Basic requirements
for the production of wood-based biofuels
for heating purposes

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1 INTRODUCTION

This document has been prepared by the BIO-PROM experts’ team based on the FNR knowledge in the field of solid biofuels as well as practical experience in developing investment projects. The document was prepared under the framework of the BIO-PROM project (www.bio-prom.net), funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) in the framework of the International Climate Initiative (ICI).

If not stated otherwise, the information is compiled from the FNR guidelines on solid biofuels and wood chip heating systems.¹

The paper is developed to assist the preparation of bioenergy projects in Russia aiming at production of solid bioenergy fuels for heating purposes. It gives an overview of the basic requirements for the production of wood-based solids and provides Russian entrepreneurs with possible solutions and ideas for the preparation and development of feasible projects.

The main focus lies on the information required by an entrepreneur thinking about the establishment of production line for wood-based biofuels (e.g. wood pellets).

Kinds of wood-based biofuels and their advantages

There are several kinds of wood-based biofuels. Wood logs are the oldest form. They are used in stoves, fireplaces and wood gasification boilers for single houses. Wood chips allow higher degree of automation. They are used in greater boilers and heating (and power) plants. Highly processed wood-based pellets and briquettes guarantee a most homogenous biofuel.

Wood-based biofuels have a number of advantages. The combustion sets free just as much CO₂ as has been bound during growth of the tree. Hence, if sustainable produced, wood-based fuels are referred to as climate-friendly and CO₂ neutral. Heating with wood-based biofuels contributes to saving fossil fuels. It also significantly reduces environmental risks like the contamination of soil and water with fossil crude oil.

Wood-based fuels also have a positive impact on the local and/or regional economy. New added value is created. The creation of new perspectives for the local population, new revenue opportunities for forestry, wood processing and agricultural companies contribute to the rural development. The logistic sector profits as well, because of the necessary distribution of the final products.

The energy required for the production of wood-based fuels is low in comparison to the stored amount of energy within the fuel. The whole production process for pellets has an energy expenditure equivalent of only 4-6% of the stored energy.

Various kinds of sustainable produced, wood-based biofuels are available. All contribute to an environmental-friendly utilization of renewable resources and open long-term perspectives for local entrepreneurs.

¹ FNR Leitfaden Feste Biobrennstoffe 2014; FNR Hackschnitzelheizungen 2015 - Was muss aktuell beachtet werden
2 MAIN STEPS AND PROCEDURES

Basically, three groups of steps are distinguished when providing energy from biofuels:

1. Provision/Cultivation of wood
2. Production/Processing of raw material / feedstock
3. Utilization of biofuels

Illustration 1 shows the principle way of the biomass from the forest or short rotation coppice to the final utilization. Each step is explained in more detail in this chapter.

Illustration 1: Basic principles for the use of solid biomass

Quality assurance is essential for low emissions and a smooth operation of the combustion plant. The quality requirements of wood chips, pellets and briquettes are explained in chapter 5.

2.1 Provision of wood

The production and provision processes greatly influence the characteristics of the final product. Hence, the quality management begins at the stage of provision/production of the raw material. The source of the raw material is crucial when planning a wood-based biofuel production. Quality and amount must fit the envisaged production goals, regardless whether it is an industrial pelletizing plant or just a mobile chipping unit.

Forestry and wood-processing industry provide wooden feedstock (e.g. residues from industrial use; saw milling). Untreated waste wood, e.g. construction timber at the end of its lifecycle, is also a potential raw material source. Finally, short rotation coppices (SRC) provide cultivated wood as well. Currently, waste wood and SRC play a minor role in Germany. The main sources providing the wooden raw material for energetic purposes are the forestry and the wood processing industry.

The main goal of the forestry is the production of high value trunk wood for the material use. Thereby, various residues, co- and by-products are produced, e.g. small-diameter timber, thinner stems, and residual forest wood. They are available for energetic purposes. Some further spare wood may occur during thinning or in parallel to the final use of the trees. As a rule of thumb, when thinning 70m³ of woodchips per hectare can be calculated. However, the

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2 Fachagentur Nachwachsende Rohstoffe e.V. (FNR), Leitfaden feste Biobrennstoffe 2014
concrete amount of chips may differ greatly. It depends on several factors, such as type of wood, age of trees, location and/or harvesting method.

When using whole trunks for the production of wood chips, needles and leaves should be kept in the forest. They have a high share of nutrients and increase the water content of the wood chips as well as the storage risk (e.g. through the development of fungal spores). The trunks should stay in the forest until the needles and leaves are fallen off. However, in summer time this approach may cause problems with bark beetles or similar forest pests especially in coniferous forests. The autumn logging significantly reduces the risk of a pest infestation.

The second important supplier is the woodworking industry. The processing of tree trunks to wooden materials ends up with a number of residues, such as small wood pieces and saw dust.

Further, SRC produce energy wood. Only few tree species, such as willow, popular or robinia, are used for cultivation in Europe. Due to relatively small diameter, wood from SRC often has a high share of bark, which negatively influences the quality of the final product. Similar problems occur when using wood-based materials from landscape conservation measures.

The main suppliers for the production of wood-based biofuels are forestry and wood processing industry. SRC is gaining importance on a small scale, especially to secure the supply of wood chips for local boilers.

2.2 Processing of wood-based fuels

The processing of wood has a major impact on the future characteristics and quality of the produced biofuels. High-quality biofuels are essential to meet the fuel requirements of boilers and combustion plants.

The technological processing can be categorized according to the complexity of the procedures. While the production of wood chips from SRC can be realized in a one-step procedure and no special expert knowledge is required, the fabrication of wood pellets from the forest wood is a complex multi-step procedure which requires a lot of professional knowledge.

Another way of looking at the processing and production procedures is the risk level. On one hand, using a conventional easy-to-handle technology such as drum chippers keeps the risk at a comparatively low level. On the other hand, the application of a highly efficient technology such as torrefication which is still under research is a high risk.

The necessary steps depend on the origin of the raw material. While particle size of wood residues from the forest or from SRC needs to be reduced, saw dust from the industry does not. The following characteristics are changed during the preparation of the fuel: form, size, bulk density, size distribution, resistance to abrasion.
2.2.1 Chipping

Chipping is a well-known and commonly used technology. The main objective is the reduction of the particle size. The wood is chipped either already in the forest, on a skid road or at a storage area.

Mobile chippers are driven by a tractor’s universal joint shaft or a separate diesel engine. Stationary chippers are shipped also with electric motors. Chippers are either fed by hand or with a crane. Mobile chippers may be built on a carrier vehicle or they are available as a trailer. Some even have a feed-in crane aboard.

The energy demand of chippers depends on the kind of wood, the cutting length and the water content of the wood. For fresh wood from the forest it is estimated between 2 and 5 kWh/t.

Three kinds of chippers are commonly used. The following table gives an overview of their design and characteristics.

Table 1: Design and characteristics of chippers; source: FNR Leitfaden Feste Biomasse p. 34 (changed)

<table>
<thead>
<tr>
<th>Design</th>
<th>Cutting tool</th>
<th>Feeding</th>
<th>Max. wood size (mm)</th>
<th>Cutting length (mm)</th>
<th>Power requirement (kW)</th>
<th>Max. Capacity (m³/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc chopper</td>
<td>1 – 4 knives</td>
<td>Without forced infeed; 1 to 3 rolls</td>
<td>100 – 300</td>
<td>4 – 80 (adjustable)</td>
<td>8 – 105</td>
<td>2 – 60</td>
</tr>
<tr>
<td>Drum chopper</td>
<td>2 – 8 continuous or 3 – 20 single knives</td>
<td>2 rolls Roll and sectional steel belts</td>
<td>80 – 450</td>
<td>5 – 80 (adjustable)</td>
<td>45 – 325</td>
<td>15 – 100</td>
</tr>
<tr>
<td>Screw-conveyor chopper</td>
<td>Auger windings</td>
<td>auger windings</td>
<td>160 – 270</td>
<td>20 – 80 (according to screw)</td>
<td>30 – 130</td>
<td>5 – 40</td>
</tr>
</tbody>
</table>

Disc chippers produce chips with a homogenous length. Due to the peripheral speed the knives wear out irregularly.

