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Pre-normative research on solid biofuels for improved European standards

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PRIORITY [6-1] – Sustainable energy systems



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Abstract

The development of European Standards (EN) is a precondition to expand the market for solid biofuels and a very important step to fulfil the political and environmental goals of the European Union.

The aim of the BioNorm II project is to carry out pre-normative research in the field of solid biofuels in close collaboration with the work of CEN TC 335 "Solid Biofuels". This includes the development of an overall quality assurance system for solid biofuels, their characterization and corpus of legislation.

In WP III the work focuses on the development of a Quality Management System in order to guarantee a defined biofuel quality. Based on the results of the former BioNorm project where a Quality Assurance and Quality Control System were developed WP III now concentrates on the Quality Policy including also Quality Planning and Quality Improvement.

A major aim of WP III is the development of a "Procedure for Quality Planning" which will give an overview about relevant quality measures within the supply chains of different biofuels. The following biofuels: wood pellets, wood chips, hog fuel, straw and olive residues cover the most common and also new and potential biofuels. Therefore relevant information about end-user requirements, quality influencing factors, Critical Control Points, appropriate test methods and the description of the supply chains is needed which was compiled by four national teams. On the basis of DIII.7 Assessment and evaluation of data this guideline DIII.8 Procedure for Quality Planning demonstrates a simple way how to optimize the quality of a biofuel with the help of management tools. The guideline is not just on the scientific level, but also for biofuel companies which want to implement a Quality Management system as common consumer.

According to ISO 9000:2005 Quality planning is "the part of quality management focused on setting quality objectives and specifying necessary operational processes and related resources to fulfil the quality objectives".

In that context this guideline describes the procedure for quality planning, including Critical Control Points (CCPs), most appropriate test methods, costs as well as necessary arrangements for provision, transport and storage along the whole supply chain.

List of Abbreviations

CCPs	Critical Control Points
PDCA	Plan, Do, Act, Control
QA	Quality Assurance
QC	Quality Control
QI	Quality Improvement
QM	Quality Management
QP	Quality Planning
TDR	Time-Domain-Reflectometry
WP	Work Package

Table of Contents

1	GENERAL PART “TERMS AND DEFINITIONS”	7
1.1	Quality Management.....	7
1.2	Quality Planning.....	8
1.3	Quality Control.....	8
1.4	Quality Assurance	9
1.5	Quality Improvement.....	9
1.6	Raw material supply	9
1.7	Customer requirements	9
1.8	Supply chain.....	9
1.9	Critical Control Points.....	10
1.10	Quality influencing factors	10
2	CORPUS OF LEGISLATION	10
3	GENERAL PART “GENERAL SUPPLY CHAIN OF BIOFUELS”	11
4	SUPPLY CHAIN OF BIOFUELS	12
4.1	Supply chain of wood pellets	13
4.2	Supply chain of wood chips	14
4.3	Supply chain of hog fuel (waste wood).....	15
4.4	Supply chain of straw	16
4.5	Supply chain of olive kernels	17
5	QUALITY INFLUENCING FACTORS	18
6	APPROPRIATE TEST METHODS	23
6.1	Methods for moisture determination overview.....	23
7	“TEST METHODS” AND COSTS	25
8	LITERATURE	26

1 General Part “Terms and definitions”

1.1 Quality Management

Quality Management (QM) consists of strategies and methods for maintaining or improving the quality of a product or service to a given level. It does not necessarily improve quality; instead it aims at constantly providing the desired quality. All activities needed to design, develop or implement a product should be both effective and efficient concerning the overall performance of a production.

The goal of QM is to keep the customer satisfied with a product while minimising the costs by setting quality objectives and specifying the steps towards fulfilling them, e. g. strategies to handle problems and complaints, strategies to maintain or improve customer satisfaction, communication schemes, staff training, documentation or standards for products and services.

QM is standardised in EN ISO 9000:2005 and EN ISO 9001:2000. It is based on the four elements Quality Planning, Quality Control, Quality Assurance and Quality Improvement. [1]

The principle of QM is often summarised in a so-called PDCA-Cycle:

PDCA is an abbreviation for Plan, Do, Control and Act. First, the desired quality improvements are planned, afterwards the planned actions are applied (Do). The product quality is assessed (Control) quality improvements are planned. In the “Act” stage, the effects of the applied changes are assessed. Based on these results, further improvements are planned, so the cycle continues iteratively.

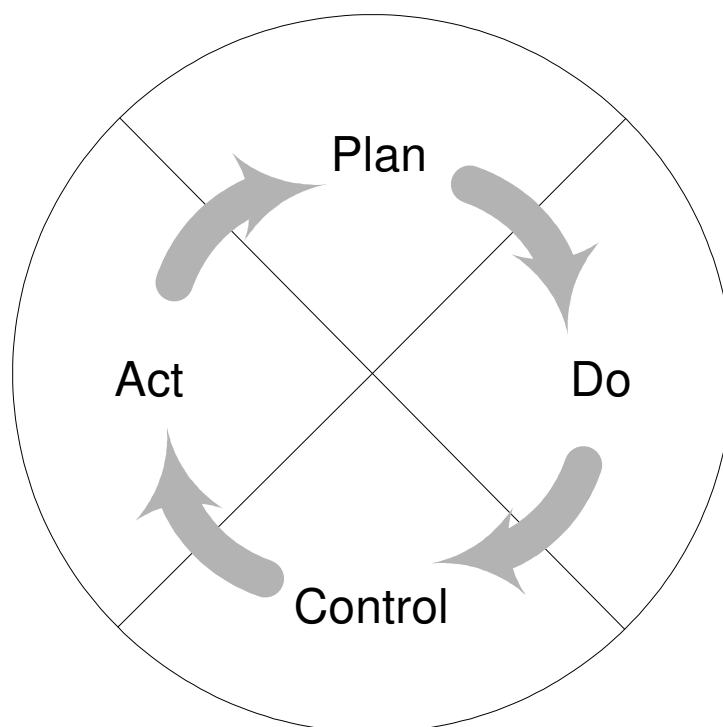


Illustration 1: PDCA cycle

In QM practice, a PDCA cycle could look like the diagram below. The planning part is carried out by the management along with resource management. Then the product is realised (Do). Measurement and analysis are the “Control” part. The management responsibility represents the “Act” part.

