. ethanol, hydrogen, methane and solid biofuel). A demonstration plant is running in Denmark since 2011.

- Room Temperature Ionic Liquids (TRL 4)

  Room Temperature Ionic Liquids (RTIL) are salts that are in the liquid phase at temperatures as low as room temperature. There is a vast variety of different RTIL, but they share a common characteristic in that they are usually comprised of an inorganic anion and an organic cation of very heterogeneous molecular structure. The difference in the molecular structure renders the bonding of the ions weak enough for the salt to appear as liquid at room temperature.

  As of yet, there is no industrial application employing RTIL. There are indications that mainly due to their polarity and in general their unique properties, they can function as selective solvents of lignin or cellulose. That would result in separation of lignin and increase of cellulose accessibility under ambient conditions and with no use of acid or alkaline solution. The formation of inhibitor compounds could also be avoided. Despite the potential this method appears to have, there are several uncertainties due to lack of experience. Among the most important ones are the ability to recover the RTIL used, the toxicity of the compounds, and the combination of water with RTIL. In addition, RTIL are expensive solvents and research is done on cheaper alternatives.

3.3.2 Explosion pretreatment processes

Explosion processes are characterized by high T and P treatment at short residence times (few minutes). At pressure release the biomass undergoes explosive decompression with hemicellulose degradation and lignin matrix disruption as result. Explosion processes are conducted with water (uncatalysed or catalysed by e.g. sulphuric acid), SO_2, NH_3 or CO_2.

- H_2O (TRL 9)
  Steam explosion is one of the most applied pretreatment processes owing to its low use of chemicals and limited energy consumption. With this method high-pressure saturated steam is injected into a batch or continuous reactor filled with biomass. During steam injection the temperature rises to 160-260 °C. Subsequently, pressure is suddenly reduced and the biomass undergoes an explosive decompression with hemicellulose degradation and lignin matrix disruption as result.
  Steam explosion is by far the most applied pretreatment technology by industrial companies. **Abengoa** (a large ethanol producer from cereals) produces ethanol from wheat straw or corn stover in demonstration plants in Spain and the US by sulphuric acid-catalysed steam explosion. All by-products, including lignin residues, are used for energy applications.
  BetaRenewables is building a commercial plant in Italy for the production of ethanol from Arundo Donax (giant cane) and wheat straw. The pretreatment applied is uncatalysed steam explosion. Sugars are further converted by SSF to ethanol, and residual lignin is used as energy source. Their technology is called PROESA and is licensed to other companies.
  In the US a demonstration plant is operated by **BP Biofuels** for the production of ethanol. The pretreatment is acid-catalysed steam explosion followed by enzymatic hydrolysis (with enzymes provided by Verenium). C5 and C6 sugars are separately fermented to ethanol, and lignin is burned for steam generation.
  Another big player is **Iogen** (a biotech company and enzyme producer) in Canada. The demonstration plant is running since 2004 and produces ethanol from wheat straw. The pretreatment is a ‘modified’ steam explosion process followed by enzymatic hydrolysis. Iogen and Shell had plans for commercial activities on this field but the plans were cancelled. Now Iogen is cooperating with the Raizen Group (producer of sugarcane ethanol) for the development of a cellulosic ethanol plant in Brazil. For this process sugarcane bagasse will be used as biomass source.
- SO_2 (TRL 5)
  It is known that impregnation of softwood with SO_2 (sulfur dioxide) prior to steam explosion improves the enzymatic saccharification. Steam explosion pretreatment with SO2 is related to a well-known technology known as sulfite pulping.
- NH_3 (TRL 5)

In the AFEX process, biomass is treated with liquid ammonia at high temperature and pressure. After a few seconds, pressure is swiftly reduced. It reduces the lignin content and removes some hemicellulose while decrystallising cellulose. The cost of ammonia and especially of ammonia recovery drives the cost of the pretreatment, although ammonia is easily recovered due to its volatility, but shipping of NH_3 will be costly due to safety reasons.

- CO_2 (TRL 4)
  This method is similar to steam and ammonia fibre explosion; high pressure CO2 is injected into the batch reactor and then liberated by an explosive decompression. It is believed that CO2 reacts to carbonic acid (H_2CO_3, carbon dioxide in water), thereby improving the hydrolysis rate. Yields of CO_2 explosion are in general lower than those obtained with steam or ammonia explosion [23].

3.3.3 Biochemical hydrolysis and fermentation processes

To this group belong biochemical processes which make use of enzymes or bacteria to convert pretreated biomass (see previous section) into intermediate products or end products. Together with the pretreatment, hydrolysis and fermentation make up the value chain from biomass to end product.

- Enzymatic hydrolysis (existing)
  This process is applied for the conversion of polymeric carbohydrates in biomass (e.g. starch, cellulose, hemicellulose) to monomeric carbohydrates (sugars like glucose or xylose) by the addition of enzymes (e.g. amylase, cellulase, xylanase). This process is also called saccharification.
- Fermentation (existing)
  Fermentation is a metabolic process in which sugars are being converted by bacteria to acids (e.g. lactic acid, succinic acid), gases or alcohols (e.g. ethanol, butanol).
- Simultaneous saccharification and fermentation (SSF) (existing?)
  SSF is a process where enzymatic hydrolysis and fermentation is combined. The enzymatic hydrolysis can be performed simultaneously with the fermentation of glucose and/or xylose in a process referred to as simultaneous saccharification and fermentation (SSF). Besides reduced capital cost, SSF process offers several advantages which include continuous removal of end-products of enzymatic hydrolysis that inhibit enzymes and gives higher product yields.

3.3.4 Applications

- Main products: biofuels (*e.g.* ethanol, butanol), chemical building blocks (*e.g.* ethanol, butanol, lactic acid, succinic acid etc)[12], cellulose pulp
- Main side products in existing processes: energy from lignin-rich residues, hemicelluloses
- Possible side products in the future: lignin and hemicelluloses (polymeric, monomeric) as chemical building blocks.

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[12] Harmsen PFH, Hackmann MM, Bos HL, Green building blocks for bio-based plastics, *Biofuels, Bioprod Bioref*, **8**(3):306-24 (2014)

3.3.5 Selection for description in database

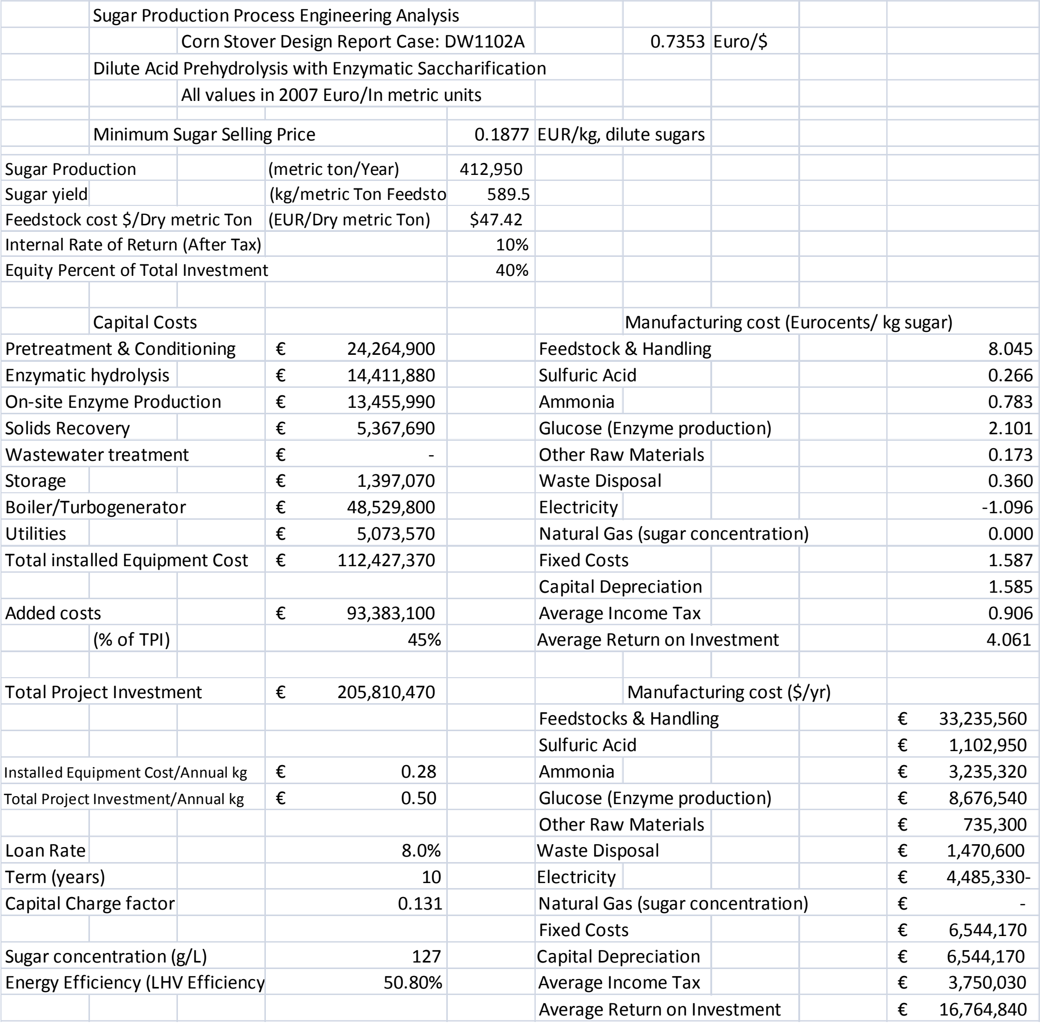
- **Dilute acid hydrolysis and enzymatic hydrolysis for the production of fermentable sugars from lignocellulose**[13]

The most extensive, publicly available techno-economic analysis of lignocellulosic biomass pretreatment is the analysis provided by the National Renewable Energy Laboratory[14]. This study analyses the cost of producing bio-ethanol from corn stover in the United States. The study provides good insights in producing fermentable sugars from lignocellulose for fermentation to chemical building blocks like ethanol or lactic acid.

In the table below, data for the production costs of fermentable sugars from corn stover are presented. An important quote from the study states that:

"It should be stressed that the sugar stream produced in this analysis is strictly "imaginary" . The purpose of this analysis is merely to separate the cost of producing sugars from the downstream costs of producing ethanol or other products."

Cost of producing fermentable sugars from lignocellulose (based on NREL 2011)



Sugar Production Process Engineering Analysis					
Corn Stover Design Report Case: DW1102A			0.7353 Euro/$		
Dilute Acid Prehydrolysis with Enzymatic Saccharification					
All values in 2007 Euro/In metric units					
Minimum Sugar Selling Price		0.1877	EUR/kg, dilute sugars		
Sugar Production	(metric ton/Year)	412,950			
Sugar yield	(kg/metric Ton Feedsto	589.5			
Feedstock cost $/Dry metric Ton	(EUR/Dry metric Ton)	$47.42			
Internal Rate of Return (After Tax)		10%			
Equity Percent of Total Investment		40%			
Capital Costs			Manufacturing cost (Eurocents/ kg sugar)		
Pretreatment & Conditioning	€	24,264,900	Feedstock & Handling		8.045
Enzymatic hydrolysis	€	14,411,880	Sulfuric Acid		0.266
On-site Enzyme Production	€	13,455,990	Ammonia		0.783
Solids Recovery	€	5,367,690	Glucose (Enzyme production)		2.101
Wastewater treatment	€	-	Other Raw Materials		0.173
Storage	€	1,397,070	Waste Disposal		0.360
Boiler/Turbogenerator	€	48,529,800	Electricity		-1.096
Utilities	€	5,073,570	Natural Gas (sugar concentration)		0.000
Total installed Equipment Cost	€	112,427,370	Fixed Costs		1.587
			Capital Depreciation		1.585
Added costs	€	93,383,100	Average Income Tax		0.906
(% of TPI)		45%	Average Return on Investment		4.061
Total Project Investment	€	205,810,470	Manufacturing cost ($/yr)		
			Feedstocks & Handling	€	33,235,560
			Sulfuric Acid	€	1,102,950
Installed Equipment Cost/Annual kg	€	0.28	Ammonia	€	3,235,320
Total Project Investment/Annual kg	€	0.50	Glucose (Enzyme production)	€	8,676,540
			Other Raw Materials	€	735,300
Loan Rate		8.0%	Waste Disposal	€	1,470,600
Term (years)		10	Electricity	€	4,485,330-
Capital Charge factor		0.131	Natural Gas (sugar concentration)	€	-
			Fixed Costs	€	6,544,170
Sugar concentration (g/L)		127	Capital Depreciation	€	6,544,170
Energy Efficiency (LHV Efficiency		50.80%	Average Income Tax	€	3,750,030
			Average Return on Investment	€	16,764,840

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[13] Harmsen PFH, Lips S, Bakker RRC, *Pretreatment of lignocellulose for biotechnological production of lactic acid; reserach review,* WUR FBR (2012).

[14] Humbird D, Davis R, Tao L, Kinchin C, Hsu D, Aden A, et al., *Process Design and Economics for Biochemical Conversion of Lignocellulosic biomass to ethanol; dilute-acid pretreatment and enzymatic hydrolysis of corn stover,* NREL (2011).

The costing study is based on a set of assumptions, that each carry an intrinsic variance in their level of confidence. For instance, the plant life is estimated to be 30 years, which can be considered as very optimistic. Furthermore, in the cost analysis for fermentable sugars, the following assumptions and modifications to the ethanol cost study are made:

- Enzymatic hydrolysis is assumed to be carried out in a sterile way and nearly to completion so that a transferable sugar stream is produced
- A lignin press with counter-current washing is added after hydrolysis to separate lignin and unreacted insoluble solids from the dilute mixed sugar stream
- The combustion section for lignin is retained, and an electricity co-product credit is assumed for these solids
- A wastewater cost is kept to account for treatment of the pretreatment flash vapor; however, given that the beer column stillage (from the ethanol model) is not applicable in the sugar model, there is no on-site wastewater facility included. Instead, an operating cost of $ 0.09/kg COD is applied for disposal of the wastewater material to off-site treatment
- Enzymatic hydrolysis is assumed to achieve 90% cellulose-to-glucose conversion

Data in the table show a minimum selling price for fermentable sugars of 187 €/ton sugars produced from corn stover, in a facility that produces approximately 413 kton of sugars on an annual basis. If the feedstock is assumed to be corn stover, the associated yearly biomass feedstock requirement amounts to 700 kton of corn stover, on a dry matter basis. The data further show that feedstock costs (taken at 47.48 €/ton feedstock price including handling) amounts to 43% of total production costs, whereas capital depreciation and return on investment combined amount to 30% of total production costs. A full distribution of cost components is provided in Figure 8:

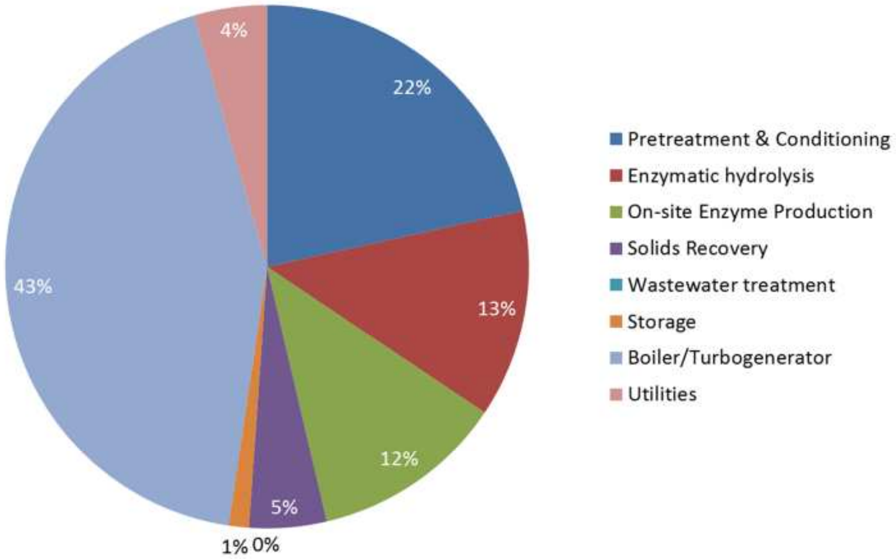

Figure 8: Distribution of cost components in lignocellulose biomass to sugars (for assumptions see table)

It is very important to point out that the cost estimates are for sugars that are contained in diluted form (i.e. they cannot be directly compared to world sugar market price, or other market data), and that it contains a significant concentration of other organic and inorganic components.

- **Fermentation**[15]

Fermentation is the conversion of an organic substrate to a product using cell cultures or microorganisms such as bacteria or fungi. The organic substrate is generally a sugar solution. Fermentation can take place in the absence of oxygen (anaerobic) or in the presence of oxygen (aerobic). Well-known examples are fermentation of biomass into biogas, sugar to alcohol and CO2 for the production of wine, beer and bread, and the conversion of lactose to lactic acid for the production of yogurt. Fermentation processes are characterized by the following aspects:

- Process conditions are of great importance. Micro-organisms can handle a certain sugar concentration, and this is different for each per micro-organism. In case of batch processes sugar concentrations are up to 120 g/l. This so-called substrate inhibition (inhibition of the process by the substrate, in this case sugar) can be prevented by dosing the substrate during the fermentation process (fed-batch).
- In addition to substrate inhibition, micro-organisms are also sensitive to the product they produce. Finished products are often more toxic than the substrate, the sugar, so inhibition takes place at lower concentrations. Product inhibition can be avoided by removing product during the fermentation process.
- Finally, other substances in the fermentation medium may hinder fermentation. A well-known example is the presence of acetic acid in the production of ethanol.