Drum chippers have the highest capacity in terms of wood diameter and throughput. They are suitable for round timber, brushwood and felling residues. Drum chippers have a small feeding opening. The following feeding systems are available for drum chippers:

Table 2: Feeding systems for chippers; source: Denkinger, B. Wie forstliche Hacker arbeiten

<table>
<thead>
<tr>
<th>feeding system</th>
<th>in-/ active</th>
<th>durability</th>
<th>maintenance</th>
<th>suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>feeding funnel</td>
<td>inactive</td>
<td>long-term</td>
<td>maintenance-free</td>
<td>round timber</td>
</tr>
<tr>
<td>chain belt</td>
<td>active</td>
<td>sensitive</td>
<td>high-maintenance</td>
<td>brush wood</td>
</tr>
<tr>
<td>rubber conveyor belt</td>
<td>active</td>
<td>sensitive to trunks with branch stubs</td>
<td></td>
<td>round timber, brush wood</td>
</tr>
<tr>
<td>roller table</td>
<td>active</td>
<td>long-term</td>
<td>low-maintenance</td>
<td>universal</td>
</tr>
</tbody>
</table>

3 Denkinger, B. Wie forstliche Hacker arbeiten, seen on 24.04.2015
Drum chippers are often used as mobile chippers. Screw conveyor chippers work under low vibration and are not widespread. The chipping of brushwood using a screw conveyor chipper may lead to irregular chips.

Before buying a chipper, the following criteria should be considered:

- What annual volume is planned?
- What kind of material will be processed (hardwood, softwood, round timber or brushwood)?
- What is the maximum diameter?
- Where shall the chipping take place?
- What are the distances to be covered by the chipper? What must be known about the terrain?

It is necessary to clarify these questions prior to the investment in expensive chippers.

Usually, a conflict of interests arises: An off-road carrier vehicle limits the operation range. The ability to chip a high-diameter wood raises the investment costs. Depending on the planned operations, there are several options to choose suitable equipment for chippers.

Discharging of the chips is possible in two different ways: (1) using the spinning wheel systems or (2) a band conveyor.

The advantages of spinning wheel systems are compactness and flexibility of direction and range of the discharge. But they are dusty, make much noise and have high power requirements.

The second possibility is a band conveyor. They are bulky, but work more silent, with less dust and fewer power requirements. Being more suitable for work in residential areas, band conveyors are not as flexible as spinning wheels.

### 2.2.2 Sieving and sorting

To avoid disturbances during the provision processes, e.g. bridging in the storage or blockage of the auger conveying, bulk materials need a certain size distribution. Each fuel charge is, therefore, not characterized by its average particle length. The main characteristic is the share of different particle size categories. The charge should be as homogenous as possible, especially when using small-scale boilers. Even though international standards are not mandatory, they do provide effective guidance. Often, boiler manufactures use international standards to define the fuel quality requirements to be used in their products.

Since 2014, the DIN EN ISO 17225 part 4 (Solid biofuels – Fuel specifications and classes – Part 4: Graded wood chips) determines the quality criteria for wood chips. It defines i.a. three size categories. (Table 7 in chapter 5.2.2)

To meet the criteria of these categories, certain elements (e.g. coarse parts) need to be sorted out. Sometimes it is also advisable to additionally sort out the fines, especially when using such machines as hammer mills.

Usually shaking screens are used in the wood processing industry to sieve and sort the wood chips. Another option is the utilisation of drum screens.
2.2.3 Pelletizing and briquetting

Pelletizing allows a maximum of homogeneity. The advantages of pellets and briquettes are described in chapter 5.3 and 5.4.

Pellets and briquettes are produced under high compression. Even though the technology is fully developed and well known, the procedures require profound expertise guaranteeing a high-quality outcome. Thus, the establishment of a pelletizing line is connected with greater risks. Several parameters influence the production of pellets and briquettes.

The intensiveness of the raw material pre-treatment depends on its kind (e.g. wood chips or saw dust). The raw material must be free of foreign particles such as stones and metals, which may cause problems in the following production steps. If necessary, a screening should be done.

The raw material for a pelletizing or briquetting process must be dry and fine. Therefore, the first production steps are drying and milling.

The dryer reduces the water content to less than 15%. In the hammer mill the particle size is reduced to less than 10 mm. Pellet mills often even require the size of 4 mm. The outcome is a quite homogenous mass. The next step in the production chain is the pelletizing press. The material may require pre-heating. The heat makes the lignin in the wood more plastic which helps the particles stick together. If necessary, additives can be injected at this stage to improve the characteristics of the final fuel product.

A successful production of hardwood pellets without additional binders is difficult. The share of resin in conifers may cause problems with residues in the oven and chimney after combustion. In Germany, the following additives may be used to improve the natural binding property: starch, plant paraffin or molasses. Maize or rye flour are commonly used additives.

Sawdust from softwood, e.g. from conifers, has better binding properties than sawdust from hard wood. A mix of soft and hard wood is possible.

Briquettes are usually made by ram extrusion. Pre-compaction of the material partly takes place before it is filled into a cylindrical press channel. A piston moves forth and back therein. The feed-in material is pressed against the already compressed material. A material strand forms. It leaves the pressing channel with each push of the piston. The necessary counter-pressure is built up in course of the friction within the pressing channel. It can be regulated through a narrowing at the end of the pressing channel. It comes to a pressure up to 1,200 bar, which leads to a major heating. The product needs to be cooled down. At the end of the cooling line, the material strand is cut or broken to form the final briquettes. Illustration 2 shows the basic principle.
Briquette presses with screw compression instead of a piston are also available. Further presses use pressing chamber with hydraulic compression. They produce no material strand.

There are briquette production lines available with capacities between 25 and 1,800 kg/h. The whole process requires 50 – 70 kWh/t (without size reduction and drying).

A pelletizing machine functions in a different way. Instead of a pressing channel, rollers are applied within a matrix. The rollers press the material through the matrix holes matrix. A shear knife cuts off the pellets as shown in the illustration 3.

Pellets leave the press in a hot and plastic condition. Just like the briquettes, they need to be cooled down (e.g. applying a counter flow cooler). During the cooling the pellets become rigid. Afterwards, they are transported by a conveyor belt to the storage fascility. Once the pellets are formed and cooled, they are packaged in bags or stored in bulk. Pellets can be stored during an indefinite period of time, but they must be kept dry to prevent deterioration.
Illustration 3: Function of pelletizing machine; source: Hartmann and Witt, 2009 (changed)

The energy consumption of the process varies depending on the necessary pre-treatment (grinding, drying, pre-heating). Without the energy necessary for the reduction of the particle size, the transport and the cooling, approx. 40 kWh/t are required to maintain the process.

Illustration 4: Model of a wood pellet production plant; Source: Hartmann and Witt 2009 (changed)
An exact coordination of all components is required during the technical production process. Experience is required to handle all variable parameters of the raw material (e.g. type of biomass, humidity and lignin share) and, if necessary, the type and amount of additives.

Finally, the pellets are whether stored in a silo as bulk goods or packed. For the domestic market, it is common to use bags of 12, 15 or 20 kg each. Another option is shipping in big bags with a content of 1 ton.

2.2.4 Torrefication
Thermochemical pre-treatment called torrefication, improves the fuel characteristics even further. It starts with solid wooden biomass. The biomass passes through an air-sealed heated reactor at temperatures between 250 and 300°C for 15 to 30 minutes. After the drying and heating up of the biomass, pyrolytic reactions take place. The goal is a mass reduction of the fuel without reducing the energy content at the same level. The calorific value rises due to the great decrease of water and low energy compounds (e.g. CO₂, CO).

Another advantage of this treatment is the reduced energy demand for the reduction of the particle size in the further process. The reduction is possible because the material is weak and brittle in course of torrefication. The material needs to be pelletized because it still has low density.

However, Torrefication still is a subject of worldwide intensive research and demonstration projects. It is not yet ready to be brought to market. The first results show an increase of the energy density of 80% compared to wood pellets.

2.3 Utilization
Wood-based solid biofuels are used in a number of different heating systems. In general, they can be used flexibly in a range of small fireplaces up to big combustion plants.

