4. Purchase and Sale of Wood for Energy Production

In Denmark, there are many different wood fuels, e.g., firewood, wood chips, wood pellets, and wood briquettes, bark, sawdust and shavings. In the following chapter, the most common methods for the purchase and sale of these fuels will be described.

Firewood

Standard firewood is paid by the volume. There are many different volume indications for wood, but they all refer to principally different units:

- One cubic metre stacked volume including air equals the content of a cube (with six equal sides) of 1 × 1 × 1 m, exterior measure.
- One cubic metre solid volume equals the amount of solid wood containing exactly 1 m^3, e.g., a solid block of wood with length, height, and width being 1 m.

In Denmark firewood is sold primarily by the stacked cubic metre (a m^3 of sawn, split and stacked wood, a m^3 stacked volume of whole-tree wood, or a loose volume cubic metre) /ref. 38/.

A m^3 stacked volume of sawn, split, and stacked wood contains the most wood of the three units, but the volume of wood depends on the density of the stack and the size of the pieces. The larger the pieces are, the more wood is in the m^3 stacked volume.

A m^3 stacked volume of whole-tree is wood that is stacked in the forest after harvesting and shortening. It is often cut into two-meter pieces, but softwood also in lengths of one and three meters. It is typically wood that is delivered for the purpose of do-it-yourself cutting/splitting. There may be a lot of air in such a stack. If the pieces are long or crooked and perhaps stacked by crane, the wood content is small. A stack consisting of short pieces of large diameters contains more wood than if it consists of long, thin pieces.

Species	Kg dry matter per m^3	Compared to beech in %
Hornbeam	640	110
Beech/oak	580	100
Ash	570	98
Sycamore	540	93
Birch	510	88
Mount. pine	480	83
Spruce	390	67
Poplar	380	65

Table 5: The most common Danish wood species average content of dry wood per cubic metre solid mass /ref. 39/.

A loose volume cubic metre consists of wood that is not stacked, but just loaded into a cube of 1 × 1 × 1 m. This gives space for a lot of air, because the pieces are placed just anyhow. It is estimated that a loose volume cubic metre of firewood contains a solid mass amounting to between half and two thirds of a m^3 of sawn, split, and stacked wood.

When fixing the value of a stacked m^3 of firewood, regard should be taken to the degree of processing of the firewood, the tree species, and the solid mass or solid mass percentage.

The degree of processing describes whether the firewood is cut in appropriate lengths and split. All Danish tree species have more or less the same calorific value per kg dry matter, but with large variations in dry weight per volume unit (Table 5).

Solid mass or solid mass percentage indicates the amount of solid mass of wood in a m^3 stacked volume of firewood. If the solid mass factor for example is 0.65, then the solid mass percentage is 65, and both designate that one stacked m^3 of firewood contains 0.65 cu-

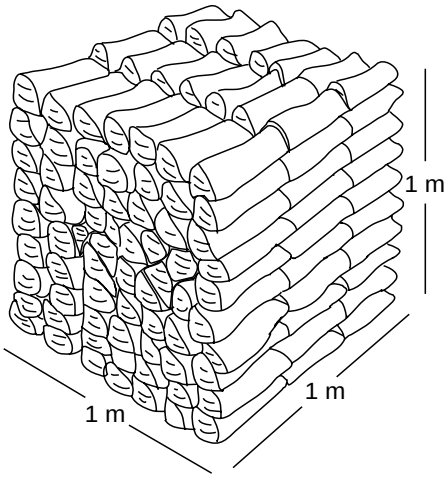

Figure 8: One cubic metre stacked volume of sawn, split, and stacked wood. The calorific value of a stacked m^3 of beech with a moisture content of 20% is 7.6-8.6 GJ.