Chemical building blocks by fermentation of sugars: Theoretical efficiency and industrial activities

Building block	**Formula**	**g/mol**	**#**	**Theoretical efficiency**	**Remarks**
Succinic acid	C4H6O4	118	2	131%	>100% by incorporation of CO_2 (commercial)
Lactic acid	C3H6O3	90	2	100%	Corbion (commercial)
3-HPA	C3H6O3	90	2	100%	Novozymes (R&D)
Propane diol	C3H8O2	76	2	84%	DuPont (Commercial)
Itaconic acid	C5H6O4	130	1	72%	Commercial
Isopropanol	C3H8O	60	2	67%	Mitsui (R&D)
Ethanol	C2H6O	46	2	51%	Commercial
Butane diol	C4H10O2	90	1	50%	Commercial
Methacrylic acid	C4H6O2	86	1	48%	Mitsubishi (R&D)
Isobutanol	C4H6O2	86	1	48%	Gevo (Commercial)
Butanol	C4H10O	74	1	41%	Cathay (Commercial)
Isoprene	C5H8	68	1	38%	Ajinomoto (Pilot/R&D)

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[15] Harmsen PFH, Lips S, Bos HL, Smit B, Berkum Sv, Helming J, et al., *Suiker als grondstof voor de Nederlandse chemische industrie; gewassen, processen, beleid,* Wageningen UR, FBR en LEI (2014)

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

S2Biom Project Grant Agreement n°608622

ANNEX II of Deliverable D2.1

Classification of biomass properties
Draft instructions

30.4.2015

Eija Alakangas, VTT

SEVENTH FRAMEWORK
PROGRAMME

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

About this document

This report corresponds to Annex I of Deliverable D2.1 of S2Biom. It has been prepared by:

VTT Technical Research Centre of Finland
P.O. Box 1603, FI-40101 Jyväskylä, Finland
Eija Alakangas
E-mail: eija.alakangas@vtt.fi
Phone: +358 400 542 454

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Table of contents

1. Raw material or fuel requirements for solid biomass

Classification of solid biofuels and raw material will be made for each traded form (see Table 2 in Annex I) separately. Fill in tables for each conversion technology, if requirements are different. For examples wood chip for small-scale applications need dried fuel and particle size should be more homogenous and length of oversized particles is smaller than for industrial applications (medium and large scale heating, CHP or power plants). Tables can also be for classification of raw material for pyrolysis oil (e.g. wood chips, hog fuel, sawdust) and thermal treatment e.g. torrefaction (forest residue chips, hog fuel etc.).

Classification of raw material will be divided in the following groups according to EN ISO 17225-1 standard (See Table 1 in Annex I).

1. Woody biomass
2. Herbaceous biomass
3. Fruit biomass
4. Aquatic biomass
5. Blends and mixtures

   The mixing can be either intentional (blends) or unintentional (mixtures).

   Examples of blends and mixtures)

   a) Blend; 80w-% sawdust from coniferous (1.2.1.2) and 20w-% reed canary grass (2.1.2.1);

   b) Mixture; whole trees without roots from birch (1.1.1.1), whole trees without roots from spruce (1.1.1.2)

Specification of properties for different traded forms are carried out by the following standards:

- Stem wood/round wood or log wood, EN ISO 17225-1, for industrial use (medium and large scale applications) (Table 6)
- Sawdust, EN ISO 17225-1 (Table 7)
- Shavings, EN ISO 17225-1 (Table 8)
- Bark, EN ISO 17225-1 (Table 9)
- Bales from straw, reed canary grass and Miscanthus, EN ISO 17225-1 (Table 10)
- Energy grain, EN ISO 17225-1 (Table 11)
- Olive residues, EN ISO 17225-1 (Table 12)
- Fruit seeds, EN ISO 17225-1 (Table 13)
- Charcoals for residential use, EN ISO 17225-1 (Table 14)

- Thermally treated biomass, pellets and briquettes under Table 3 and 4, EN ISO 17225-1 (Table 15).

- Wood chips and hog fuel, EN ISO 17225-1, for medium and large scale applications (Table 4) and for residential and commercial applications[1], EN ISO 17225-4 (Table 20)

- Biopellets for general use including also thermally treated pellets, EN ISO 17225-1 (Table 4) and for residential and commercial applications, EN ISO 17225-2 (Table 17) and wood pellets for industrial use (Table 18)

- Biobriquettes for general use including also thermally treated briquettes, EN ISO 17225-1 (Table 3) and wood briquettes for residential and commercial applications, EN ISO 17225-3 (Table 19)

- Oven-ready firewood for residential and commercial applications, EN ISO 17225-5 (Table 21)

- Non-woody pellets for residential and commercial applications, EN ISO 17225-6 (< 1 MW), Table 22 for blends and mixtures of different agrobiomass, Table 23 for cereal straw, miscanthus and reed canary grass pellets

- Non-wood briquettes residential and commercial applications, EN ISO 17225-7, Table 24

- Other traded forms, EN ISO 17225-1 (Table 16)

Please specify properties listed in the Tables for each traded form. Minimum requirement is to get data of those properties, which are normative (mandatory).

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[1] commercial application is a facility that utilise solid biofuel burning appliances or equipment that have the similar fuel requirements as residential appliances. Commercial applications should not be confused with industrial applications, which can utilise a much wider array of materials and have vastly different fuel requirements.

2. Template for solid biofuel or raw material classification

		add photo of raw material and traded form					

Origin and source

1	Raw material	select from Annex 1 – Table 1					
2	Species of biomass	e.g. spruce, reed canary grass (Latin name to be added if possible)					
3	Content of lignin, cellulose hemicellulose, min – max, g/kg	Lignin		Cellulose		Hemi-sellulose	
4	Traded form	select from Annex 1 – Table 2 for solid biofuels					
5	Conversion technology	select from D2.1					

Property class requirements (according to Tables 3 – 24)

6	Dimensions, L, D or P, mm	select from appropriate table for different traded form
7	Amount of F, (w-% as received)	Only for wood chips, pellets and energy grain
8	Ash, A, (w-% of dry basis)	
9	Moisture, M, w-%	select from appropriate table for different traded form Minimum and maximum value, typical value
10	Bulk density, BD, (kg/m^3 as received)	for wood chips or hog fuel
11	Bale density, BD, (kg/m^3 as received)	for bales
12	Particle density, DE (g/cm^3 as received)	for briquettes
13	Net calorific value, dry (MJ/kg)	for all biomass
14	Net calorific value as received (MJ/kg)	for all biomass (minimum requirement)
15	Mechanical durability, DU(%)	for briquettes and pellets
16	Fixed carbon, C (w-% of dry basis)[2]	only only for thermally treated biomass (e.g. torrefied or steam exploded) and charcoal
17	Volatile matter, VM, (w-% of dry basis)	only for thermally treated biomass (e.g. torrefied or steam exploded)
18	Ash melting behavior (DT), ^{o}C	It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Chemical composition (minimum, maximum and typical value)

19	C, w-% dry basis		20	H, w-% dry basis		21	N, w-% dry basis	
22	Cl, w-% dry basis		23	S, w-% dry basis				
24	As, mg/kg dry basis		25	Cd, mg/kg dry basis		26	Cr, mg/kg dry basis	
27	Cu, mg/kg dry basis		28	Pb, mg/kg dry basis		29	Hg, mg/kg dry basis	
30	Ni, mg/kg dry basis		31	Zn, mg/kg dry basis		32	Mg, mg/kg dry basis	
33	K, mg/kg dry basis		34	Na, mg/kg dry basis				

Other

35	Torrefaction degree by TGA (Thermogravimetric analysis)[3]						
	Source: xx						

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[2] Fixed carbon (%) is calculated by the following: 100 - [moisture (w-%) + ash (w-%)+volatile matter (w-%)]. All percentages are on the same moisture base.

[3] Weight loss at 280-290 °C with residence time of 30 minutes at T> 200ºC (% AWL)

3. Example of wood chips from logging residues, coniferous

Origin and source

1	Raw material	1.1.4.2 Logging residues, coniferous, fresh or 1.1.4.4 Logging residues, coniferous, stored					
2	Species of biomass	Norway spruce (*Picea abies)*					
3	Content of lignin, cellulose hemicellulose, min – max, g/kg or w-%	Lignin	28 w-%	Cellulose	41 w-%	Hemi-sellulose	24 w-%
4	Traded form	wood chips or hog fuel					
5	Conversion technology	grate combustion (medium and large scale) Fluidized bed combustion raw material for pyrolysis oil production or thermally treated biomass production					

Property class requirements (according to Table 4)

6	Dimensions, L, D or P, mm	Select from Table 4, from P16 to P63,
7	Amount of F, (w-% as received)	for grate combustion amount of fines maximum F25
8	Ash, A, (w-% of dry basis)	A 1.5 to A3.0
9	Moisture, M, w-%	Minimum and maximum value (M30 to M45), typical value (M40 for seasoned logging residues)
10	Bulk density, BD, (kg/m^3 as received)	BD 250 to BD 300
11	Bale density, BD, (kg/m^3 as received)	not applicable
12	Particle density, DE (g/cm^3 as received)	not applicable
13	Net calorific value, dry (MJ/kg)	19.00 – 19.30 MJ/kg
14	Net calorific value as received (MJ/kg)	10.00 – 12.40 MJ/kg (depends on moisture content)
15	Mechanical durability, DU(%)	not applicable
16	Fixed carbon, C (w-% of dry basis)	not applicable
17	Volatile matter, VM, (w-% of dry basis)[4]	81 – 88 w-%
18	Ash melting behavior (DT), °C	1205

Chemical composition (minimum, maximum and typical value)

19	C, w-% dry basis	51	20	H, w-% dry basis	6.1	21	N, w-% dry basis	0.3 – 0.8 (0.5)
22	Cl, w-% dry basis	<0.01 – 0.06 (0.05)	23	S, w-% dry basis	< 0,02 max. 0,05			
24	As, mg/kg dry basis	1 – 6 (< 1)	25	Cd, mg/kg dry basis	0.1 – 0.8	26	Cr, mg/kg dry basis	0.7 – 1.2
27	Cu, mg/kg dry basis	10 -200	28	Pb, mg/kg dry basis	0.4 – 4.0	29	Hg, mg/kg dry basis	0.03
30	Ni, mg/kg dry basis	0.4 – 3.0	31	Zn, mg/kg dry basis	8 - 30	32	Mg, mg/kg dry basis	400 - 2 000
33	K, mg/kg dry basis	80 - 170	34	Na, mg/kg dry basis	0.4 – 4.0			

Source: VTT

Annex I – Classification of raw material and traded forms according to EN ISO 17225-series (confidential)

Table 1 — Classification of origin and sources of solid biofuels

1. Woody biomass	1.1 Forest, plantation and other virgin wood	1.1.1 Whole trees without roots	1.1.1.1 Broad-leaf
			1.1.1.2 Coniferous
			1.1.1.3 Short rotation coppice
			1.1.1.4 Bushes
			1.1.1.5 Blends and mixtures
		1.1.2 Whole trees with roots	1.1.2.1 Broad-leaf
			1.1.2.2 Coniferous
			1.1.2.3 Short rotation coppice
			1.1.2.4 Bushes
			1.1.2.5 Blends and mixtures
		1.1.3 Stemwood	1.1.3.1 Broad-leaf with bark
			1.1.3.2 Coniferous with bark
			1.1.3.3 Broad-leaf without bark
			1.1.3.4 Coniferous without bark
			1.1.3.5 Blends and mixtures
		1.1.4 Logging residues	1.1.4.1 Fresh/Green, Broad-leaf (including leaves)
			1.1.4.2 Fresh/Green, Coniferous (including needles)
			1.1.4.3 Stored, Broad-leaf
			1.1.4.4 Stored, Coniferous
			1.1.4.5 Blends and mixtures
		1.1.5 Stumps/roots	1.1.5.1 Broad-leaf
			1.1.5.2 Coniferous
			1.1.5.3 Short rotation coppice
			1.1.5.4 Bushes
			1.1.5.5 Blends and mixtures
		1.1.6 Bark (from forestry operations)	
		1.1.7 Segregated wood from gardens, parks, roadside maintenance, vineyards, fruit orchards and driftwood from freshwater	
		1.1.8 Blends and mixtures	
	1.2 By-products and residues from wood processing industry	1.2.1 Chemically untreated wood by-products and residues	1.2.1.1 Broad-leaf with bark
			1.2.1.2 Coniferous with bark
			1.2.1.3 Broad-leaf without bark
			1.2.1.4 Coniferous without bark
			1.2.1.5 Bark (from industry operations)
		1.2.2 Chemically treated wood by-products, residues, fibres and wood constituents	1.2.2.1 Without bark
			1.2.2.2 With bark
			1.2.2.3 Bark (from industry operations)
			1.2.2.4 Fibres and wood constituents
		1.2.3 Blends and mixtures	

	1.3 Used wood	1.3.1 Chemically untreated used wood	1.3.1.1 Without bark
			1.3.1.2 With bark
			1.3.1.3 Bark
		1.3.2 Chemically treated used wood	1.3.2.1 Without bark
			1.3.2.2 With bark
			1.3.2.3 Bark
		1.3.3 Blends and mixtures	
	1.4 Blends and mixtures		

NOTE 1 If appropriate, also the actual species (e.g. spruce, wheat) of biomass may be stated according to EN 13556, *Round and sawn timber — Nomenclature of timbers used in Europe*[1].

NOTE 2 Driftwood from saltwater is not recommended as a fuel.

Table 1 — (continued)

2. Herbaceous biomass	2.1 Herbaceous biomass from agriculture and horticulture	2.1.1 Cereal crops	2.1.1.1 Whole plant
			2.1.1.2 Straw parts
			2.1.1.3 Grains or seeds
			2.1.1.4 Husks or shells
			2.1.1.5 Blends and mixtures
		2.1.2 Grasses	2.1.2.1 Whole plant
			2.1.2.2 Straw parts
			2.1.2.3 Seeds
			2.1.2.4 Shells
			2.1.2.5 Bamboo
			2.1.2.6 Blends and mixtures
		2.1.3 Oil seed crops	2.1.3.1 Whole plant
			2.1.3.2 Stalks and leaves
			2.1.3.3 Seeds
			2.1.3.4 Husks or shells
			2.1.3.5 Blends and mixtures
		2.1.4 Root crops	2.1.4.1 Whole plant
			2.1.4.2 Stalks and leaves
			2.1.4.3 Root
			2.1.4.4 Blends and mixtures
		2.1.5 Legume crops	2.1.5.1 Whole plant
			2.1.5.2 Stalks and leaves
			2.1.5.3 Fruit
			2.1.5.4 Pods
			2.1.5.5 Blends and mixtures
		2.1.6 Flowers	2.1.6.1 Whole plant
			2.1.6.2 Stalks and leaves
			2.1.6.3 Seeds
			2.1.6.4 Blends and mixtures
		2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards	
		2.1.8 Blends and mixtures	
	2.2 By-products and residues from food and herbaceous processing industry	2.2.1 Chemically untreated herbaceous residues	2.2.1.1 Cereal crops and grasses
			2.2.1.2 Oil seed crops
			2.2.1.3 Root crops
			2.2.1.4 Legume crops
			2.2.1.5 Flowers
			2.2.1.6 Blends and mixtures
		2.2.2 Chemically treated herbaceous residues	2.2.2.1 Cereal crops and grasses
			2.2.2.2 Oil seed crops
			2.2.2.3 Root crops
			2.2.2.4 Legume crops
			2.2.2.5 Flowers
			2.2.2.6 Blends and mixtures
		2.2.3 Blends and mixtures	
	2.3 Blends and mixtures		

Table 1 — (continued)

3. Fruit biomass	3.1 Orchard and horticulture fruit	3.1.1 Berries	3.1.1.1 Whole berries
			3.1.1.2 Flesh
			3.1.1.3 Seeds
			3.1.1.4 Blends and mixtures
		3.1.2 Stone/kernel fruits	3.1.2.1 Whole fruit
			3.1.2.2 Flesh
			3.1.2.3 Stone/kernel/fruit fibre
			3.1.2.4 Blends and mixtures
		3.1.3 Nuts and acorns	3.1.3.1 Whole nuts
			3.1.3.2 Shells/husks
			3.1.3.3 Kernels
			3.1.3.4 Blends and mixtures
		3.1.4 Blends and mixtures	
	3.2 By-products and residues from food and fruit processing industry	3.2.1 Chemically untreated fruit residues	3.2.1.1 Berries
			3.2.1.2 Stone/kernel fruits/fruit fibre
			3.2.1.3 Nuts and acorns
			3.2.1.4 Crude olive cake
			3.2.1.5 Blends and mixtures
		3.2.2 Chemically treated fruit residues	3.2.2.1 Berries
			3.2.2.2 Stone/kernel fruits
			3.2.2.3 Nuts and acorns
			3.2.2.4 Exhausted olive cake
			3.2.2.5 Blends and mixtures
		3.2.3 Blends and mixtures	
	3.3 Blends and mixtures		
4. Aquatic biomass	4.1 Algae	4.1.1 Micro algae (latin name to be stated)	
		4.1.2 Macro algae (latin name to be stated)	
		4.1.3 Blends and mixtures	
	4.2 Water hyacinth		
	4.3 Lake and sea weed	4.3.1 Lake weed (latin name to be stated)	
		4.3.2 Sea weed	4.3.2.1 Blue sea weed (latin name to be stated)
			4.3.2.2 Green sea weed (latin name to be stated)
			4.3.2.3 Blue-green sea weed (latin name to be stated)
			4.3.2.4 Brown sea weed (latin name to be stated)
			4.3.2.5 Red sea weed (latin name to be stated)
		4.3.3 Blends and mixtures	
	4.4 Reeds	4.4.1 Common reed	
		4.4.2 Other reed	
		4.4.3 Blends and mixtures	
	4.5 Blends and mixtures		
5 Blends and mixtures	5.1 Blends		
	5.2 Mixtures		

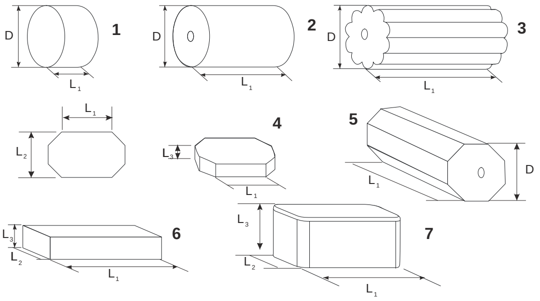
NOTE 3 Group 5 "Blends and mixtures" include blends and mixtures from the main origin-based solid biofuel groups 1 to 4.

