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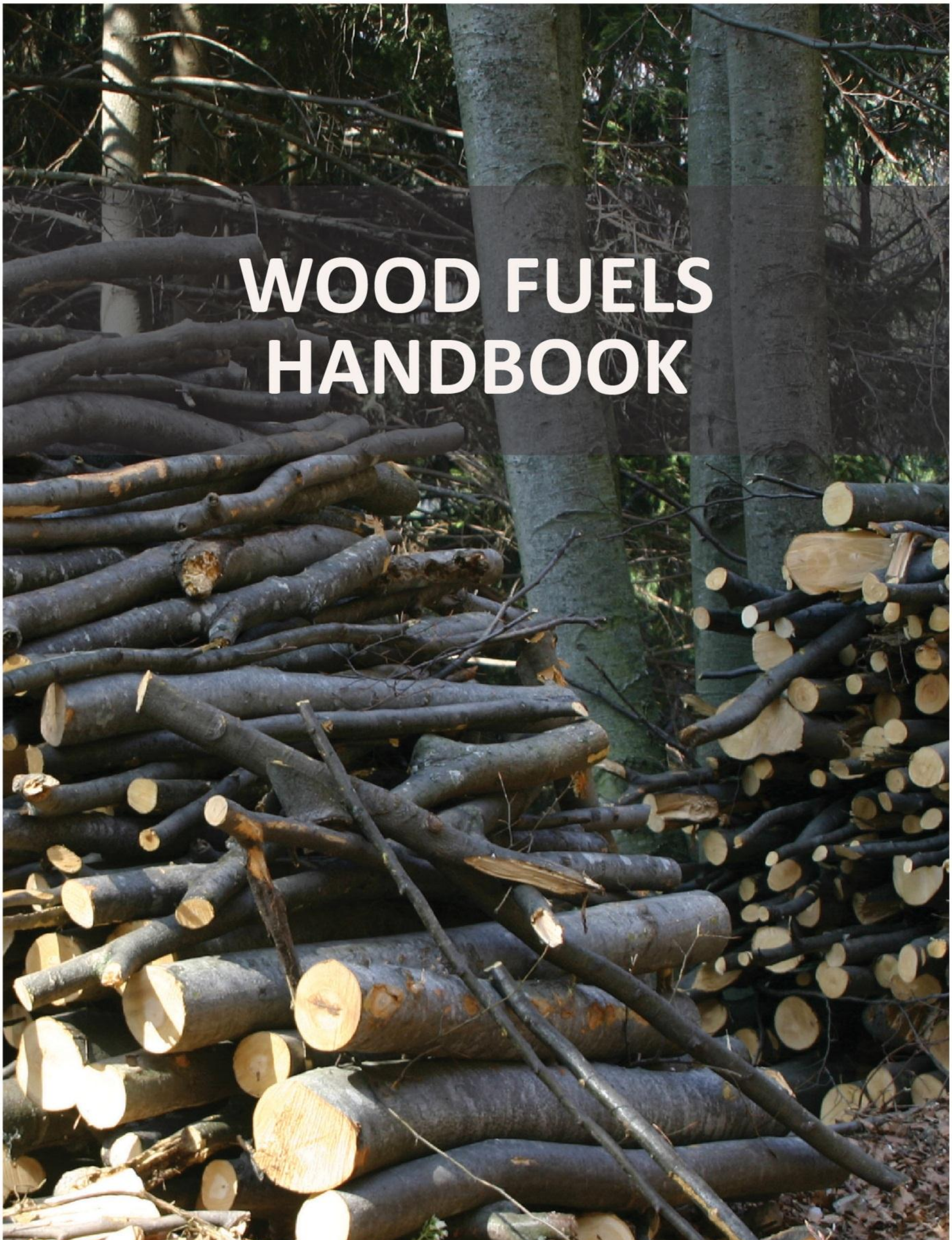

WOOD FUELS HANDBOOK

Cover photo: Nike Krajnc

WOOD FUELS HANDBOOK

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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ABBREVIATIONS AND SYMBOLS

- m^3: solid cubic metre
- Stacked m^3: stacked cubic metre
- Bulk m^3: bulk cubic metre
- u: moisture on dry basis [%]
- M: moisture on wet basis [%]
- Mv: solid density, [volumic mass] [kg/m^3]
- Ms: stacked and bulk density [kg/msa, kg/msr]
- Ww: wet weight [kg, t]
- W0: dry weight [kg, t]
- d.b.: dry basis [kg, t]
- wt: wet basis [kg, t]
- GCV: gross calorific value [MJ per kg, kWh per kg]
- NCV_M: net calorific value [MJ per kg, kWh per kg]
- toe: ton of oil equivalent
- Q: thermal boiler capacity [kW]
- Q_B: gross boiler capacity [kW]
- Q_N: nominal thermal capacity [kW]
- η_{k}: efficiency [%]
- β_{v}: volumic shrinkage [%]
- α_{v}: volumic swelling [%]
- SRC: Short Rotation Coppices

INTRODUCTION

Wood biomass is a renewable and CO_2 neutral source of energy, which, if used in a sustainable and efficient way can contribute to a cleaner environment. Wood has been used as a source of fuel for millennia and is still used in households around the world.

Wood is the most important source of energy for the majority of households in South East Europe; the main form of wood fuel used in the region today is wood logs. Wood pellets are used mainly in bigger towns (urban areas), while wood chips are slowly entering the market. We can find new pellet producers, as well as some new wood chips producers. The main problems identified in wood fuel consumption in the region today are:

- Wood fuel is used in old stoves and boilers that are inefficient and have high emissions.
- Wood fuel has a high water content (water content is higher than 30 percent).
- Wood fuels are often sold as solid m^3 but in reality buyers get stock m^3.
- There is lack of relevant information for both users and producers.

To help users and wood fuel producers we have summarized some information in this handbook. The information in this booklet comes from various sources and has already been published in the publications listed in the bibliography. The main aim of this publication is to provide useful information on wood fuels to a variety of stakeholders in the wood biomass production chain.

We would like to promote modern technologies, bring different conversion factors to end users and help biomass producers to produce high quality logs, wood chips and pellets. A more transparent market in terms of prices and trading conditions will enhance the stable growth of the biomass sector in the future.

Dr. Nike Krajnc

1 WOOD FUELS - DEFINITIONS

Biomass is defined – from a scientific and technical point of view – as material of biological origin form (EN 14558:2010)**.** Biomass is organic material that is plant or animal based, including but not limited to dedicated energy crops, agricultural crops and trees, food, feed and fibre crop residues, aquatic plants, alga, forestry and wood residues, agricultural waste, processing by-products and other non-fossil organic matter (prENISO/DIS 16559:2013).

Biofuels are solid, liquid or gaseous fuel produced directly or indirectly from biomass**.**

Forest fuel (fuelwood) is produced directly from forest wood or plantation wood through mechanical process, the raw material has not previously had another use (prENISO/DIS 16559:2013).

Wood fuels are defined as all types of *biofuels* originating from *woody biomass,* where the original composition of the wood is preserved and unaltered from its original form (FAO unified bioenergy terminology (UBET)),

Wood fuels are specified by:

a) origin and source
b) major traded forms and properties

1.1 Major traded forms of wood fuels

Following the definitions of major traded forms of wood fuels are in line with European standard (EN 14558:2010).

1. Firewood

Cut and split oven-ready fuelwood used in household wood burning appliances like stoves, fireplaces and central heating systems *(NOTE Firewood usually has a uniform length, typically in the range of 200 mm to 1000 mm).*

Author: N.Krajinc

2. Log wood

Cut *fuelwood* in which most of the material has a length of 500 mm or more.

Author: N.Krajinc

3. Wood chips

Chipped woody biomass in the form of pieces with a defined particle size produced by mechanical treatment with sharp tools such as knives. *(NOTE 1 Wood chips have a sub-rectangular shape with a length of between 5 and 50 mm and a low thickness compared to other dimensions).*

Author: N.Krajinc

4. Wood pellets

Densified biofuel made from pulverised woody biomass with or without additives, usually in cylindrical form, of various lengths but typically 5 to 40 mm, with broken ends.

