Natural Resources Canada
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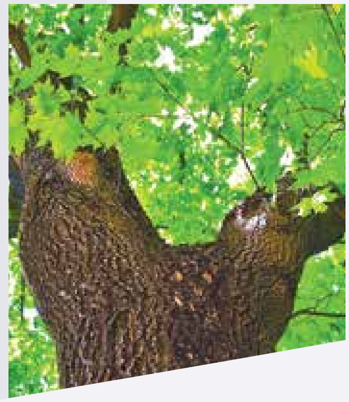
Solid Biofuels Bulletin No. 2

PRIMER FOR SOLID BIOFUELS

DEFINITIONS, CLASSES/GRADES AND FUEL PROPERTIES



This is the second in a series of bulletins, based on the CAN/CSA-ISO 17225 Solid Biofuels – Fuel Specifications and Classes. This bulletin explains the most important terms and definitions used in the Standard, the basic principles of classification of solid biofuels and provides details on key fuel properties and their significance. Subsequent bulletins on the various grades of firewood, wood chips, briquettes and wood pellets elaborate on the information described in this bulletin. This primer will help end users and consumers ask appropriate questions and make informed decisions on solid biofuel purchases.

CAN/CSA-ISO 16559 and CAN/CSA-ISO 17225 – Part 1 to 8 Solid Biofuel Standards establish terms and definitions, classifications, traded forms, grades and specification of properties for solid biofuels[1]. The principle for classification of solid biofuels under the CAN/CSA-ISO standards is based on:

- Origin and source
- Major traded forms
- Fuel Properties

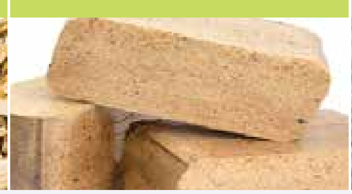
Classification by the Origin and Source: The main origins of raw biomass materials, as classified in a hierarchical system under the CAN/CSA-ISO 17225 Part 1 standard include:

- Woody biomass
- Herbaceous biomass
- Fruit biomass
- Aquatic biomass
- Blends and mixtures

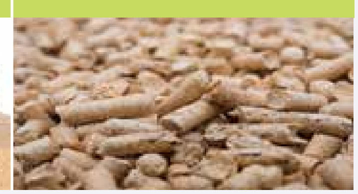
Firewood

Wood Chips

Briquettes



Wood Pellets



The above main grouping is further divided into second level of classification to differentiate the sources within the main groups (Table 1). The source-based classification makes distinction whether the woody biomass (Classification 1) is virgin material from forest and plantation (Classification 1.1), by-products/residues from the industry (Classification 1.2), or used wood (Classification 1.3). Groups in Table 1 are further divided into a third level sub-group.

In Canada, woody biomass comes most commonly from the following sources:

- Logging residues – generated during tree harvesting, and includes branches, tree tops and low-grade logs. All these biomass sources are identified under Classification 1.1.4.
- By-products and residues from wood processing operations – such as slabs, sawdust, shavings and bark. Sawdust and shavings are primarily used for wood pellets and briquettes. "Chemically untreated" is a term that is used to describe residues from debarking, sawing or size reduction, shaping, and pressing processes (Classification 1.2.1).

There are other woody biomass sources, which are available in limited amounts and currently have restricted use in Canada:

- Segregated wood collected from parks, gardens, roadside maintenance, vineyards, fruit orchards and driftwood from freshwater—is identified under Classification 1.1.7.