Table 2 — Major traded forms and raw materials of solid biofuels

Fuel name	Typical particle size	Common preparation method
Whole tree	> 500 mm	No preparation or delimbed
Wood chips	5 mm to 100 mm	Cutting with sharp tools
Hog fuel	Varying	Crushing with blunt tools
Stemwood/roundwood	> 100 cm	Cutting with sharp tools
Logwood	50 cm to 100 cm	Cutting with sharp tools
Firewood	5 cm to 100 cm	Cutting with sharp tools
Slabs and offcuts	Varying	Cutting with sharp tools
Bark	Varying	Debarking residue from trees (shredded or unshredded)
Bundle (e.g. logging residue bundles)	Varying	Lengthwise oriented & bound
Fuel powder	< 1 mm	Milling
Sawdust	1 mm to 5 mm	Cutting with sharp tools
Shavings	1 mm to 30mm	Planing with sharp tools
Briquettes	Ø > 25 mm	Mechanical compression
Pellets	Ø ≤ 25 mm	Mechanical compression
Bales Small square bales Big square bales Round bales	 0,1 m^3 3,7 m^3 2,1 m^3	 Compressed and bound to squares Compressed and bound to squares Compressed and bound to cylinders
Chopped straw or energy grass	10 mm to 200 mm	Chopped during harvesting or before combustion
Grain or seed	Varying	No preparation or drying except for process operations necessary for storage for cereal grain
Fruit stones or kernel	5 mm to 15 mm	No preparation or pressing and extraction by chemicals.
Fibre cake	Varying	Prepared from fibrous waste by dewatering
Charcoal	Varying	Charcoal is prepared by the destructive distillation and pyrolysis of biomass.
Thermally treated biomass (e.g. torrefied or steam explosed)	Varying	Mild pre-treatment of biomass at a temperature between 200-300 °C for a short time period (e.g. 60 minutes).

NOTE 1 Also other forms may be used.

Table 3 — Specification of properties for briquettes (EN ISO 17225-1)

	Master table	
	Origin: According to 6.1 and Table 1	Woody biomass (1); Herbaceous biomass (2); Fruit biomass (3); Aquatic biomass (4); Blends and mixtures (5).
	Traded Form (see Table 2)	Briquette
Normative	**Dimensions** (mm)	
	Diameter (D) and **Length** (L)	
	Diameter, height, width and length to be stated L_1 length, L_2 width, L_3 height Specify shape according to Figure 2 e.g. 1 or 2, etc.	 L Length D Diameter **Figure 2 — Examples of briquettes**
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2	
	M10	≤ 10 %
	M12	≤ 12 %
	M15	≤ 15 %
	Ash, A (w-% of dry basis) ISO 18122	
	A0.5	≤ 0,5 %
	A0.7	≤ 0,7 %
	A1.0	≤ 1,0 %
	A1.5	≤ 1,5 %
	A2.0	≤ 2,0 %
	A3.0	≤ 3,0 %
	A5.0	≤ 5,0 %
	A7.0	≤ 7,0 %
	A10.0	≤ 10,0 %
	A10.0+	> 10,0 % (maximum value to be stated)
	Particle density, DE (g/cm^3 as received) ISO 18847	
	DE0.8	≥ 0,8 g/cm^3
	DE0.9	≥ 0,9 g/cm^3
	DE1.0	≥ 1,0 g/cm^3
	DE1.1	≥ 1,1 g/cm^3
	DE1.2+	> 1,2 g/cm^3 (maximum value to be stated)
	Additives [a] (w-% of pressing mass)	Type and content of pressing aids, slagging inhibitors or any other additives have to be stated
	Net calorific value, Q (MJ/kg or kWh/kg as received) ISO 18125	Minimum value to be stated [b]

Normative / informative	**Mechanical durability, DU** (w-% of briquettes after testing) ISO 17831-2		
	DU95.0 DU90.0 DU90.0-	≥ 95,0 % ≥ 90,0 % < 90,0 % (minimum value to be stated)	Informative: only if traded in bulk
	Nitrogen, N (w-% of dry basis) ISO 16948		
	N0.2 N0.3 N0.5 N0.7 N1.0 N1.5 N2.0 N3.0 N3.0+	≤ 0,2 % ≤ 0,3 % ≤ 0,5 % ≤ 0,7 % ≤ 1,0 % ≤ 1,5 % ≤ 2,0 % ≤ 3,0 % >3,0 % (maximum value to be stated)	Normative: Chemically treated biomass (1.2.2; 1.3.2; 2.2.2; 3.2.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	Sulphur, S (w-% of dry basis) ISO 16994		
	S0.02 S0.03 S0.04 S0.05 S0.08 S0.10 S0.20 S0.20+	≤ 0,02 % ≤ 0,03 % ≤ 0,04 % ≤ 0,05 % ≤ 0,08 % ≤ 0,10 % ≤ 0,20 % > 0,20 % (maximum value to be stated)	Normative: Chemically treated biomass (1.2.2; 1.3.2; 2.2.2; 3.2.2) or if sulphur containing additives have been used. Informative: All fuels that are not chemically treated (see the exceptions above)
	Chlorine, Cl (w-% of dry basis) ISO 16994		
	Cl0.01 Cl0.02 Cl0.03 Cl0.07 Cl0.10 Cl0.20 Cl0.30 Cl0.30+	≤ 0,01 % ≤ 0,02 % ≤ 0,03 % ≤ 0,07 % ≤ 0,10 % ≤ 0,20 % ≤ 0,30 % > 0,30 % (maximum value to be stated)	Normative: Chemically treated biomass (1.2.2; 1.3.2; 2.2.2; 3.2.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	Fixed carbon, C [c] (w-% of dry basis)		
	Minimum value to be stated		Normative only for thermally treated biomass briquettes
	Volatile matter, VM (w-% of dry basis) ISO 18123		
	Maximum value to be stated		Normative only for thermally treated biomass briquettes
Informative: **Ash melting behaviour** [d] (°C) CEN/TS 15370-1 [4]			Should be stated

[a] The maximum amount of additive is 20 w-% of pressing mass. Type stated as chemical substance (e.g. starch, corn flour, potato flour, vegetable oil, lignin). If amount is greater, then raw material for briquette is blend.

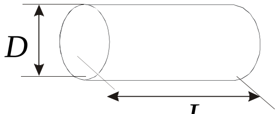
[b] Minimum value for torrefied or other thermally treated biomass briquettes are usually ≥ 18 MJ/kg.

[c] Fixed carbon (%) is calculated by the following: 100 – [moisture (w-%) + ash (w-%) + volatile matter (w-%)]. All percentages are on the same moisture basis.

[d] Special attention should be paid to the ash melting behaviour for some biomass fuels, for example eucalyptus, poplar, short rotation coppice, straw, miscanthus and olive stone. It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

NOTE 5 Thermally treated biomass briquettes (e.g. torrefied briquettes) are also included in Table 3.

Table 4 — Specification of properties for pellets (EN ISO 17225-1)

	Master table		
	Origin: According to 6.1 and Table 1		Woody biomass (1); Herbaceous biomass (2); Fruit biomass (3); Aquatic biomass (4); Blends and mixtures (5).
	Traded Form (see Table 2)		Pellets
Normative	**Dimensions** (mm) ISO 17829		
	Diameter (D) and **Length** (L) [a]		
	D06	6 mm ± 1,0 mm and 3,15 mm < L ≤ 40 mm	 **Figure 3 — Dimensions (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	
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2		
	M05	≤ 5 %	
	M08	≤ 8 %	
	M10	≤ 10 %	
	M12	≤ 12 %	
	M15	≤ 15 %	
	Ash, A (w-% of dry basis) ISO 18122		
	A0.5	≤ 0,5 %	
	A0.7	≤ 0,7 %	
	A1.0	≤ 1,0 %	
	A1.2	≤ 1,2 %	
	A1.5	≤ 1,5 %	
	A2.0	≤ 2,0 %	
	A3.0	≤ 3,0 %	
	A4.0	≤ 4,0 %	
	A5.0	≤ 5,0 %	
	A6.0	≤ 6,0 %	
	A7.0	≤ 7,0 %	
	A8.0	≤ 8,0 %	
	A10.0	≤ 10,0 %	
	A10.0+	> 10.0 % (maximum value to be stated)	
	Mechanical durability, DU (w-% of pellets after testing) ISO 17831-1		
	DU97.5	≥ 97,5 %	
	DU96.5	≥ 96,5 %	
	DU95.0	≥ 95,0 %	
	DU95.0-	< 95,0 % (minimum value to be stated)	
	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)	
	Additives (w-% of pressing mass) [b]		Type and content of pressing aids, slagging inhibitors or any other additives have to be stated
	Bulk density (BD) (kg/m^3 as received) ISO 17828		
	BD550	≥ 550 kg/m^3	
	BD580	≥ 580 kg/m^3	
	BD600	≥ 600 kg/m^3	
	BD625	≥ 625 kg/m^3	
	BD650	≥ 650 kg/m^3	
	BD700	≥ 700 kg/m^3	
	BD750	≥ 750 kg/m^3	
	BD800+	> 800 kg/m^3 (minimum value to be stated)	
	Net calorific value, Q (MJ/kg or kWh/kg as received) ISO 18125		Minimum value to be stated [c]

Normative / informative	**Nitrogen, N** (w-% of dry basis) ISO 16948		
	N0.2	≤ 0,2 %	Normative: Chemically treated biomass (1.2.2; 1.3.2; 2.2.2; 3.2.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	N0.3	≤ 0,3 %	
	N0.5	≤ 0,5 %	
	N0.6	≤ 0,6 %	
	N0.7	≤ 0,7 %	
	N1.0	≤ 1,0 %	
	N1.5	≤ 1,5 %	
	N2.0	≤ 2,0 %	
	N3.0	≤ 3,0 %	
	N3.0+	> 3,0 % (maximum value to be stated)	
	Sulphur, S (w-% of dry basis) ISO 16994		
	S0.02	≤ 0,02 %	Normative: Chemically treated biomass (1.2.2; 1.3.2; 2.2.2; 3.2.2) or if sulphur containing additives have been used. Informative: All fuels that are not chemically treated (see the exceptions above)
	S0.03	≤ 0,03 %	
	S0.04	≤ 0,04 %	
	S0.05	≤ 0,05 %	
	S0.08	≤ 0,08 %	
	S0.10	≤ 0,10 %	
	S0.20	≤ 0,20 %	
	S0.20+	> 0,20 % (maximum value to be stated)	
	Chlorine, Cl (w-% of dry basis) ISO 16994		
	Cl0.01	≤ 0,01 %	Normative: Chemically treated biomass (1.2.2; 1.3.2; 2.2.2; 3.2.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	Cl0.02	≤ 0,02 %	
	Cl0.03	≤ 0,03 %	
	Cl0.05	≤ 0,05 %	
	Cl0.07	≤ 0,07 %	
	Cl0.10	≤ 0,10 %	
	Cl0.20	≤ 0,20 %	
	Cl0.30	≤ 0,30 %	
	Cl0.30+	> 0,30 % (maximum value to be stated)	
	Fixed carbon, C [d] (w-% of dry basis)		
	Minimum value to be stated		Normative only for thermally treated biomass pellets
	Volatile matter, VM (w-% of dry basis) ISO 18123		
	Maximum value to be stated		Normative only for thermally treated biomass pellets
	Particle size distribution of disintegrated pellets (w-% of dry basis) ISO 17830		Values to be stated of pellets for industrial use
	Informative: **Ash melting behaviour** [e] (°C) CEN/TS 15370-1 [4]		Should be stated

[a] Amount of pellets longer than 40 mm (or 50 mm) can be 5 w-%. Maximum length for classes *D*06, *D*08 and *D*10 shall be ≤ 45 mm. Pellets are longer than 3,15 mm, if they stay on a round hole-sieve of 3,15 mm.

[b] The maximum amount of additive is 20 w-% of pressing mass. Type stated (e.g. starch, corn flour, potato flour, vegetable oil, lignin). If amount is greater, then raw material for pellet is blend.

[c] Minimum value for torrefied or other thermally treated biomass pellets are usual ≥ 18 MJ/kg.

[d] Fixed carbon (%) is calculated by the following: 100 – [moisture (w-%) + ash (w-%) + volatile matter (w-%)]. All percentage are on the same moisture basis.

[e] Special attention should be paid to the ash melting behaviour for some biomass fuels, for example eucalyptus, poplar, short rotation coppice, straw, miscanthus and olive stone. It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

NOTE 6 Thermally treated biomass pellets (e.g. torrefied pellets) are also included in Table 4.

Table 5 — Specification of properties for wood chips and hog fuel (EN ISO 17225-1)

	Master table				
	Origin: According to 6.1 and Table 1.			Woody biomass (1)	
	Traded Form			Wood chips or hog fuel [a]	
Normative	**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)			
	Moisture, M [e] (w-% as received) ISO 18134-1, ISO 18134-2				
	M10	≤ 10 %			
	M15	≤ 15 %			
	M20	≤ 20 %			
	M25	≤ 25 %			
	M30	≤ 30 %			
	M35	≤ 35 %			
	M40	≤ 40 %			
	M45	≤ 45 %			
	M50	≤ 50 %			
	M55	≤ 55 %			
	M55+	> 55 % (maximum value to be stated)			
	Ash, A (w-% of dry basis) ISO 18122				
	A0.5	≤ 0,5 %			
	A0.7	≤ 0,7 %			
	A1.0	≤ 1,0 %			
	A1.5	≤ 1,5 %			
	A2.0	≤ 2,0 %			
	A3.0	≤ 3,0 %			
	A5.0	≤ 5,0 %			
	A7.0	≤ 7,0 %			
	A10.0	≤ 10,0 %			
	A10.0+	> 10,0 % (maximum value to be stated)			

Normative / Informative	**Nitrogen, N** (w-% of dry basis) ISO 16948		
	N0.2	≤ 0,2 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	N0.3	≤ 0,3 %	
	N0.5	≤ 0,5 %	
	N1.0	≤ 1,0 %	
	N1.5	≤ 1,5 %	
	N2.0	≤ 2,0 %	
	N3.0	≤ 3,0 %	
	N3.0+	> 3,0 % (maximum value to be stated)	
	Sulphur, S (w-% of dry basis) ISO 16994		
	S0.02	≤ 0,02 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	S0.03	≤ 0,03 %	
	S0.04	≤ 0,04 %	
	S0.05	≤ 0,05 %	
	S0.08	≤ 0,08 %	
	S0.10	≤ 0,10 %	
	S0.10+	> 0,10 % (maximum value to be stated)	
	Chlorine, Cl (w-% of dry basis) ISO 16994		
	Cl0.02	≤ 0,02 %	Normative: Chemically treated biomass (1.2.2, 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	Cl0.03	≤ 0,03 %	
	Cl0.05	≤ 0,05 %	
	Cl0.07	≤ 0,07 %	
	Cl0.10	≤ 0,10 %	
	Cl0.10+	> 0,10 % (maximum value to be stated)	
Informative	**Net calorific value, Q** (MJ/kg or kWh/kg as received) or **energy density, E** (MJ/ m^3 or kWh/m^3 loose) ISO 18125		Minimum value to be stated
	Bulk density (BD) (kg/m^3 as received) ISO 17828		
	BD150	≥ 150	Recommended to be stated if traded on a volume basis
	BD200	≥ 200	
	BD250	≥ 250	
	BD300	≥ 300	
	BD350	≥ 350	
	BD400	≥ 400	
	BD400+	> 400 (minimum value to be stated)	
	Ash melting behaviour [f] (°C) CEN/TS 15370-1 [4]		Should be stated

[a] For the production of hog fuel often raw material with high content of stones is used e.g. stumps/roots or wood from gardens/parks. It is recommended to determine and specify the maximum content of these stones in w-% since the declaration of the ash content alone may not provide sufficient information to describe the impacts of a hog fuel batch on feeding and combustion processes. The content of stones is determined by hand sorting of the fraction > 3,15 mm and weighing the stones. A suitable large sample has to be used for the determination, see ISO 14778. Small stones, sand and soil which pass the 3,15 mm sieve contribute to the ash content but not to the content of stones.