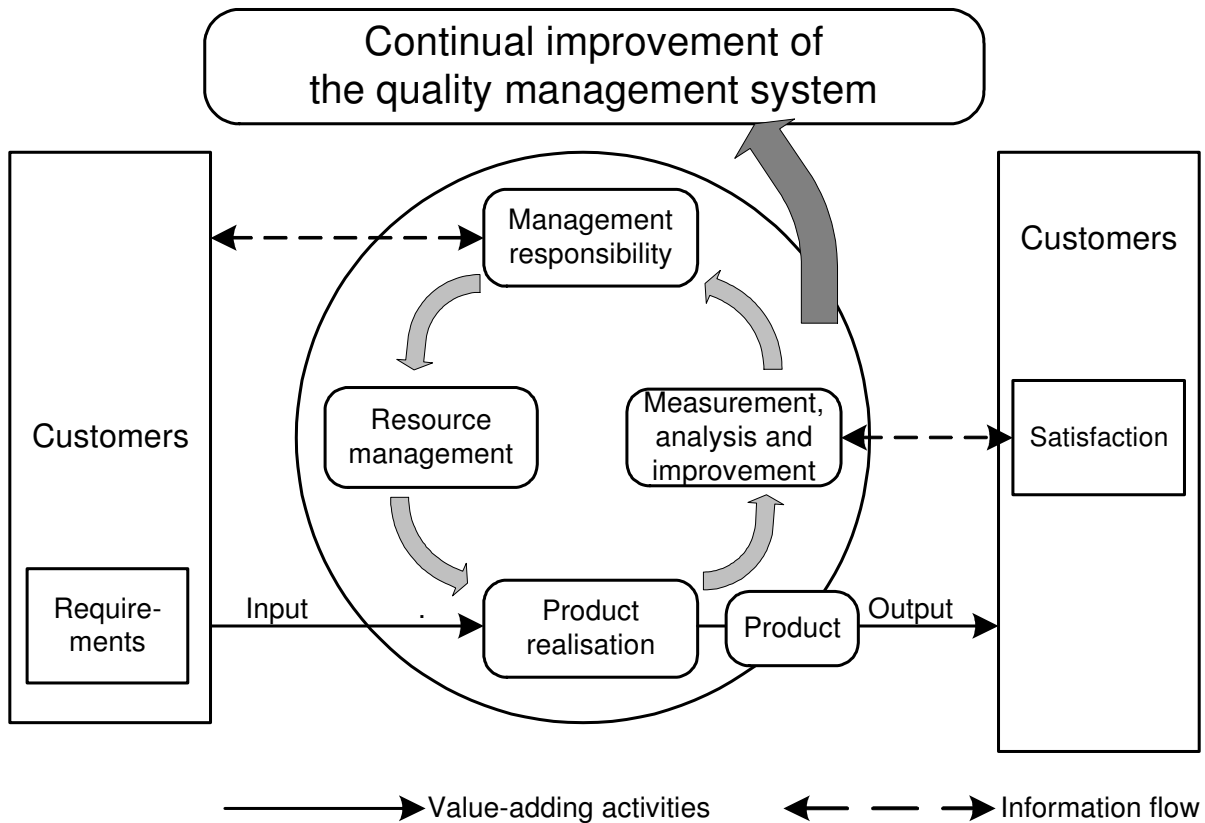


Illustration 2: PDCA cycle (ISO 9000:2006)

By applying a QM system, it is possible to give the customer assured or even certified information about the quality of a product which creates confidence in the product as well as the manufacturer. In that context both the customer and the supplier benefit from QM.

1.2 Quality Planning

In Quality Planning (QP), the status quo is analysed regarding product requirements along the supply chain, available technical resources, the staffs' know-how, market position and image. Potentials for quality improvement are identified and quality objectives (e. g. ash content) are set to meet customer requirements. Necessary steps to fulfil them (e. g. change the raw material) are defined. [1]

QP also includes the discovery of hidden customer needs and the translation of these needs into the production process, as well as the design of the process in the most efficient way.

1.3 Quality Control

Quality Control (QC) seeks to reach the targets set by Quality Planning. It does so by measurements or inspections at Critical Control Points after a defined QC plan and their documentation. QC only answers the question whether a piece or batch of product meets the quality requirements (and can be sold) or not. It does not track down error sources nor are sets of results interpreted.

This is the point where Quality Assurance comes into play.

An example for QC could be the measurement of the moisture content in wood before pelletising on a regular basis: Every time a load is delivered, the moisture content is determined. Then, the dryer is adjusted accordingly to provide a constant quality after drying.

1.4 Quality Assurance

Quality Assurance (QA) focuses on providing confidence that quality requirements will be fulfilled. The goal is to improve transparency, consistency and efficiency which create confidence in the product and to reduce the amount of sampling and testing to an indispensable level which reduces costs.

QA uses mostly Quality Control data to assure that products are produced within specifications in correctly operated processes and to maintain or improve product quality. It does so by trending and reviewing data not only to determine whether a given product fulfils specifications but also to identify the roots of a problem. Quality Assurance covers actions like staff training, setting of general procedures, their documentation and control of the results.

The amount of data to be reviewed can be cut down by exception reporting, where only cases outside the specifications are reported to the quality team. [3]

The two essential messages of Quality Assurance are that a product should be "fit for purpose", i. e. it should meet the requirements for its intended purpose, and it should be done "right first time", i. e. the source of errors should be eliminated instead of removing defective products from a lot.

1.5 Quality Improvement

Quality Improvement (QI) strategies help to increase the ability to meet quality requirements. The status quo is compared to the desired state and improvement measures are implemented, if necessary. The results are checked regarding the effectiveness of the taken improvement actions. By doing so, the probability of mistakes is reduced and the quality of the product constantly increased until it meets customer requirements.

In some cases, the fuel quality is mostly governed by factors beyond the control of any of the actors in the handling chain. For instance, the major challenge in straw quality management is, that in a given year the weather is the one dominant factor determining the possibilities of producing high quality straw for combustion. So securing straw in sufficient amounts and of an acceptable quality (i.e. quality improvement) is more a matter of implementing routines and actions, which over a number of years will optimize the production and improve the average straw quality.

1.6 Raw material supply

The raw material supply delivers unprocessed or minimally processed materials at the start of the supply chain. For solid biofuels, raw materials are e. g. wood logs, straw bales or saw dust.

1.7 Customer requirements

Customers expect a product to fulfil minimum requirements in order to be able to use the product. This could be a minimum required mechanical durability for wood pellets or a maximum nitrogen content.

1.8 Supply chain

A supply chain is the system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. [4]

1.9 Critical Control Points

Controls can be applied to monitor the quality of the product at Critical Control Points where the greatest potential for quality improvement lies. Relevant properties are measured in or between processes. Here, crucial decisions can be made to prevent quality loss or damaged product.

1.10 Quality influencing factors

Quality influencing factors refer to technological aspects as well as to management related activities which influence the fuel quality significantly. These factors e. g. refer to

- Effectiveness of the preliminary inspection for the required fuel sources,
- Effectiveness of the checking for the incoming loads,
- Appropriateness of the applied methods for handling, storing and processing the materials,
- Quality Control measures adopted,
- Effectiveness of the company's' management and operational responsibilities to control the business and processes,
- Qualifications and knowledge of staff

2 Corpus of legislation

Quality Planning (QP) should help to guarantee a high and constant fuel quality. For QP a lot of helpful standards already exist and their knowledge is essential to produce, trade or use solid biofuels.

CEN/TS 14588 is a standard about terminology, definition and description of bio fuel terms. This standard describes and defines all relevant terms (about 150 different terms) and contains also the translation of this terms in different languages. This is important for every participant on the biofuel market starting with the raw material trader who should know what kind of biomass he sells, up to the producer to know the right product-labeling and the end user, to know what he is buying.

CEN/TS 14961 is a standard about fuel specification and classes and describes very detailed all kind of biofuel sources and origin, requirements and their right labeling. The knowledge of this standard is essential for all fuel producer and traders because of the description of all parameters of a fuel class a biofuel should have. Furthermore this document contains tables with typical values for different biomass sources, what is essential for the biofuel producer if they decide to produce a fuel with special quality and is available in 6 parts, where each part is specialized for one fuel group. This standard is one of the most important documents for producer and trader and also laboratories and end user should know it.

CEN/TS 15234-Fuel Quality Assurance, covers the Fuel Quality Assurance of the supply chain and the information to be used in the quality control of the biofuel. This standard is essential for fuel producer and should be known before starting to produce the fuel.

These documents should be common to every participant on the biofuel market. The following table shows all solid-biofuel standards that exist at the moment (standards for solid biofuels will be permanently developed in the BioNorm project) and give also the information who should know the single standards.