Table 1. Hierarchical classification and grading of Woody Biomass (Classification 1) by origin and sources*

1.1 Forest, plantation and other virgin wood		**Grade A**	**Grade B**
1.1.1	Whole tree without roots	yes	yes
1.1.2	Whole trees with roots	no	yes
1.1.3	Stem wood	yes	yes
1.1.4	Logging residues**	no	yes
1.1.6	Bark (from forestry operations)	no	yes
1.1.7	Segregated wood from gardens, parks, roadside maintenance, vineyards, fruit orchards, driftwood from fresh water	no	yes

1.2 By-products / residues from wood processing industries	**Grade A**	**Grade B**
1.2.1 Chemically untreated wood by-products, residues, wood constituents**	yes	yes
1.2.2 Chemically treated wood by-products, residues, wood constituents***	no	yes

1.3 Used wood******	**Grade A**	**Grade B**
1.3.1 Chemically untreated used wood	no	yes

* The focus of this bulletin is solid biofuels for residential, commercial and institutional heating applications, i.e. Grades A and B; industrial grade solid biofuels, Grade (I), are excluded. Furthermore, the blends and mixtures as raw materials are excluded.

** Woody biomass sourced from Classifications 1.1.4 and 1.2.1 is the main source for solid biofuel production in Canada

*** To qualify, chemically treated wood by-products and residues shall not contain heavy metals or halogenated organic compounds as a result of treatment with wood preservatives or coatings

**** To qualify, used wood shall not contain heavy metals or halogenated organic compounds as a result of its usage and treatment with wood preservatives or coatings.

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Table 2. Comparison of key specifications of properties for selected woody solid biofuels and fossil fuels

Fuel Type	Density* (kg/m^3)	Density* (lb/ft^3)	High Heating Value by Mass (MJ/kg)	High Heating Value by Mass (Btu/lb)
Wood chips (about 45 % Moisture, loosely packed)	300–400	19–25	10–11	4,300–4,700
Firewood (stacked; air dry to about 25% moisture)	300–500	19–31	14–15	6,200–6,500
Wood pellets** (≤10% moisture)	550–800	34–50	18–20	7,700–8,500
Heating Oil (No.2)	850	53	42	18,000
Propane (LPG)***	1.7	0.12	50	21,500
Natural Gas	0.7–0.9	0.04–0.06	43	19,000

* Bulk density is typically used for solid biofuels (see Bulk Density section) while density is used for gaseous and liquid fossil fuel
** Typical bulk density for wood pellets is about 650–700 kg/m^3
*** Liquid Petroleum Gas (LPG).

- Used wood, or post-consumer wood waste—such as construction woods, pallets, and wood packages—is identified under Classification 1.3.

Commonly Traded Forms of Solid Biofuels: The CAN/CSA-ISO 17225 Part 1 Standard[1] establishes classification for solid biofuels based on shapes and sizes under which biomass fuels are traded. Storage, handling and combustion properties of the fuel are influenced by the shape and size of the fuel. Most commonly traded forms of woody solid biofuels that are most relevant to Canada are:

- firewood
- wood chips
- wood briquettes
- wood pellets

Physical and chemical properties of woody solid biofuels vary within each traded form. Some key property classes which are included in the specifications are:

- Ash
- Moisture content
- Bulk density
- Calorific value
- Particle size (diameter/length)

Classification by Properties: The CAN/CSA-ISO 17225 Parts 2 to 5 Standards[1] establish grades for common forms of woody solid biofuels based on (i) origin and source and (ii) specifications of properties. Grade designations make distinctions according to the types of application. Grades A and B are suitable for residential, commercial, and institutional heating applications; Grade I is suitable for industrial uses. The grade designations can be used both by buyers and sellers in contracts and specification sheets to eliminate confusion and clearly identify the required fuel specification.

From a fuel buyer or operator perspective, what is important and useful is whether the biomass fuel meets the appropriate standards, of grading, classification and fuel specifications, not how it is produced. In the following sections, most significant fuel properties will be introduced.

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Bulk Density (BD)

Bulk density is defined as the mass of solid fuel particles divided by the total volume they occupy (i.e. kg/m^3). The denser a solid biomass fuel is, the more energy it contains per volume (Table 2). Solid biofuels with greater bulk density are more economical to transport and take up less storage space.