[b] The numerical values (P-class) for dimension refer to the particle sizes (at least 60 w-%) passing through the mentioned round hole sieve size (ISO 17827-1). Use S classes for wood chips and hog fuel for residential and small scale commercial applications. Lowest possible property class to be stated.

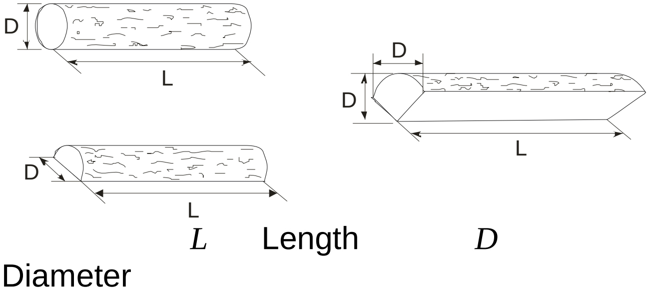
[c] Length and cross sectional area only have to be determined for those particles, which are to be found in the coarse fraction. Maximum 2 pieces of about 10 litre sample may exceed the maximum length, if the cross sectional area is < 0,5 cm^2.

[d] For measuring the cross sectional area it is recommended to use a transparent set square, place the particle orthogonally behind the set square and estimate the maximum cross sectional area of this particle with the help of the cm^2-pattern.

[e] Lowest possible property class to be stated. Certain boilers require minimum moisture content, which should be stated.

[f] Special attention should be paid to the ash melting behaviour for some biomass fuels, for example eucalyptus, poplar, short rotation coppice. It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT, hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Table 6 — Specification of properties for log wood, firewood (EN ISO 17225-1)

	Master table		
	Origin: According to 6.1 and Table 1.		Woody biomass (1.1 or 1.2.1) Wood species to be stated
	Traded Form		Stem wood/round wood, Log wood, firewood
Normative	**Dimensions** (cm)		
	Length (*L*) (maximum length of a single piece), cm [a]		
	L20-	< 20 cm	 **Figure 4 — Examples**
	L20	20 cm ± 2 cm	
	L25	25 cm ± 2 cm	
	L30	30 cm ± 2 cm	
	L33	33 cm ± 2 cm	
	L40	40 cm ± 2 cm	
	L50	50 cm ± 4 cm	
	L100	100 cm ± 5 cm	
	L100+	> 100 cm (maximum value has to be stated)	
	Diameter (*D*) (maximum diameter of a single piece), cm [a]		
	D2-	< 2 cm ignition wood (kindling)	
	D5	2 cm $\le D \le$ 5 cm	
	D10	5 cm $\le D \le$ 10 cm	
	D15	10 cm $\le D \le$ 15 cm	
	D20	10 cm $\le D \le$ 20 cm	
	D25	10 cm $\le D \le$ 25 cm	
	D35	20 cm $\le D \le$ 35 cm	
	D35+	> 35 cm (maximum value to be stated)	
	Moisture, M (w-% as received) [b] ISO 18134-1, ISO 18134-2		
	M10	≤ 10 %	
	M15	≤ 15 %	
	M20	≤ 20 %	
	M25	≤ 25 %	
	M30	≤ 30 %	
	M35	≤ 35 %	
	M40	≤ 40 %	
	M45	≤ 45 %	
	M55	≤ 55 %	
	M55+	> 55 % (maximum value to be stated)	
	Volume, m^3 stacked or loose **or weight, kg** as received		To be stated which unit is used when retailed (m^3 stacked or m^3 loose, kg) and/or packaged log woods weight.
Informative	**Moisture content, U** (w-% of dry basis) [b]		
	U10	≤ 10 %	
	U11	≤ 11 %	
	U15	≤ 15 %	
	U20	≤ 20 %	
	U25	≤ 25 %	
	U30	≤ 30 %	
	U50	≤ 50 %	
	U100	≤ 100%	
	U100+	> 100 % (maximum value to be stated)	

Informative	**Energy density, E** [C] (MJ/m^3 or kWh/m^3 stacked or loose) or **Net calorific value, Q** (MJ/kg or kWh/kg as received) ISO 18125	Recommended to be specified when retailed.
	Proportion of split volume (% of pieces)	No split (= mainly round wood) ≥ 90 % ≥ 50 %
	The cut-off surface	To be stated if the cut-off surface of log wood is even and smooth [d] or ends of log wood is uneven
	Decay and mould	No visible decay or mould ≤ 5 % of pieces If significant amount (more than 10 % of pieces) of decay or mould exists it should be stated.
	Drying	Recommended to be stated, if firewood is dried by natural seasoning by ambient air or artificially by hot air.

[a] 85 % of the firewood should be kept in specified diameter property class. It is allowed to have 15 % firewood shorter than requested length including the limit value.

[b] M (w-%) on wet basis and U (w-%) on dry basis. Moisture content should not be less 12 w-% on wet basis (M) or 13,64 w-% on dry basis (U) for oven-ready firewood. The lowest possible moisture content class to be stated. Calculation from M to U or from U to M is presented in informative Annex E.

[c] The energy density may be calculated according to Annex D on the basis of the bulk density and the net calorific value of the dry fuel. Example: For a firewood with a net calorific value on dry basis, E of 5,3 kWh/kg and an actual moisture content M_{ar} of 15 w-%, the net calorific value on as received basis E_{ar} is 4,43 kWh/kg. For a bulk density BD of 410 kg/stacked m^3, the energy density E_{ar} is 1 800 kWh/stacked m^3.

[d] Use of chainsaw or circular saw is considered to be smooth and even.

Table 7 — Specification of properties for sawdust (EN ISO 17225-1)

	Master table		
	Origin: According to 6.1 and Table 1.		Woody biomass (1)
	Traded Form		Sawdust
Normative	**Moisture, M** (w-% as received) [a] ISO 18134-1, ISO 18134-2		
	M10	≤ 10 %	
	M15	≤ 15 %	
	M20	≤ 20 %	
	M25	≤ 25 %	
	M30	≤ 30 %	
	M35	≤ 35 %	
	M45	≤ 45 %	
	M50	≤ 50 %	
	M55	≤ 55 %	
	M60	≤ 60 %	
	M65	≤ 65 %	
	M65+	> 65 % (maximum value to be stated)	
	Ash, A (w-% of dry basis) ISO 18122		
	A0.5	≤ 0,5 %	
	A0.7	≤ 0,7 %	
	A1.0	≤ 1,0 %	
	A1.5	≤ 1,5 %	
	A2.0	≤ 2,0 %	
	A3.0	≤ 3,0 %	
	A5.0	≤ 5,0 %	
	A7.0	≤ 7,0 %	
	A10.0	≤ 10,0 %	
	A10.0+	> 10,0 % (maximum value to be stated)	
	Net calorific value, Q (MJ/kg or kWh/kg as received) or **energy density, E** (MJ/m^3 or kWh/m^3 loose) ISO 18125		Minimum value to be stated
Normative / informative	**Nitrogen, N** (w-% of dry basis) ISO 16948		
	N0.2	≤ 0,2 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	N0.3	≤ 0,3 %	
	N0.5	≤ 0,5 %	
	N1.0	≤ 1,0 %	
	N2.0	≤ 2,0 %	
	N3.0	≤ 3,0 %	
	N3.0+	> 3,0 % (maximum value to be stated)	
	Chlorine, Cl (weight of dry basis, w-%) ISO 16994		
	Cl0.01	≤ 0,01 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	Cl0.02	≤ 0,02 %	
	Cl0.03	≤ 0,03 %	
	Cl0.07	≤ 0,07 %	
	Cl0.10	≤ 0,10 %	
	Cl0.10+	> 0,10 % (maximum value to be stated)	
Informative	**Bulk density (BD)** (kg/m^3 as received) ISO 17828		
	BD100	≥ 100 kg/m^3	Recommended to be stated if traded by volume basis
	BD150	≥ 150 kg/m^3	
	BD200	≥ 200 kg/m^3	
	BD250	≥ 250 kg/m^3	
	BD300	≥ 300 kg/m^3	
	BD350	≥ 350 kg/m^3	
	BD400+	> 400 kg/m^3 (minimum value to be stated)	
	Ash melting behaviour [b] (°C) CEN/TS 15370-1 [4]		Should be stated
	Sieving		Sieving and the screen size of the sieve should be stated

[a] Lowest possible property class to be stated. Certain boilers require minimum moisture content, which should to be stated.

[b] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

NOTE 7 Particle size of sawdust is considered to be homogenous. Particle size distribution may be specified if requested.

Table 8 — Specification of properties for shavings (EN ISO 17225-1)

	Master table		
	Origin: According to 6.1 and Table 1.		Woody biomass (1)
	Traded Form		Shavings
Normative	**Moisture, M** (w-% as received) ISO 18134-1, ISO 18134-2		
	M10	≤ 10 %	
	M15	≤ 15 %	
	M20	≤ 20 %	
	M30	≤ 30 %	
	M30+	> 30 % (maximum value to be stated)	
	Ash, A (w-% of dry basis) ISO 18122		
	A0.5	≤ 0,5 %	
	A0.7	≤ 0,7 %	
	A1.0	≤ 1,0 %	
	A1.5	≤ 1,5 %	
	A2.0	≤ 2,0 %	
	A3.0	≤ 3,0 %	
	A5.0	≤ 5,0 %	
	A7.0	≤ 7,0 %	
	A10.0	≤ 10,0 %	
	A10.0+	> 10,0 % (maximum value to be stated)	
	Net calorific value, Q (MJ/kg or kWh/kg as received) or **energy density, E** (MJ/m^3 or kWh/m^3 loose) ISO 18125		Minimum value to be stated
Normative / informative	**Nitrogen, N** (w-% of dry basis) ISO 16948		
	N0.2	≤ 0,2 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	N0.3	≤ 0,3 %	
	N0.5	≤ 0,5 %	
	N1.0	≤ 1,0 %	
	N2.0	≤ 2,0 %	
	N3.0	≤ 3,0 %	
	N3.0+	> 3,0 % (maximum value to be stated)	
	Chlorine, Cl (weight of dry basis, w-%) ISO 16994		
	Cl0.01	≤ 0,01 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	Cl0.02	≤ 0,02 %	
	Cl0.03	≤ 0,03 %	
	Cl0.07	≤ 0,07 %	
	Cl0.10	≤ 0,10 %	
	Cl0.10+	> 0,10 % (maximum value to be stated)	
Informative	**Bulk density (BD)** (kg/m^3 as received) ISO 17828		
	BD100	≥ 100 kg/m^3	Recommended to be stated if traded by volume basis
	BD150	≥ 150 kg/m^3	
	BD200	≥ 200 kg/m^3	
	BD250	≥ 250 kg/m^3	
	BD300	≥ 300 kg/m^3	
	BD350+	> 350 kg/m^3 (minimum value to be stated)	
	Ash melting behaviour [a] (°C) CEN/TS 15370-1 [4]		Should be stated
	Sieving		Sieving and the screen size of the sieve should be stated

[a] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

NOTE 8 Particle sizes of shavings are considered to be homogenous. Particle size distribution may be specified if requested.

Table 9 — Specification of properties for bark (EN ISO 17225-1)

	Master table		
	Origin: According to 6.1 and Table 1.		Woody biomass (1.1.6, 1.2.1.5, 1.2.2.3, 1.3.1.3, 1.3.2.3)
	Traded Form:		Bark
Normative	**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
	Moisture, M (w-% as received) [b] ISO 18134-1, ISO 18134-2		
	M20	≤ 20 %	
	M25	≤ 25 %	
	M30	≤ 30 %	
	M35	≤ 35 %	
	M40	≤ 40 %	
	M45	≤ 45 %	
	M50	≤ 50 %	
	M55	≤ 55 %	
	M60	≤ 60 %	
	M65	≤ 65 %	
	M65+	> 65 % (maximum value to be stated)	
	Ash, A (w-% of dry basis) ISO 18122		
	A1.0	≤ 1,0 %	
	A1.5	≤ 1,5 %	
	A2.0	≤ 2,0 %	
	A3.0	≤ 3,0 %	
	A5.0	≤ 5,0 %	
	A7.0	≤ 7,0 %	
	A10.0	≤ 10,0 %	
	A10.0+	> 10,0 % (maximum value to be stated)	
	Shredding		To be stated if bark is shredded or not into pieces
	Net calorific value, Q (MJ/kg or kWh/kg as received) or **energy density, E** (MJ/m^3 or kWh/m^3 loose) ISO 18125		Minimum value to be stated
Normative / informative	**Nitrogen, N** (w-% of dry basis) ISO 16948		
	N0.5	≤ 0,5 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	N1.0	≤ 1,0 %	
	N2.0	≤ 2,0 %	
	N3.0	≤ 3,0 %	
	N3.0+	> 3,0 % (maximum value to be stated)	
	Chlorine, Cl (w-% of dry basis) ISO 16994		
	Cl0.02	≤ 0,02 %	Normative: Chemically treated biomass (1.2.2; 1.3.2) Informative: All fuels that are not chemically treated (see the exceptions above)
	Cl0.03	≤ 0,03 %	
	Cl0.07	≤ 0,07 %	
	Cl0.10	≤ 0,10 %	
	Cl0.10+	> 0,10 % (maximum value to be stated)	
Informative	**Bulk density (BD)** (kg/m^3 as received) ISO 17828		
	BD250	≥ 250 kg/m^3	Recommended to be stated if traded on a volume basis
	BD300	≥ 300 kg/m^3	
	BD350	≥ 350 kg/m^3	
	BD400	≥ 400 kg/m^3	
	BD450	≥ 450 kg/m^3	
	Ash melting behaviour [c] (°C) CEN/TS 15370-1 [4]		Should be stated

[a] The numerical values (P-class) for dimension refer to the particle sizes (at least 95 % by mass) passing through the mentioned round hole sieve size (ISO 17827-1). If a sample fulfils the criteria of more than one class attach it to the lowest possible class.

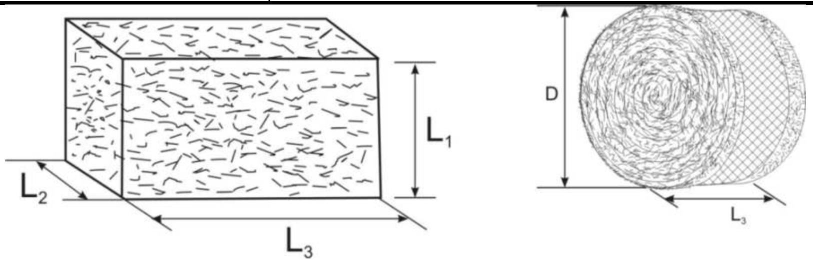
[b] Lowest possible property class to be stated. Certain boilers require minimum moisture content, which should to be stated.

[c] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Table 10 — Specification of properties for bales of straw, reed canary grass and Miscanthus (EN ISO 17225-1)

Master table	
Origin: According to 6.1 and Table 1.	2.1.1.2 Cereal crop straw, 2.1.2.1 Whole plant (Reed canary grass and Miscanthus), 2.1.2.2 Grass straw, 2.1.3.2 Oil seed crops stalks and leaves
Traded Form	Round bale and square bale

Normative



L_1	Height	D	Diameter
L_2	Width	L_3	Length

Figure 5 — Dimensions (m)

Round bale	Diameter (D)	Length (L_3)	
D1	1,2 m – 1,5 m	1,2 m	
D2	1,6 m – 1,8 m	1,5 m	
Square bale	Height (L_1)	Width (L_2)	Length (L_3)
P1	≤ 0,35 m	≤ 0,4 m	≤ 0,5 m
P2	≤ 0,9 m	≤ 1,2 m	1,5 m – 2,8 m
P3	≤ 1,3 m	≤ 1,2 m	1,0 m – 3,0 m
P3+	> 3 m (maximum values to stated)		

Bale density, BD (kg/m^3 as received) ISO 17828	
BD100	≥ 100 kg/m^3
BD120	≥ 120 kg/m^3
BD160	≥ 160 kg/m^3
BD180	≥ 180 kg/m^3
BD220	≥ 220 kg/m^3
BD240+	≥ 240 kg/m^3 (minimum value to be stated)
Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2	
M10	≤ 10 %
M15	≤ 15 %
M20	≤ 20 %
M25	≤ 25 %
M30	≤ 30 %
M30+	> 30 % (maximum value to be stated)
Ash, A (w-% of dry basis) ISO 18122	
A4.0	≤ 4 %
A5.0	≤ 5 %
A6.0	≤ 6 %
A7.0	≤ 7 %
A8.0	≤ 8 %
A10.0	≤ 10 %
A10.0+	> 10 % (maximum value to be stated)
Chlorine, Cl (w-% of dry basis) ISO 16994	
Cl0.01	≤ 0,01 %
Cl0.02	≤ 0,02 %
Cl0.03	≤ 0,03 %
Cl0.07	≤ 0,07 %
Cl0.10	≤ 0,10 %
Cl0.10+	> 0.10 % (maximum value to be stated)
Species of biomass	Has to be stated (Example: spring harvested reed canary grass (*Phalaris arundinacea L.*) or Miscanthus (*Miscanthus Giganteus*))
Net calorific value, Q (MJ/kg or kWh/kg as received) or **energy density, E** (MJ/m^3 or kWh/m^3 loose) ISO 18125	Minimum value to be stated

Informative	**Production method**	It is recommended to declare production methods that influence the size of the straw particles in the bale. That is for instance whether the crop has been trashed by rotation or oscillation or whether it has been chopped. Harvested as a whole plant for Reed canary grass and Miscanthus.
	Binding type of bales	Tying material recommended to be specified (net binding, plastic line).
	Ash melting behaviour [a] (°C) CEN/TS 15370-1 [4]	Should be stated
[a] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.		