Author: T.Jemec

5. Wood briquettes

Densified biofuel made with or without additives in cubiform or cylindrical units, produced by compressing pulverised biomass.

From Bioles Horizont

1.2 The main sources of wood fuel

1. Forests, plantations and other virgin wood

Author: Marjan Dolenšek

Forests are the most important source of wood fuels in southeast Europe. About half of the region's territory is covered by forests and this represents a significant source of wood fuel production. Wood has been used as a source of fuel for millennia and is still used in households around the world. Wood fuel is used mainly in rural areas and less so in urban areas.

Author: Marjan Dolenšek

Plantations are usually defined as short rotation energy plantations. They are generally established on agricultural land, by regenerating new stems (shoots) from stumps or roots, harvested over a 1-5 year cycle. Fast-growing species like poplar, willow, black locust and eucalyptus are commonly used. Short rotation coppice harvested on a 2-3 year cycle is the most common across Europe (European model), with a planting density of between 5 000 and 16 000 plants per ha and a planting design of 0.5 x 3 m. The rotation cycle may vary from 1 to 3 years. A growing interest in coppice with a lower planting density (from 1 000 to 5 000 plants per ha and a planting design of 2 x 3 m) and rotation cycles up to 5-8 years (American model) has also been registered. The obtainable assortments in this case are firewood and wood chips.

Other virgin wood: under this category segregated wood from gardens, parks, roadside maintenance, vineyards, fruit orchards and driftwood from freshwater can also be considered.

2. By-products and residues from the wood processing industry

Author: N.Krajnc

This wood fuel can be chemically untreated wood residues (wood either with or without bark, or the bark itself) from primary wood processing (mainly sawmills) or chemically treated wood residues, fibres and wood constituents but without heavy metals or halogenated organic compounds that result from treatment with wood preservatives or coating.

3. Used wood

Author: N.Krajnc

This group includes post-consumer / post society wood waste; and natural or merely mechanically processed wood. It is important to understand that this kind of wood should not contain either any more heavy metals than virgin wood, or halogenated organic compounds as a result of treatment with wood preservatives or coating.

2 UNITS OF MEASUREMENT FOR WOOD FUELS

2.1 Volume

In general, we define three different volume types:

- **Solid volume:** volume of individual particles
- **Stacked volume:** volume of a determined stacked material including the space between the material pieces
- **Bulk volume, loos volume:** volume of a material including space between the particles.

For practical use in the fuelwood sector the following definitions can be used:

1 solid cubic metre (scm – m^3) is the unit of measurement for a cubic metre of solid wood without air gaps. This unit of measurement is commonly used for timber – round wood.

1 stacked cubic metre (stcm - stacked m^3) is the unit of measurement for stacked wood that attains a total volume of one cubic metre including air gaps. Is the unit of measurement used for neatly stacked logs.

1 bulk cubic metre (bcm - bulk (loos) m^3) is the unit of measurement for small pieces of loose wood (e.g. wood chips, sawdust, wood pieces) that attain a total volume of one cubic metre including air gaps. This unit of measurement is used for logs and, more typically, wood chips.

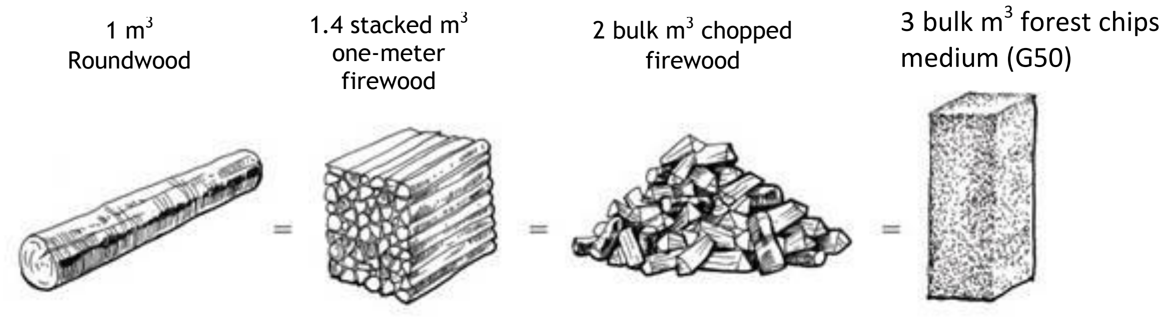


Figure 1 - Basic conversion factors

Table 1 - Conversion factors for different wood fuels[4]

Assortments	Round wood	1 m long wood	Logs (25-30 cm)		Wood chips	
			Stocked	Loos	Fine	Medium size
	Solid m^3	Stock m^3	Stock m^3	Loos m^3	Loos m^3	
1 m^3 round wood	1	1.4	1.2	2	2.5	3
1 stock m3 of 1m long logs	0.7	1	0.85	1.4	1.8	2.15
1 stock m3 of logs (25-30 cm)	0.85	1.2	1	1.67	2	2.5
1 loos m3 of logs (25-30 cm)	0.5	0.7	0.6	1	1.25	1.5
1 loos m^3 of fine wood chips	0.4	0.55	0.5	0.8	1	1.2
1 loos m^3 of medium size wood chips	0.33	0.47	0.4	0.67	0.85	1

Table 2 - Conversion factors for selected wood residues [4]

Conversion factors for wood residues:	
1 stock m^3 of bundle slabs	0.65 m^3 round wood equivalent
1 loos m^3 wood chips	0.33 m^3 round wood equivalent
1 loos m^3 sawdust (≤5mm)	0.33 m^3 round wood equivalent
1 loos m^3 shavings	0.20 m^3 round wood equivalent
1 loos m^3 bark	0.30 m^3 round wood equivalent

2.2 Weight

The units of weight used for wood fuels are the kilogram and the metric ton. It is always stated whether the weight refers to dry or fresh tonne or kilogram of wood fuel and whether the mass of *moisture* in the material is included or not.
The table below shows the units of measurement for volume and weight that are commonly used in the marketing of wood fuel.

Table 3 - Units of measurement

Tonne	Kilogram	Stacked cubic metre	Bulk cubic metre
t	kg	stacked m^3	bulk m^3
log woods chips pellets and briquettes		log woods	firewood chips

2.3 Density

Density always refers to the ratio of mass to *volume.*
For wood fuel it should be stated whether the density refers to the density of individual particles or to the bulk density of the material and whether the mass of water in the material is included.
Different units of measurement can be used to express the density of wood fuels.

1. **Basic density** is the ratio of the mass on a *dry basis* and the *solid volume* on a *green basis.*
2. **Bulk density** is the mass of a portion of a solid *fuel* divided by the *volume* of the container which is filled by that portion under specific conditions (according to ISO 1213-2:1992.). It is used for piles of wood fuel (log woods and wood chips) that create spaces between the wood pieces which may be larger or smaller depending on the size and shape of the latter. It is expressed in either kg per stacked m^3 or kg per bulk m^3, depending on whether the pile is stacked or bulk.
3. **Particle density** is the *density* of a single particle.