Table 1: Standards and target group

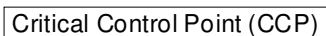
Standards	Titel/ Parameter	alloted to
CEN/TS 14588	Terminology, definition and description	Every participant on bio fuel market
CEN/TS 14774	Determination of moisture content	Laboratory and on site quality control
CEN/TS 14775	Determination of ash content	Laboratory
CEN/TS 14778	Sampling - Methods of sampling	Laboratory and bio fuel producer/trader
CEN/TS 14780	Methods for sample preparation	Laboratory and bio fuel producer/trader
CEN/TS 14918	Determination of calorific value	Laboratory
CEN/TS 14961	Fuel specification and classes	Every participant on bio fuel market
CEN/TS 15103	Determination of bulk density	Laboratory and bio fuel producer/trader
CEN/TS 15104	Determination of total content of carbon, hydrogen and nitrogen - Instrumental method	Laboratory
CEN/TS 15105	Determination of the water soluble content of chloride, sodium and potassium	Laboratory
CEN/TS 15148	Determination of the content of volatile matter	Laboratory
CEN/TS 15149	Determination of particle size distribution	Laboratory
CEN/TS 15150	Determination of particle density	Laboratory
CEN/TS 15210	Determination of mechanical durability of pellets and briquettes	Laboratory and on site quality control
CEN/TS 15234	Fuel quality assurance	Every participant on bio fuel market
CEN/TS 15289	Determination of total content of sulphur and chlorine	Laboratory
CEN/TS 15290	Determination of major elements	Laboratory
CEN/TS 15296	Calculation of analyses to different bases	Every participant on bio fuel market
CEN/TS 15297	Determination of minor elements	Laboratory
CEN/TS 15370	Determination of ash melting behaviour	Laboratory

This standards can be bought in national standardization institutes and some of them are also available in different languages.

3 General Part “General supply chain of biofuels”

Legend

 Process step

 Critical Control Point (CCP)

⊙ influencing factor to be measured

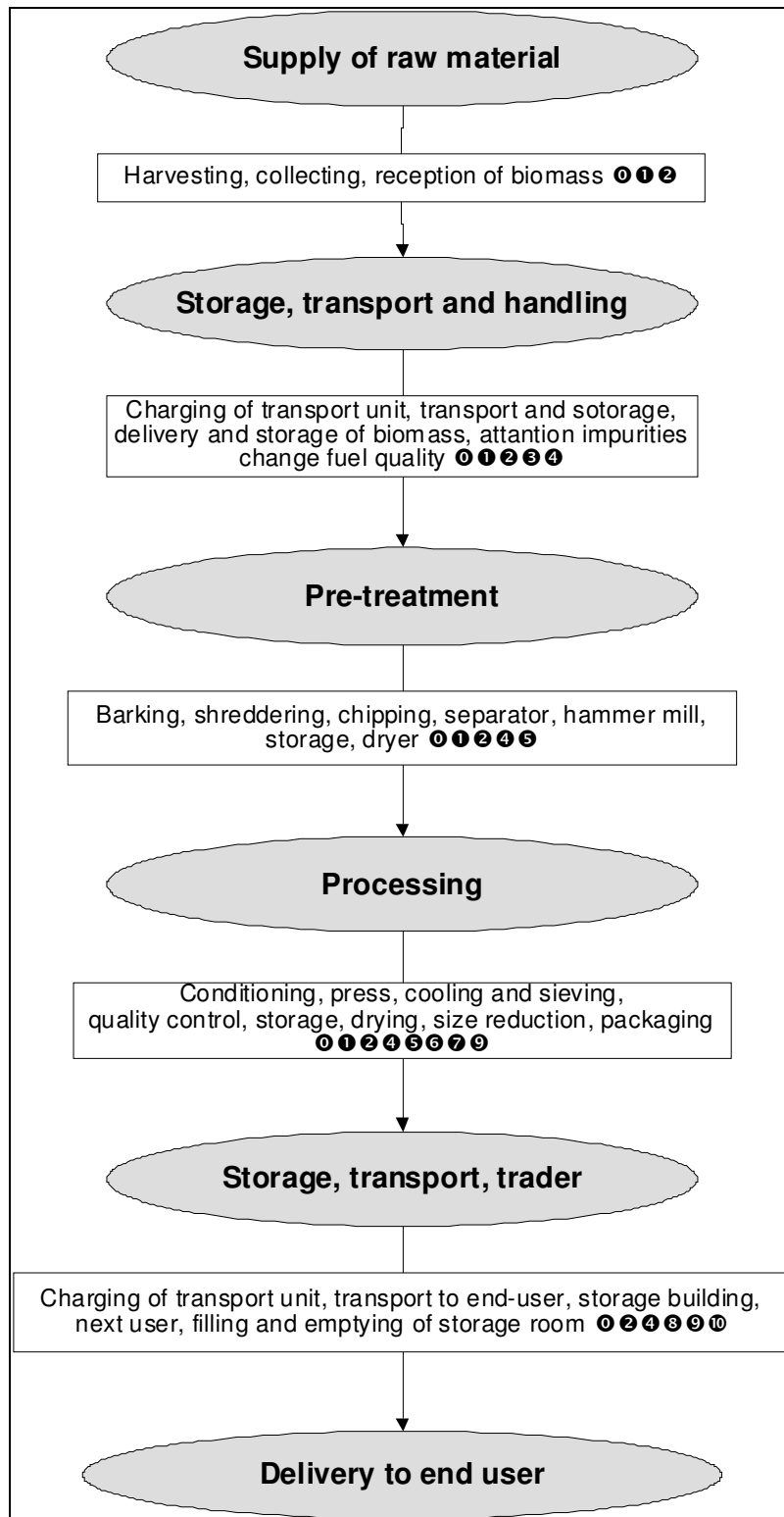


Illustration 3: General supply chain

4 Supply chain of biofuels

The following illustrations of supply chains of wood pellets, wood chips, hog fuel, straw and olive residues show the Critical Control Points (CCPs) and the respective influencing factors, which are numbered from ① to ⑩.