Table 11 — Specification of properties for energy grain (EN ISO 17225-1)

	Master table	
	Origin:According to 6.1 and Table 1	Herbaceous biomass (2.1.1.3)
	Traded Form	Grain (species to be stated e.g. wheat)
Normative	**Dimensions** (mm), Diameter (D) (5 w-% may have diameter over the class) ISO 17827-1, ISO 17827-2	
	D05	1 mm ≤ D ≤ 5 mm
	D10	3,15 mm ≤ D ≤ 10 mm
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2	
	M10	≤ 10 %
	M15	≤ 15 %
	Ash, A (w-% of dry basis) ISO 18122	
	A2.0	≤ 2,0 %
	A3.0	≤ 3,0 %
	A5.0	≤ 5,0 %
	A5.0+	> 5,0 % (maximum value to be stated)
	Net calorific value, Q (MJ/kg or kWh/kg as received) ISO 18125	Minimum value to be stated
	Nitrogen, N (w-% of dry basis) ISO 16948	
	N2.0	≤ 2,0 %
	N2.0+	> 2,0 % (maximum value to be stated)
	Sulphur, S (w-% of dry basis) ISO 16994	
	S0.20	≤ 0,20 %
	S0.20+	> 0,20 % (maximum value to be stated)
	Chlorine, Cl (w-% of dry basis) ISO 16994	
	Cl0.05	≤ 0,05 %
	Cl0.10	≤ 0,10 %
	Cl0.15	≤ 0,15 %
	Cl0.15+	> 0,15 % (maximum value to be stated)
Informative	**Amount of fines, F** (w-%, < 1 mm for D 05 and w-%, < 3,15 mm for D 10) ISO 17827-1	
	F1.0	≤ 1,0 %
	F1.0+	> 1,0 % (without additive)
	Bulk density (BD) (kg/m^3 as received) ISO 17828	
	BD350	≥ 350 kg/m^3
	BD450	≥ 450 kg/m^3
	BD550	≥ 550 kg/m^3
	BD600	≥ 600 kg/m^3
	BD650+	> 650 kg/m^3 (minimum value to be stated)
	Ash melting behaviour [a] (°C) CEN/TS 15370-1 [4]	Should be stated

[a] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

NOTE 9 When using cereal grain materials for combustion special attention should be paid to risk of corrosion in small- and medium-scale boilers and flue gas system. Be aware that different types and varieties of grains, grown under different conditions and soil type, may have a fuel ash composition, i.e. high content of P, K, that will capture chlorine (K will form K-phosphates instead of KCl) in the ash that will result in high hydrochloric emissions.

Table 12 — Specification of properties for olive residues (EN ISO 17225-1)

	Master table	
	Origin: According to 6.1 and Table 1	Fruit biomass (3.2.1.2, 3.2.1.4,3.2.2.2,3.2.2.4)
	Traded Form	Grain or seed, kernel
Normative	**Dimensions** (mm)	
	Diameter (D) [a]	
	D 03	1 mm $\leq D \leq$ 3,15 mm
	D 05	1 mm $\leq D \leq$ 5 mm
	D 10	1 mm $\leq D \leq$ 10 mm
	D 10+	> 10 mm (maximum value to be stated)
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2	
	M10	≤ 10 %
	M15	≤ 15 %
	Ash, A (w-% of dry basis) ISO 18122	
	A1.5	≤ 1,5 %
	A2.0	≤ 2,0
	A3.0	≤ 3,0
	A5.0	≤ 5,0 %
	A7.0	≤ 7,0 %
	A10.0	≤ 10,0 %
	A10.0+	> 10,0 % (maximum value to be stated)
	Additives (w-%)	Type and amount of additive to be stated
	Net calorific value, Q [b] (MJ/kg or kWh/kg as received) ISO 18125	Minimum value to be stated
	Nitrogen, N (w-% of dry basis) ISO 16948	
	N1.0	≤ 1,0 %
	N1.5	≤ 1,5 %
	N2.0	≤ 2,0 %
	N3.0	≤ 3,0 %
	N3.0+	> 3,0 % (maximum value to be stated)
Informative	**Amount of fines, F** (w-%, < 1 mm) ISO 17827-1	
	F1.0	≤ 1,0 %
	F1.0+	> 1,0 % (without additive)
	Bulk density (BD) as received (kg/m^3 loose) ISO 17828	Recommended to be stated if traded on a volume basis
	Chlorine, Cl (w-% of dry basis) ISO 16994	
	Cl 0.10	≤ 0,10 %
	Cl 0.15	≤ 0,15 %
	Cl0.15+	> 0,15 % (maximum value to be stated)
	Sulphur, S (w-% of dry basis) ISO 16994	
	S0.15	≤ 0,15 %
	S0.20	≤ 0,20 %
	S0.20+	> 0,20 % (maximum value to be stated)
	Ash melting behaviour [c] (°C) CEN/TS 15370-1 [4]	Should be stated

[a] 5 w-% may have diameter over the class.

[b] Additives can reduce net calorific value.

[c] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Table 13 — Specification of properties for fruit seeds (EN ISO 17225-1)

	Master table	
	Origin: According to 6.1 and Table 1	Fruit biomass (3.1.1.3, 3.1.3, 3.2.1.2, 3.2.1.3, 3.2.2.2, 3.2.2.3)
	Traded Form	Fruit seed or kernel
Normative	**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 $\le D \le$ 3,15 mm
	D 05	1 mm $\le D \le$ 5 mm
	D 10	1 mm $\le D \le$ 10 mm
	D 10+	$D >$ 10 mm (maximum value to be stated)
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2	
	M10	M $\le$ 10 %
	M15	M $\le$ 15 %
	Ash, A (w-% of dry basis) ISO 18122	
	A1.5	$\le$ 1,5 %
	A2.0	$\le$ 2,0
	A3.0	$\le$ 3,0
	A5.0	$\le$ 5,0 %
	A7.0	$\le$ 7,0 %
	A10.0	$\le$ 10,0 %
	A10.0+	> 10,0 % (maximum value to be stated)
	Additives (w-%)	Type and amount of additive to be stated
	Net calorific value, Q [a] (MJ/kg or kWh/kg as received), ISO 18125	Minimum value to be stated
	Nitrogen, N (w-% of dry basis) ISO 16948	
	N1.0	$\le$ 1,0 %
	N1.5	$\le$ 1,5 %
	N2.0	$\le$ 2,0 %
	N3.0	$\le$ 3,0 %
	N3.0+	> 3,0 % (maximum value to be stated)
Informative	**Amount of fines, F** (w-%, < 1 mm) ISO 17827-1	
	F1.0	$\le$ 1,0 %
	F1.0+	> 1,0 %
	Bulk density (BD) (kg/m^3 as received) ISO 17828	Recommended to be stated if traded on a volume basis
	Chlorine, Cl (w-% of dry basis) ISO 16994	
	Cl 0.10	$\le$ 0,10 %
	Cl 0.15	$\le$ 0,15 %
	Cl 0.15+	> 0,15 % (maximum value to be stated)
	Sulphur, S (w-% of dry basis) ISO 16994	
	S0.15	$\le$ 0,15 %
	S0.20	$\le$ 0,20 %
	S0.20+	> 0,20 % (maximum value to be stated)
	Ash melting behaviour [b] (°C) CEN/TS 15370-1 [4]	Should be stated

[a] Additives can reduce net calorific value.

[b] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

NOTE 10 Fruit seeds include kernels, nuts and acorns.

Table 14 — Specification of properties for charcoals (EN ISO 17225-1)

	Master table			
	Origin: According to 6.1 and Table 1		Woody biomass (1.1 and 1.2.1); Fruit biomass (3)	
	Traded Form (see Table 2)		Charcoal	
Normative	**Dimensions** (mm)			
		Main fraction (minimum 75 w-%), mm	Fines fraction, w-% (< 10 mm)	Coarse fraction, (w-%), max. length of particle, mm
	P150	16 mm ≤ P ≤ 150 mm	≤ 7 %	≤ 10 % > 100 mm, and all < 150mm
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2			
	M8	≤ 8 %		
	M10	≤ 10 %		
	Ash, A (w-% of dry basis) ISO 18122			
	A5.0	≤ 5,0 %		
	A8.0	≤ 8,0 %		
	A8.0+	> 8,0 % (maximum value to be stated)		
	Fixed carbon, C [a] (w-% of dry basis)			
	C60	≥ 60 %		
	C75	≥ 75 %		
	Bulk density (BD) (kg/m^3 as received) ISO 17828			
	BD130	≥ 130 kg/m^3		
	BD150	≥ 150 kg/m^3		
	Net calorific value, Q (MJ/kg or kWh/kg as received) ISO 18125			Minimum value to be stated

[a] Fixed carbon (%) is calculated by the following: 100 – [moisture (w-%) + ash (w-%) + volatile matter (w-%)]. All percentage are on the same moisture basis.

Table 15 — Specification of properties for thermally treated biomass (e.g. mild form pyrolysis/torrefaction) (EN ISO 17225-1)

	Master table	
	Origin: According to 6.1 and Table 1	Woody biomass (1); Herbaceous biomass (2); Fruit biomass (3); Aquatic biomass (4); Blends and mixtures (5).
	Traded Form (see Table 2)	Thermally treated biomass
Normative	**Dimensions** (mm)	to be stated
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2	
	M3	≤ 3 %
	M5	≤ 5 %
	M8	≤ 8 %
	M10	≤ 10 %
	M10+	> 10 % (maximum value to be stated)
	Ash, A (w-% of dry basis) ISO 18122	
	A0.5	≤ 0,5 %
	A0.7	≤ 0,7 %
	A1.0	≤ 1,0 %
	A1.5	≤ 1,5 %
	A2.0	≤ 2,0 %
	A3.0	≤ 3,0 %
	A5.0	≤ 5,0 %
	A7.0	≤ 7,0 %
	A10.0	≤ 10,0 %
	A10.0+	> 10,0 % (maximum value to be stated)
	Bulk density (BD) (kg/m^3 as received) ISO 17828	
	BD200	≥ 200 kg/m^3
	BD250	≥ 250 kg/m^3
	BD300	≥ 300 kg/m^3
	Net calorific value, Q (MJ/kg or kWh/kg as received) ISO 18125	≥ 17 MJ/kg (minimum value to be stated)
	Fixed carbon, C (w-% of dry basis) [a]	
	C20	≥ 20 %
	C25	≥ 25 %
	C30	≥ 30 %
	C35	≥ 35 %
	C40	≥ 40 %
	Volatiles, VM, (w-% of dry basis), ISO 18123	Maximum value to be stated
[a] Fixed carbon (%) is calculated by the following: 100 – [moisture (w-%) + ash (w-%) + volatile matter (w-%)]. All percentage are on the same moisture basis.		

NOTE 11 Thermally treated biomass briquettes and pellets are specified in Table 3 and Table 4.

Table 16 — General master table for specification of properties for other solid biofuels (EN ISO 17225-1)

	General Master Table		
	Origin		To be specified in accordance with to 6.1 and Table 1, as detailed as needed.
	Traded Form		A short description of the form of the biofuel (see Table 2 for guidelines).
Normative	**Dimensions** (mm)		If dimensions are not suitable to express as diameter and length other formats may be used, but shall then be clearly stated.
	D_x	x = Maximum diameter	
	L_y	y = Maximum length	
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2		Recommended to be stated as a class: M10, M15, M20, M25, M30; M35, M40, M45, M50; M55, M60; M65, M65+ (maximum value to be stated)
	MXX	≤ XX %	
	Ash, A (w-% of dry basis) ISO 18122		Recommended to be stated as a class: A0.5, A0.7, A1.0, A1.5, A2.0, A3.0, A5.0, A7.0, A10, A10+ (maximum value to be stated)
	AXX.X	≤ XX,X %	
Normative/informative	**Additives** (w-% of dry basis)		If any type of additive is added to the fuel, amount and type shall be stated. The maximum amount of additive is 20 w-% of in solid biofuels. If amount is greater, then solid biofuel is a blend.
	Type and content of additives to be stated		
	Net calorific value, Q (MJ/kg or kWh/kg as received) or **energy density, E** (MJ/m^3 or kWh/m^3 loose) ISO 18125		Minimum value to be stated.
	Bulk density (BD) (kg/m^3 as received) ISO 17828		Recommended to be stated in the classes (minimum value): BD200, BD250, BD300, BD300, BD350, BD400, BD450, BD500, BD550, BD600, BD650, BD750, DB850+.
	Nitrogen, N (w-% of dry basis) ISO 16948		Nitrogen is normative only for chemically treated biomass. Recommended to be stated as a class N0.5, N1.0, N1.5, N2.0, N3.0, N3.0+ (maximum value to be stated)
	NX.X	≤ X,X %	
	Sulphur, S (w-% of dry basis) ISO 16994		Sulphur is normative only for chemically treated biomass or if sulphur containing additives have been used. Recommended to be stated as a class S0,03, S0,05, S0,1, S0,2 and S0,2+ (if S > 0,2 % maximum value to be stated)
	SX.XX	≤ X,XX %	
	Chlorine, Cl (weight of dry basis, w-%) ISO 16994		Chlorine is normative only for chemically treated biomass. Recommended to be state as a class: Cl 0.01, Cl 0.02, Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10+ (if Cl > 0,10% maximum value to be stated)
	ClX.XX	≤ X,XX %	
	Further specification of dimensions		It is recommended that maximum allowed amount of fine and coarse particles of the fuel should be stated.
	Others e.g. major (ISO 16967) and minor elements (ISO 16968)		Properties that are specific to the actual solid biofuel and considered as containing useful information.
Informative			
	Ash melting behaviour [a] (°C), CEN/TS 15370-1 [4]		Should be stated

[a] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

NOTE 12 Property classes from Table 3 to 15 can be used if also appropriate in this master table.

Table 17 — Specification of graded wood pellets for commercial and residential applications (EN ISO 17225-2)

	Property class, Analysis method	**Unit**	**A1**	**A2**	**B**
Normative	**Origin and source**, ISO 17225-1		1.1.3 Stemwood 1.2.1 Chemically untreated wood residues [a]	1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues [a]	1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3.1 Chemically untreated used wood
	Diameter, D [b] and **Length L**, [c] ISO 17829 According Figure 1	mm	D06, 6 ± 1; 3,15 < L ≤ 40 D08, 8 ± 1; 3,15 < L ≤ 40	D06, 6 ± 1; 3,15 < L ≤ 40 D08, 8 ± 1; 3,15 < L ≤ 40	D06, 6 ± 1; 3,15 < L ≤ 40 D08, 8 ± 1; 3,15 < L ≤ 40
	Moisture, M, ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M10 ≤ 10	M10 ≤ 10	M10 ≤ 10
	Ash, A [d], ISO 18122	w-% dry	A0.7 ≤ 0,7	A1.2 ≤ 1,2	A2.0 ≤ 2,0
	Mechanical durability, DU, ISO 17831-1	w-% as received	DU97.5 ≥ 97,5	DU97.5 ≥ 97,5	DU96.5 ≥ 96,5
	Fines, F [e], ISO 18846	w-% as received	F1.0 ≤ 1,0	F1.0 ≤ 1,0	F1.0 ≤ 1,0
	Additives [f]	w-% as received	≤ 2 Type and amount to be stated	≤ 2 Type and amount to be stated	≤ 2 Type and amount to be stated
	Net calorific value, Q, ISO 18125	MJ/kg or kWh/kg as received	Q16.5 ≥ 16,5 or Q4.6 ≥ 4,6	Q16.5 ≥ 16,5 or Q4.6 ≥ 4,6	Q16.5 ≥ 16,5 or Q4.6 ≥ 4,6
	Bulk density, BD [g], ISO 17828	kg/m^3 as received	BD600 ≥ 600	BD600 ≥ 600	BD600 ≥ 600
	Nitrogen, N, ISO 16948	w-% dry	N0.3 ≤ 0,3	N0.5 ≤ 0,5	N1.0 ≤ 1,0
	Sulphur , S, ISO 16994	w-% dry	S0.04 ≤ 0,04	S0.05 ≤ 0,05	S0.05 ≤ 0,05
	Chlorine, Cl, ISO 16994	w-% dry	Cl0.02 ≤ 0,02	Cl0.02 ≤ 0,02	Cl0.03 ≤ 0,03
	Arsenic, As, ISO 16968	mg/kg dry	≤ 1	≤ 1	≤ 1
	Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5	≤ 0,5	≤ 0,5
	Chromium, Cr, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Copper, Cu, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Lead, Pb, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1	≤ 0,1	≤ 0,1
	Nickel, Ni, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Zinc, Zn, ISO 16968	mg/kg dry	≤ 100	≤ 100	≤ 100
	Informative: **Ash melting behaviour** [h], CEN/TS 15370-1 [4]	°C	Should be stated	Should be stated	Should be stated

[a] Negligible levels of glue, grease and other timber production additives used in sawmills during production of timber and timber product from virgin wood are acceptable, if all chemical parameters of the pellets are clearly within the limits and/or concentrations are too small to be concerned with.