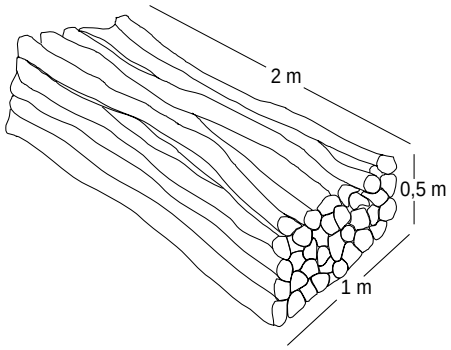

Figure 9: One cubic metre stacked volume of whole-tree wood. A m^3 stacked volume of beech consisting of 1-meter pieces contains 65% solid mass, while one m^3 stacked volume of 3-meter pieces contains 55% solid mass. The calorific value of one stacked m^3 of beech in 2-meter pieces with a moisture content of 20% is approx. 6.5 GJ.

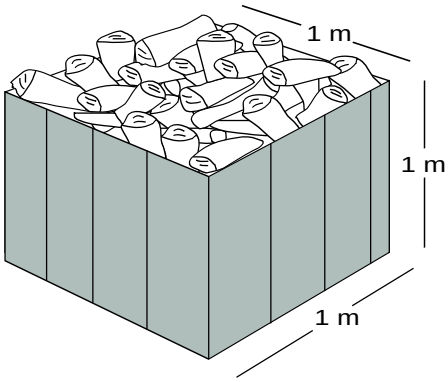

Figure 10: A loose volume cubic metre. For beech and spruce with a moisture content of 20% of the total weight, the solid mass content is 45%. The calorific value of a loose volume cubic metre of beech in 40 cm pieces with a moisture content of 20% is approx. 4.8 GJ.

bic metre of solid wood or 65% wood. The remaining part is air.

The solid mass varies a lot and the care with which the firewood has been stacked plays an important role. The tree species and lenghts of the firewood pieces also affect the solid mass, as illustrated by Table 6.

The wood content for the same solid mass figure is the same in a stacked m^3 of firewood irrespective of the moisture content. Thus, when purchasing and selling firewood, the moisture content is normally not taken into consideration. However, it is a prerequisite of firing with firewood in a wood stove that the firewood is dry. This means that the moisture content in percentage of the total weight should be below 20%.

Wood Chips

The sale of wood chips for firing requires a measurement of the wood chips for the purpose of fixing the price. However the price must depend on the quality and calorific value of the wood chips.

Quality

The quality of the wood chips depends on the size distribution, moisture content, and on impurities (soil, stone etc.). We often associate the quality of wood chips with its handling and burning properties. Thus a poor wood chip quality is often tantamount to difficult handling, i.e. disadvantageous properties of the chips as to angle of friction, angle of slide, and its propensity to bridging. The wood chip quality may also have an important influence on the combustion efficiency and on the content of harmful substances in smoke/flue gas and ash.

In 1987, the Danish Forestry Society published a standard for the determination of the quality of fuel chips as regards the size distribution of wood chips chipped in average lengths from 5 to 50 mm /ref. 26/. Time and technological advances in the field of firing technology have surpassed the standard, and it is now being revised (see Chapter 2.4).

Calorific Value

The number of heat units obtained either per weight or volume unit by the complete combustion of a unit mass of a fuel is termed the calorific value. There are different calorific values: gross calorific value, net calorific value, and actual calorific value. The most commonly used calorific value in Denmark and the one that forms the basis of the sale and purchase of wood chips is the net calorific value.

Gross calorific value or, as it is also termed, the calorimetric value, is defined as the heat units developed by the complete combustion of a well-defined amount of wood fuel at constant pressure and with condensation of the original moisture content of the wood and the water vapour that is formed during combustion (approx. 0.5 kg water per kg dry matter). Unit: Often MJ per kg or GJ per tonne.

Net calorific value is defined as the units of heat produced by the complete combustion of a well-defined amount of wood fuel with the moisture content in the wood and the vapour that is formed during combustion (approx. 0.5 kg water per kg dry matter) being in a gaseous state. This means that the recovery of heat by condensing the vapour in the flue gas is not included. Unit: Often MJ per kg or GJ per tonne.