Table 4 - Basic density of selected tree species – air dry wood (u = 12–15 % oz. w = 11–13 %) [13]

Tree species	Typical value (kg/m^3)	Typical variation
Norway spruce	470	330–680
Silver fir	450	350–750
Scots pine	510	330–890
Beech	720	540–910
Oak	690	430–960
Hornbeam	830	540–860
Chestnut	620	590–660
Black locust	770	580–900

Table 5 - Basic density of selected tree species oven dry wood (wood free of moisture) [6]

Tree species	Basic density of oven dry wood (kg/m^3)
Norway spruce	430
Silver fir	410
Scots pine	490
Larch	550
Beech	680
Oak	650
Birch	610
Poplar	410
Black locust	730

Table 6 - Typical values of bulk density for selected wood fuels [14]

Wood fuel		Bulk density (kg/m^3)
Firewood - stocked	Beech	460
Firewood - stocked	Norway spruce	310
Wood chips	Coniferous	195
Wood chips	Broadleaves	260
Bark	Coniferous	205
Bark	Broadleaves	320
Sown dust		170
Shavings		90
Wood pellets		600

Table 7 - Mass and bulk density of main tree species [3]

Moisture M %	Beech			Oak			Spruce			Pine		
	RWE m^3	Fw stacked m^3	Cw loos m^3	RWE m^3	Fw stacked m^3	Cw loos m^3	RWE m^3	Fw stacked m^3	Cw loos m^3	RWE m^3	Fw stacked m^3	Cw loos m^3
Mass or bulk density in kg(1)												
0	680	422	280	660	410	272	430	277	177	490	316	202
10	704	437	290	687	427	283	457	295	188	514	332	212
15	716	445	295	702	436	289	472	304	194	527	340	217
20	730	453	300	724	450	298	488	315	201	541	349	223
30	798	495	328	828	514	341	541	349	223	615	397	253
40	930	578	383	966	600	397	631	407	260	718	463	295
50	1117	694	454	1159	720	477	758	489	312	861	556	354

The equivalence 1m^{3}roundwood=2.43 bulk m^3 (volumetric index=.,41 m^3/ bulk m^3) of wood chips has been used.
Initial: RWE=Round wood equivalent; Fw=chopped log woods (33 cm, stacked); Cw=wood chips.

3 MAIN CHARACTERISTICS OF WOOD FUELS

3.1 Moisture content

Water in wood can be defined as “water content” and “humidity”. In practice, the terms “water content” and “humidity” are often confused or even equated with one another. However, this is inaccurate.

Water content (M) expresses the mass of water present in relation to the mass of fresh wood. This value describes the quantity of water in the entire moist biomass (fresh mass). This measure is used in the marketing of wood fuels.

The formula for calculating water content (M) is:

$$M = \frac{W_w - W_0}{W_w} x100$$

Where in:

W_w = wet weight of wood
W_0 = oven-dry weight of wood

A practical example of calculation of water content– where in total 100 kg of wood water represents 20 kg

$$w = \left(\frac{20}{100}\right) * 100 = 20\ \%$$

Wood humidity (u) expresses the mass of water present in relation to the mass of oven-dry wood. This value describes the ratio of water mass to dry mass. Moisture can thus be converted into water content and calculated from this. In summary, wood moisture can be described as the ratio between water and dry substance. Wood moisture is a common term in the wood industry.

Formula for calculation of humidity (u)

$$u = \frac{W_w - W_0}{W_0} x100$$

Practical example of calculation of humidity – where in total 100 kg of wood water represents 20 kg

Conversion formulas

The following two formulas are used to calculate u from M and vice versa.

$$u = \frac{100xM}{100 - M}$$

$$M = \frac{100xu}{100 + u}$$

Table 8 - Conversion between moisture and water content

M %	15	20	25	30	35	40	45	**50**	60
u %	18	25	33	43	54	67	82	**100**	150
u %	15	20	**30**	40	50	65	80	**100**	150
M %	13.0	16.7	**23.1**	28.6	33.3	39.4	44.4	**50.0**	60.0

Assuming that the mass of newly-chopped fresh wood is made up half by water and half by wood substance, wood has moisture on w.b. (M) of 50 percent and moisture on d.b. (u) of 100 percent.

Quick measuring devices for determining the water content of fuel often measure the wood humidity.

The final stage of natural drying is the “air-dried” stage. Here, the water content is between 15 and 20 percent.

3.2 Units of measurement for thermal energy

Fuel has a certain amount of energy called **primary energy,** which is converted through combustion into **final energy** to be used for any desired purposes (e.g. heating, hot water for sanitary purposes and process heat).
The SI (International System of Units) units of measurement to be used are the Joule (J), the Watt-hour (Wh) and multiples of these units.
The units that are most commonly used are:

MJ per kg	MJ/ms	kWh per kg	kWh/ms	MWh/t

Table 9 - Conversion factors of thermal energy units[3]

	kJ	Kcal(*)	kWh	toe
1 kJ	1	0.239	0.278×10^{-3}	23.88×10^{-9}
1 kcal(*)	4.1868	1	1.163×10^{-3}	0.1×10^{-6}
1 kWh	3.600	860	1	86×10^{-6}
1 toe	41.87×10^{6}	10×10^{6}	11.63×10^{3}	1

(*)The calorie is a pre-SI unit of energy.

Most common conversions:

1 kWh	= 860 kcal	= 3.600 kJ (3.6 MJ)
1 MJ	= 239 kcal	= 0.278 kWh
1 kcal	= 4.19 kJ	= 0.00116 kWh
1 toe	= 41.87 GJ	= 11.63 MWh

Tonne of oil equivalent (toe) is a conventional unit of measurement used for statistical-comparative purposes. It corresponds to the amount of energy released by burning one ton of crude oil.

3.2.1 Calorific value

Calorific value, heating value (q) is defined as the amount of energy per unit mass or volume released on complete combustion.

The moisture content of wood changes the calorific value of the latter by lowering it. Indeed, part of the energy released during the combustion process is spent in water evaporation and is consequently not available for any desired thermal use.

Water evaporation involves the 'consumption' of **2.44 MJ per kilo of water**. It is thereby possible to distinguish between the following:

Gross calorific value (q_{gross}): measured value of the specific energy of combustion for unit mass of a *fuel* burned in oxygen in a calorimetric bomb under the specified conditions.

Net calorific value (q_{net}) calculated value of the specific energy of combustion for unit mass of a fuel burned in oxygen at constant pressure under such conditions that all the water of the reaction

products remain as water vapour (at 0.1 MPa) and the other products being as for the *gross calorific value*, all at the reference.
When not specified, 'calorific value' is to be intended as net calorific value.

The **net calorific value** (NCV_0) of oven-dry wood of different species varies within a very narrow interval, from 18.5 to 19 MJ per Kg. In conifers it is 2 percent higher than in broad-leaved trees. This difference is due especially to the higher lignin content, and partly also to the higher resin, wax and oil content present in conifers. Compared to cellulose (17.2-17.5 MJ per kg) and hemicellulose (16 MJ per kg), lignin has a higher energy content (26-27 MJ per kg ncv). Some variability in the anhydrous calorific value is also due to the slight variability in hydrogen (H) content and to the comparatively much wider variability in ash contents.
The calorific value (kWh per kg) is the maximum usable heating volume released in complete burning of a specific volume of fuel.

However, when taking into account agricultural biofuels as well, the anhydrous calorific value varies within a 16.5 to 19 MJ per Kg interval. The anhydrous calorific value of wood fuels is on average 9 percent higher than that of herbaceous plants.

Table 10 Caloric value and ash content for selected wood fuels [CEN/TS 14961:2010].