4.1 Supply chain of wood pellets

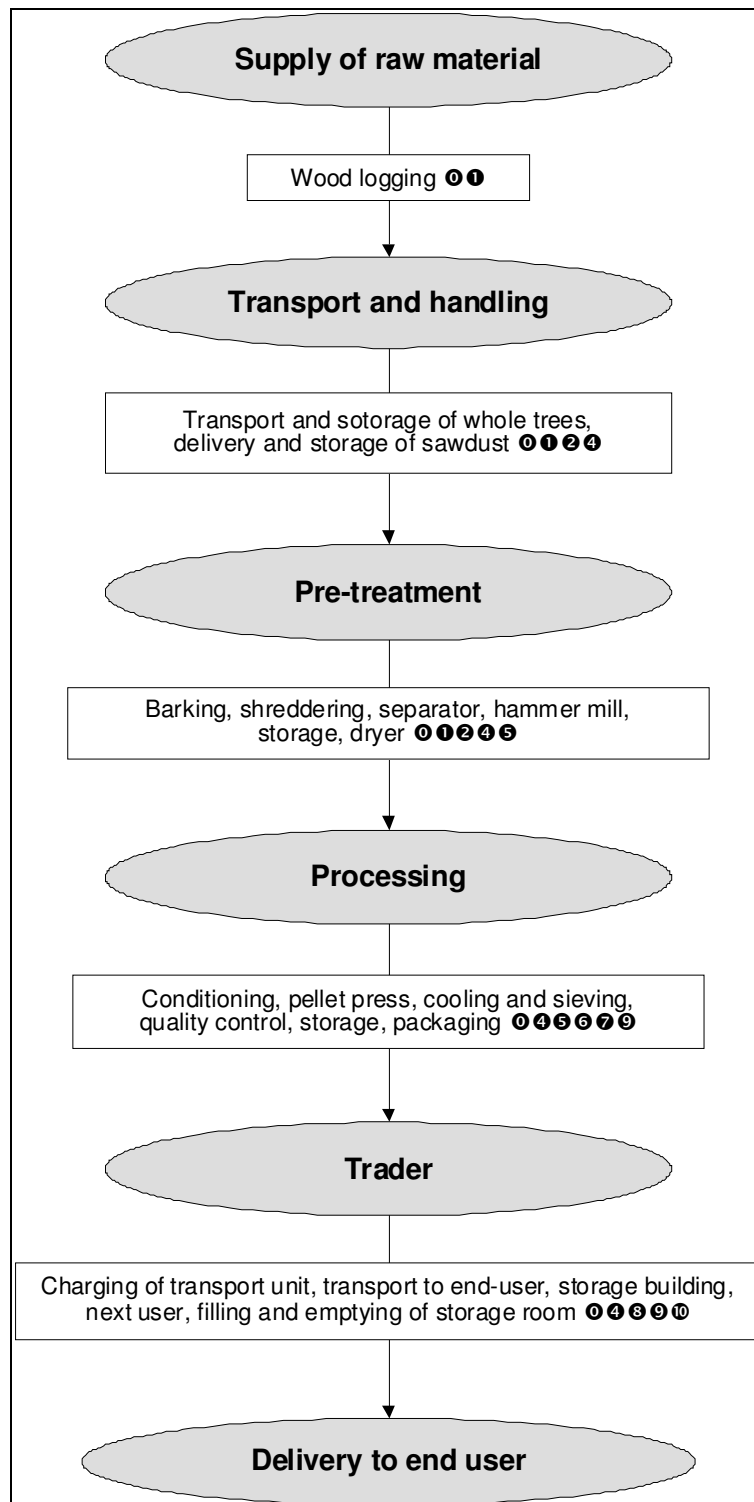


Illustration 4: supply chain of wood pellets

Wood pellets can be made of several raw materials like residues and by-products from the wood processing industry, woody residues, short rotation coppice and stem wood. For the pelletising process the raw material is chipped – unless it is already chopped to saw dust or wood chips. Afterwards the material is dried to equal moisture content and metals are separated before the drying process. After a temporary storage the saw dust is milled in a hammer mill, on order to provide an adequate particle size for the pellet press. Additionally pressing aids as well as water or steam – if

necessary – are added, in order to increase the binding qualities of the raw material as well pelletising properties. The conditioned raw material is forwarded via a mixer to the pellet press, where the characteristically shaped wood pellet is produced under high pressure. The hot wood pellets are cooled for stabilisation purpose and sieved, in order to reduce the amount of fines which adheres to them. Depending on the type of distribution the wood pellets are either packed in 25 kg sacks or in big bags or stored in a silo, where they can be loaded directly into a pumping truck. In order to guarantee the amount of fines remains $\leq 1\%$ the wood pellets should be sieved after each handling step, especially before entering the trucks.

4.2 Supply chain of wood chips

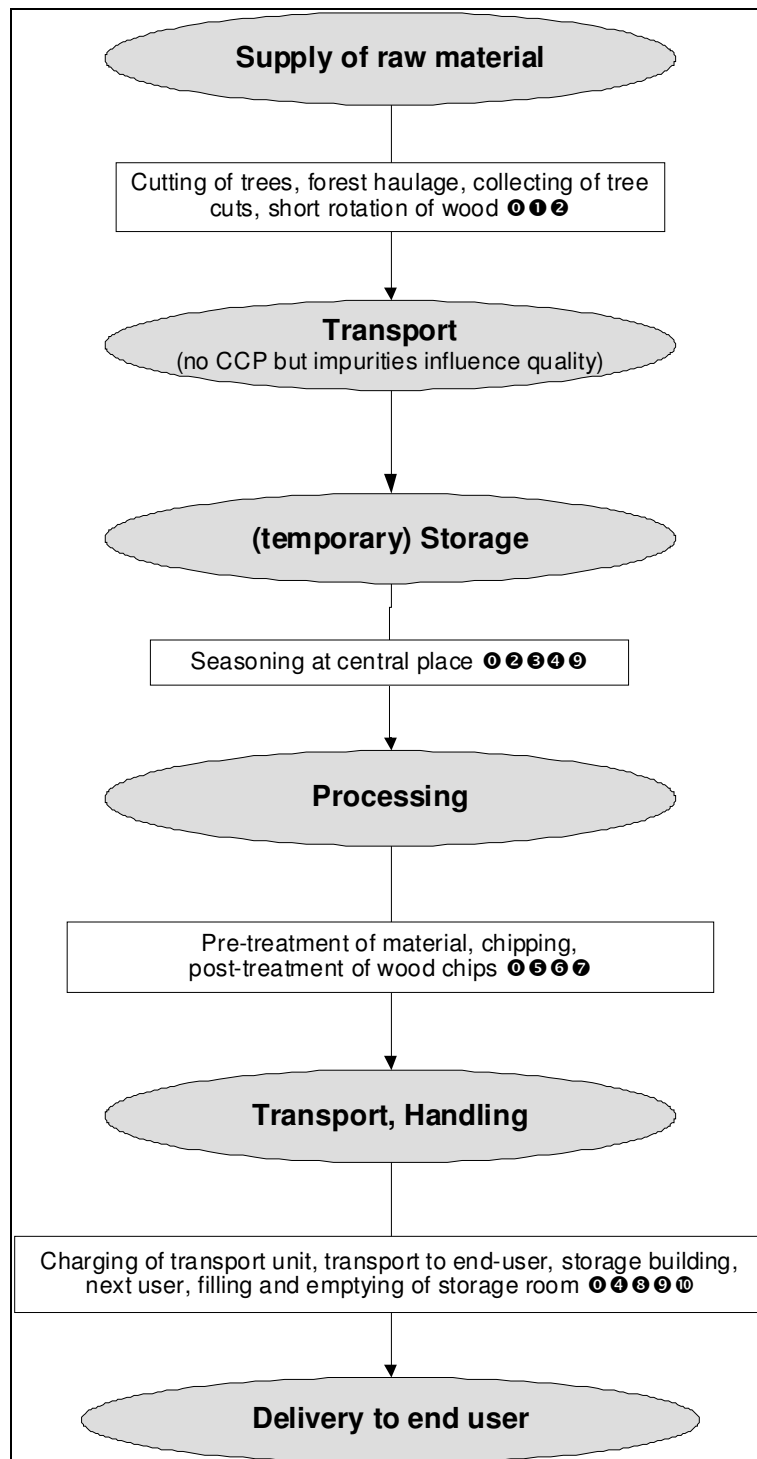


Illustration 5: supply chain of wood chips

Wood chips are produced from woody residues, landscape management wood and/or short rotation coppice. After harvesting the raw material there are two possible paths for the further processing of the material.

On the one hand the fresh material can be chipped (with sharp tools) directly for a just-in-time delivery. The resulting wood chips have moisture content around 50 % and are foreseen for heat (and power) plants that can handle high moisture contents.

On the other hand harvested raw material can be collected and seasonally stored for a certain period of time, in order to reduce the moisture content to an adequate level for small and medium scale combustion units. After seasoning the material has to be cleaned from impurities like sand, mud etc. Needles and leaves should be removed also in order to keep the ash content as low as possible. When chipping the wood it is up to the (plant) operator to produce the correct wood chips size by adjusting the settings of the chipping machine. Depending on the required quality an additional drying might become necessary as well as a sieving process that sorts out fines and coarse fraction. The produced wood chips are delivered as bulk material on trucks or tractor trailers that should be kept free from impurities that affect the desired raw material quality.