The main heating systems with a solid biomass fuel are:

- Single room heaters, like ovens, (tiled) stoves, fireplace
- Heating boilers in a central heating system
- Heating (and power) plants

With rising capacity the heat generation, the heat distribution and the heat utilization become more independent aspects. The illustration below shows the differences.

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4 FNR, heizen.fnr.de, seen on 24.04.2015
Single room heaters burn wood logs, wood briquettes or wood pellets in a closed combustion chamber. Usually they are loaded manually. The heat is transferred to a carrier medium (air or water) and through thermal radiation to the room. A chimney leads the exhaust gases out of the heated room.

Heating boilers in central heating systems are installed in a separate room. They transfer almost all produced heat to a buffering storage. These boilers have a higher automation stage. In case of manual operation, the loading has to be done only once or twice a day. Especially if loaded with wood chips or pellets, the work is delivered automatically. Fuel storages need to be installed close to the boilers to secure the continuous fuel supply. A screw or other mechanical devices load the fuel into the combustion chamber.

Heating (and power) plants have separate buildings for the boiler and the fuel storage. Usually, they provide heat for more than one building and feed-in heat into a local heating network. Screw conveyors operate without producing noise and dust. However, they are suitable only for distances of a few meters. Therefore, the fuel is loaded either mechanically e.g. via conveyor screws, push floors or via pneumatic removal systems (mainly for pellets). Boilers of this size have also an ash discharging unit.

Heating systems based on the utilization of high-quality pellets are easy to handle. They become more and more common in German households replacing old fossil-based boilers. Bigger commercial boilers are able to operate with the cheaper industrial pellets. Wood logs and briquettes are used mainly in private stoves and fireplaces. Wood chips are usually deployed in commercial or municipal combustions plants of greater capacity.

However, all combustion units need a defined and consistent fuel quality to operate properly. The chosen fuel strongly influences the emissions. Mainly needles, leaves and bark cause the development of dust elements. Furthermore, humus and mineral soil within the fuel may crucially affect the combustion sequence. A smooth operation leads to low ash contents and avoids slagging and corrosion. Using homogeneous wood chips prevents the blocking of the conveyor system.

It is obvious that high fuel quality is obligatory to allow a smooth operation of a combustion plant with low emissions.
3 Logistics in the Supply Chain of Wood-based Biofuels\textsuperscript{5}

Logistics play an important role when talking about wood-based biofuels. The aspects transport and storage of the goods must be considered along the whole line, during provision of the raw material, within the production process and even for the final utilization.

3.1 Transport

Transportation is necessary to move raw materials and goods to the next step within the line of provision. The type of transport is categorized either by the kind of goods (piece or bulk goods) or by the distance (short or long).

Forestry and agricultural vehicles (e.g. tractor or forwarder) move goods over short distances. A forwarder, for instance, carries felled trunks from the stump to a skid road. A tractor with a follower delivers wood chips to a nearby combustion plant. Truck, trailer, and if suitable also train and ship, are used to cover greater distances. Great piece goods, like trunks, demand special transport vehicles (e.g. timber trucks).

Bulk goods, like chips or pellets, may be transported in containers or followers. The difference between bulk goods and piece goods becomes important when transporting goods over a greater distance. Standard containers enable an easy change of the carrier vehicle, e.g. truck to ship. However, when transporting wood pellets (bulk density: 450 – 750 kg/m\textsuperscript{3}) or fresh wood chips (bulk density: 350 kg/m\textsuperscript{3}) by truck and trailer/exchange container the permissible maximum mass becomes a restrictive condition.

The transport of wood pellets to the final consumer might be problematic, because of narrow streets and difficult to access depots. Thus bulk goods, especially pellets, are often delivered to the end consumer with pump vehicles. A flexible tube allows even the supply of difficult to access storages. Pumping the bulk goods greatly reduces the dust development. An on-board weighing machine allows determining the exact weight of the delivered goods.

Piece and bulk goods are also available packed in small or big bags.

Transport aspects need to be taken into account from the beginning. Depending on the distances and the type of good different transport carrier vehicles are required.

\textsuperscript{5} FNR Leitfaden Feste Biobrennstoffe
3.2  Export logistics

There are two basic ways to organise the production of biofuels for export purposes. The easiest way is to export the raw material itself. In this case, the biofuels are produced abroad.

To create added value locally, the production has to take place within the country of the biomass origin. This way the produced biofuels can be used both by local consumers and for exports. However, this option might require the import of technical devices and know-how to build up a production line.

Illustration 6: Biofuel export options

The export of biofuels has to go along with a well-planned logistic chain. To minimize logistic costs the storage should have an optimal transport connection. Access to streets fit for heavy loads are mandatory. A train station or a harbor is desirable.

3.3  Storage and drying

The storage is an indispensable element within the logistic chain. Storage bridges the time between harvest, processing and demand. It contributes to the securing of the fuel supply. And it can strongly influence the quality of the biofuel. Fuel producers, traders and users need storage capacities.

Drying increases the storage capability and the calorific value of biofuels. Often storage and drying are combined.

The first possibility to store wood based fuels is to do it already in the forest. Fresh trunks are often stored at the skid road. The first drying takes place here as well. This storage is not recommended for coniferous forests due to the danger of creating a breeding ground for bark beetles or similar forest pests. To reduce this risk, conifer felling should be done in autumn. In spring, the wood should be dry enough to avoid an infestation with bark beetles.

The storage of biofuels, especially of bulk goods, is connected to a number of risks:

- Risk of loss of substance through biological processes.
- Fungal growth and fungal spores (health risk)
- Spontaneous combustion and fire risk
• Explosion
• Risk of smell emissions
• Risk of remoistening (quality risk)

The main problems are the loss of substance and the development of fungal spores. Both are caused by high moisture that enhances biological processes. Hence, wood should be as dry as possible when being stored and remoistening must be avoided.

Storage risks especially for vulnerable goods such as wood chips can be minimized by the following measures:

1. Store the biofuels only with a low water content of 15% or less. If necessary, apply an active drying prior to the storage.
2. Avoid to store needles and leaves which are easy targets for biological processes.
3. Minimize the time of storage
4. Avoid remoistening. Protect the goods of precipitation.
5. Ensure a good air access and ventilation. This will decrease the humidity and the heat.
6. Don’t exceed the optimal dumping height.
7. If possible apply active drying or an active ventilating.
8. Avoid blunt knives for the chopping of the wood.

Usually, not all measures can be applied in an economic way. Hence, a loss of dry mass should be part of the calculation. Table 3 gives an overview of the actual yearly losses of selected goods.

Table 3: Loss of substance; source: Hartmann and FNR 2013

<table>
<thead>
<tr>
<th>Material / storage</th>
<th>Loss in % dry mass / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine forest wood chips, fresh, uncovered</td>
<td>20 up to &gt;35</td>
</tr>
<tr>
<td>Fine forest wood chips, dried, covered</td>
<td>2 to 4</td>
</tr>
<tr>
<td>Coarse forest wood chips (7 to 15 cm), covered</td>
<td>Approx. 4</td>
</tr>
<tr>
<td>Bark, fresh, uncovered</td>
<td>5 to 22</td>
</tr>
<tr>
<td>Small diameter timber (spruce, pine), fresh, uncovered</td>
<td>1 to 3</td>
</tr>
<tr>
<td>Young whole trees (pobulus, salix), fresh, uncovered</td>
<td>6 to 15</td>
</tr>
</tbody>
</table>

Another well-known way to store wood-based biofuels is the storage on the open ground. This option is commonly used for unprocessed wood, such as whole trunks. Remoistening and contamination with dirt shall be avoided. Wooden planks or gravel suit for logs. For bulk good, such as wood chips, a solid and even ground is required. In open woods, chips are stored in a pyramidal form to prevent chips from precipitation as much as possible. Sometimes a portable cover is also used.

Another possibility is the storage within a (special) building. It allows higher protection against climatic influences and reduces the labour input for the entry and removal of goods. The pressure stability of the walls must be sufficient in case of bulk goods storage.