Parameter	Unit	Coniferous wood		Broad-leaf wood	
		Typical value	Typical variation	Typical value	Typical variation
Ash	w–% daf[1]	0.3	0.2 - 0.5	0.3	0.2 - 0.5
Gross calorific value	MJ per kg_{daf}	20.5	20.2 - 20.8	20.2	19.5 - 20.4
Net calorific value	MJ per kgdaf	19.2	18.8 - 19.8	19.0	18.5 - 19.2
Parameter	**Unit**	**Coniferous bark**		**Broad-leaf bark**	
		Typical value	Typical variation	Typical value	Typical variation
Ash	w–% d	4	2 - 6	5	2 - 10
Gross calorific value	MJ per kg_{daf}	21	20 - 23	21	20 - 23
Net calorific value	MJ per kg_{daf}	20	19 - 21	20	19 -21
Parameter	**Unit**	**Coniferous - forest residues**		**Broad-leaf forest residues**	
		Typical value	Typical variation	Typical value	Typical variation
Ash	w–% d	2	1 - 4	1.5	0.8 - 3
Gross calorific value	MJ per kgdaf	21	20.8 - 21.4	20	19.7 - 20.4
Net calorific value	MJ per kgdaf	20	19.5 - 20.0	19	18.4 - 19.1
Parameter	**Unit**	**Short rotation plantations - willow**		**Short rotation plantations - poplar**	
		Typical value	Typical variation	Typical value	Typical variation
Ash	w–% d	2.0	1.1 - 4.0	2.0	1.5 - 2.5
Gross calorific value	MJ per kgdaf	20.3	20.0 - 20.6	20.2	20.0 - 20.4
Net calorific value	MJ per kgdaf	18.8	18.4 - 19.2	18.8	18.6 - 19.1

[1]w–% d – on dry basis

Table 11- Weight and calorific value relative to volume and water content[2]

Water content	Bulk density in kg/m³				Calorific value in kWh/m³			
%	Beech	Oak	Pine	Spruce	Beech	Oak	Pine	Spruce
20	277	280	216	188	1 048	1 062	867	759
30	316	320	246	216	1 022	1 034	846	740
40	369	374	287	251	986	998	818	716
50	443	449	345	302	936	948	780	682

The most decisive factor for a high energy yield is **water content** followed by **wood type. For small heating systems (for heating private houses or apartments) the wood fuel should not have more than 25 percent water content**. If wood has higher water content then the temperatures fall below the ideal range, which leads to increased smoke formation, higher emissions and damage to the chimney.

Table 12 - Calorific value of wood depending on water content [2]

Condition of wood	Water content(M)	Calorific value(H)
Fresh timber	50–60%	**2.0kWh per kg**
Timber stored for a summer	25–35%	**3.4kWh per kg**
Timber stored several years	**15–25%**	**4.0kWh per kg**

3.2.2 Theoretical calculation of caloric value

To calculate the caloric value (MJ per kg) of wood with specific water content (M %) the following formula can be used:

$$H_i = \frac{H_{i0} * (100 - w) - 2,44 * w}{100}$$

During seasoning, the 10 percent decrease in moisture entails an approximate 0.6 kWh per kg (2.16 MJ per kg) increase in energy content.

Table 13 - For practical purposes the following average values are used for wood fuels:

NCV_0	= 18.5 MJ/kg = 5.14 kWh/kg	OVEN-DRY WOOD	(M 0%)
NCV_{10}	= 17.0 MJ/kg = 4.7 kWh/kg	PELLETS	(M 10%)
NCV_{20}	= 14.4 MJ/kg = 4.0 kWh/kg	FIREWOOD	(M 20%)
NCV_{30}	= 12.2 MJ/kg = 3.4 kWh/kg	WOOD CHIPS	(M 30%)

Table 14 Caloric value (H_i = 18,5 MJ per kg) as function of water content (M %)[3]

M (%)	MWh per tonne	GJ per tonne		M (%)	MWh per tonne	GJ per tonne
15	4.27	15.36		38	2.93	10.54
16	4.21	15.15		39	2.87	10.33
17	4.15	14.94		40	2.81	10.12
18	4.10	14.73		41	2.76	9.91
19	4.04	14.52		42	2.70	9.71
20	3.98	14.31		43	2.64	9.50
21	3.92	14.10		44	2.58	9.29
22	3.86	13.89		45	2.52	9.08
23	3.80	13.68		46	2.47	8.87
24	3.75	13.47		47	2.41	8.66
25	3.69	13.27		48	2.35	8.45
26	3.63	13.06		49	2.29	8.24
27	3.57	12.85		50	2.23	8.03
28	3.51	12.64		51	2.17	7.82
29	3.45	12.43		52	2.12	7.61
30	3.40	12.22		53	2.06	7.40
31	3.34	12.01		54	2.00	7.19
32	3.28	11.80		55	1.94	6.98
33	3.22	11.59		56	1.88	6.77
34	3.16	11.38		57	1.82	6.56
35	3.11	11.17		58	1.77	6.35
36	3.05	10.96		59	1.71	6.15
37	2.99	10.75		60	1.65	5.94

Practical example 1 Example of calculation of caloric value with determination of the water content

If we have 100 tonnes of fresh wood chips with measured water content of 35 percent (w %).

The correct calculation of caloric value is:

100 tonne *3.165 MWh per tonne = 316.5 MWh

(we considered that 1 tonne of fresh wood chips has caloric value 3.165 MWh – see table 16)

In theory we could also consider the following calculation:

100 tonnes of fresh wood chips = 65 tonnes of dry matter + 35 tonnes of water (because M = 35 %)

The calculation of caloric value in this case is different and it is based on the assumption that 1 tonne of dry matter has a caloric value of 5.235 MWh (see table 17). **Calculation of caloric value in this case is**:

65 tonnes of dry matter*5.235 MWh per tonne $_{dm}$= 340 MWh

The second calculation is wrong, because energy for evaporation of water is not accounted for. The difference between first and second calculation for 100 tonne is 23 MWh (or 7 percent)

In the following tables some practical conversion factors are presented for selected wood fuels, including water content.

Table 15- Conversion factor for firewood- Broad-leafs with water content 20 % [3]

	Bulk	Stocked (length 25–30cm)	Stocked (length 1m)	Solid m^3	Fresh matter	Dry matter	Caloric value		Unit
	loos m^3	stm	stm	m^3	T	t	MWh	GJ	
Firewood (Broad-leafs)	1	0.847	0.699	0.500	0.365	0.292	1.411	5.079	loosm^3
	1.180	1	1.214	0.850	0.621	0.497	2.398	8.634	stm
	1.430	0.824	1	0.700	0.512	0.409	1.975	7.111	stm
	2.000	1.176	1.429	1	0.730	0.584	2.822	10.158	m^3
	2.740	1.610	1.953	1.370	1	0.800	3.864	13.911	t
	3.425	2.012	2.445	1.712	1.250	1	5.000	18.000	t
	0.709	0.417	0.506	0.354	0.259	0.200	1	3.600	MWh
	0.197	0.166	0.141	0.098	0.072	0.056	0.278	1	GJ

Table 16- Conversion factor for firewood - coniferous with water content 20 % [3]

	Bulk	Stocked (length 25–30cm)	Stocked (length 1m)	Solid m^3	Fresh matter	Dry matter	Caloric value		Unit
	loos m^3	stm	stm	m^3	t	t	MWh	GJ	
Firewood (Coniferous)	1	0.847	0.699	0.500	0.250	0.200	1.021	3.675	loosm^3
	1.180	1	1.214	0.850	0.425	0.340	1.735	6.248	stm
	1.430	0.824	1	0.700	0.350	0.280	1.429	5.145	stm
	2.000	1.176	1.429	1	0.500	0.400	2.042	7.350	m^3
	4.000	2.353	2.857	2.000	1	0.800	4.086	14.711	t
	5.000	2.941	3.571	2.500	1.250	1	5.278	19.000	t
	0.779	0.576	0.700	0.490	0.245	0.189	1	3.600	MWh
	0.272	0.160	0.194	0.136	0.068	0.053	0.278	1	GJ

Table 17- Conversion factor for wood chips – mixed wood with water content 35 % [3]

	Bulk	Solid m^3	Fresh matter	Dry matter	Caloric value		Unit
	loos m^3	m^3	t	t	MWh	GJ	
Wood chips (M35, mixed wood)	1	0.400	0.256	0.167	0.811	2.921	loosm^3
	2.500	1	0.641	0.417	2.028	7.302	m^3
	3.906	1.560	1	0.650	3.165	11.393	T
	5.988	2.398	1.538	1	5.235	18.846	t
	1.233	0.493	0.316	0.191	1	3.600	MWh
	0.342	0.137	0.088	0.053	0.278	1	GJ

3.2.3 Energy equivalents

Often simple conversion factors are needed to compare different wood fuels with fossil fuels. These comparisons are important especially when a decision regarding fuel change has to be taken. Conversion factors between different fuels are presented in the following tables.