[b] Selected size D06 or D08 of pellets to be stated.

[c] Amount of pellets longer than 40 mm can be 1 w-%. Maximum length shall be ≤ 45 mm. Pellets are longer than 3,15 mm, if they stay on a round hole-sieve of 3,15 mm. Amount of pellets shorter than 10 mm, w-% recommended to be stated.

[d] For household burners and stoves an ash content <0.5% is recommended.

[e] At factory gate in bulk transport (at the time of loading) and in small (up to 20 kg) and large sacks (at time of packing or when delivering to end-user).

[f] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin).

[g] It is recommended actual value of bulk density to be stated. This is especially important for household burners and stoves with no automatic control of air supply and thus are sensitive to variations in bulk density. Maximum value of bulk density 750 kg/m^3.

[h] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated. Pre-ashing temperature other than 550 °C should be stated.

Table 18 — Specification of graded wood pellets for industrial use (EN ISO 17225-2)

	Property class, Analysis method	**Unit**	**I1**	**I2**	**I3**
Normative	**Origin and source**, ISO 17225-1		1.1 Forest, plantation and other virgin wood 1.2.1 Chemically untreated wood residues [a]	1.1 Forest, plantation and other virgin wood 1.2.1 Chemically untreated wood residues [a]	1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3.1 Chemically untreated used wood
	Diameter, D [b] and **Length L** [c], ISO 17829 According Figure 1	mm	D06, 6 ± 1; 3,15 < L ≤ 40 D08, 8 ± 1; 3,15 < L ≤ 40	D06, 6 ± 1; 3,15 < L ≤ 40 D08, 8 ± 1; 3,15 < L ≤ 40 D10, 10 ± 1; 3,15 < L ≤ 40	D06, 6 ± 1; 3,15 < L ≤ 40 D08, 8 ± 1; 3,15 < L ≤ 40 D10, 10 ± 1; 3,15 < L ≤ 40 D12, 12 ± 1; 3,15 < L ≤ 40
	Moisture, M, ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M10 ≤ 10	M10 ≤ 10	M10 ≤ 10
	Ash, A, ISO 18122	w-% dry	A1.0 ≤ 1,0	A1.5 ≤ 1,5	A3.0 ≤ 3,0
	Mechanical durability, DU, ISO 17831-1	w-% as received	97,5 ≤ DU ≤ 99,0	97,0 ≤ DU ≤ 99,0	96,5 ≤ DU ≤ 99,0
	Fines, F [d], ISO 18846	w-% as received	F4.0 ≤ 4,0	F5.0 ≤ 5,0	F6.0 ≤ 6,0
	Additives [e]	w-% as received	< 3 Type and amount to be stated	< 3 Type and amount to be stated	< 3 Type and amount to be stated
	Net calorific value, Q, ISO 18125	MJ/kg as received	Q16.5 ≥ 16,5	Q16.5 ≥ 16,5	Q16.5 ≥ 16,5
	Bulk density, BD [f], ISO 17828	kg/m^3	BD600 ≥ 600	BD600 ≥ 600	BD600 ≥ 600
	Nitrogen, N, ISO 16948	w-% dry	N0.3 ≤ 0,3	N0.3 ≤ 0,3	N0.6 ≤ 0,6
	Particle size distribution of disintegrated pellets, ISO 17830	w-% dry	≥ 99% (< 3,15 mm) ≥ 95% (< 2,0 mm) ≥ 60% (< 1,0 mm)	≥ 98% (< 3,15 mm) ≥ 90% (< 2,0 mm) ≥ 50% (< 1,0 mm)	≥ 97% (< 3,15 mm) ≥ 85% (< 2,0 mm) ≥ 40% (< 1,0 mm)
	Sulphur , S, ISO 16994	w-% dry	S0.05 ≤ 0,05	S0.05 ≤ 0,05	S0.05 ≤ 0,05
	Chlorine, Cl, ISO 16994	w-% dry	Cl0.03 ≤ 0,03	Cl0.05 ≤ 0,05	Cl0.1 ≤ 0,1
	Arsenic, As, ISO 16968	mg/kg dry	≤ 2	≤ 2	≤ 2
	Cadmium, Cd, ISO 16968	mg/kg dry	≤ 1,0	≤ 1,0	≤ 1,0
	Chromium, **Cr**, ISO 16968	mg/kg dry	≤ 15	≤ 15	≤ 15
	Copper, Cu, ISO 16968	mg/kg dry	≤ 20	≤ 20	≤ 20
	Lead, Pb, ISO 16968	mg/kg dry	≤ 20	≤ 20	≤ 20
	Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1	≤ 0,1	≤ 0,1
	Zinc, Zn, ISO 16968	mg/kg dry	≤ 200	≤ 200	≤ 200
	Informative **Ash melting behaviour** [g], CEN/TS 15370-1 [4]	°C	Should be stated	Should be stated	Should be stated

[a] Negligible levels of glue, grease and other timber production additives used in sawmills during production of timber and timber product from virgin wood are acceptable if all chemical parameters of the pellets are clearly within the limits and/or concentrations are too small to be concerned with.

[b] Selected size D06, D08, D10 or D12 of pellets to be stated.

[c] Amount of pellets longer than 40 mm can be 1 w-%. Maximum length shall be ≤ 45 mm. Pellets are longer than 3,15 mm, if they stay on a round hole-sieve of 3,15 mm. Amount of pellets shorter than 10 mm, w-% recommended to be stated.

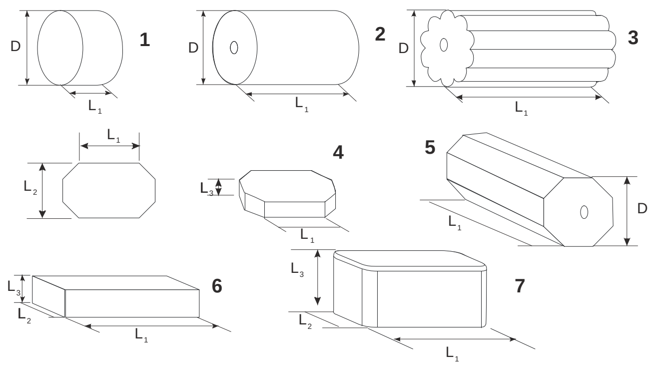
[d] At factory gate in bulk transport (at the time of loading) and in small (up to 20 kg) and large sacks (at time of packing or when delivering to end-user).

[e] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin).

[f] Maximum bulk density is 750 kg/m^3.

[g] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Table 19 – Specification of graded wood briquettes (EN ISO 17225-3)

	Property class, Analysis method	**Units**	**A**		**B** [a]
			1	**2**	
Normative	**Origin and source**, ISO 17225-1		1.1.3 Stemwood 1.2.1 Chemically untreated wood residues [b]	1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues [b]	1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3.1 Chemically untreated used wood
	Diameter (D) or length (L_1), width (L_2) and height (L_3) According Figure	mm	Diameter, width, height and length to be stated	Diameter, width, height and length to be stated	Diameter, width, height and length to be stated
		Shape	Specify according to Figure e.g. 1 or 2, etc. 		
	Moisture, M, ISO 18134-1, ISO 18134-2	w-% as received	M12 ≤ 12	M15 ≤ 15	M15 ≤ 15
	Ash, A, ISO 18122	w-% dry	A1.0 ≤ 1,0	A1.5 ≤ 1,5	A3.0 ≤ 3,0
	Particle density, DE, ISO 18847	g/cm^3 as received	DE1.0 ≥ 1,0	DE0.9 ≥ 0,9	DE0.9 ≥ 0,9
	Additives [c]	w-% dry	≤ 2 Type and amount to be stated	≤ 2 Type and amount to be stated	≤ 2 Type and amount to be stated
	Net calorific value, Q, [d] ISO 18125	MJ/kg or kWh/kg as received	Q15.5 ≥ 15,5 or Q4.3 ≥ 4,3	Q15.3 ≥ 15,3 or Q4.25 ≥ 4,25	Q14.9 ≥ 14,9 or Q4.15 ≥ 4,15
	Nitrogen, N, ISO 16948	w-% dry	N0.3 ≤ 0,3	N0.5 ≤ 0,5	N1.0 ≤ 1,0
	Sulphur, S, ISO 16994	w-% dry	S0.04 ≤ 0,04	S0.04 ≤ 0,04	S0.05 ≤ 0,05
	Chlorine, Cl, ISO 16994	w-% dry	Cl0.02 ≤ 0,02	Cl0.02 ≤ 0,02	Cl0.03 ≤ 0,03
	Arsenic, As, ISO 16968	mg/kg dry	≤ 1	≤ 1	≤ 1
	Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5	≤ 0,5	≤ 0,5
	Chromium, Cr, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Copper, Cu, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Lead, Pb, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1	≤ 0,1	≤ 0,1
	Nickel, Ni, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Zinc, Zn, ISO 16968	mg/kg dry	≤ 100	≤ 100	≤ 100

Informative	**Surface area of briquettes,** including the hole surface if any	cm^2/kg	Should be stated	Should be stated	Should be stated

[a] Class B is not recommended for baking ovens.

[b] Negligible levels of glue, grease and other timber production additives used in sawmills during production of timber and timber product from virgin wood are acceptable if all chemical parameters of the briquettes are clearly within the limits and concentrations are too small to be concerned with.

[c] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin).

[d] See Annex D from ISO 17225-1 for calculation of net calorific value as received.

NOTE The combustion time may also be an important parameter for further characterisation of the combustion behaviour. The combustion time indicates in which time the energy of the briquettes is released. The combustion time depends on both the shape and density of the briquettes as well as the air ratio.

Table 20 – Specification of graded wood chips (EN ISO 17225-4)

	Property class, Analysis method	**Unit**	**A**		**B**	
			1	**2**	**1**	**2**
Normative	**Origin and source,** ISO 17225-1		1.1.1 Whole trees without roots [a] 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues	1.1.1 Whole trees without roots [a] 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues	1.1 Forest, plantation and other virgin wood [b] 1.2.1 Chemically untreated wood residues	1.1 Forest, plantation and other virgin wood [b] 1.2. By-products and residues from wood processing industry 1.3.1.Chemically untreated used wood
	Particle size, P ISO 17827-1	mm	to be selected from Table 4 S classes		to be selected from Table 4 S classes	
	Moisture, M [c], ISO 18134-1, ISO 18134-2	w-%	M10 $\leq$ 10 M25 $\leq$ 25	M35 $\leq$ 35	Maximum value to be stated	
	Ash, A, ISO 18122	w-% dry	A1.0 $\leq$ 1,0	A1.5 $\leq$ 1,5	A3.0 $\leq$ 3,0	
	Bulk density, BD [d], ISO 17828	kg/loose m^3 as received	BD150 $\geq$ 150 BD200 $\geq$ 200 BD250 $\geq$ 250	BD150 $\geq$ 150 BD200 $\geq$ 200 BD250 $\geq$ 250 BD300 $\geq$ 300	Minimum value to be stated	
	Nitrogen, N, ISO 16948	w-% dry	Not applicable	Not applicable	N1.0 $\leq$ 1,0	
	Sulphur , S, ISO 16994	w-% dry	Not applicable	Not applicable	S0.1 $\leq$ 0,1	
	Chlorine, Cl, ISO 16994	w-% dry	Not applicable	Not applicable	Cl0.05 $\leq$ 0,05	
	Arsenic, As, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 1	
	Cadmium, Cd, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 2,0	
	Chromium, Cr, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 10	
	Copper, Cu, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 10	
	Lead, Pb, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 10	
	Mercury, Hg, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 0,1	
	Nickel, Ni, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 10	
	Zinc, Zn, ISO 16968	mg/kg dry	Not applicable	Not applicable	$\leq$ 100	
Informative	**Net calorific value, Q** [e], ISO 18125	MJ/kg or kWh/kg as received	Minimum value to be stated		Minimum value to be stated	

[a] Excluding class 1.1.1.3 Short rotation coppice, if reason to suspect contamination of land or if planting has been used for the sequestration of chemicals or growing trees have been fertilized by sewage sludge (issued from waste water treatment or chemical process).

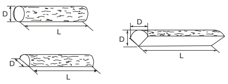
[b] Excluding classes 1.1.5 Stumps/roots and 1.1.6 Bark

[c] Lowest possible property class to be stated. Certain boilers require minimum moisture content, which should to be stated. Moisture class M10 is for artificially dried wood chips.

[d] The bulk density is lower for coniferous than for broadleaf wood, see informative Annex A.

[e] See Annex D from ISO 17225-1 for calculation of net calorific value as received.

Table 21 – Specification of graded firewood (EN ISO 17225-5)

	Property class, Analysis method	**Units**	**A1**	**A2**	**B**
Normative	**Origin and source,** ISO 17225-1		1.1.3 Stemwood 1.2.1 Chemically untreated wood residues	1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues	1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues
	Wood species [a]		To be stated		To be stated
	Diameter, D [b]	cm	D2 ≤ 2 D5 2 < D ≤ 5 D15 5 < D ≤15 D15+ >15 (actual value to be stated)		D15 5 < D ≤15 D15+ >15 (actual value to be stated)
	Length, L [c] 	cm	L20 ≤ 20 (± 2 cm) L25 ≤ 25 (± 2 cm) L30 ≤ 30 (± 2 cm) L33 ≤ 33 (± 2 cm) L40 ≤ 40 (± 2 cm) L50 ≤ 50 (± 4 cm) L100 ≤ 100 (± 5 cm)		L30 ≤ 30 (± 2 cm) L33 ≤ 33 (± 2 cm) L40 ≤ 40 (± 2 cm) L50 ≤ 50 (± 4 cm) L100 ≤ 100 (± 5 cm)
	Moisture, M [d] ISO 18134-1, ISO 18134-2	w-% as received wet basis	M20 ≤ 20 M25 ≤ 25		M20 ≤ 20 M25 ≤ 25 M35 ≤ 35
	Volume or weight	Volume m^3 stacked or loose or weight, kg as received	To be stated which unit is used when retailed (m^3 stacked or loose, kg) and/or packaged log woods weight.		
Informative	**Energy density, E** [e] or **Net calorific value, Q,** ISO 18125	MJ/m^3 or kWh/m^3 stacked or loose MJ/kg or kWh/kg, as received	Recommended to be stated.		
	Drying		Recommended to be stated, if firewood is dried by natural seasoning by ambient air or artificially by hot air.		
	Moisture, U [d]	w-% dry basis	U25 ≤ 25 U33 ≤ 33		U33 ≤ 33 U54 ≤ 54
	Decay and mould	% of pieces	No visible decay	≤ 5	If significant amount (more than 10 % of pieces) of decay or mould exists it should be stated.
	Proportion of split volume	% of pieces	≥ 90	≥ 50	No requirements
	The cut-off surface		Even and smooth [f]	No requirements	No requirements

[a] Wood species (e.g. spruce, birch, beech) can be stated by using EN 13556 Round and sawn timber Nomenclature[8]. If firewood includes different wood species, the main wood species should be mentioned first.

[b] 85 % of the firewood should be kept in specified diameter property class. For stoves it is recommended to use firewood with a diameter less than 15 cm. D2 and D5 are recommended for cookers and as kindling (ignition wood). In informative Annex B a simple method for measuring of the diameter is specified.

[c] It is allowed to have 15 % firewood shorter than requested length including the limit value.

[d] Moisture content should not be less 12 w-% on wet basis (M) or 13,64 w-% on dry basis (U). Calculation from M to U-basis is shown in informative Annex A.

[e] The energy density (E) may be calculated according to Annex C on the basis of the bulk density (BD) and the net calorific value .

[f] Use of chainsaw and circular saw will give a smooth and even cut-off surface.