The amount of water always contained in wood fuel in practice, will be evaporated during the first stage of combustion. The energy for that is produced by the combustion of the wood. This means that the amount of energy that can actually be utilised is reduced. The influence of the moisture content on the calorific value can be calculated by the following formula:

$$H_{n,v} = H_n \left(\frac{100 - F}{100}\right) - \frac{2.442 \quad F}{100}$$

where:

- $H_{n,v}$ is the net calorific value of wet wood (GJ per tonne total weight)

photo: biopress/torben skøtt

Processing of fuelwood, ingeniously stacked in old-fashioned, round stacks improving drying.

- H_n is the net calorific value of dry wood (GJ per tonne total weight)
- F is the moisture content in percentage of total weight
- 2.442 is the latent heat of evaporation of water at 25°C (GJ per tonne)

The following conditions should be taken into account where calorific values are stated /ref. 15/:

- Whether the calorific value in question is the: (1) gross calorific value, (2) net calorific value of kiln-dry wood, or (3) the net calorific value of wet wood.
- Pay attention to the fact that the term actual calorific value sometimes is used instead of net calorific value for wet wood.
- In the case of net calorific value, i.e., the calorific value with deduction of the condensed evaporation heat for the water vapour produced, the moisture content should be specified. Attention should be paid to whether the moisture content is stated on the basis of (1) total weight (F) or (2) dry matter (u). In foreign and some Danish literature, the symbols "F" and "u" are not necessarily used, but may be indicated by "w" instead of "F".
- In addition attention should be paid to whether the net calorific value at the given moisture content has been stated: (1) per dry matter weight, (2) per total weight, (3) per m^3 stacked volume or (4) per m^3 solid volume.

Forest Chip Payment

For most Danish chip-fired heating and CHP plants by far, the payment of forest chips is based on the energy content of the wood chips determined as the net calorific value per tonne total weight. In a few cases, there may be consignments that are paid per m^3 l. vol of wood chips. The net calorific value is calculated according to the above-mentioned formulae and can be converted to:

For forest chips of Scandinavian origin consisting of primarily pine, spruce and birch wood

$$H_{n,v} = 19.2 - 0.2164 \times F$$
(GJ per tonne total weight)

where F is the moisture content of the wood chips in percentage of the total weight of the wood chips.

Firewood length m	Solid mass in beech fuelwood	Solid mass in spruce fuelw.
0.40	0.70	0.80
1.00	0.65	0.75
2.00	0.60	0.70
3.00	0.55	0.65

Table 6: Figures for the solid mass contained in one m^3 stacked volume of beech and spruce firewood, respectively, stacked in different lengths /ref. 39/.

For mixed wood chips of various origin consisting primarily of hardwood of unknown mixture

$$H_{n,v} = 19.0 - 0.2144 \times F$$
(GJ per tonne total weight)

where F is the moisture content of the wood chips in percentage of the total weight of the wood chips.

The calculation of the value of a truckload of wood chips requires knowledge of the weight of the load and the moisture content. The weight of the load is determined by a weighbridge as the gross weight of the loaded vehicle minus the weight of the vehicle itself. The difference shows the total weight of the load, i.e. the content of dry matter + water of the load.

In practice, the moisture content of the load is determined by taking representative samples totalling 5-10 litres with a bucket at 3-5 places in the pile after unloading. Then the samples are mixed thoroughly, and one sample of approx. 3 litres is taken for the determination of the average moisture content in the load. The moisture content is normally expressed in percentages of the total weight in the following way:

- The sample is weighed after sampling.
- The sample is dried in a drying cabinet at 105 °C to constant weight. In practice, the drying of three litres of wood chips distributed in a tray in a ventilated drying cabinet to constant weight takes 16 hours.

	Dry matter calorific value in GJ/tonne
Pure wood	19.5
Forest chips	19.2
Bark	18.0
Wood pellets	19.0

Table 7: Net calorific value of different forms of biomass /ref. 40/.

$$\text{Water content} = \frac{\text{fresh weight - kiln-dry weight}}{\text{fresh weight}} \quad 100\%$$

- The difference in weight between the fresh sample and the dried sample expressed in percentage shows the moisture content in percentage (F) of the total weight.