Table 18 - Caloric value of selected fuels [3]

Fuel	Caloric value (average values)	
	MJ	kWh
Extra light heating oil	36.17 MJ/l (42.5 MJ per kg)	10 kWh/l. (11.80 kWh per kg)
Heating oil	38.60 MJ/l (41.5 MJ per kg)	10.70 kWh/l (11.50 kWh per kg)
Natural gas[2]	36.00 MJ/m^3	10.00 kWh/m^3
Liquid petroleum gas (LPG)[3]	24.55 MJ/l (46.30 MJ per kg)	6.82 kWh/l (12.87 kWh per kg)
Coal	27.60 MJ per kg	7.67 kWh per kg
Coke40/60	29.50 MJ per kg	8.20 kWh per kg
Lignite briquettes	20.20 MJ per kg	5.60 kWh per kg
1 kWh electricity	3.60 MJ	1 kWh
1 kg mixed wood (M 20%)	**14.40 MJ per kg**	**4.00 kWh per kg**

For simple calculation we can use the following energy equivalents, which do not include information on boiler efficiency.

1 kg heating oil ≈ 3 kg wood
1 l heating oil ≈ 2.5 kg wood

1000 l of heating oil≈	5–6 loose m^3 of firewood Broad-leafs
	7–8 loos m^3 of firewood coniferous
	10–15 loose m^3 of wood chips
	2.1 tonnes of wood pellets

[2] 1 kg = 5,8 l (20 °C, 216 barov)
[3] 1m^3 LPG = 4 l = 2 kg

Practical example 2 Example of calculation of wood chips amount for selected boiler[3]

The needed amount of wood chips can be calculated from data about past consumption of fossil fuels. In our case we will foresee change from heating oil to wood chips.

a) Calculation based on data about past consumption of light heating oil (average from the past three years will be taken into consideration)

– Average yearly amount of light heating oil: 23 530 l per year

– Heating value (H_i)heating oil: 10 kWh per l

– Efficiency of the boiler (ŋk): 85 percent

Yearly heat production in kWh:

$$\text{Heat (kWh per year)} = 23\,530\ \text{l} * 10\ \ \text{per kWh per year}$$

b) Calculation of yearly amount of wood chips

–Needed amount of heat: 200 000 kWh/year

–Heating value (H_i) wood chips (M 30 percent): 3.4 kWh per kg

– Efficiency of the boiler (ŋk): 80 percent

Estimation of yearly amount of wood chips:

$$wood\ \ chips\ \ (kg/\,year) = \frac{200\,000\ \ kWh/\,year}{3.4\ \ kWh/\,kg * 0{,}80} = 73.530kg\ \ (\approx 75t)$$

In case of wood chips with w = 35 %, 75 tonnes is equivalent to 293 nm^3

c) Rough estimation of necessary installed capacity of wood chip boiler (1 500 working hours per year)

$$Q\ (kW) = \frac{200\,000\ kWh}{1\,500\ h} * \frac{1}{0.80} \approx 160\ kW$$

To calculate wood chip requirements in small-medium size plants, the following empiric formulas may be used:

Boiler capacity in **kW x 2.5** = wood chips requirement in **bulk m^3 per year** (softwood P45, M30)

Boiler capacity in **kW x 2.0** = wood chips requirement in **bulk m^3/year** (hardwood P45, M30)

Practical example 3 Example of calculation of firewood amount for selected boiler[3]

The needed amount of firewood can be calculated from data about past consumption of fossil fuels and according data about heating value of selected wood fuel.

a) Calculation based on data about past consumption of light heating oil (average from the past three years will be taken in consideration)

– Average yearly amount of light heating oil: 2 000 l per year

– Heating value (H_i) heating oil: 10 kWh per l

– Efficiency of the boiler (ŋk): 75 percent

Yearly heat production in kWh:

$$\text{Heat (kWk per year)} = 2.000\,\text{l} * 10\text{per l} * \ 0.75 \ = 15\,000\ \text{kWh per year}$$

b) Calculation of yearly firewood amount

– Needed amount of heat: 15.000 kWh/year

– Heating value (H_i) fire wood (M 20 percent) for spruce is 1 350 kWh per stm^3, beech 1 930 kWh per stm^3 and for black lacost 2 200 kWh per stm^3

– Efficiency of the boiler (ŋk): 75 percent

Estimated amount of beech fire wood:

$$Estimation\ of\ fire\ wood\ (stm^3) = \frac{15000\ ^{kWh}/_{year}}{1\,930\,kWh/stock\ m3 * 0{,}75} \approx 10\ stm^3/year$$

Estimated amount of spruce fire wood:

$$Estimation\ of\ fire\ wood\ (stm^3) = \frac{15000\ ^{kWh}/_{year}}{1\,340\,kWh/stock\ m3 * 0{,}75} \approx 15\ stm^3/year$$

c) *) Rough estimation of needed installed capacity of wood chips boiler (1 500 working hours per year)*

$$Q\ (kW) = \frac{15\,000\ kWh}{1\,500\ h} * \frac{1}{0.75} \approx 13\ kW$$

3.3 Ash content and ash melting point

Among solid biofuels, bark free wood has one of the lowest ash contents, whereas agricultural biofuels typically have high ash contents.

Using fuels with low ash fusion temperatures increases the risk of **ash slag** being formed on the grate. Fusion slag disturbs the combustion process by altering primary air flows and favouring the overheating of the grate as well as corrosive phenomena.

However, it is possible to handle and solve the problems related to the formation of slag by intervening, for example, by cooling the grate and fume recirculation, and by inserting mechanical systems for automatic cleaning (self-cleaning screens) or, in the case of cereal, by using calcium additives.[4]

Wood and bark have a relatively high melting point (1 300-1 400°C) and thus do not have any criticalities. Contrary to this, the melting point of herbaceous plants is below 1 000°C and, consequently, slag can easily be created during combustion. In the case of cereal (grains), the melting point is lower than 750°C and is thus particularly critical (table 2.7.1).

For the reasons listed above, agricultural biofuels have higher criticalities as compared to wood and are only to be used in specific combustion devices.

3.4 Biomass chemical composition

Vegetal biomass mainly consists of carbon (C), oxygen (O) and hydrogen (H). Trough oxidation of carbon the fuel energy content is released.

Table 19- Chemical composition of solid biomass [15].

wt% (d.b.)	C	H	O	N	K	S	Cl
Spruce (with bark)	49.8	6.3	43.2	0.13	0.13	0.015	0.005
Beech (with bark)	47.9	6.2	43.3	0.22	0.22	0.015	0.006
Poplar SRC	47.5	6.2	44.1	0.42	0.35	0.031	0.004
Willow SRC	47.1	6.1	44.2	0.54	0.26	0.045	0.004
Bark	51.4	5.7	38.7	0.48	0.24	0.085	0.019
Miscanthus	47.5	6.2	41.7	0.73	0.7	0.150	0.220
Wheat straw	45.6	5.8	42.4	0.48	1.0	0.082	0.190
Triticale (grains)	43.5	6.4	46.4	1.68	0.6	0.11	0.07
Rape cake	51.5	7.38	30.1	4.97	1.60	0.55	0.019
Fossil fuels							
Coal	72.5	5.6	11.0	1.30	-	0.940	< 0.1
Lignite	65.9	4.6	23.0	0.70	-	0.390	< 0.1
Heating oil	85-86	11-13	1-4	-	-	-	-
Natural gas	75	25	-	-	-	-	-

Effects of the chemical composition of solid biofuels on combustion and emissions

The elements that bear a direct effect on the level of harmful emissions produced by combustion are: sulphur (S), nitrogen (N), chlorine (C) and ash contents. The following rule generally applies to

[4] Ca and Mg usually increase ash fusion temperature.

the above-mentioned elements: the higher their content in the fuel, the greater their presence in the emissions into the atmosphere.