Tanks and silos are used solely for bulk goods storage.
Since the reduction of the water content is very important, storage is often combined with drying processes ensuring the quality of the solid biofuels. Some wood-based biofuels need drying to improve their ability to be stored. Moreover, the drying process increases the calorific value. (Illustration 7)

Illustration 7: Calorific value of wood in relation to the water content; source: Hartmann and FNR 2013

There are two principle ways of drying: natural and technical drying. Most of the times, an expensive technical drying process is not necessary. This particularly concerns coarse wood chips:

- with a water content below 30%
- with a short storage period
- under relatively closed storage conditions with low mechanical interventions (low risk of spore release)

If drying is done without any technical devices for ventilation or heating, the drying procedure belongs to the natural drying. This could be the drying on the floor. This is for example done when using forest or skid roads as an intermediate store. Fresh forest wood has water contents between 45% (beech) up to 55% (spruce). It may decrease to below 20% within a year. This does not apply for the storage within the forest itself with its higher air humidity and less air ventilation. A second way of natural drying makes use of the self-heating in bulk goods. Biological processes generate heat that dries the goods. It also leads to a loss of substance. The heat creates an upwardly stream of air. Cool air streams in from the sides and the bottom. It is of advantage if the storage ground is permeable to air. Coarse wood chips can be dried very efficiently this way without losing a great part of the substance. The self-heating leads to an increase of temperature of maximal 20°C above the surrounding temperature. In general the self-heating without ventilation is not without risks (spontaneous combustion and fire risk; explosion). Natural drying of small diameter wood chips leads to not satisfying results. The necessary ventilation to dissipate the heat is hindered by small particles. This also applies for wood chips that are piled up 5m or more, because of the compression. The self-heating could end up in self-combustion. Illustration 7 gives an overview about the possible temperature rise depending on the water content and time of storage.
There are four possible ways of technical drying. The cooling ventilation uses cold external air. The self-heating of the wood chips leads to an increased saturation deficit of the air and therefore also the water absorption capacity of the air rises. The intermittent ventilated cold external air replaces the humid air. The difference between the temperature within the store and outside should be at least 5°C.

The drying ventilation works with a continuous air flow. External air is pressed through the wood chips. The drying procedure is faster when the air temperature rises. The air may also come from an air exhaust system of a company building. The bulk good should have a height of at least 1m.

Even though a high temperature heat source (20-100°C) is required, warm air drying leads to much better results. This may be done in containers with waste heat e.g. from a biogas plant.

Hot air drying is used if wet goods like saw dust shall be used for pelletizing. The temperature level reaches 300 to 600°C.

Active drying devices are often just an addition to existing storage facilities.

Concerning big wood pellet stores, a carbon monoxide detector should be installed to prevent accidents because of spontaneous carbon monoxide emissions.
4 SUSTAINABILITY AND QUALITY ASPECTS / CERTIFICATION SYSTEMS

The quality and main characteristics of solid biofuels strongly vary. Assurance and improvement of the fuel quality is of increasing importance to meet the high environmental and technical standards. European and worldwide standardization bodies are active in establishing quality norms for solid biofuels. The norm series DIN EN ISO 17225 “Solid biofuels – Fuel specifications and classes” defines quality based fuel categories and specifications for solid biofuels. It consists of the following parts: part 1 “General requirements”, part 2 “Graded wood pellets”, part 3 “Graded wood briquettes”, part 4 “Graded wood chips”, part 5 “Graded firewood”, part 6 “Graded non-woody pellets”, part 7 “Graded non-woody briquettes”.

Certification systems, which are based on international standards, ensure the sustainable production of the raw materials and the fuel quality of the final products. Chapter 4.1 deals with forestry certification systems, while biofuel certification systems are explained in chapter 4.2.

4.1 Sustainable forestry management

Most wood-based biofuels have their origins in the forestry sector. To ensure a long-term sustainable production, a sustainable forestry management has to be established. Forestry certification systems help to consider the forest-related requirements.

What is sustainability?

Many facets need to be taken into account when considering the sustainability. The best environmental concept cannot be sustainable if it is unaffordable and/or if it cannot be harmonised with the social needs of the parties involved. Many facets need to be taken into account when considering the sustainability. Some examples are given in illustration 9 below.

Illustration 9: Sustainability; source: FNR

The components cannot be looked on separately; they interlock and influence one another.
Why is it necessary to consider sustainable aspects when producing wood-based solid biofuels in Russia? Sustainable development aims to reach a balance of economic, social and ecologic goals. To establish successful business in the long term, all these aspects are of importance.

Men profit especially from environmental services of healthy forests. They contribute in various ways to the ecosystem. They have positive influence on the climate, the water balance, the air cleaning, and the soil fertility. Forests also host a great number of species – many forests are a hoard of biodiversity. A forest is functioning as a place of recreation for local population as well. Finally wood is of great economic interest.

Forest certification systems ensure the economic exploitation of the forests goes along with the consideration of other issues as well. This approach of long term sustainability is necessary, because forests grow in generations.

There are two international recognized forest certification systems aiming at the improvement of the forest management: PEFC (Program for Endorsement of Forest Certification) and FSC (Forest Stewardship Council).

“Forest certification is a mechanism for forest monitoring, tracing and labeling timber, wood and pulp products and non-timber forest products, where the quality of forest management is judged against a series of agreed standards. Credible forest certification cover[s] much more than just logging practices – it also accounts for the social and economic well-being of workers and local communities, transparency and inclusiveness in decision making.”

4.1.1 PEFC

PEFC is a worldwide active forestry certification system. Currently (2015) two thirds of German forests are certified by PEFC. Worldwide more than 255 million hectares are managed according to PEFC standards. The products made of wood from certified forest may apply for a Chain-of-Custody (CoC)-Certificate. “Chain of Custody certification outlines requirements for tracking certified material from the forest to the final product to ensure that the wood contained in the product or product line originates from certified forests.” To receive the PEFC label a product has to be processed of wood from sustainable managed forests. Independent certification authorities are controlling the requirements yearly.

The PEFC label assures the following:

1. No more wood is cut down than is growing again
2. Where trees are felled, trees are planted again
3. Forest stays a secure habitat for animals and plants
4. The forest biodiversity is preserved
5. A sustainable managed forest keeps its function as natural protection of water bodies, soil and climate
6. The wood is of legal origin
7. Forest operations are done considering high work safety standards
8. Workers' rights are respected
9. Operations are carried out by professional staff
10. Rights of people living from or depending on the forest are secured

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6 WWF Global, WWF – Forest Certification, seen on 23.04.2015
7 PEFC; seen on 23.04.2015
8 PEFC Chain of Custody Certification; seen on 23.04.2015
The certification procedures for forest or chain-of-custody certification are explained on the PEFC website.

4.1.2 FSC
The FSC is the second forest certification system. Main goal of FSC is to keep the forests for future generations.

“FSC works to improve forest management worldwide, and through certification creates an incentive for forest owners and managers to follow best social and environmental practices.”

This way “FSC certification ensures that products come from well managed forests that provide environmental, social and economic benefits.”

FSC products are a guaranty for protection of endangered animal and plant species, protection against illegal wood use, avoidance of overexploitation of wood and use of plants that are not genetically modified. The process of certification is very similar to the PEFC procedure.

The concrete procedures and requirement to get a FSC label are described on their website.

4.1.3 Comparison of selected aspects of FSC and PEFC
The world resources institute has compiled information on selected standards of the forest certification system FSC and PEFC. They are shown in the table below.