4.3 Supply chain of hog fuel (waste wood)

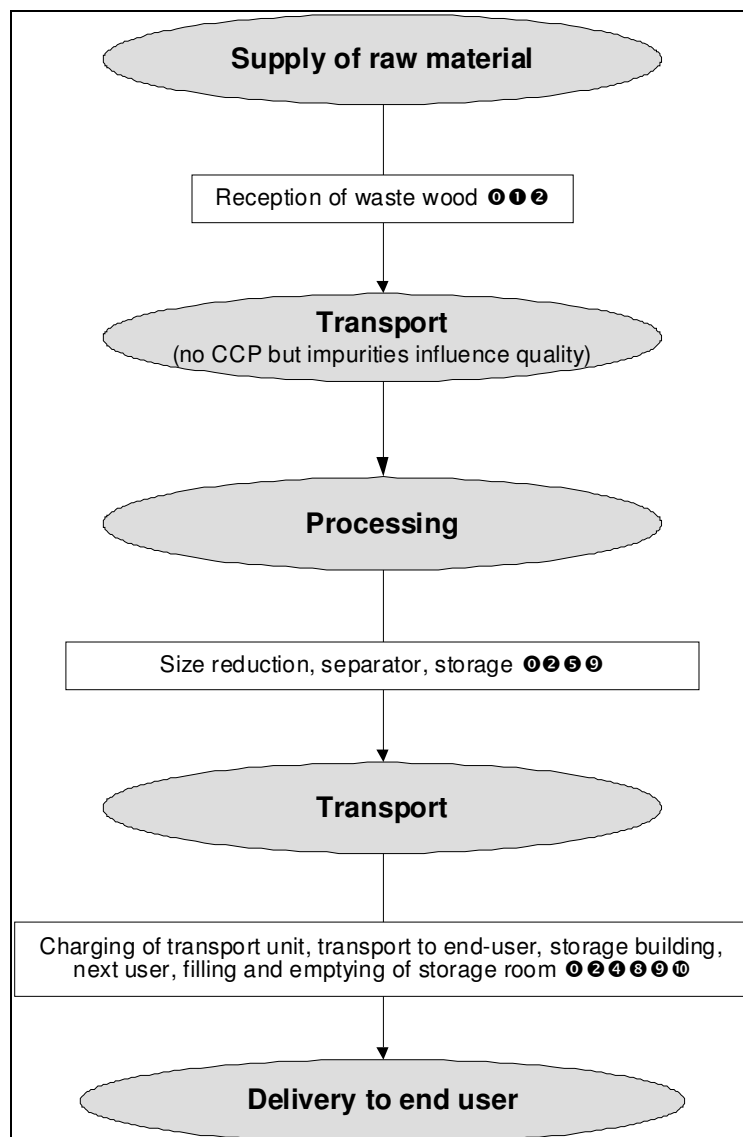


Illustration 6: supply chain of hog fuel of waste wood

Hog fuel can be produced from different raw materials. Besides of natural wood (like untreated log wood) hog fuel can also be produced from used wood. Hog fuel from used wood becomes available with waste recycling companies as a by-product from building demolition activities. The raw material is usually manually selected and stored in different piles or storages for different classes of used wood. Used wood is transported from these storages to the processing plant on trucks. Here the hog fuel is produced by size reduction and removal of impurities like metals and sand. In contrast to wood chips that are typically cut with relatively sharp knives, size reduction of hog fuel is typically carried out by cutting with relatively blunt tools using a shredder. The size of hog fuel can be adapted with the settings of the shredder and the mesh size of the sieve.

The produced hog fuel is temporarily stored. The hog fuel is delivered to the end user as bulk material on trucks or ships or by train. The hog fuel is used in both dedicated small boilers and larger multifuel combustion furnaces, like grate furnaces, fluidised bed boilers and cofiring facilities.

The production of hog fuel is not a constant process in general, but is strongly influenced by the possibility to obtain contracts for supply of suitable raw materials and the weather conditions and season.

4.4 Supply chain of straw

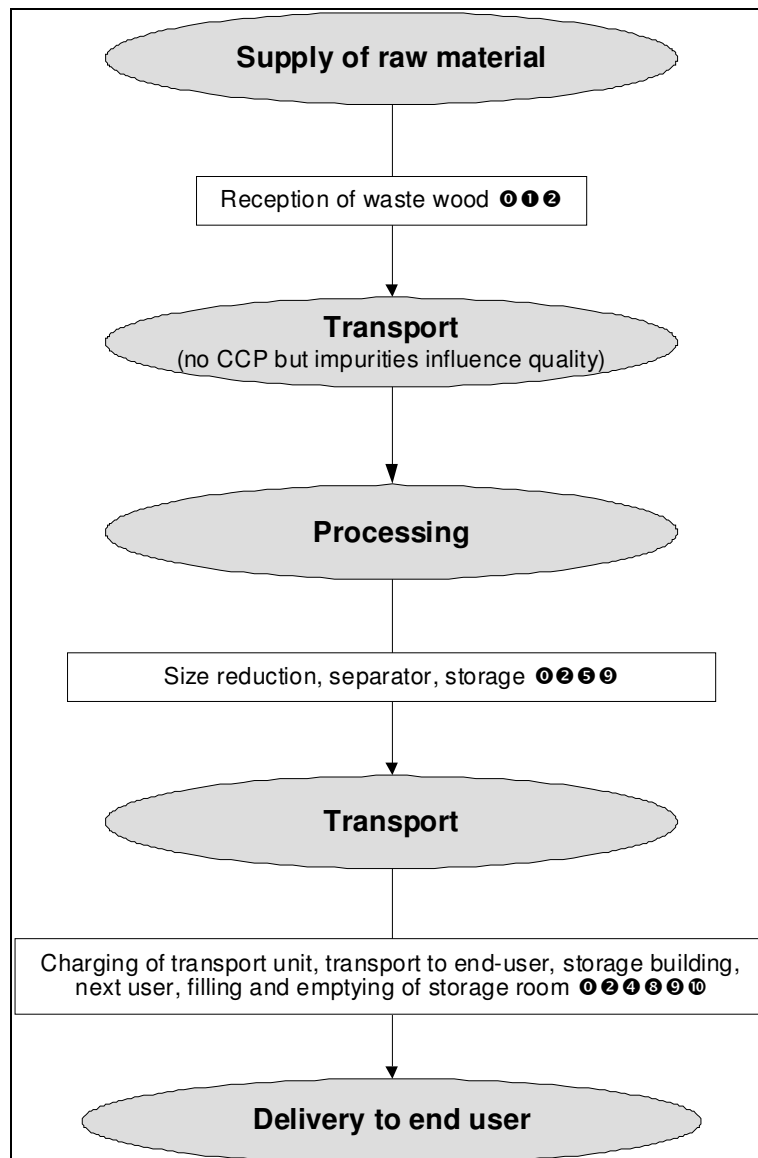


Illustration 7: supply chain of straw

Straw is normally regarded as a by-product in the production of cereals. After combined harvesting, the straw is left in swaths in the field. Ideally, the straw can be baled immediately (or – in some countries, especially in Eastern Europe – collected as “loose straw” without baling). However, if the moisture content is too high, the straw should be left for drying. The moisture content should preferably be below 15% but up to 18% is acceptable when baling the straw. If there is a rainfall, while the straw is lying in swaths, it will often be necessary to dry the straw by turning/raking the swaths. There are several different types of balers, but for large scale energy production, “big bales” (120x130x240cm) is the dominating type. The bales are then collected in the field by tractors with front-end loader and stacked in storages. Storage of straw bales can be carried out either in barns or in the field covered with waterproof folio or wrapped in plastic. The bales can be transported from storage to the energy plant by either tractor trail or by truck. Tractor trail should only be used with rather short distances (a few kilometres) between storage and energy plant. All Danish experiences point to the fact, that straw handling as big bales is the most cost-effective method for use of straw for energy production. However, handling chains with chaffed straw or straw pellets can be considered as alternatives.