Nitrogen content in wood fuels is relatively low, whereas it is much higher in cereal - particularly if we include grains as well. This bears a direct impact on the formation of nitrogen oxides (NO_x) which, during combustion, become gaseous and do not remain in the ashes.

Potassium (K), which is mainly to be found in agricultural biofuels, lowers the melting point of the ashes, thus favouring the formation of slag in the grate that are the cause of considerable problems for the combustion process. Moreover, potassium, which as a consequence of combustion, is released in the form of fine particles.

Sulphur (S) content in solid biofuels is much lower than that in fossil fuels; sulphur generally remains for the most part in the ashes (40 to 90 percent)..

Chlorine (Cl) wood fuels are characterised by a rather low chlorine content. Cl takes part in the formation of compounds like HCl and dioxins/furans. Despite the most part of Cl will be bound in the fly-ash (40-95 percent), the rest goes forming HCl, enhanced by condensing processes, which together with other compounds, causes corrosive effects on metal internal parts of boiler.

4 BIOMASS PRODUCTION CHAINS

Working phases

The wood biomass production chain has several steps, starting in the forest with harvesting operations and ending at the heating plant storage place. With reference to forest harvesting operations, it is possible to differentiate between the following working phases:

- Felling: cutting a tree from its stump so that the tree falls to the ground;
- Processing: de-limbing (removing branches from the trunk and topping it) and cross-cutting (cutting the trunk to predetermined lengths);
- Skidding: transporting wood from felling site to extraction routes and transporting wood along extraction routes to the landing site;
- Debarking: partially or completely removing the bark from a log;
- Transporting: moving wood using forest roads and public roads;
- Wood fuel production: production of different wood fuels (cutting, splitting, chipping).

The last phase can be performed at forest lending sites or at storage places outside the forest. One of the most important steps in the biomass production chain is storage and drying. Drying can be done before or after wood fuel production. For wood chips it is recommended that round wood is dried in the sun with the wood chips then being produced from the dry material. For logs it is the other way around – it is recommended that fresh wood is cut to length (1m) and chopped into smaller pieces and then stored for drying.

4.1 Machines for producing wood fuels

Depending on the operation, machines for log production can be classified as:

- **Wood cutters**: if based on disc saw or chainsaw, they can process diameters bigger than 40 cm and have low cutting loss; if based on disc saw, they can only process smaller diameters and have a higher cutting loss;

- **Wood splitters**: these are equipped with either a wedge or a screw breaking device. Many log splitters consist of a hydraulic or electrical rod and piston assembly and are often rated by the tonnes of pressure they can generate. The higher the pressure rating, the greater the thickness or length of the rounds that can be split. Most log splitter models for home use have a rating around 10 tonnes, but professional hydraulic models may exert 25 tons of pressure or more. The ones with wedge devices for domestic use have either two or four sides. They work keeping the log vertical and can exert up to 15 tonnes of splitting power, while for industrial use the logs are kept horizontal and pushed against a wedge, or a grate, on up to 16 sides. The ones with screws are equipped with a threaded cone which spins into the wood so as to split it; they are faster than the former, but less precise.

Author: Marjan Dolenšek

- **Combined – fuelwood processors** (saw-split wood): there are mobile models, or stationary machines which combine the two operations: sawing and splitting, allowing automation of the process and a higher productivity, working both on logs and large branches. These are endowed with electric or spark-ignition engines (up to 55 kW) and can work with logs up to 6 m long and 60 cm in diameter and can produce more than 12 t/h of material.

Processing hardwood requires more power than processing softwood and all types of wood can more easily be split when fresh rather than seasoned.

Chippers

A chipper is a machine that is especially built to reduce wood to chips and can either be stationary or mounted on a carriage, on a trailer, on a truck or on the rear three point hitch of a tractor. It can be equipped with its own engine or activated by the tractor power take off. Depending on the chipping unit, it is possible to differentiate between disc chippers, drum chippers and feed screw chippers. The following classification of chipper according to the required power is more practical:

*Author: **Mus max***

- **Low power**: usually installed on the rear three point hitch of a tractor or on a trailer, these chippers are powered by the tractor power take off or by an independent engine (~50 kW). They can only process small diameters (20 cm max) and can produce no more than 10 bulk m^3 of wood chips per hour. They are mainly for domestic use;
- **Medium power**: trailer-mounted, usually with independent engines (50-110 kW), or installed on the rear three point hitch of a tractor; they can chip diameters up to 30 cm and produce up to 50 bulk m^3 of wood chips per hour;
- **High power**: installed on trailers or on trucks, these chippers are sometimes activated by the truck's engine, but normally they are provided with an autonomous engine (>110 kW); they can chip large diameters (>30 cm) and easily produce more than 100 bulk m^3 of wood chips per hour.

Sieves are important tools for the selection of chips according to their size, thus refining the material but at the same time lowering productivity.

When chipping is performed in a place other than the final plant, chips are transported either by truck or truck and trailer, rarely by articulated vehicle, set up with large cases in light alloy. A clamshell bucket loader can be installed on the truck and trailer to make possible an autonomous loading of the chips.

5 STORAGE OF QUALITY WOOD FUELS

Storing wood fuels presents three fundamental risks:

1. the growth of mould, which poses a health hazard;
2. losses in mass through decomposition;
3. losses of energy value.

For the production of quality wood fuels (wood chips of logs), it is important to ensure that the fuel wood that is processed is as dry as possible.

Wood biomass is best dried naturally in the sun and wind. Technical drying is, in most cases, a difficult process from an economic point of view and is generally only worthwhile if cheap waste heat from energy generation or process heat (e.g. from a biogas plant) is available.

5.1 Log wood and firewood

The most commonly traded form of log wood in Kosovo are 1m long fresh round logs (un-split and with a moisture content more than 45 percent). Log wood is sold on local markets, which means it is hard to estimate the total yearly production. After purchasing, logs are split and cut to length (to length 25 to 50 cm). Firewood is mainly purchased in solid cubic metres (without air gaps), which should not be used for firewood. Log wood and firewood should be purchased in stacked cubic metres. The most commonly used factor for recalculating solid cubic metres into stacked cubic metres is 1.4. To put is in other way: for 1 stock cubic metre of log wood or firewood you need 0.7 solid cubic metre of wood. The most recommended unit for usage in trading is tonnes (but water content should be determined).

In order to more easily calculate the amount of firewood that is needed, this simple calculation can be used: to substitute 1 000 litters of heating oil we need approximately 7 to 8 stacked cubic metres of soft wood or 5 to 6 stacked cubic metres of hard wood.

5.1.1 Quality requirements

The quality of log wood depends on tree species, wood conservation and especially on water content and particle size. Quality depends mainly on storage. **For use in households log wood should have no more than 25-30 percent water content. With proper storage this can be achieved in less than 1 year.**

Author: Marjan Dolenšek

Testing the drying off our different piles of log wood in Slovenia confirmed the above mentioned rules. We have proven that the most important factor for drying is the position of a pile (whether sunny or shady), followed by the shape of fire wood (split or non-split) and finally whether or not the pile was covered. Firewood stored in sunny positions was dry in less than six months. In these piles split logs dried faster than non-split wood (with bark). Round wood stored in piles in the shade was affected by fungi after one year and the water content was still over 35 percent. It was confirmed that weather conditions have a bigger influence on firewood stored in non-covered piles, which was seen when the rainy season started and the water content increased over 40 percent.