Table 22 – Specification of pellets produced from herbaceous biomass, fruit biomass, aquatic biomass and blends and mixtures (EN ISO 17225-6)

	Property class, Analysis method	**units**	**A**	**B**
Normative	**Origin and source** [a], ISO 17225-1 Table 1		2 Herbaceous biomass 3 Fruit biomass 4 Aquatic biomass 5 Blends and mixtures	2 Herbaceous biomass 3 Fruit biomass 4 Aquatic biomass 5 Blends and mixtures
	Diameter, D [b] and **Length L** [c], ISO 17829 According Figure 1	mm	D06 to D25, $D \pm 1$; $3{,}15 < L \leq 40$ (from D06 to D10) $3{,}15 < L \leq 50$ (from D12 to D25)	D06 to D25, $D \pm 1$; $3{,}15 < L \leq 40$ (from D06 to D10) $3{,}15 < L \leq 50$ (from D12 to D25)
	Moisture, M, ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M12 ≤ 12	M15 ≤ 15
	Ash, A, ISO 18122	w-% dry	A6.0 ≤ 6	A10 ≤ 10
	Mechanical durability, DU, ISO 17831-1	w-% as received	DU97.5 ≥ 97,5	DU96.0 ≥ 96,0
	Fines, F [d], ISO 18846	w-% as received	F2.0 ≤ 2,0	F3.0 ≤ 3,0
	Additives [e]	w-%, dry	≤ 5 Type and amount to be stated	≤ 5 Type and amount to be stated
	Net calorific value, Q, ISO 18125	MJ/kg or kWh/kg as received	Q14.5 ≥ 14,5 or Q4.0 ≥ 4,0	Q14.5 ≥ 14,5 or Q4.0 ≥ 4,0
	Bulk density, BD, ISO 17828	kg/m^3 as received	BD600 ≥ 600	BD600 ≥ 600
	Nitrogen, N, ISO 16948	w-% dry	N1.5 ≤ 1,5	N2.0 ≤ 2,0
	Sulphur, S, ISO 16994	w-% dry	S0.20 ≤ 0,20	S0.30 ≤ 0,30
	Chlorine, Cl, ISO 16994	w-% dry	Cl0.10 ≤ 0,10	Cl0.30 ≤ 0,30
	Arsenic, As, ISO 16968	mg/kg dry	≤ 1	≤ 1
	Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5	≤ 0,5
	Chromium, Cr, ISO 16968	mg/kg dry	≤ 50	≤ 50
	Copper, Cu, ISO 16968	mg/kg dry	≤ 20	≤ 20
	Lead, Pb, ISO 16968	mg/kg dry	≤ 10	≤ 10
	Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1	≤ 0,1
	Nickel, Ni, ISO 16968	mg/kg dry	≤ 10	≤ 10
	Zinc, Zn, ISO 16968	mg/kg dry	≤ 100	≤ 100
Informative	**Ash melting behaviour** [f], CEN/TS15370-1 [3]	°C	Should be stated	Should be stated

[a] To be stated the 4-digit classification (Table 1 ISO 17225-1). Blends and mixtures can include also woody biomass. If composition of blend is known, the w-% can be used to specify blends. *Example 1*: 80 w-% 2.1.1.2 Straw, 20 w-% 2.1.2.2 Grasses, straw plant. In the case of mixture, the main component should be stated first. *Example 2:* 2.1.1.2 Straw, 2.1.2.2 Grasses, straw plant.

[b] Selected size (e.g. D06, D08, D10, D12 or D25) of pellets to be stated

[c] Amount of pellets longer than 40 mm can be 1 w-% (from D06 to D10). Maximum length shall be ≤ 45 mm for pellets from D06 to D10. Pellets are longer than 3,15 mm, if they stay on a round hole-sieve of 3,15 mm.

[d] At factory gate in bulk transport (at the time of loading) and in small (up to 20 kg)and large sacks (at time of packing or when delivering to end-user).

[e] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin).

[f] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Table 23– Specification of pellets produced from cereal straw, miscanthus and reed canary grass (EN ISO 17225-6)

	Property class, Analysis method	**units**	**Cereal Straw pellets**	**Miscanthus pellets** (*Miscanthus Giganteus*)	**Reed canary grass pellets** (*Phalaris arundinacea L.*)
Normative	**Origin and source**, ISO 17225-1 Table 1		2.1.1.2 Straw parts	2.1.2.1 Grasses, Whole plant	2.1.2.1 Grasses, Whole plant
	Diameter, *D* [a] and **length *L*,** [b] ISO 17829 According Figure 1	mm	D06 to D25, *D* ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, *D* ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, *D* ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)
	Moisture, M, ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M10 ≤ 10	M10 ≤ 10	M12 ≤ 12
	Ash, A[c], ISO 18122	w-% dry	A6.0 ≤ 6 A6.0+ > 6 [d]	A4.0 ≤ 4 A4.0+ > 4 [d]	A8.0 ≤ 8 A8.0 + > 8 [d]
	Mechanical durability, DU, ISO 17831-1	w-% as received	DU97.5 ≥ 97,5	DU97.5 ≥ 97,5	DU96.5 ≥ 96,5
	Fines, F [d], ISO 18846	w-% as received	F1.0 ≤ 1,0	F1.0 ≤ 1,0	F1.0 ≤ 1,0
	Additives [f]	w-%, dry	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated
	Net calorific value, Q, ISO 18125	as received, MJ/kg or kWh/kg	Minimum value to be stated	Minimum value to be stated	Q14.5 ≥ 14,5 Q4.0 ≥ 4,0
	Bulk density, BD, ISO 17828	kg/m^3 as received	BD600 ≥ 600	BD580 ≥ 580	BD550 ≥ 550
	Nitrogen, N, ISO 16948	w-% dry	N0.7 ≤ 0,7	N0.5 ≤ 0,5	N 2.0 ≤ 2,0
	Sulphur, S, ISO 16994	w-% dry	S0.10 ≤ 0,10	S0.05 ≤ 0,05	S0.20 ≤ 0,20
	Chlorine, Cl, ISO 16994	w-% dry	Cl0.10 ≤ 0,10	Cl0.08 ≤ 0,08	Cl0.10 ≤ 0,10
	Arsenic, As, ISO 16968	mg/kg dry	≤ 1	≤ 1	≤ 1
	Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5	≤ 0,5	≤ 0,5
	Chromium, Cr, ISO 16968	mg/kg dry	≤ 50	≤ 50	≤ 50
	Copper, Cu, ISO 16968	mg/kg dry	≤ 20	≤ 20	≤ 20
	Lead, Pb, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1	≤ 0,1	≤ 0,1
	Nickel, Ni, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Zinc, Zn, ISO 16968	mg/kg dry	≤ 100	≤ 100	≤ 100
	Informative **Ash melting behaviour** [g], CEN/TS 15370-1	°C	Should be stated	Should be stated	Should be stated

[a] Selected size (e.g. D06, D08, D10, D12 or D25) of pellets to be stated

[b] Amount of pellets longer than 40 mm can be 1 w-% (for D06 to D10). Maximum length shall be ≤ 45 mm for pellets for D06 to D10. Pellets are longer than 3,15 mm, if they stay on a round hole-sieve of 3,15 mm.

[c] Actual ash property class shall be stated.

[d] Value to be stated.

[e] At factory gate in bulk transport (at the time of loading) and in small (up to 20 kg)and large sacks (at time of packing or when delivering to end-user).

[f] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin).

[g] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Table 24 – Specification of graded non-woody briquettes (EN ISO 17225-7)

	Property class, Analysis method	**units**	**A**	**B**
Normative	**Origin and source** [a], ISO 17225-1 Table 1		2 Herbaceous biomass 3 Fruit biomass 4 Aquatic biomass 5 Blends and mixtures	2 Herbaceous biomass 3 Fruit biomass 4 Aquatic biomass 5 Blends and mixtures
	Diameter (D) or length (L_1), width (L_2) and height (L_3), According Figure in Table 19	mm	Diameter, width and length to be stated	Diameter, width and length to be stated
		Shape	Specify shape according to Figure in Table 19 e.g. 1 or 2, etc.	Specify shape according to Figure in Table 19 e.g. 1 or 2, etc.
	Moisture, M, ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M12 ≤ 12	M15 ≤ 15
	Ash, A, ISO 18122	w-% dry	A6.0 ≤ 6	A10.0 ≤ 10
	Particle density, DE, ISO 18847	g/cm^3 as received	DE0.9 ≥ 0,9	DE0.6 ≥ 0,6
	Additives [b]	w-%, dry	≤ 5 Type and amount to be stated	≤ 5 Type and amount to be stated
	Net calorific value, Q, ISO 18125	MJ/kg or kWh/kg as received	Q14.5 ≥ 14,5 or Q4.0 ≥ 4,0	Q14.5 ≥ 14,5 or Q4.0 ≥ 4,0
	Nitrogen, N, ISO 16948	w-% dry	N1.5 ≤ 1,5	N2.0 ≤ 2,0
	Sulphur , S, ISO 16994	w-% dry	S0.20 ≤ 0,20	S0.30 ≤ 0,30
	Chlorine, Cl, ISO 16994	w-% dry	Cl0.10 ≤ 0,10	Cl0.30 ≤ 0,30
	Arsenic, As, ISO 16968	mg/kg dry	≤ 1	≤ 1
	Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5	≤ 0,5
	Chromium, Cr, ISO 16968	mg/kg dry	≤ 50	≤ 50
	Copper, Cu, ISO 16968	mg/kg dry	≤ 20	≤ 20
	Lead, Pb, ISO 16968	mg/kg dry	≤ 10	≤ 10
	Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1	≤ 0,1
	Nickel, Ni, ISO 16968	mg/kg dry	≤ 10	≤ 10
	Zinc, Zn, ISO 16968	mg/kg dry	≤ 100	≤ 100
Informative	**Surface area of briquettes,** including the hole surface if existing	cm^2/kg	To be stated	To be stated

[a] To be stated the 4-digit classification (Table 1 ISO 17225-1). Blends and mixtures can include also woody biomass. If composition of blend is known, the w-% can be used to specifying blends. *Example 1*: 80 w-% 2.1.1.2 Straw, 20 w-% 2.1.2.2 Grasses, straw plant. In the case of mixture, the main component should be stated first. *Example 2:* 2.1.1.2 Straw, 2.1.2.2 Grasses, straw plant.

[b] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin).

NOTE The combustion time may also be an important parameter for further characterisation of the combustion behaviour. The combustion time indicates in which time the energy of the briquettes is released. The combustion time depends on both the shape and density of the briquettes as well as the air ratio.

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

S2Biom Project Grant Agreement n°608622

ANNEX III of D2.1
Instructions on the database of conversion technologies
WP2

30 April 2015

About S2Biom project

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

Project coordinator

Scientific coordinator

Project partners

About this document

This report corresponds to (number and name of deliverable) of S2Biom. It has been prepared by:

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

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1.0	31/3/2014	M.W. Vis	First version	
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Table of contents

List of Figures

List of Tables

1. Introduction

This document was written within the S2BIOM project for Task 2.1. 'Identification and characterisation of existing and future non-food biomass conversion technologies for energy and bio based products".

In the document *"Identification and characterization of conversion technologies"* an overview of conversion technologies is presented that are potentially relevant for the production of energy and materials in the period up till 2030. Based on this overview, a selection is made of conversion processes that are relevant today, and that are expected to contribute significantly to renewable energy and the biobased economy in 2020 and 2030. The following main classification of conversion technologies has been used:

I. Thermal conversion technologies

1. Direct combustion of solid biomass	VTT
2. Gasification technologies	VTT
3. Fast pyrolysis	BTG
4. Torrefaction	ECN
5. Syngas platform	ECN
6. Treatment in subcritical water	BTG
7. Treatment in supercritical water	BTG

II . Chemical and biochemical conversion technologies

8. Anaerobic digestion	DLO
9. Techniques from pulp and paper industry	VTT
10. Pretreatment, hydrolysis and fermentation	DLO

For each conversion technologies a number of chains of processes and applications have been selected for inclusion in the database. The long list of technologies, selected processes and applications and motivation of the selection can be found in the document *"Identification and characterization of conversion technologies"*.

Based on own research and inputs from WP2 partners and in cooperation with WP3 and taking into account the models used elsewhere in the S2BIOM project, BTG has selected a number of relevant technical properties and biomass input specification for inclusion in the database. This instruction document describes the fields that can be found in the database with further explanation where required.

2. Practicalities

2.1 Login

The database is set up and maintained by DLO and can be found on http://flexwood.felis.uni-freiburg.de:8080/en/web/guest/maintain-conversions. All WP2 partners will receive a login name and password, which give access to the database.

2.2 The database

After login, you will find a screen with biomass chains described so far. If not, go to “maintain” and selected “conversions”.

For adding a description of a **new** conversion chain, click “add item”. Now you can fill in the database. **See chapter 3 for further instruction on the data items.** The second page is reached by clicking “save and proceed”.

If you would like to **edit** a conversion chain that was already described, please find the conversion chain in the list and click the edit button at the utmost right column.

If you would like to **delete** a conversion chain, please find the conversion chain in the list and click the edit button at the utmost right column.

Don’t edit or delete conversion chains, if you are not the author.

2.3 Contact persons

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

In case of questions about this instruction document or content of the database, please contact Rik te Raa, teraa@btgworld.com, +31 53 486 1187.

In case of other questions on WP2 please contact Martijn Vis, vis@btgworld.com, +31 53 486 1193.

3. Properties to be described

For each input (one or preferably more) data sources need to be provided. For existing technologies values based on practical experience will be used. Where appropriate, data ranges and typical values will be required.

3.1 General properties

- Name:
    - Use a unique name (commercial name, brand name, name technology supplier whatever is appropriate)

  Beware: <u>this is the only field that cannot be changed later by editing.</u>

- Description of the main category of the technology (drop down list)
    - For instance "combustion", see the titles of each sub paragraph of section 4.1 and 4.2.

- Description of sub-category of the technology (drop down list + option new)
    - F.i. "fixed bed combustion for combined heat and power", see the technologies selected for database.
    - The drop down list is based on earlier discussions with WP2 partners. If the list of sub-categories needs to be extended please contact Rik te Raa.

- Image(s) of the technology (URL to the image)

- Year of first implementation
    - Year of the first pilot/demo introduction of the technology

- Estimated number of systems in operation (number)

- Description of main operating principle of technology (text)
    - Including brief description of the technology and most common/suitable applications
    - Three or four lines should be sufficient

- Level of commercial application (text)
    - Describe the main markets of the technologies and if it is commonly applied.

- Names important pilots-demo´s, and EU projects
    - Relevant reference projects

- Current Technology Readiness level in 2014 (drop down list 1-9)
    - see the box below for the meaning of each number.

Box 1: Technology Readiness levels 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.

- Expected developments = expected Technology Readiness Level in 2030 (drop down list 1-9)

- Justification of expected TRL is 2030 (text)
    - Please use arguments and references to relevant literature (energy outlooks etc.).

- References to information sources, section general properties (text).
    - E.g. reference to article, reference to report, web address, personal communication, etc. used in the general properties part.

3.2 Technical properties

- Capacity of outputs (typical values)
    - Select the relevant outputs e.g. power, heat, products, fuels, that are listed.
        - Power: MW_{power}output
        - Heat: MW_{heat}output
        - Fuels: Production: m3/hour + LHV of the fuel: GJ/m3
        - Products, chemicals: tonnes/hour
    - **If the technology produces outputs that are not listed, please contact Rik te Raa, BTG. As a database manager he can add outputs to the list.**

- Conversion efficiencies (2014, 2020 and 2030)
    - Provide the conversion efficiency for each output.
    - Only typical values for 2020 and 2030, if technical development is expected to cause a change in conversion efficiency.
    - Net energy returns electricity (useable GJ/GJ biomass input)
        - Typical value
        - Min
        - Max
    - Net energy returns useable heat (GJ useable heat/GJ biomass input)
        - Typical value
        - Min
        - Max
    - Net energy returns fuels (fuel GJ/GJ biomass input)
        - Typical value
        - Min
        - Max
    - Net product returns (kg product/kg dry biomass input; possibility to introduce new product type, please contact Rik te Raa (teraa@btgworld.com) if this is needed.)
        - Typical value
        - Min
        - Max

- Data sources to define conversion efficiencies in 2014, 2020 and 2030 (text)

  - All conversion efficiencies need to be justified by relevant literature. This is one of the most important inputs for further modelling, so please do this carefully.

- indication: experience based data (yes, no)
  - Experience based data is preferred above theoretical efficiencies.

- External inputs, not generated by the biomass in the conversion process).
  - Auxiliary power, heat, fuels and products like
    - Power (kW) (number)
    - Heat (kW) (number)
    - Natural gas (GJ/hour)
    - Other fuels (GJ/hour) (possibility to make new category)
  - Other input demand like materials, chemicals, enzymes, etc.;
  - **There is a possibility to introduce new input types. Please contact Rik te Raa (teraa@btgworld.com) if this is needed.**

- Number possible full load hours per year
  - technically possible (hours/year)

- Number of typical full load hours per year
  - E.g. in case of application for residential heating the number of typical full load hours can be much lower than the technical maximum.

- Typical lifetime of equipment (years)
  - Technical lifetime is required here

- General data sources technical properties (text)
  - List data sources used in the technical properties section.

[save and proceed]

3.3 Biomass input specifications

This section describes information on the minimum requirements of biomass supplied to the site of the conversion unit, coming e.g. from the biomass supplier or pretreatment unit, (before possible further on site pretreatment before conversion).

- Biomass input common for the technology used
    - Selection from drop down list of biomass types described in WP1 (selection of 1-5 biomass types)

    N.B. This selection of five common biomass types is indicative. Later, the suitability of the each biomass type for the conversion technology will be evaluated based on the biomass properties of each biomass type by a Matching Tool to be developed in Task 2.3.

- Biomass input that could technically be possible to convert but not commonly applied
    - drop down list from text, categories WP1 (selection of 0-10 biomass types)

    N.B. This selection of 0-10 other biomass types is indicative. Later, the suitability of the each biomass type for the conversion technology will be evaluated based on the biomass properties of each biomass type by a Matching Tool to be developed in Task 2.3.

The full list of biomass types is defined in WP1 and is presented in the Box below.