Table 4: Comparison of selected aspects of FSC and PEFC; source: World Resources Institute

<table>
<thead>
<tr>
<th>Social issues</th>
<th>Programme for the Endorsement of Forest Certification (PEFC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest Stewardship Council (FSC)</td>
<td>Four principles of the FSC system include various social concerns: tenure and use rights and responsibilities, indigenous people's rights, community relations, and workers' rights. Principle related to high conservation value forests (HCVF) also addresses social aspects for areas of archaeological, historical or cultural value. Standard setting processes at the national and sub-national level are conducted in a transparent way and involve all interested parties.</td>
</tr>
<tr>
<td>Forests with unique values</td>
<td>Criteria 1 and 6 cover various social concerns. Criteria 1 requires that forest management activities aim to maintain or increase cultural and social values among others. Criteria 6 (maintenance of socio-economic functions and conditions) covers the following among others: stimulation of rural development, property and ownership rights and land tenure, recognition of customary and traditional rights, access to the public for recreational purposes, recognition of areas with historical, cultural or spiritual significance, FPIC, workers' health, labor, and community consultation. Principle 9 addresses high conservation value forests (HCVF), which are areas to be managed in such a way that these values are maintained or enhanced. HCVF include:</td>
</tr>
<tr>
<td>Forests with unique values</td>
<td>• Forests that contain globally, regionally, or nationally significant concentrations of biodiversity values</td>
</tr>
<tr>
<td>Forests with unique values</td>
<td>• Globally, regionally, or nationally significant large landscape level forests</td>
</tr>
<tr>
<td>Forests with unique values</td>
<td>• Rare, threatened or endangered</td>
</tr>
<tr>
<td>Forests with unique values</td>
<td>Forest management shall aim to maintain, conserve and enhance biodiversity on ecosystems, species and genetic levels and, where appropriate, diversity at the landscape level (Criterion 4). Forest management shall identify, protect and/or conserve ecologically important areas containing significant concentrations of:</td>
</tr>
<tr>
<td>Forests with unique values</td>
<td>• Protected, rare, sensitive or representative forest ecosystems such as riparian areas and wetland biotopes</td>
</tr>
<tr>
<td>Forests with unique values</td>
<td>• Areas containing endemic species and</td>
</tr>
</tbody>
</table>
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ecosystems
- Forest areas providing basic services of nature in critical situations
- Forest areas fundamental to meeting basic needs of local communities
- Forest areas critical to local communities’ traditional cultural identity

habitats of threatened species
- Endangered or protected genetic in situ resources; and take into account
- Globally, regionally and nationally significant large landscape areas with natural distribution and abundance of naturally occurring species.

Criterion 5 require special care of forest areas that are on sensitive soils, erosion-prone areas, or forests that protect water resources.

Criterion 6 requires special care for sites with recognized historical, cultural, or spiritual significance for the local communities.

Forest plantations
Principles 6 and 10 of the FSC principles address forest plantations. Certified forest plantations should meet a set of requirements concerning:
(i) representation on landscape;
(ii) time of establishment; and,
(iii) design of the management blocks (i.e., blocks promote biodiversity).
Forest conversion to plantations or non-forest land uses should not occur except in circumstances where conversion entails a very limited portion of the forest management unit, does not occur in high conservation value areas, and will deliver long-term conservation benefits.

Various elements of Criterion 5 are relevant to forest plantations. Certified plantations should meet a set of requirements concerning, among others, the following aspects:
(i) time of establishment;
(ii) impacts on forests with unique values; and,
(iii) impacts on soil and water.

Chemicals
Principle 6 of FSC addresses chemicals. Chemicals should be minimized. Integrated Pest Management (IPM) is the preferred approach, i.e., to minimize chemical use through the use of alternative prevention and biological control techniques. Documentation, monitoring, and control are required. Prohibits the use of pesticides type 1A and 1B, as defined by the World Health Organization, as well as chlorinated hydrocarbon pesticides; pesticides that are persistent, toxic or whose derivatives remain biologically active and accumulate in the food chain.

Use of pesticides and herbicides should be minimized, used in controlled manner, and take into account appropriate silvicultural alternatives and other biological means. Prohibits the use of pesticides type 1A and 1B, as defined by the World Health Organization. Chlorinated hydrocarbons and other toxic pesticides whose derivatives remain biologically active and accumulate in the food chain are also prohibited unless there are no viable alternatives. (PEFC, 2010).

Clearcuts
Principle 6 of FSC addresses clearcuts. Restrictions on size and location vary among national/regional standards as long as ecological functions and values are maintained intact, enhanced or restored.

Management plans – including clearcutting – should be based on legislation as well as existing land-use plans and adequately cover forest resources. Regeneration, tending, and harvesting should be carried out in time and manner that do not reduce the productive capacity of the site.

GMOs
Use of GMOs (genetic modified organisms) is prohibited; addressed in Principle 6 of FSC.

Use of GMOs is prohibited.

Exotic species
Addressed in Principle 6. Exotic species are permitted, but not promoted. Careful monitoring is required to avoid adverse environmental impacts.

Criterion 3 addresses exotic species. Native species and local provenances should be preferred in reforestation and afforestation. Introduced species can be used after potential impacts on the ecosystem and the genetic integrity of native species is evaluated and if negative impacts can be avoided or minimized.

4.2 Certification for wood-based biofuels

The produced biofuels have to meet certain quality requirements, which are determined in the standardization documents. The latest and most important norm is the DIN EN ISO 17225 “Solid biofuels - Fuel specifications and classes” with its parts: 1: General
requirements, 2: Graded wood pellets, 3: Graded wood briquettes, 4: Graded wood chips, 5: Graded firewood, 6: Graded non-woody pellets, 7: Graded non-woody briquettes.

To ensure the defined quality of wood-based biofuels, certification systems for pellets and briquettes have been implemented. A certification system for wood chips is still in development.

4.2.1 ENplus Pellets

The ENplus certification system covers the whole supply chain and ensures high quality pellets. It defines three categories ENplus-A1, ENplus-A2 and EN-B, which are based on the requirements of the international standard ISO 17225-2 “Solid biofuels - Fuel specifications and classes – Part 2: Graded wood pellets” Nevertheless ENplus goes beyond the norm in certain points.

The following points are significant within the certification system:

- Requirements concerning the pellet production and quality assurance
- Requirements concerning the final product
- Requirements concerning labelling, logistics and intermediate storage
- Requirements concerning the distribution to the final customer

Quality class A1 is the premium quality with low ash content and the most severe requirements. They are used in small private household boilers or stoves. Quality class A2 are characterized by higher ash content. They are used in larger plants. Both classes may apply for the ENplus label.

ENplus B are pellets for industrial use.

The product is controlled the whole way from the production until the final delivery to the end consumer, ensuring an adequate transport and storage along the supply chain. The production process and the quality management of the pellet plants is audited once a year. Samples of the produced pellets are taken and analysed. Producers and traders are free to choose a listed and recognized audit company.

Detailed information on the certification process is given on the website of ENplus (in German).

4.2.2 ENplus Briquettes

In 2013, the German Pellet Institute has implemented a certification system for wood briquettes as well. ENplus-Briketts was established on the basis of the DIN EN 14961-3 “Solid biofuels - Fuel specifications and classes - Part 3: Wood briquettes for non-industrial use”.

Two quality categories (ENplus-Briketts A1 and ENplus-Briketts A2) are defined. They meet the requirements of the European standard and go beyond in certain points.

The certification itself is similar to the pellet certification.

The ENplus-Briketts website gives information on the requirements and process of the whole certification.

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12 Deutsches Pelletinstitut GmbH, ENplus; seen on 24.04.2015
13 Deutsches Pelletinstitut GmbH, ENplus-Briketts; seen on 24.04.2015
4.2.3 DIN CERTCO – labelling of wood pellets, wood biquettes

DIN CERTCO is company certifies a wide range of products, services and companies. It began certifying wood-based solid biofuels in the 90s according to the form standard DIN 51731.

DIN CERTCO certifies wood pellets on the basis of the international standard DIN EN ISO “Solid biofuels - Fuel specifications and classes – Part 2: Graded wood pellets” and in parts according to the European norm on DIN EN 15234-2 “Solid biofuels – Fuel quality assurance - Part 2: Wood pellets for non-industrial use”. Only the premium pellets of class A1 get the label “DINplus”.

With the certificate “DIN-Geprüft Industriepellets” the company provides also an opportunity for producers of class B pellets for industrial use to get a certification.

Wood briquettes of quality class A1 according to the DIN EN 14961-3 are certified as well with a “DINplus”-label.

All necessary documents, applications and procedures can be found on the DIN CERTCO website.

4.2.4 Hackzert

Wood chips with a wide variety of qualitative characteristics are used for combustion in Germany. The lack of harmonized trade sorting makes it difficult for wood chip combustion plants to achieve the emission requirements of the 1.BImSchV (stage 2). The development and implementation of a certification program will ensure the provision of homogeneous wood chip qualities in the future. The German Pellet Institute (DEPI) began on February 1, 2015, with the development of a certification system for wood chips (HackZert). It is planned to be implemented in 2016. The utilization of certified wood chips will not only improve the emission behaviour, the entire heating system can be optimized with certified wood chips.