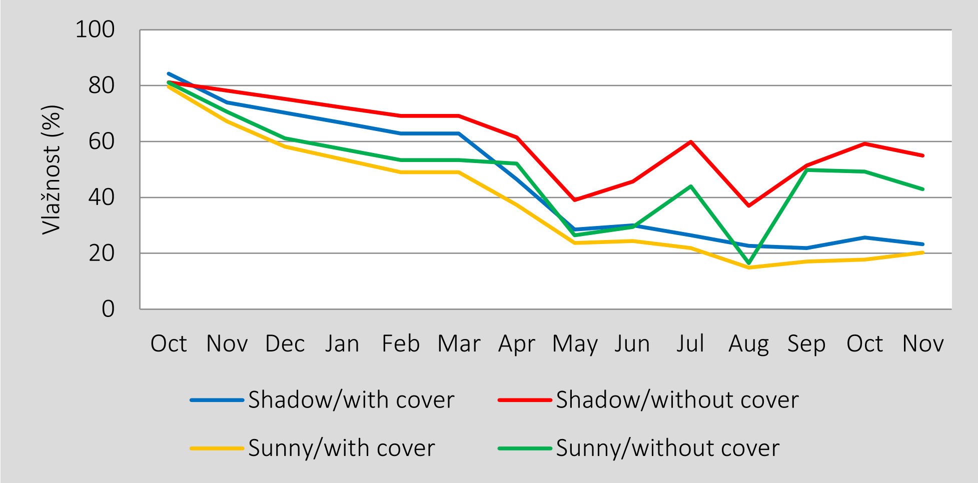


Figure 2 - Test of monthly measurements of drying of four different piles of log wood

Table 20 - Energy content of different types of log wood (with moisture content 20 %) [2]

Wood type	Cal. value in kWh/kg	Cal. value in Wh/stm^3	Equivalent in litre of heating oil	1 stock m^3 beech wood is equivalent
Beech	3.8	1 900	190	**1**
Oak	3.8	1 900	190	**1**
Birch	4.0	1 800	180	**1.1**
Poplar	3.8	1 200	120	**1.6**
Spruce	4.1	1 350	135	**1.4**
Pine	**4.0**	**1 500**	**150**	**1.2**

5.1.2 How to store firewood correctly

- For efficient drying, the wood should be split into thinner pieces. Un-split wood requires up to twice as long for appropriate drying than split wood.
- The drying area should be in a sunny and windy position.
- The pile should be lifted at least 10 cm from the ground, so the circulation of air is insured and the influence of ground moisture is lower.
- Fresh wood should not be stored in closed rooms or storage houses (or even in basements) where water cannot evaporate and fungi and bacteria thrive, which can also represent a health hazard.
- After the summer, wood piles should be covered to protect against rain.
- The distance between different piles and between piles and walls of storage houses should be at least 10 cm so that the air can circulate.

Ways to store fuel wood:

Author: N.Krajnc

Round wood which will be used to prepare fuelwood can be stored at the forest road side but this should be in sunny position and it should be considered as temporary storage.

Author: N.Krajnc

Round wood should be split and stored in a sunny position. Storage as seen in this picture can be considered temporary storage. The main problem is that the pile is not covered and is not lifted at least 15 cm from the ground. Piles like this can be left at forest road sides during summer but is should be covered or moved to other location before autumn.

Author: N.Krajnc

The wood logs (1 m long) are split and stored in piles covered with plastic foil; however, the use of plastic foil for covering piles is not ideal.

Author: N.Krajnc

Round wood with smaller diameter was cut to 25-30 cm and stored next to a boiler house. It is important that storage like this is in a sunny and windy position. Wood will be dry in 4 to 6 months even if it is not split.

Author: Marjan Dolenšek

The most highly recommended method of storing and drying fuel wood is as presented in this picture. 1 m long fire wood should be split and stored in a sunny position in piles with covers. Fuel wood should be stored for at least 4 to 6 months.

5.2 Wood Chips

The quality of wood chips is determined by water content, tree species, the quality of the wood itself, particle size, the amount of dirt (like stones, soil, plastic...). All of these parameters have an important influence on caloric value, bulk density and share of ash.

For production of wood chips, only low quality and small diameter round wood, forest residues and wood wastes are used. Typical areas of application for wood chip plants are agricultural and wood processing companies, commercial companies, apartment buildings and public buildings as well as micro and local heating systems. The biggest disadvantage of wood chips is their lower energy density, which is caused by the lower bulk density of this type of fuel. All of this will influence the size of storage needed.

Table 21 Comparison of storage requirements – Cubic volume required for 20 000 kWh stored energy

Fuel	Heating oil – 2000l	Log wood	Wood chips	Wood pellets
Size of a storage house	2 – 3 m^3	12 m^3	24 m^3	6 m^3

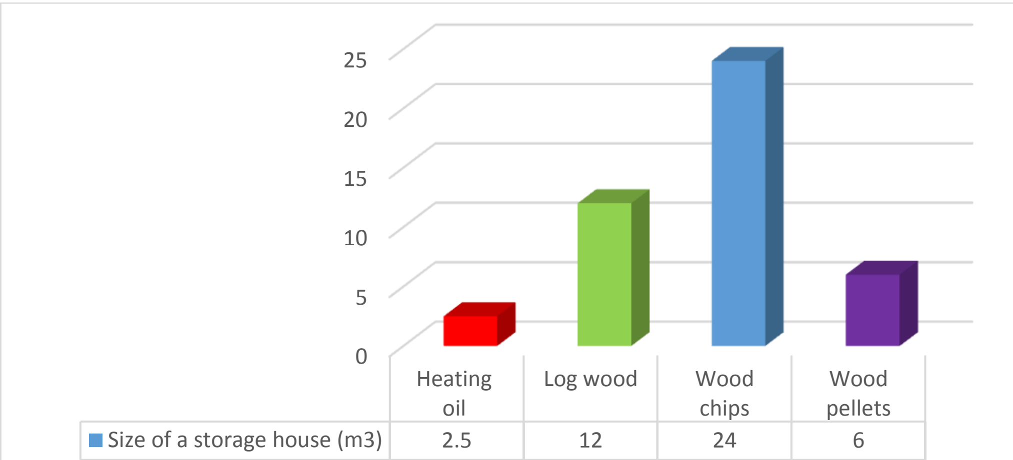


Figure 3 - Comparison of storage size for different wood fuels

5.2.1 Buying wood chips

Wood chips are traded on the fuel market in bulk cubic metres or absolute dry mass (tonnes). One bulk cubic metre corresponds to 200 kg to 450 kg, depending on the respective wood type, size and water content. The net caloric value of one bulk cubic metre is between 630 kWh and 1 100 kWh, depending mostly on water content. For this reason wood chips should be bought and sold based on weight and water content.

Although the gravimetric method (CEN 14774-1) is the only recognized reference method for exactly determining wood moisture (The gravimetric method is applied in the laboratory and consists in weighing a sample before and after complete drying in at 103 °C for 24 hours), modern technology offers a series of portable practical tools for rapidly determining moisture. This proves particularly useful in the implementation of contracts for supply by weight.

5.2.2 Quality requirements

To ensure the efficient and environmentally friendly operation of small or medium-sized biomass burning plants, only dry, high quality wood chips should be used.

Rotten, contaminated and mouldy wood, as well as demolition wood or shrubs with thin twigs are not suitable for producing high quality wood chips.

Water content of wood chips

Water content is the most important quality parameter, since it is significant for the energetic value and the storage properties of the fuel. Fresh wood chips have a water content of more than 50 percent and they are not suitable for long-term storage or use in small and medium-sized biomass heating systems.

In larger district heating plants and industrial combustion plants, application of low quality and very wet wood chips is normal for economic reasons. Low-emission, efficient burning is ensured by their technical equipment (e.g. flue gas cleaning, flue gas condensation).