Box 2: Biomass types considered in the S2BIOM project

Grasses

1 Cardoon, Energy Grasses, Annual Crops, Perennial Crops
2 Sorghum, Energy Grasses, Annual Crops, Perennial Crops
3 Miscanthus, Energy Grasses, Annual Crops, Perennial Crops
4 Switchgrass, Energy Grasses, Annual Crops, Perennial Crops
5 Giant_reed, Energy Grasses, Annual Crops, Perennial Crops
6 Reed Canary Grass, Energy Grasses, Annual Crops, Perennial Crops
7 Grass, Abandoned grassland
8 Grass, Biomass (roadside Verges)
9 Grass, Landscape care

Agricultural residues

10 Cereals Rice, Straw/stubbles
11 Maize, Straw/stubbles
12 Rape, Straw/stubbles
13 Sugarbeet, Straw/stubbles
14 Sunflower, Straw/stubbles
15 Cotton_acorn, Cotton Industry by-products
16 Others, Cotton Industry by-products
17 Nuts, Woody prunnings/orchard residues
18 Olive-stones, Sec. Residues (food/fruit processing Industries)

19 Others, Sec. Residues (food/fruit processing Industries)

Woody biomass

Woody energy crops

20 Willow, SRC on ag. land
21 Poplar, SRC on ag. land
22 Other (incl. Eucalyptus), SRC on ag. Land

Forest wood

23 Broadleaf, Stem/Crown Biomass (early thinnings)
24 Broadleaf, Stemwood (thinnings & final fellings)
25 Broadleaf, Logging residues (thinnings & final fellings)
26 Broadleaf, Stumps (thinnings & final fellings)
27 Conifer, Stem/Crown Biomass (early thinnings)
28 Conifer, Stemwood (thinnings & final fellings)
29 Conifer, Logging residues (thinnings & final fellings)
30 Conifer, Stumps (thinnings & final fellings)

Woody Prunings/orchard residues

31 Citrus, Woody prunnings/orchard residues
32 Fruit trees, Woody prunnings/orchard residues
33 Olives, Woody prunnings/orchard residues
34 Vineyards, Woody prunnings/orchard residues

Wood outside forests

35 Wood, Biomass (roadside Verges)
36 Wood, Landscape care
37 Paper cardboard, Other Biomass (trees/hedges outside forests)
38 Other, Other Biomass (trees/hedges outside forests)

Secondary wood residues

39 Chips, Sec. Residues (Wood-products Industries)
40 Sawdust, Sec. Residues (Wood-products Industries)
41 Other SawMill Byproducts, Sec. Residues (Wood-products Industries)
42 Veneer cores, Sec. Residues (Wood-products Industries)
43 Other residues, Sec. Residues (Wood-products Industries)
44 Black liquor, Sec. Residues (Pulp/Paper Industries)
45 Semi-finished, Sec. Residues (wood-based production)
46 Finished, Sec. Residues (wood-based production)

Tertiary wood residues

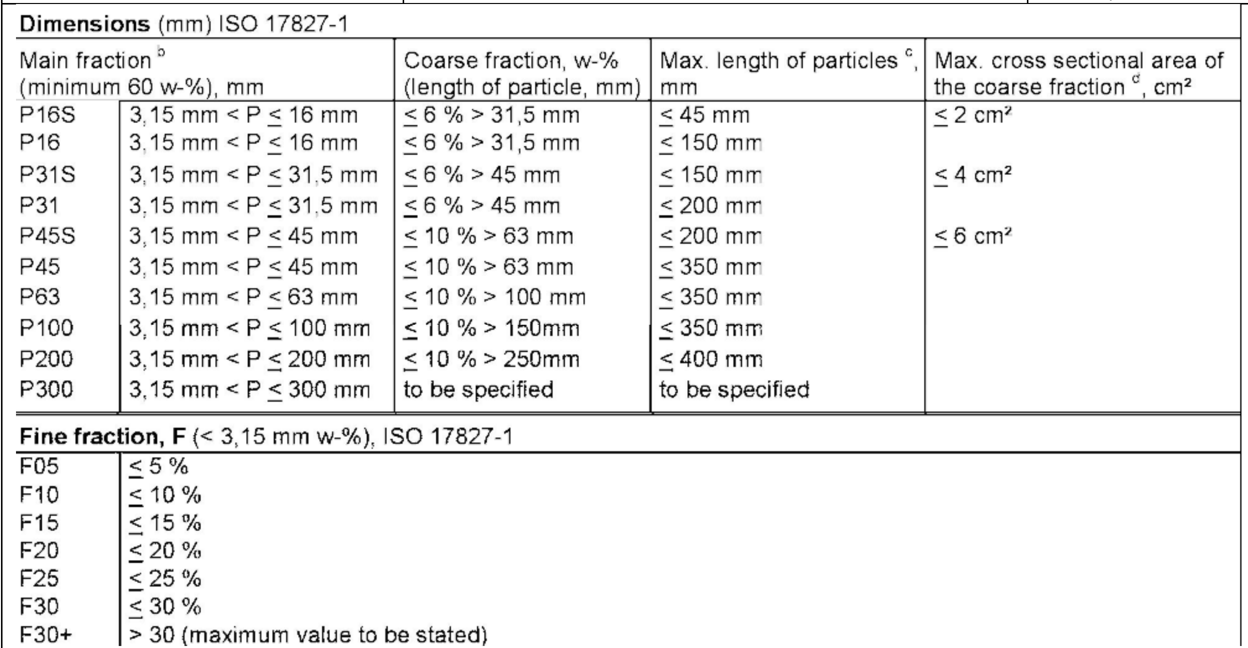
47 A_quality, Construction and demolition wood
48 B_quality, Construction and demolition wood
49 C_quality, Construction and demolition wood
50 Organic fraction, Biodegradable municipal waste
51 Post consumer wood, Woody waste

- Traded form (drop down list)
    - E.g. chips, pellets, grassy material etc. (See p 11, Table 2 of document VTT)

- Dimensions
    - The dimensions depend on the traded form, and will be described according to ISO standards. IN the table below the meaning of the dimensions is further explained.
    - For some traded forms information on the fine fraction is required.

Table 1 Overview of dimensions of the different traded forms

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)



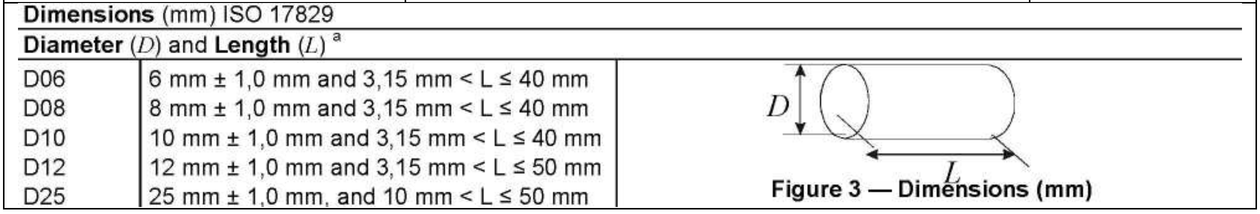
Dimensions (mm) ISO 17827-1

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)

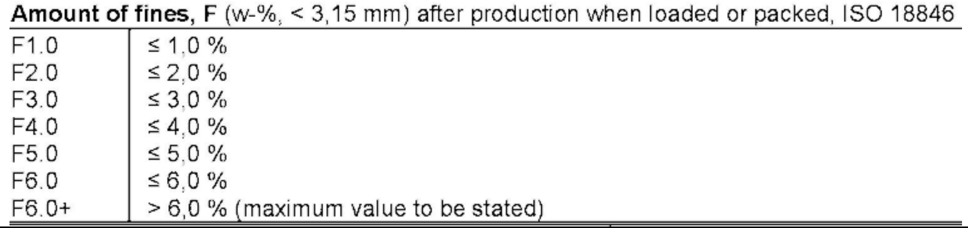


Dimensions (mm) ISO 17829

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

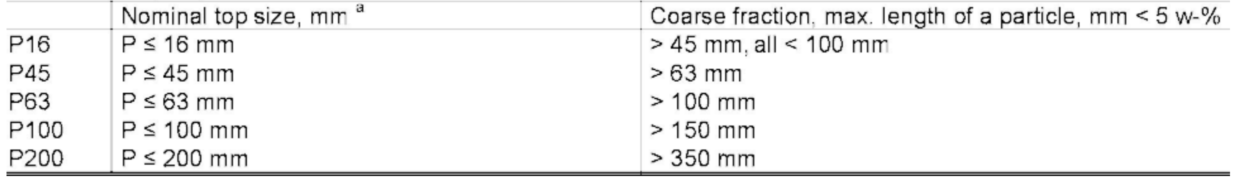
Figure 3 — Dimensions (mm)



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)

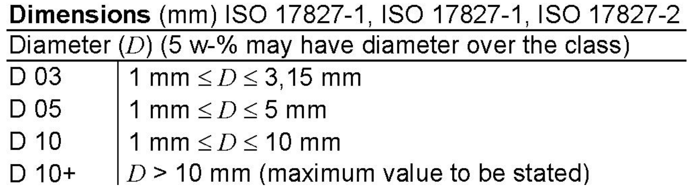
shavings	not applicable	
sawdust	not applicable	
bark	P16-P200 (see below)	



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

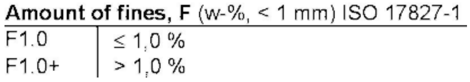
chopped straw or energy grass	Length	
round bales	length x diameter	
square bales	Length x width x height	
fruit seeds, olive residues	D03-D10+ (see below)	F1.0-F1.0+ (see below)



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 %

Other (for example examples of other are black liquor, BMW, PO etc.)	not applicable	

- Typical moisture content (% wet basis)
    - Will be used for the mass/energy balance

- Maximum moisture content (% wet basis)
    - Maximum moisture content that the technology can handle

- Minimum bulk density (kg/m^3, wet basis)

- Maximum ash content (weight %, dry basis)

- Minimal ash melting point (= initial deformation temperature) (°C)

- Volatile matter (VM%, only for thermally trated material, torrefied or steam exploded)

- Maximum allowable content of
    - Nitrogen (N) (wt%, dry basis)
    - Sulphur, S (wt%, dry basis)

  - Chlorine (Cl) (wt%, dry basis)

Optional attributes
Please fill in the following optional biomass input requirement (min and max values), except if it the requirement has no meaning for the technology considered.

- Net calorific value (MJ/kg) (number)

- Gross calorific value (MJ/kg) (number)

- Cellulose content (g/kg dry matter) (number)
- Hemicellulose content (g/kg dry matter) (number)
- Lignin content (g/kg dry matter) (number)

- Crude fibre content (g/kg dry matter)
- Starch content (g/kg dry matter)
- Sugar content (g/kg dry matter)
- Fat content (g/kg dry matter)
- Protein content (g/kg dry matter)

- Acetyl group content (g/kg dry matter)

3.4 Financial/economic properties

Financial properties will be based on the typical values as described in the section on technical properties. The financial properties will be average values for the EU28, collection of country specific financial data (like labour costs/FTE) is outside the scope of WP2. Biomass costs will be provided in WP1.

- Investment costs (2014, 2020 and 2030, in Euro)
  - Investment of complete installation including equipment, engineering, building, excluding land (Euro)
  - Please ensure that the investment costs meet with the output capacities that have been indicated under technical properties.

  N.B. This value can easily be converted to Euro/kW, or Euro/kg product, whenever needed for further modelling.

- Labour requirements for typical installation (FTE for typical installation)
  - Operators (primary education - technician) (FTE)
  - Staff and engineering (B.Sc, M.Sc, dr. level) (FTE)

  Can be recalculated to hours/tonne input
  Wages differ much between regions, this data will not be collected here.

4. General considerations

In the selection and description of conversion technologies the following general considerations should be taken into account.

- The S2BIOM project focusses on lignocellulosic conversion technologies. Therefore, the classification should be relevant for this category of biomass. For instance technologies using sugar, starch or oil crops are not considered.
- The DOW makes a distinction between “existing” and “future” conversion technologies. This distinction will be replaced by an indication of the Technology Readiness Levels (TRL) to describe the state of the technology. The EC uses TRL in its Horizon 2020 programme. See Annex A. TRL 7-8 can be regarded as “existing”; TRL 1-6 as “future”.
- The technology descriptions consider - when appropriate - changes in time for conversion efficiency and investment costs for 2020 and 2030. This is especially relevant for the future conversion technologies. For other data items a single value will be provided. Uncertainty and variations within one technology are at present day already large, which makes estimation of future variations not useful.
- Conversion technologies will be described that produce heat, power, heat & power, fuels, chemicals and products. In the technology description, all outputs will be indicated and described.
- A number of conversion technologies will be divided into sub-categories (especially combustion, gasification, anaerobic digestion) related to their technical properties, biomass input and capacity range.
- The distinction between thermochemical and biochemical technologies in the Task 2.1 description is further worked out into a more extended list.
- The focus will be on conversion technologies that can be applied in Europe and meet European environmental standards and requirements of BAT.
- 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. need of electricity, natural gas, chemicals) will be described in the mass and energy balance. Complete calculation of GHG performance or GHG factors are case specific and will not be described. Emissions for construction of the conversion technologies will not be described in WP2.
- Carbonization is not included in the list of technologies. In Europe charcoal is mainly used for barbeque, an application that provides heat & smoke but does not add to the renewable energy targets of the EU.
- Avoid long descriptions of technologies, refer to relevant literature and actual data from running plants/demo’s/projects.
- Selection of the most relevant conversion pathways is an important part of the work.
- The selection of technologies will be matched with requirements from other WPs in advance. WP2 will have limited possibilities to deliver tailor made datasets during the course of the project.
    - WP1: technologies should cover the biomass sources assessed in WP1. (BTG participates in WP1)

- WP3: close cooperation with WP3 logistics (Bert Annevelink, DLO)
- The database structure for conversion technologies will be developed in close cooperation with WP 4. (Contact person: Berien Elbersen, DLO)
- The RESolve model in WP7 requires information on several types of combustion, and wishes to expand to biobased options. Contact person: Joost van Stralen, ECN.
- The BeWhere Model and ME4 model will use data on biomass conversion developed in WP2. Information can be provided through WP4 (Contact person: Igor Staritsky)
- WP5: mass and energy balances as input for environmental assessment (IINAS).

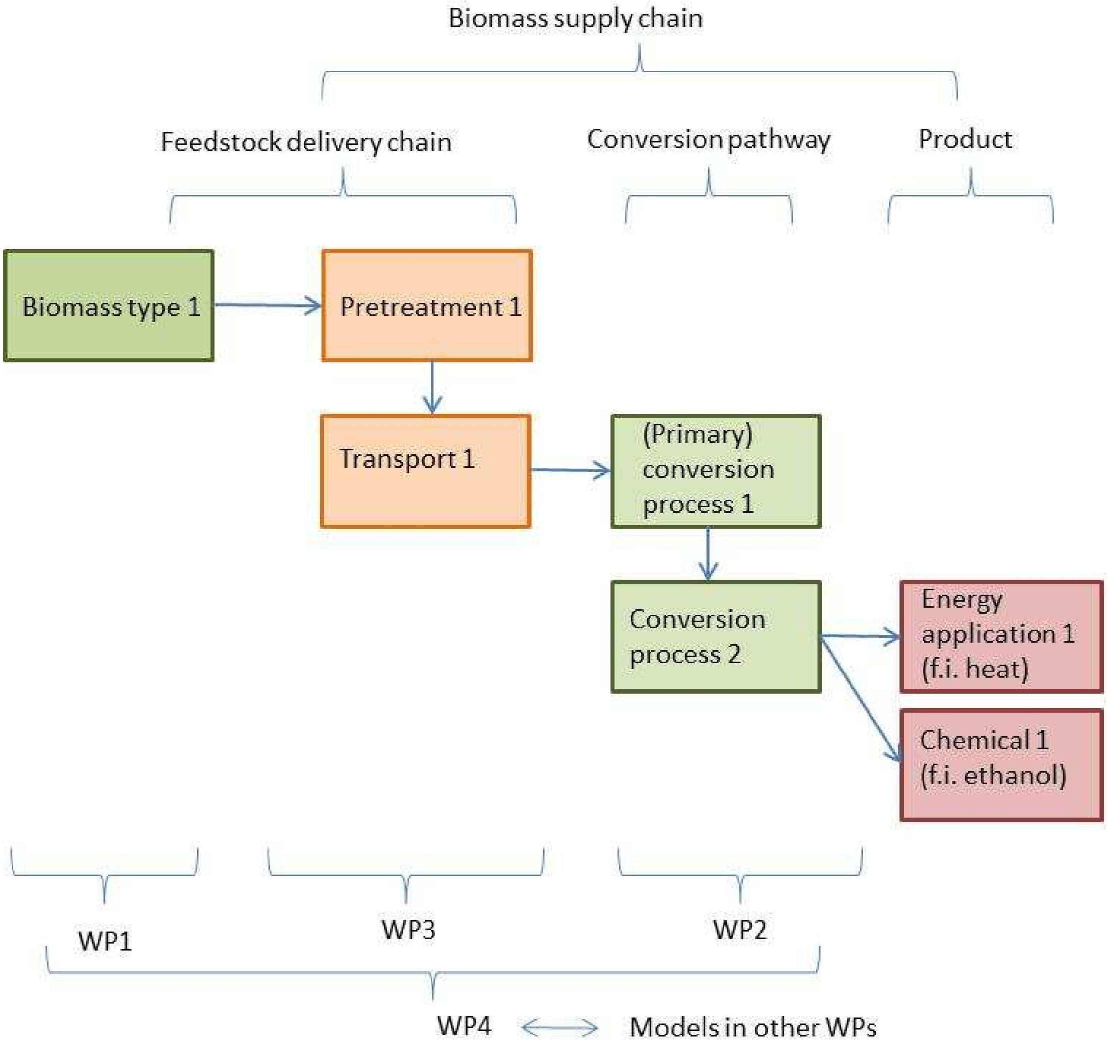


Figure 1 Structure of WP2 in WP1-4 of S2BIOM project