4.5 Supply chain of olive kernels

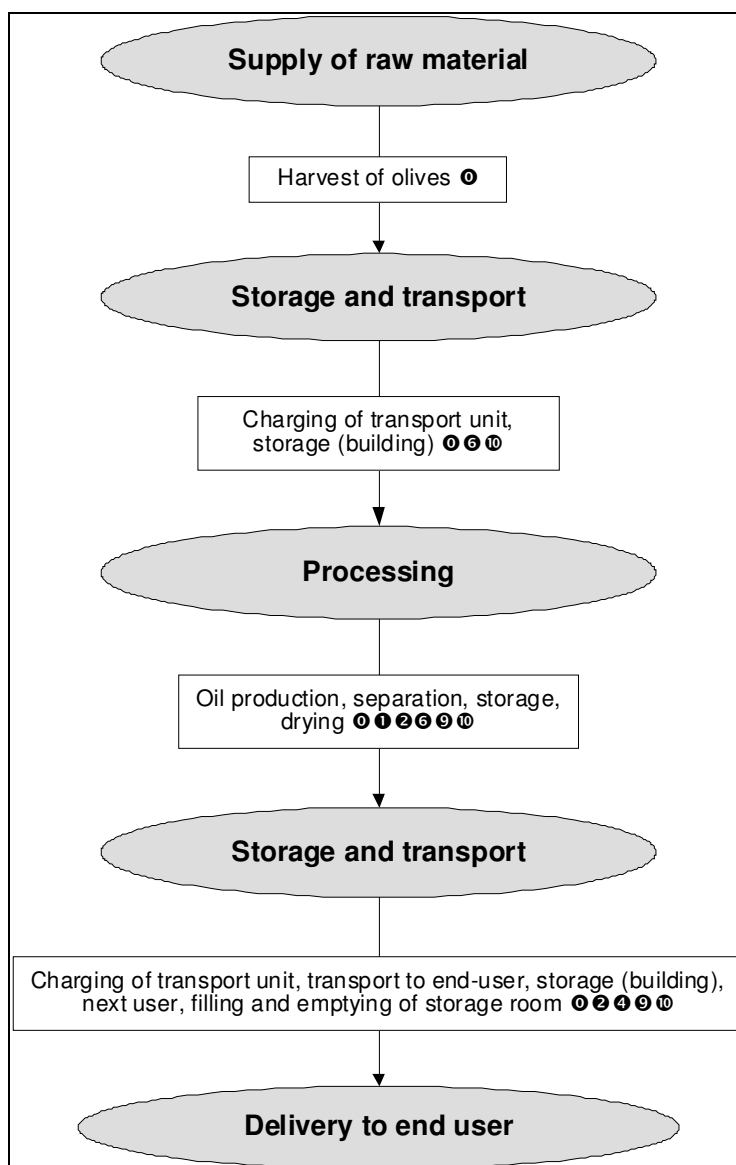


Illustration 8: supply chain of olive kernels

During the harvest of olives also leaves and branches are collected which are separated before the oil production takes place (sieving process). The collected olives are transported to the processing plant by trucks and tractors where the olive oil is produced. In the production process the olives are pressed, the oil is extracted and what is left behind are kernels, pulp and skin. Pure olive kernels have other fuel properties than pulp and skin. Normally the fuel quality of pure kernels is better than the fuel quality of olive residues because of lower contents of ash building elements and out of this fewer corrosion problems. A simple quality check is the smell of the biofuel, because dried kernels do not smell but the whole olive residues smells before and after drying like olives. Olive residues or olive kernels are stored on a mostly unpaved floor, outside of the processing facility where they are influenced by any weather conditions to appear. Olive residues are just a by product of oil production.

The aim of drying is to get as little water as possible into the combustion chamber of the boiler by maximising the heating value of the biomass and increasing the fuel quality. Low water content also avoids biological activities and the aging of material. Because of the unpaved ground the danger is high that during the loading procedure on the truck (with a front loader) some dirt from the ground is removed and mixed with the residues. These impurities (like earth and stones) worsen the fuel quality, because the ash content and the content of ash building elements increases.

It is highly recommendable to improve storage infrastructure by paving the floors and possibly placing a roof to protect the residues from adverse weather conditions. This will increase the efficiency of the drying and therefore the quality of the fuel. Drying of the residues helps the material to stay stable for longer periods of time. The storage also depends on the size of the boiler. In small application usually a roofed and paved storage room is available. Big boilers however need huge amounts of fuel that for financial reasons can not be stored on a properly protected site. This is another critical point where the quality worsens through weather conditions.

5 Quality influencing factors

In chapter 3 ten different influencing factors are mentioned, which are most important and relevant for all biofuels regarded (wood pellets, wood chips, hog fuel, straw and olive residues). In the following they will be described more in detail.

①: Impurities:

Impurities influence the fuel quality very strongly and there are different kinds of impurities (e. g. earth, snow, old loads, stones, plastics, needles and leaves). To guarantee a good biofuel quality it is important to protect the fuel from weather effects, also from contamination with earth, sand or stones and to reveal the danger of impurities. Other kind of impurities like nails or metals in log wood can be easily removed by a magnetic separator but these impurities are not a natural part of biomass.

Especially the contamination with earth or sand strongly influences the fuel quality, because the content on ash building elements increases with each grain of sand and causes problems like slagging during combustion.

The contamination of material can happen everywhere, beginning with the transport of log wood from the forest, where soil can cling on the log and the bark; up to old loads on trucks and lorries or old material in the storage room. If the delivered raw material is already contaminated, the quality of the biofuel can not be really enhanced. Some producers of biofuel try to wash the raw material to remove the grains of sand and earth from the material, but this method is very expensive and not really effective.

To guarantee a good fuel quality, the raw material should already have a high quality and all kinds of contamination should be prevented. Precautions like good and protected storage rooms, clean

transport machines, carefulness during the harvesting and use of fresh and healthy material strongly influence the fuel quality.



Illustration 9 and 10: impurities (stone and metal) in hog fuel [5]

❶: Species and quality of raw material

Depending on the quality the producer wants to produce, the raw material should also have the respective quality level. E. g. for premium pellets (pellets with best quality) the pellet producer should use fresh soft wood without bark. For industrial pellets the quality of the fuel depends on the contract with the consumer. This is why industrial pellets can be made of hard wood, with higher amounts of bark, or produced out of older wood resources.

For the pellets production it is the knowledge of the raw material quality and raw material species that is crucial for the quality of the end product, the pellets. E. g. saw dust from hard wood and from soft wood are visual very similar but the physical parameters like ash content can be quite different. Also the use of log wood requires experience. The contents of bark and maybe of impurities like earth and sand from the transport on ground after felling of the tree in the wood have an impact on the product quality. Producer often debark the log wood after the delivery to avoid this problem.

Also the quality of other kind of biomasses like straw bales or hog fuel depends on the quality of the raw material. If used wood is chipped, the quality of the product is of minor quality due to e. g. heavy metals, halogens or any other chemical treatment compared to wood chips from fresh wood logs. Nevertheless also a market for used wood chips exists.

Quality of olive residues can be also very different. The fuel quality of pressed olive residues (kernels, pulp and skin) is not as good as from pure olive kernels. The content of corrosive elements in kernels is much lower than in olive residues. Also the ash content is lower and these facts allow a good combustion of pure kernels. Also the sieving of olive kernels to separate possible impurities like leaves or stones is an essential step.

The quality of raw material also depends on the origin of biomass. The ground and the weather conditions influence the growing of biomass up to the harvesting time and the same kind of biomass (e. g. spruce wood) has different physical and chemical parameter because of the environmental conditions.

❷: Weather conditions and ❸: storage time

Biofuels (raw material and also intermediate and final biomass products) should not be stored unprotected too long (not roofed), because the weather conditions affect the quality of the product. The effect of the weather conditions on biomass depends on the specific surface of the raw material.

Aging of saw dust caused by microbiological activities in wet material is faster than aging of log wood; shredded wood can also change quality quite fast because of microbiological activities. A lot of project and long term stability studies show that unprotected and long stored material loses the heating value and the content of ash and ash building elements increases. Beside the loss of quality, high water content can cause self ignition. In this case a big, heavy and wet heap can become very hot because of the microbiological activity and ignite itself. Also moulding of the material can happen if the material is too wet. If the material is dried the microbiological activity is low and the danger of self ignition and moulding decreases.

Another aspect is the quality of fuel. Most of the standards restrict the water content in biofuels because of the negative effect of the heating value and unprotected storage causes a relevant change of the water content.

Sometimes the storage and storage time for the product (e. g. pellets) can become very important, because it is, at the same time, the conditioning of the material. For some biomass it is very important to control and influence the water content e. g. wood pellets to facilitate the pressing procedure.

For olive residues this part is essential, because kernels and olive residues are always stored outside to increase the water content of the wet fuel after oil pressing process. The production of olive oil happens in south Europe, where the hot summer time is very long, but also there rainy weather is possible and if this happens short before fuel delivery to end user the water content can be too high and cause problems during the combustion.