Calorific Value of Load

The calorific value of the load in GJ per tonne total weight is determined by using one of the two above-mentioned formulae for the net calorific value ($H_{n,v}$). Then the weight of the load in tonne total is multiplied with the number of GJ per tonne and with the price agreed per GJ (e.g. in 1998 DKK 35 per GJ). Figure 11 illustrates the net calorific value (total weight-basis) in GJ per tonne as a function of the moisture content in percentage of the total weight.

Calculation example for softwood forest chips:

- Moisture content in wood chips: 55% of total weight
- Weight of load: 15 tonnes
- Energy price (1998): DKK 35.00/GJ
- Wood chip calorific value $H_{n,v}$: 19.2 GJ/tonne - (0.2164 × 55) = 7.30 GJ/tonne
- Wood chip energy content: 15 tonnes × 7.30 GJ/tonne = 109.50 GJ
- Wood chip price: DKK 35.00/GJ × 109.50 GJ = DKK 3,832.50

The Danish method that has been used since 1980 is simple and easy to use in practice, and there have only been minor problems in practical use. The method can be simplified if it has to do with a large number of truckloads from the same supplier. If so, the number of wood chip samples for the determination of the moisture content in the loads can be reduced. Deviations from the official sampling method can be agreed by the parties upon entering into the contract. It can also be agreed who is to take the samples.

Wood Pellets and Wood Briquettes

Of those two categories of fuel, the amount of wood pellets is the largest by far. Pellets are used in district heating plants and have the advantageous property that they can be used in boilers designed for coal-firing without any difficulties. In addition to being used at district heating plants, wood pellets are very popular as a fuel in single-family houses where they typically replace oil and electrical power for heating purposes. Wood pellets and wood briquettes are sold per kg total weight. The moisture content is so small (5-10% of the total weight) and uniform that it is almost superfluous to decide the moisture content in the individual supply. So far, Denmark has no standard or norm for the determination of the quality of the pellets, but the law stipulates limits beyond which impurities should not be found in wood pellets /ref. 31/.

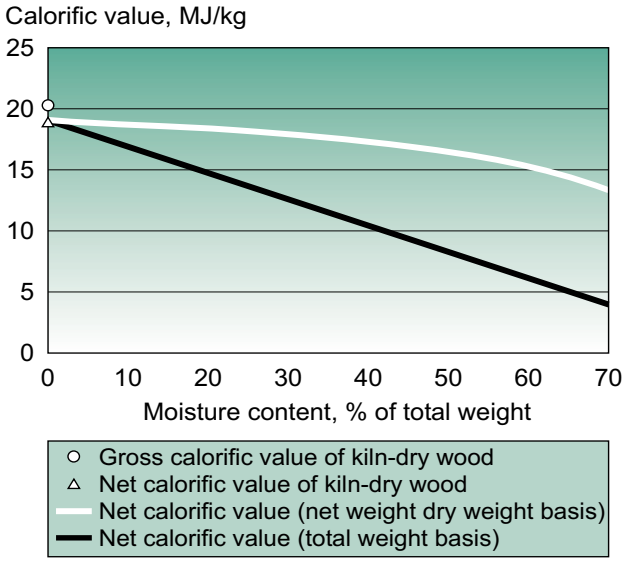

Figure 11: Gross and net calorific values of wood without bark as a function of the moisture content in percentage of total weight /ref. 15/.

Bark

Danish bark is used to a great extent for firing purposes at district heating plants, and the payment is calculated in the same way as for fuel chips. This means that the weight of the load and its moisture content is determined, and the payment is per GJ. Since bark is often of poorer quality than wood chips, the price per GJ is often lower than for wood chips.

Sawdust and Shavings

Sawdust and shavings can be paid in the same way as bark and wood chips, i.e. by payment according to energy content, determined by the total weight of the fuel and its moisture content. However, with dry fuel with a moisture content below 10-15 % of the total weight, it will often only be necessary to weigh the truckload and then agree on a price per tonne total irrespective of minor variation in the almost dry material.