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14 DIN CERTCO Gesellschaft für Konformitätsbewertung mbH, DIN CERTO, seen on 24.04.2015
15 German Pellet Institute, press release "Ab 2016: ENplus-Siegel auch für Hackschnitzel"
16 Erste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung über kleine und mittlere Feuerungsanlagen)
17 2. Stufe der Verordnung über kleine und mittlere Feuerungsanlagen zum Immissionsschutz
5 WOOD-BASED BIOFUELS CHARACTERISTICS AND REQUIREMENTS

5.1 Common characteristics of wood-based biofuels

Wood-based biofuels have some common general characteristics, which should be considered when planning a respective production line, storage and various utilization pathways.

In general, highly processed wood-based biofuels, e.g. chips, pellets and briquettes, must be clearly advantageous in contrary to fossil fuels and common wood logs. If the advantages of the highly processed wood-based biofuels are not clear, the high costs and time required for their production cannot be justified. A significant advantage over wood logs is the possibility for automatic feeding of the combustion plant. It is (almost) as comfortable as it is with fossil fuels. The main advantage over fossil fuels is their climate friendliness (CO$_2$-neutral), and usually they are cheaper and more stable in price.

Regardless the final product, several characteristics of wood-based biofuels are directly influenced by the technical equipment. Hence, the technical solution must be exactly adapted to the raw material input and optimally results in a standardized high quality. To obtain a good combustion, the final ash content should be as low and the ash melting temperature as high as possible.

The mineral composition of biofuels is important with regard to ash melting, slagging and emissions. The main components of plant material are carbon (C), hydrogen (H) and oxygen (O). The shares of carbon and hydrogen determine the calorific value of a dry biofuel. Wood-based biofuels have the highest share of carbon with 47 – 50% of the dry mass. Mineral elements of biofuels like alkali compounds cause dropping of the ash softening temperature resulting in slagging. The shares of nitrogen (N), potassium (K), chlorine (Cl) and sulphur (S) are relevant for emissions. A high share of nitrogen and chlorine also leads to corrosion of heating surfaces. Heavy metal contents, like cadmium, lead to environmental problems when the ashes shall be deposited. They cannot be used as fertilizers. Because of this Cl, N, S and certain trace elements (heavy metals) are limited in specification norm. Table 5 shows the average amount of the main elements of three different trees.

**Table 5: Average amount of main elements in selected natural solid biofuels; Source: Hartmann in Leitfaden Feste Biomasse p.45**

<table>
<thead>
<tr>
<th>Biofuel</th>
<th>C</th>
<th>H</th>
<th>O</th>
<th>N</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>P</th>
<th>S</th>
<th>Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willow (SRC)</td>
<td>47.1</td>
<td>6.1</td>
<td>44.3</td>
<td>0.54</td>
<td>0.26</td>
<td>0.68</td>
<td>0.05</td>
<td>0.09</td>
<td>0.045</td>
<td>0.004</td>
</tr>
<tr>
<td>Spruce (with bark)</td>
<td>49.8</td>
<td>6.3</td>
<td>43.2</td>
<td>0.13</td>
<td>0.13</td>
<td>0.70</td>
<td>0.08</td>
<td>0.03</td>
<td>0.015</td>
<td>0.005</td>
</tr>
<tr>
<td>Beech (with bark)</td>
<td>47.9</td>
<td>6.2</td>
<td>45.2</td>
<td>0.22</td>
<td>0.15</td>
<td>0.29</td>
<td>0.04</td>
<td>0.04</td>
<td>0.015</td>
<td>0.006</td>
</tr>
</tbody>
</table>

The physical-mechanical characteristics are important when planning the logistic chain. Energy and bulk density for example determine the required space capacities for transport and storage. The low fines content, the particle sizes and its distributions are important for flow purposes and dust development. Too big or long particles cause blockades and slow down the production process or halt the firing.
Pourability is a characteristic that facilitates feeding, storage and transport possibilities. Due to the pourability high automation levels are applicable for loading and feeding steps along the line of provision. The pourability deteriorates with rising moisture, dumping height and/or the share of oversized particles.

In general bulk goods are easier to handle than piece goods, because there are more possible ways for transport.

The following list gives an overview of the most important characteristics that need to be considered.

- Energy density
- Bulk density / storage density
- Moisture
- Share of carbon
- Share of nitrogen, sulphur and chlorine
- Share of heavy metals
- Homogeneity
- Particle size distribution / low fines content
- Pourability

The following table gives an overview on selected wood-based biofuels and their figures.

**Table 6: Selected planning figures to evaluate the amount of energy of biofuels; source: Hartmann in Leitfaden Feste Biomasse p. 51**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Unit</th>
<th>Water content</th>
<th>Mass (incl. Water)</th>
<th>Calorific value</th>
<th>Amount of fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>in %</td>
<td>in kg</td>
<td>in MJ/kg</td>
<td>in MJ</td>
</tr>
<tr>
<td>Wood logs</td>
<td>1 m³</td>
<td>15</td>
<td>304</td>
<td>15.6</td>
<td>4,753</td>
</tr>
<tr>
<td>(33cm) spruce air-dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood chips spruce, dry</td>
<td>1 m³</td>
<td>15</td>
<td>194</td>
<td>15.6</td>
<td>3,032</td>
</tr>
<tr>
<td>Wood chips spruce</td>
<td>1 m³</td>
<td>30</td>
<td>223</td>
<td>12.4</td>
<td>2,768</td>
</tr>
<tr>
<td>Wood pellets</td>
<td>1 m³</td>
<td>8</td>
<td>650</td>
<td>17.1</td>
<td>11,115</td>
</tr>
<tr>
<td>Wood pellets</td>
<td>1 t</td>
<td>8</td>
<td>1,000</td>
<td>17.1</td>
<td>17,101</td>
</tr>
</tbody>
</table>

5.2 Chips

Wood chips are used in material and energetic ways. They provide heat energy for single households, in municipal and commercial buildings. In great biomass heat and power plants they even provide heat, power, process steam and power.

Characteristics and qualities of sold wood chips differ considerably and therefor also the suitability for different wood chip heating plants.
5.2.1 Product characteristics

The use of wood chips instead of logs or branches facilitates a more automatic utilization, e.g. with a screw or conveyor belt. Dosage, transport and storage become easier. In contrast to trunk wood, wood chips have a very low bulk density and need 4 times the volume. For this reason transportation of wood chips is only suitable for short distances and only partly suitable for export. But one does not need a special vehicle for whole trunks anymore. Chips can be shipped in containers or trailers.

One important quality parameter of wood chips is the water content. In order to keep it as low as possible, the storage of the goods is very important. This involves the wood raw material (e.g. trunks) prior to processing and the processed woodchips themselves. Therefore the weather influences should be kept as low as possible along the line of distribution. Also during transport precipitation must be avoided.

At the consumers place storage buildings and silos near the furnace ensure a dry storing.

5.2.2 Quality requirements

Wood chips are made of wood from different raw material (e.g. industrial residues, bush wood or wood trunks). Depending on the used wood the share of needles, leaves and bark varies. The used machines, process adjustments and working methods also influence the fuel characteristics. To allow an undisturbed operation in small boilers and combustion plants (capacity below 100kW), the wood chips need to be as homogenous as possible with clearly defined quality requirements. This becomes even more important if legal regulations (like the 1. BImSchV) raise the standards for the emission behaviour of boilers.

The quality requirements of wood chips are defined by certain physically and material characteristics. The most important quality criterion is the water content, since it influences the effectively usable heat energy as well as the emission behaviour and the storability of the chips. Other characteristics are ash quality and content or the calorific value. A high content of bark for example leads to a bigger ash appearance. Further requirements concern the particle size and form. The particle size or better the particle size distribution strongly influences the flow behaviour (blockage of conveyor, bridging).

To define a certain fuel quality wood chips are classified according to international standards. In 2014 the standard series DIN EN ISO 17225 “Solid biofuels - Fuel specifications and classes” was introduced. It replaces previously used standards (DIN EN 14961, ÖNorm M7133). While part 1 deals with general requirements, part 4 defines size categories and quality requirements for wood chips.