③: Seasoning at central place

Piling construction of trees influences the fuel quality with regard to impurities and moisture content. To prevent a loss of quality due to impurities trees should not be stored with direct contact to the ground but with a distance to it. In dependence of whether trees shall dry fast or not, the environment influences the drying procedure. Piling constructions, which are stored in the forest area, run through a much slower drying process as piling constructions, which are unprotected from sun and wind.

⑤: Selection of chipper technique and chipper settings, settings of barking machines, shredder, hammer mill, dryer, transport technique

The right technique and settings of machines which reduce the particle size influence the dimension and bulk density of the material. For wood chips and hog fuel e. g. the CEN/TS 14961 describes and defines different biofuels qualities. For producing defined biofuels the setting of special machines should be very precise. Also good barking machines, shredder and hammer mills can retain the quality of the raw material. Also for separation of olive kernels from pulp and skin special equipment is used.

The use of all these machines can also have a negative effect, if e. g. old loads and impurities in the machines (because of the problematic cleaning process) influence the raw material quality.

Also the whole transport technique is very important for guaranteeing the quality. Biofuels like pellets and straw bales have got own technique (pump silo wagon and front loader truck or crane) and the use of these technique avoids unnecessary contaminations of fuel.

The transport of e. g. straw bales in Denmark is performed by special tractors with front-end-loader, with farm trailers or telescopic handler for storage of bales on storage room. Tractors with front-end loader can transport 2-3 bales at the same time. Trailer or trucks transport the bales to the plant and telescopic handlers allow a good handling with the bales. Forklift trucks also transport 2-3 bales at the same time. This special technique allows a secure handling of this big bales and avoids contaminations of material.

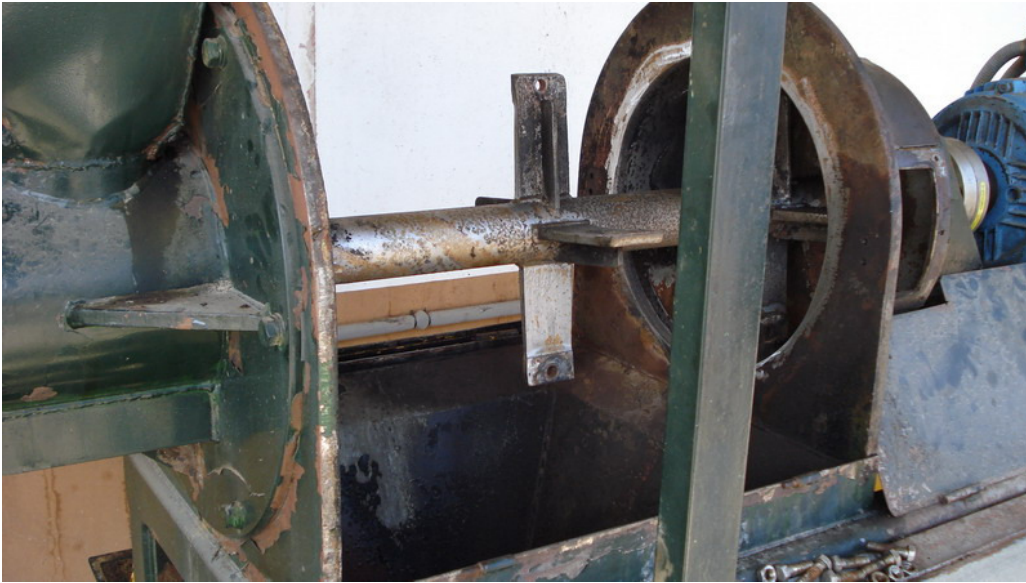


Illustration 10 Machine to separate the olive kernels from pulp and skin [6]

⑥: Belated drying

The correct water content is very important and a part of the limited and defined biofuels parameter. It influences the calorific value (as received) and also the bulk density of material. For pellets the drying has got two important points:

- drying of raw material optimizes the pressing-process and
- drying of fuel is performed for conditioning.

The most important point is that microbiological activity happens only, if the microorganisms have got enough water. Than moulding, self ignition and the formation of fungi result. If the material is dry, these problems are avoided and drying of material helps the material to stay stable for longer time.

If the respective weather conditions aren't satisfying for drying the material (for olive kernels the storage in the sun for 2-5 month is enough to achieve a satisfying water content), sometimes drier are used. Especially for pellets production drier are essential, because the raw material needs a very good conditioning to enhance the pressing-process. After that pellets should be dried or conditioned before the transport to end user.

⑦: Fines and coarse fraction

Fines but also coarse fractions change the fuel quality and sometimes the defined fuel size (e. g. sizes of wood chips according to CEN/TS 14961). Also over lengths of pellets are restricted. If particles are too long or too small biofuels cause problems during transport. E.g. to long pellets can block conveyor screws. Special transport wagons like a silo pump wagon help, but if the content of fines is very high the danger of dust explosions increases. Fines and coarse fractions should be sieved out for guaranteeing good biofuel quality. This sieving steps are not just important for pellets, also for olive kernels and olive residues sieving steps are important to separate leaves and brunches.



Illustration 12: bad storage because of impurity danger from stone heap (right) and ground [5]

⑧: Number of handlings

A high amount of handlings influences nearly each fuel parameter. Before handling the biofuel it is transported, where

- the biofuel can be contaminated with (mineral) impurities, which changes the ash content and the ash melting behaviour,
- the biofuel can get wet e. g. because of rain and an unprotected transport and
- parameters like calorific value or bulk density can change.

For some biofuels like pellets, a high number of handlings (and transport) can additionally increase the content of fines. For this reason it is recommended to sieve each pellet load every time it is handled and to keep the amount of fines $\leq 1\%$ by that.

Beside the changes of chemical and physical parameter, also the loss of information with regard to origin and species of biofuel (e. g. raw material) is possible.

⑨: Construction of storage room

The right storage of raw material and fuel is one of the most important things during, after and before the fuel production. The storage in storage rooms can protect the raw material and also the fuel from bad weather conditions (e. g. rain, snow) and from impurities like e. g. sand and earth and other kind of impurities. The storage room should be optimised for the fuel.

Sometimes the storage room can be outside e.g. storage of straw bales can be carried out either in barns or also in the field, but covered with waterproof folio or wrapped in plastic to protect the fuel and keep it dry.

Ⓢ: Microbiological activities

Microbiological activities are monitored in wet and longer stored material. Because of the higher water content and often a higher pressure (in bigger heaps) of the material the microorganisms are very active. As a result temperature increases and might cause self ignition. The material can also mould and fungi can be monitored. All kinds of microbiological activities in biofuels are not intended.

6 Appropriate test methods

The test methods which are developed during the BIONORM II project were tested for years and because of this detailed optimising step this methods are the most appropriate test methods for solid biofuels. (see Table 1, Chapter 2)

The most important quality affecting property of solid biofuels is the moisture content. Moisture content has an effect on fuel quality because of the effective heating value; with increasing moisture content in biofuels the heating value decrease. This is because of the changes caused by biological activities (danger of self ignition) like moulding or fungi. Besides of the standardised test method, different “rapid and online test methods” exist and are used for the moisture content determination (quality control) on site production.

One very important parameter can also be the content of impurities. There are no methods to analyse impurities, because impurities can also be snow or sand and it is difficult to measure something that is naturally part of the biofuel. For the determination of impurities no test method at the moment exist (only possibility to check for impurities at the moment is a visual control).

Also parameter like ash content and the mechanical durability of pellets are very important, but for the determination of ash content or abrasion no special rapid test methods exist. The mechanical durability is often checked during the production of biofuel to guarantee a good fuel quality. Other parameter like ash content, major and minor elements etc. normally are just analysed in a laboratory because of the high equipment costs and the required know how.

Parallel to the European standards also national standards for determination of the fuel parameter are used. These standards are often adapted coal standards and are often limitedly comparable with the European standards, i.e. that the European standards should be implemented to guarantee the same fuel quality checks in Europe. National standards can be used if they don't amend regulated topics e. g. dimensioning and construction of a pellets storage room.

