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# Energy content and density of forest biomass – part 1

This is part 1 of a 2-part infosheet. Here in part 1, we present calculations for the energy content and density of forest biomass.

**Data and calculation formulas**

When calculating the energy content in a fuel, the amount of energy per weight or volume, moisture content and density are central parameters.

Moisture content

The moisture content is the proportion of water in the total mass of a moist material, expressed as a percentage.

$$M = \frac{m_m - m_d}{m_m}$$

where

$M$ = moisture content of the material [%]

$M_m$ = mass of the moist material

$M_d$ = mass of the dry material

Green density, solid cubic meter (kg/m³):

The green density is the ratio between mass and volume in fresh wood. Green density is expressed in solid cubic meters, for example, when calculating transport costs. The green density of wood material is influenced by and can be derived from the basic density of the wood and its moisture content.

$$r_g = \frac{100 \cdot r_{0,g}}{100 - M}$$

where

$r_g$ = green density of the material [kg/m³]

$r_{0,g}$ = basic density of the material [kg dry matter (TS) /m³] (**Table 1**)

Basic density (kg TS/m³) is the ratio of dry mass to green volume. In practice, a piece of wood shrinks slightly when it dries, but in these calculations, the shrinkage is assumed to be negligible.

Loose cubic meter (loose-m³):

The volume of wood can be expressed as solid cubic meters (m³) or loose cubic meters (loose-m³).

$$1\ loose - m^3 = \frac{1\ m^3}{F}$$

where

*F is the commonly used conversion factor between loose, stacked, or other actual cubic meters to solid cubic meters. For chips, the conversion factor is often 2.5 [loose-m³/m³].*

Bulk density (kg/loose-m³)

The bulk density of fresh wood or chips, i.e., the mass per volume as received (loose-m³), can be calculated using the following

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equation:

$$D_{wood,\ fresh} = \frac{r_{0,g}}{F} \cdot \frac{100}{100 - M}$$

## Energy content

The energy content in dry matter, the net calorific value, $q_{net\ dry}$ (MJ/kg$_{TS}$) is the lower heating value. It is the amount of energy released during combustion when the energy used to evaporate the water in the fuel is lost. The amount of water evaporated depends on the hydrogen content in the fuel, which is about 6% in wood fuels. $q_{net\ dry}$ is relatively constant for a specific type of wood, so it rarely needs to be analyzed to obtain acceptable estimates of the energy content in forest biomass at the moisture content it is received. **Table 1** shows suggested calorific values.

## Net calorific value, $q_{net\ ar}$ (MJ/kg)

The net calorific value of a wet fuel at delivery or as received, $q_{net\ ar}$, is calculated using the net calorific value of dry matter and the fuel's moisture content.

$$q_{net\ ar} = q_{net\ DS} \cdot \left(\frac{100 - M_{ar}}{100}\right) - 0.02443 \cdot M_{ar}$$

where

$q_{net\ ar}$ = net calorific value as received, wet fuel (MJ/kg)

$q_{net\ dry}$ = net calorific value in dry matter (MJ/kg)

$M_{ar}$ = moisture content as received (weight-%, of wet fuel)

*0.02443* = the correction factor for the enthalpy of vaporization for water (at constant pressure at 25 °C, MJ/kg per 1 weight-% of moisture content)

The conversion of the net calorific value as received, from the unit MJ/kg to the unit kWh/kg (or MWh/t), is performed by dividing $q_{net\ ar}$ with 3.6.

**Table 1.** The basic density and corresponding calorific value in potential fuel woods ((Hakkila, 1978; Virkola, 1983), modified).

| Type of energy wood | Wood species | $r_{0,g}$ Basic density kg TS/m³ | $q_{net,\ dry}$ Calorific value of TS MJ/kg |
|---|---|---|---|
| Stemwood with bark | pine | 390 | 19.26 |
| | spruce | 380 | 19.12 |
| | birch | 490 | 19.50 |
| Thinning wood (whole tree chips) | pine | 385 | 19.59 |
| | spruce | 400 | 19.19 |
| | birch | 475 | 19.04 |
| Logging residues without needles | pine | 405 | 20.36 |
| | spruce | 465 | 19.70 |
| | birch | 500 | 19.70 |
| Logging residues with needles | pine | 395 | 20.54 |
| | spruce | 425 | 19.82 |
| Bark | pine | 305 | 19.40 |
| | spruce | 375 | 19.80 |
| | birch | 515 | 22.30 |
| Stumps and roots | pine | 475 | 19.53 |
| | spruce | 435 | 19.07 |

See part 2 for graphs that can be derived from these calculations.

**Read more:**

Hakkila, P., 1978. Pienpuun korjuu polttoaineeksi. Folia Forestalia 342.

Virkola, N.-E., 1983. Puumassan valmistus, 2nd ed. Teknillisten tieteiden akatemia.

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**SECURE-BIO-SUPPLY-** Development of Long-Term Storage of Solid Biofuels to Enable a Sustainable Energy Transition

**Contact us:**
abo.fi/secure-bio-supply

**Project information:**

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The goal of the **SECURE-BIO-SUPPLY** project is to analyse the challenges and opportunities that changes in long-term fuel storage can create in Ostrobothnia.

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