The norm defines three size categories: P16S, P31S and P45S. The name of the category describes the main fraction. It defines also the maximum share of low fines content, the permitted coarse parts, the maximum length and the maximum cross sectional area of the parts. In table 7 you can see the requirements of the three categories.


<table>
<thead>
<tr>
<th>Size</th>
<th>Main fraction</th>
<th>Share of fine material</th>
<th>Share of coarse material</th>
<th>Max. length of</th>
<th>Max. cross</th>
</tr>
</thead>
<tbody>
<tr>
<td>P16S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P31S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P45S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Ma% – percentage by mass

Part 4 of the norm on solid biofuels (DIN EN ISO 17827-4) describes also four quality categories: A1, A2, B1 and B2. There are certain requirements for these classifications concerning the raw material and physical fuel characteristics like water and ash content, calorific value and bulk density (table 5). There are separate standards for physical and chemical testing methods (20 single norms), quality assurance and methodological questions (sampling, sample division, etc.). Some are named in the left column.

Table 8: Classification categories; source: TFZ-Merkblatt: 14BKu002

<table>
<thead>
<tr>
<th>Origin and source, ISO 17225-1</th>
<th>A1</th>
<th>A2</th>
<th>B1</th>
<th>B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content, W; ISO 18134-1:2</td>
<td>m - %</td>
<td>M10 ≤ 10</td>
<td>M25 ≤ 25</td>
<td>M35 ≤ 35</td>
</tr>
<tr>
<td>Ash content, A; ISO 18122</td>
<td>m - % water free</td>
<td>A1,0 ≤ 1,0</td>
<td>A1,5 ≤ 1,5</td>
<td>A 3,0 ≤ 3,0</td>
</tr>
<tr>
<td>Bulk density, BD; ISO 17828</td>
<td>Kg/m² bulk volume</td>
<td>BD 150 ≤ 150</td>
<td>BD 200 ≤ 200</td>
<td>BD 250 ≤ 250</td>
</tr>
<tr>
<td>Limitation of undesirable substances (e.g. nitrogen, sulphur, chlorine or heavy metals)</td>
<td>m - % or mg/kg water free</td>
<td>-</td>
<td>-</td>
<td>Maximum levels established</td>
</tr>
<tr>
<td>Calorific value ISO 18125</td>
<td>MJ/kg or kWh/kg</td>
<td>Smallest value</td>
<td>Smallest value</td>
<td></td>
</tr>
</tbody>
</table>

The Bavarian State Institute for forest and forestry recommends the use of the quality requirements according to DIN EN ISO 17225-4 only for combustions plants and boilers up to a capacity of around 1 MW. Fuels classified as A1 or A2 wood chips are suitable for private boilers up to around 100 kW. The categories B1 and B2 are rather fed in commercial and municipal heating networks with a central combustion plant with a capacity up to around...
1 MW. For heating plants with a capacity greater 1 MW the fuel requirements of the DIN EN ISO 17225-4 are often too strict. In this case it is recommended to agree on special quality criteria according to part 1 of the norm between the supplier and the operator.

Table 9: Recommended fuel quality for heating plants;
source: Kuptz, D. and Hartmann, H. in LWF aktuell 103/2014

<table>
<thead>
<tr>
<th>Heating plant</th>
<th>Recommended fuel quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small heating plant (&lt; 100 kW)</td>
<td>DIN EN ISO 17225-4, class A1 and A2, size category P16S, P31S or P45S</td>
</tr>
<tr>
<td>Fixed-bed gasifiers</td>
<td>DIN EN ISO 17225-4, class A1 and A2, size category according to DIN EN ISO 17225-1</td>
</tr>
<tr>
<td>Small combustion plant (up to 1 MW)</td>
<td>DIN EN ISO 17225-4, class B1 and B2, size category P31S or P45S</td>
</tr>
<tr>
<td>Heating (and power) station (&gt; 1 MW)</td>
<td>Individual agreements according to DIN EN ISO 17225-1</td>
</tr>
</tbody>
</table>

5.2.3 Provision of raw material
The raw material supply for wood chip production can be secured from several sources. Either wood residues from forestry or energy wood of fast-growing tree species from short rotation plantations can be used. Most of the times raw material for wood chip production are residues from forestry, processing, sawing or landscape management. Sometimes wood of short rotation plantations with similar characteristics to those of wood from landscape conservation is used. Contrary to the high availability, higher bark content and a higher risk of contamination is given. The bark content influences the calorific value of wood chips. The highest quality is achieved by processing of whole wood trunks. In this case, wood chip processing competes with material use (building material, furniture manufacture etc.).

5.2.4 Technical solutions and application options
As mentioned before, wood chips have a low bulk density. Therefore they require a lot of space, making transport over long distances expensive. Thus, export is seldom advisable from the economical point of view. But they are very suitable to provide feedstock for local combustion plants. Municipalities and (agricultural) companies can use wood chips in highly automatic boilers to provide heat energy for a local heating grid.

Feeding systems
On agricultural farms, wheel loaders or tractors are often used for loading and restocking of wood chips stores. There are different feed-in systems in automatically operated combustion plants to feed the boiler with woodchips. The easiest way, if the boiler is located next to storage place, is the installation of discharge screws to feed the boiler. Uneven floors in the storage place or tanks are necessary to gather the chips in the centre where the screw is installed. For square stocks and bigger combustion plants pushed floors and wandering screws are suitable. Pushed floors have one or more push rods with carriers that move horizontally forward and back. The rods are driven by hydraulic cylinders that operate outside the storage room. Often conveyor systems have a protection from back burning, if the heating room is located next to the storage room.

Wood chips are stored in silos as well.

Because of relatively high investment costs the installation of a wood chip heating system is only profitable, if a high amount of energy is required, e.g. apartment or production buildings. However wood chips are less expensive than pellets, briquettes or fossil fuels. At agricultural
farms the installation of a wood chip heating could be profitable if a large amount of wood chips from landscape management is available. But dry high quality chips are essential to avoid blockages in automatic systems and guarantee even and effective combustion. Automatic systems for wood chips are vulnerable for blockages if low quality chips with unequal size distribution are used. Wood chip heating systems have a great demand of storage space because of the wood chip bulk density.

5.3 Pellets

A wood pellet is a small cylindrical and compressed piece of dried natural wood. Wood pellets are produced in pellet plants that are often installed close to saw mills. This allows for creation of added value for saw mill and wood processing residues. Additional forestry residues and other raw wood assortments are also used.

The most important reason for the production of pellets as well as briquettes is the higher level of energy with less volume than unprocessed wood or wood chips. This allows an economic transport even over greater distances. Next to the logistic advantages, they show favourable flow and dosing characteristics.

The use of additives during the production can improve the chemical and material characteristics which are important for the combustion.

5.3.1 Product characteristics

There are various kinds of pellets according to the size and fit. The cylindrical shape, a diameter of approximately 4 - 10 mm and a length of about 20-50 mm is, however, typical.

The calorific value of two kilograms wood pellets corresponds to one litre heating oil or to one m³ natural gas.

The ash content is usually below 5 %. The water content is less than 10 %. The ashes of certified pellets produced of untreated wood can be used as an ecologically sound fertilizer.

The significantly higher production costs compared to wood chips are more than compensated by the advantages. First of all there is the high storage stability without biological degradation. Furthermore the small pellet size leads to good flowing and dosage characteristics enabling automation procedures. Finally wood pellets have uniform physical characteristics and a high energy density, which allows easy standardization and comparison of quality parameters.

5.3.2 Quality requirements

Pellet heating systems require a certain pellet quality. For a smooth operation of pellet combustion plants one has to use the standardized pellets prescribed in the manuals or warranty conditions.

There are two international standards dealing with pellets. The most recent standard is the international valid DIN EN ISO 17225-2 that defines the quality requirements for pellets. It replaces the European standard DIN EN 14961-2 which still is used by the certification ENplus.

18 FNR, Pelletheizungen Marktübersicht 2013
According to DIN EN ISO 17225-2, pellets are classified in A1, A2 and B of which the class A1 is relevant for private households. Class A2 and B (Industrial pellets) are used in bigger municipal, commercial or industrial plants. A1 is the best quality with ash contents ≤ 0,7%. A wider range of wooden feedstock is permitted for the production of A2 pellets. They may have a higher ash content of up to 1,2%. Table 10 shows the classification criteria according to DIN EN ISO 17225-2.