6.1 Methods for moisture determination overview

Determination of moisture content by measuring the loss of mass in a drying oven as described in the standardised method is often too time consuming for on-site quality control. A need for fast and reliable detection methods is evident. In recent years, some already established methods such as infrared reflectance were optimised for online use in solid biofuel production, whereas some other interesting new methods such as TDR (Time-Domain-Reflectometry) have been developed.

Illustration 1 gives a brief overview of the relevant moisture analysis methods for biomass.

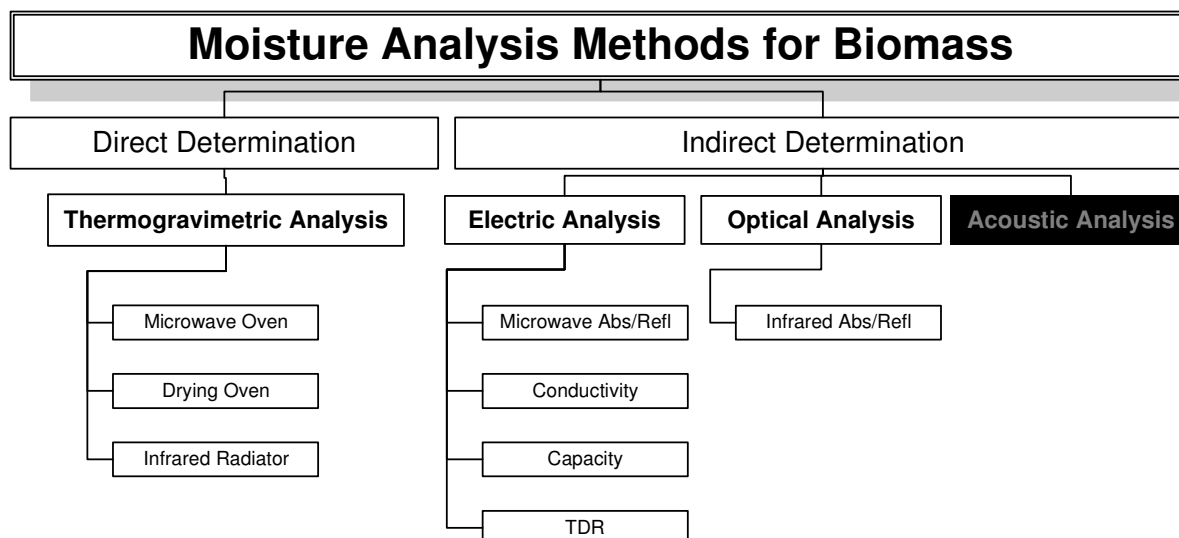


Illustration 13: Overview of moisture analysis methods for Biomass

In practice the microwave and infrared absorption and reflection methods are often used. Big sized fuel producer also use indirect determination (IR reflection or TDR) methods as online methods.

The following table describes the technique and also the instruments for moisture content determination.

Table 2: A selection of available instruments for moisture detection

Principle	Technique	Instrument (example)
Thermogravimetric analysis	Drying oven Duration ca. 6-24h	Memmert UF series
		Nabertherm TR series
	IR drying Duration up to 1h Working range 1-100% Sample Mass below 100 g	Sartorius MA series
		Kern ML series
		Mettler-Toledo HG63, MJ33
	Microwave drying Duration a few minutes Working range 8-100% Sample mass below 70 g	Sartorius LMA200
Anton Paar Multiwave 3000		
Electric analysis	Conductivity Duration a few seconds Working range 5-50%	Gann Hydromette Series
		Testo 606
	Capacity Online measurement possible Working range 0-100%	Pandis FMG 3000
		Schaller Humimeter pellets analyzer
	Microwave absorbance/reflectance Online measurement possible Working range 0-100%	Liebherr Litronic FMS II
		hf-Sensor MOIST series
Time-Domain-Reflectometry Online measurement possible Working range 0-100%	Sartorius PMD 300	
	Imko Trime-GW or Trime-TDR	

Optical analysis	IR reflectance	Sartorius LMA500
	Online measurement Working range 0-90%	Moist-Tech IR-3000
		Pier Reflexionsphotometer

The main advantages of instruments for direct determination are their accuracy and the fact that they can be moved from one place to another without expensive demounting from one and remounting in another production site. On the other hand, time-consuming direct determination needs much manpower (standardised test method).

There are two types of instruments for indirect determination: small, relatively cheap handheld devices and expensive stationary ones for on-line measurement.

Handheld devices are extremely easy to transport and easy to operate. They quickly deliver results and are a good option for moisture determination, e. g. at the delivery of raw material. However, since indirect methods rely on calibration, which is only valid for constant ambient conditions, handheld devices are relatively inaccurate. They also need manpower to be operated.

Stationary instruments for online measurements are extremely difficult to move. Mounting, adjusting and calibration takes much time and a considerable amount of manpower. As soon as they are installed properly and calibrated, they deliver fast and reliable results, which can be processed automatically, so that no personnel is needed to operate these devices. The results can be displayed directly in a process control room and can be used for automated process control. The major disadvantage is their high price, starting at a few thousand euros.

7 “Test methods” and costs

In the following illustration costs and appropriate test methods for the determination of all chemical and physical parameters are described. The costs are an overview of laboratory costs from different laboratories in Europe (except the new EU-countries) and differ because of laboratory quality, the calibration degree, the possible combination of some analysis (packages are often cheaper than single analysis) and determination methods (standardized methods or not) etc.

The analysis and the equipment costs in this table should help to decide about self or external monitoring and inspection. Also the purchase of a online measurement equipment with information about the single analysis costs.

Table 3: Test methods and laboratory costs

Standards	Parameter	work time (without sample preparation)	typical prices incl. proportional calibration etc.	equipment required	cost of equipment needed
		[min]	[€]		[€]
CEN/TS 14780	preparation of analysis sample	15- 180	30-300 ****	various mills, sample divider	various, wide range! **
CEN/TS 14774	moisture content	30	20-50	drying oven *	1000-5000
CEN/TS 14775	ash content	30	25-70	muffle furnace *	1000-3000
CEN/TS 14918	calorific value	45**	70-150***	bomb calorimeter* (gov only!)	Bomb calorimeter: 17500-25000
CEN/TS 15103	bulk density	30-45	20-130	container *	500-2000
CEN/TS 15104	content of C,H,N	60	70-120	C,H,N analyser*	30000-60000
CEN/TS 15105	water soluble content of Cl, Na, K	45	100-150	drying oven, detection method*	1000-5000 (without detection);
CEN/TS 15149	particle size distribution/dimension	90	60-150	sieve apparatus *	1700-3500
CEN/TS 15150	particle density	15	50	e.g. caliper rule, sand paper*	100 - 200
CEN/TS 15210	durability	10 - 20	30-60	Tumbler, Ligno Tester*	3500-5000
CEN/TS 15289	content of S,O	30 (bomb comb.) + 30 (IC)	60-120	bomb calorimeter, IC*	Bomb calorimeter: 17500-25000; IC: 15000-20000
CEN/TS 15290	major elements	45-120	100-260	AAS, ICP, Microwave*	Microwave: 15000-20000; ICP: 50000-75000;
CEN/TS 15297	minor elements	45-180	100-260	AAS, ICP, Microwave*	GAAS: ~40000
CEN/TS 15370	ash melting behaviour	90-180****	160-320	ash melting apparatus	30000-60000

*other equipment needed for the analysis: analytical balance (0,01g-300g) 2000-5000€; balance (500g-5000g) 100-2000€

** examples: cutting mill 5000-8000€, ultracentrifugal mill ~5000€, ball mill 2000-3000€, riffle box 400-800€, rotary sample divider

*** gross calorific value only; for net calorific value add time for acid correction (CEN/TS 15289) and H-content (CEN/TS 15104)

**** without preparation of ash

**** some laboratories include costs for sample preparation and report in costs of analysis.

8 Literature

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- [6] ofi 2008: internal data basis