Table 22 - Weight and calorific value depending on weight and water content

Water content	Bulk density in kg/m³				Net caloric value in kWh/ loosem³			
In %	Beech	Oak	Pine	Spruce	Beech	Oak	Pine	Spruce
20 %	277	280	216	188	1 048	1 062	867	759
30 %	316	320	246	216	1 022	1 034	846	740
40 %	369	374	287	251	986	998	818	716
50 %	443	449	345	302	936	948	780	682

Table 23 - Mean values for quantification

Unit of measure	Wood type	Water content (%)	Bulk m³	t	t_{atro}	kWh
1 bcm wood chips (volume)	Spruce	15 %	1	0.20	0.17	**876**
		30 %	1	0.25	0.17	**847**
		45 %	1	0.31	0.17	**819**
	Beech	15 %	1	0.32	0.27	**1298**
		30 %	1	0.39	0.27	**1252**
		45 %	1	0.49	0.27	**1180**
1t wood chips (net weight)	Spruce	15 %	5	1	0.85	**4380**
		30 %	4	1	0.68	**3388**
		45 %	3,2	1	0.55	**2621**
	Beech	15 %	3,1	1	0.85	**4024**
		30 %	2,6	1	0.69	**3255**
		45 %	**2,1**	**1**	**0.55**	**2478**

5.2.3 How to store wood chips correctly

Wood chips that are used in small or medium sized boilers should be dry (water content should be lower than 30 percent). The main recommendations for producing and storing wood chips are:

- Wood should be stored for at least three months (during summer) in a dry, windy and sunny position (natural drying);
- Wood that is properly stored during summer should have water content of less than 30 percent;
- After the dry season (at the beginning of autumn) wood piles should be covered;
- Only dry wood chips (water content below 30 percent) can be stored in closed storage;
- Wood chips should be removed from storage following the simple FIFO "first in – first out" rule;
- Always wear a mask to protect from fine dust particles and various microorganisms when handling wood chips in closed storage houses;
- Avoid storing wet wood chips with many needles and leaves. The temperature in the pile of this kind of wood chips (green wood chips) will increase (activity of microorganisms).

Decomposition will start in less than three weeks. Wood chips should be stored in piles with a maximum height of 7 m and for only 2-3 weeks.

Ways to store wood chips:

Author: Marjan Dolenšek

Round wood which will be used for making wood chips can be stored at forest road sides but this should be in a sunny position and it should be considered temporary storage. It is recommended to produce wood chips from dry wood material.

Author: N. Krajinc

The most recommended material for making wood chips is wood residues (residues from wood processing industry). This material should be stored in a dry position and should be chipped when it is dry.

Author: N.Krajinc

Wood chips produced from fresh material have a higher water content. They can be stored only for short time and they can be used only in larger boilers with moving grade.

Author: N. Krajinc

Dry wood chips should be placed in storage with efficient air circulation.

Author: N. Krajinc

Biomass trade centres are market spots where quality wood fuels (wood logs, chips and pellets) are sold in a transparent way all year round.

5.3 Wood pellets

Wood pellets for non-industrial use have a diameter 6 mm and a length of1-4 cm. Besides this type of wood pellet, industrial pellets can also be bought on the market. The quality of industrial pellets is lower; they have a diameter of 6, 8 or 10 mm; their ash content can be over 3 percent. Mechanical durability is not an important issue. For normal and efficient operation of smaller boilers, use of standardized and certified pellets is recommended.

5.3.1 How to select the right pellets

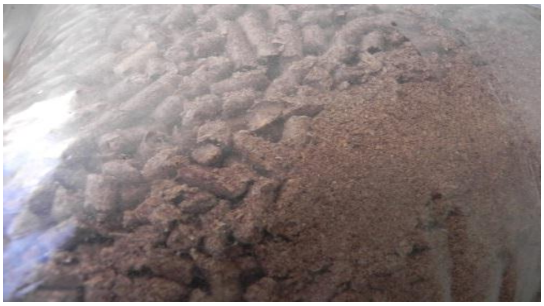
1. Colour of pellets does not determine their quality.
2. The only characteristic of pellets that can be determined by the buyer (without special measurement) is the mechanical durability; the fine dust in the bottom of 15 kg sack shows the durability of pellets.
3. The label that confirms the certificate (ENplus, DINplus) provides insurance that the quality of wood pellts is controlled by independent institutions. This means that there is a much higher probability that wood pellets will be of good quality (or at least the quality that is written on declaration).

4. There is no legislation about data that should be published on declarations and it is always best to select pellets from producers that provide more data on the labels. It is also good to check the origin of pellets.
5. All wood pellets have nearly the same gross caloric value (regardless of tree species), net caloric value changes only depending on water content. This means that tree species or share of bark has no significant influence on the energy content of pellets.
6. Bulk density of pellets is important only because of volume that will be taken by a 15 kg sack. Lower bulk density means larger volume of 15 kg sack (sometimes a 15 kg sack can even weight less than 15 kg).
7. The quality of pellets should be adapted to the needs of the customer (and especially to the requirements of the customer's heating system).
8. The price of wood pellets shouldn't be the main selection criteria.
9. When buying pellets from new and untested producers, first a smaller amount of pellets should be bought and tested (only a few 15 kg sack).
10. Wood pellets should be bought at the end of the heating season when the prices are lower.

Different types of wood pellets

Author: P.Prislan

The colour of pellets does not determine the quality classes of pellets. Darker colour is caused by proportion of bark and tree species. Usually in this case the ash percentage is higher**.**



Author: Tina Jemec

Small particles in the bag are usually caused by lower mechanical durability of pellets.

From Internet - Unknown

Pellets with ENplis labels on the bag are certified according to European standard EN 14961-2. If the pellets are marked with this label that means that they are A1 quality (ash content < 7 percent, water content < 10 percent, mechanical durability > 97.5 percent and bulk density >600 kg per m^3).

6 LIST OF STANDARDS FOR SOLID BIOFUELS MENTIONED IN THIS HANDBOOK

Terminology

EN 14588:2010 Solid biofuels – Terminology, definitions and descriptions
ISO/DIS 16559

Fuel specifications and classes

EN 14961-1:2010 ISO/DIS 17225-1	Solid biofuels – Fuel specifications and classes – Part 1: General requirements
EN 14961-2:2011 ISO/DIS 17225-1	Solid biofuels – Fuel specifications and classes – Part 2: Wood pellets for non-industrial use
EN 14961-3:2011 ISO/DIS 17225-3	Solid biofuels – Fuel specifications and classes – Part 3: Wood briquettes for non-industrial use
EN 14961-4:2011 ISO/DIS 17225-4	Solid biofuels – Fuel specifications and classes – Part 4: Wood chips for non-industrial use
EN 14961-5:2011 ISO/DIS 17225-5	Solid biofuels – Fuel specifications and classes – Part 5: Firewood for non-industrial use
EN 14961-6:2012 ISO/DIS 17225-6	Solid biofuels – Fuel specifications and classes – Part 6: Non-woody pellets for non-industrial use

Fuel quality assurance

EN 15234-1:2011	Solid biofuels – Fuel quality assurance – Part 1: General requirements
EN 15234-2:2012	Solid biofuels – Fuel quality assurance – Part 2: Wood pellets for non-industrial use
EN 15234-3:2012	Solid biofuels – Fuel quality assurance – Part 3: Wood briquettes for non-industrial use
EN 15234-4:2012	Solid biofuels – Fuel quality assurance – Part 4: Wood chips for non-industrial use
EN 15234-5:2012	Solid biofuels – Fuel quality assurance – Part 5: Firewood for non-industrial use
EN 15234-6:2012	Solid biofuels – Fuel quality assurance – Part 6: Non-woody pellets for non-industrial use

Physical and mechanical properties

EN 14774-1:2009 ISO/CD 18134-1	Solid biofuels – Determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method
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This Handbook was prepared by wood biomass expert, Dr. Nike Krajnc, as a deliverable of the Climate Change mitigation component in the frame of the FAO project “Support to Implementation of the Forest Policy and Strategy in Kosovo”, which is supported by the Ministry of Foreign Affairs of Finland.

This handbook offers a collection of information on wood biomass for both producers and consumers and is adapted for the market needs and problems identified in Southeast Europe.

Also, this publication is aimed at promoting modern technology as well as efficient and sustainable use of wood biomass throughout the production chain. A market more transparent in terms of values and trading conditions will stabilize growth of the biomass sector in the future thus helping biomass producers to produce different wood fuel products meeting the demand of future markets.

FAO thanks all participants of this project and hopes that this publication encourages many farmers, forest owners and decision makers to promote locally grown biomass.

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