Table 10: Classification criteria of wood pellets; source: C.A.R.M.E.N.\(^{19}\)

<table>
<thead>
<tr>
<th>Criteria and their determination standards</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origin and source, ISO 17225-1</strong></td>
<td></td>
</tr>
<tr>
<td>- Wood trunks</td>
<td>- Wood trunks</td>
</tr>
<tr>
<td>- Untreated wood residues</td>
<td>- Untreated wood residues</td>
</tr>
<tr>
<td>- Wood residues from forestry</td>
<td>- Wood residues from forestry</td>
</tr>
<tr>
<td>- Trees without roots</td>
<td>- Trees without roots</td>
</tr>
<tr>
<td><strong>Diameter, D and length, L; ISO 17829</strong></td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>D06, 6 ± 1; D08, 8 ± 1</td>
<td>D06, 6 ± 1; D08, 8 ± 1</td>
</tr>
<tr>
<td>3,15 &lt; L ≤ 40</td>
<td>3,15 &lt; L ≤ 40</td>
</tr>
<tr>
<td><strong>Water content, W; ISO 18134-1;2</strong></td>
<td>m - %</td>
</tr>
<tr>
<td>m10 ≤ 10</td>
<td>m10 ≤ 10</td>
</tr>
<tr>
<td><strong>Ash content, A; ISO 18122</strong></td>
<td>m - % water free</td>
</tr>
<tr>
<td>A0,7 ≤ 0,7</td>
<td>A1,2 ≤ 1,2</td>
</tr>
<tr>
<td><strong>Mechanical stability, DU; ISO 18846</strong></td>
<td>m - %</td>
</tr>
<tr>
<td>DU 97,5 ≥ 97,5</td>
<td>DU 97,5 ≥ 97,5</td>
</tr>
<tr>
<td><strong>Fine material, F; ISO 18846</strong></td>
<td>m - %</td>
</tr>
<tr>
<td>F1,0 ≥ 1,0</td>
<td>F1,0 ≥ 1,0</td>
</tr>
<tr>
<td><strong>Additives</strong></td>
<td>m - %</td>
</tr>
<tr>
<td>≤ 2 (obligatory description of type and amount)</td>
<td></td>
</tr>
<tr>
<td><strong>Limitation of undesirable substances (e.g. nitrogen, sulphur, chlorine or heavy metals)</strong></td>
<td>m - % or mg / kg water free</td>
</tr>
<tr>
<td>Maximum levels are determined</td>
<td></td>
</tr>
<tr>
<td><strong>Calorific value ISO 18125</strong></td>
<td>MJ / kg or kWh / kg</td>
</tr>
<tr>
<td>Q16,5 ≥ 16,5 or Q4,6 ≥ 4,6</td>
<td>Q16,5 ≥ 16,5 or Q4,6 ≥ 4,6</td>
</tr>
<tr>
<td><strong>Bulk density, BD; ISO 17828</strong></td>
<td>kg / m³</td>
</tr>
<tr>
<td>BD 600 ≥ 600</td>
<td>BD 600 ≥ 600</td>
</tr>
<tr>
<td><strong>Ash melting behaviour CEN/TS 15370-1[4]</strong></td>
<td>°C</td>
</tr>
<tr>
<td>Should be mentioned</td>
<td></td>
</tr>
</tbody>
</table>

\(^{19}\) C.A.R.M.E.N. e.V. [Normierung und Qualität]; seen on 22.04.2015
Certificates, such as the ENplus from the German Pellet Institute or the DIN CERTCO Company, ensure the high quality of the pellets. These certificates are used for private households only.

5.3.3 Technical solutions and application option
The processing of pellets is described in chapter 2.2.3.

The storage and transport of pellets requires special attention. Due to their high bulk density, less storage space is required for pellets than for chips or logs. Pellets need no ventilation during storage because their water content is 12% or below. However, the protection against moisture must be ensured to avoid degradation and mould formation. Depending on the type of utilization, there are different ways for storing pellets.

The storage in small bags (12-20 kg) or big bags (800-1200 kg) is common. Boiler tanks, reusable containers or small silos are used as well.

If delivered as bulk goods by vacuum vehicles, the pellets are usually blown into the storing place. This allows moving the bulk goods in higher situated storing places as well.

Most pellet boiler work with mechanized feeding systems. To ensure the automatic feed-in, the pellets must converge at a deep point to be taken from there via a screw or automatic extraction. Therefore the usually are stored on an inclined plane.

Pellets are used in private households for room heating in specific pellet ovens and for the central heating of a building. There are three kinds of pellet ovens for a single room:

1. Pellet oven that heats the air through convection and radiation
2. Pellet oven with a connection to the central heating system
3. Tiled stove with for wood logs with an additional automatic pellet feed-in system

Pellet central heating systems are available for operation with pellet only and as a two fuel boiler for pellets and wood logs.

If a fuel change to pellets is planned and the previous oil boiler is still in a good shape, it is possible to just attach a pellet burner to the boiler.

Central pellet heating’s usually include an automatically fed boiler which is provided with pellets through an electrically screw or a suction system.

5.4 Briquettes

Wood briquettes are bigger than pellets. Their diameter is at greater than 25mm. They have different forms, round or square, with smooth edges. Often they are stackable. Their physical and mechanical characteristics are very homogenous.

5.4.1 Product characteristics and application options
Due to the fact that briquettes have low water content, often below 10%, they have a high calorific value. Compared to wood logs, briquettes burn a longer time, generate more heat and are easier handle. Depending on the raw material, different briquettes have different combustion characteristics as well. Soft wood briquettes are easy flammable generating great heat while burning. In contrast hardwood briquettes
burn for a longer time. Further the burning characteristics are improved by the abrasion resistance, the particle density and the chemical composition of the briquettes. The DIN EN ISO 17225-3 “Solid biofuels - Fuel specifications and classes - Part 3: Graded wood briquettes” is the international standard for quality requirements of wood briquettes. It replaced the DIN EN 14961-3 which still is basis for the certification according to DIN CERTO and ENplus-Brikkets.

The combustion of briquettes can take place in stoves, chimneys or wood gasification boilers. Mostly briquettes are used in boilers and ovens designed for wood logs or coal.

5.4.2 Differences compared to pellets

Even though there are a great number of similarities between wood pellets and wood briquettes, there are though some significantly differences. First of all, the sheer size of briquettes affects the transport and storage capacities. Due to their porosity, briquettes should be transhipped on pallets. The problems relating to briquettes are the insufficient bulk properties and the possibility of crumbling when loading or unloading.

Moreover the dosing and feeding characteristics differ greatly. Briquettes have no flowing suitability. For that reason automatically feeding systems are not applicable. Briquettes are loaded manually.
6 SUMMARY
The planning and establishment of a production line for wood-based biofuels is a complex process. Many aspects need to be taken into account.

To provide energy from biomass, three steps are necessary. The process starts with provision of the raw material. The decision of whether wood chips, pellets or briquettes shall be produced is the next step. It depends on the targeted market, the available know-how and production facilities, as well as the quality of the raw material. The final step is related to the utilization of the biofuels by end consumers for energy purposes.

Along the line, transport and storage are important aspects worth addressing. Logistic aspects have to be considered from the provision/cultivation of the raw material up to the final utilization of the biofuels. Especially storage conditions of bulk goods are crucial for the planning of security and quality issues.

Even though wood-based biofuels such as wood chips, wood pellets and wood briquettes share some common general characteristics, they differ in ways of production, quality and utilization options.

Norms and certification systems ensure high quality of sustainably produced products. The international norm series DIN EN ISO 17225 “Solid biofuels – Fuel specifications and classes” sets standards for solid biofuels. Certification systems guarantee that the products comply with the standards. Two international recognized forest certification systems, PEFC and FSC, address aspects of sustainable production.
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Deutsches Pelletinstitut GmbH; ENplus
Deutsches Pelletinstitut GmbH; ENplus-Briketts
DIN CERTCO Gesellschaft für Konformitätsbewertung mbH