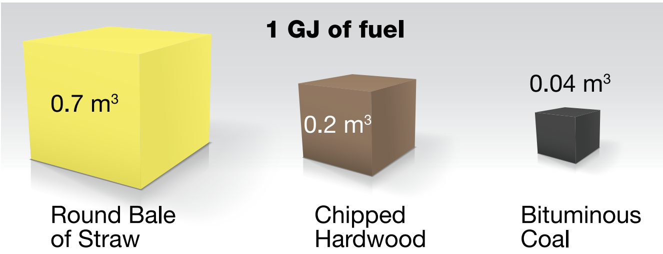

Figure 1. Comparison of bulk densities of fuels

Moisture Content (M)

Moisture content is defined as the quantity of water contained in a fuel. It is most commonly expressed on a wet basis, which gives the moisture content as a fraction of the total weight of a sample (e.g. a moisture content of 20% means that 20% of the weight of a solid biomass fuel is water).

The CAN/CSA-ISO 17225 Part 1 to 8 Standards define the range of moisture content for each type of graded solid biofuels. High moisture content has several disadvantages, such as increased transportation costs per unit of energy, risks of degradation through fungal and bacterial activities during storage (composting), self-heating and off-gassing. High moisture content also lowers the amount of useful energy captured from combustion as more energy is necessary to evaporate water. Extremely dry fuels can also cause problems, producing excessive fine particles and dust, and thereby creating an explosion hazard.

Most commercial heating equipment can only tolerate solid biofuels with a maximum of about 50% moisture (wet basis). Therefore, drying is important, as is keeping the solid biofuels dry during storage.

Calorific Value (Q)

The calorific value is a measure of energy content. It is defined as the amount of heat released from a specific amount of fuel during complete combustion, and is expressed in mega joules per kilogram (MJ/kg) or British thermal units per pound (BTU/lb) (Table 2). The term calorific value is synonymous with heating value.

The term high heating value (HHV), or gross calorific value (GCV), is typically used in North America and includes energy from condensation of water vapour from the combustion products. The term low heating value (LHV), or net calorific value (NCV), is more commonly used in Europe and does not include energy from condensation of water vapour. For biomass, there is about 5-8% more energy recorded in HHV as compared to LHV measures (Figure 2). This often leads to confusion when comparing the energy efficiencies of different systems.

Moisture content is the most important factor affecting calorific value. However, ash content, chemical composition and bulk density also influence calorific values to varying degrees. Wood species have a minimal effect on calorific value. When purchasing biomass fuels, payment should be based on energy content ($/MJ).

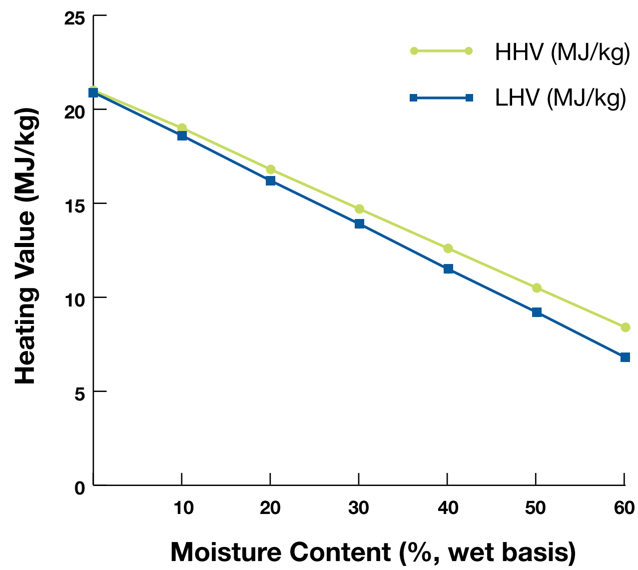

Figure 2. Impact of moisture content on calorific value (HHV and LHV) of a solid biofuel.

Ash (A)

Ash is the inorganic residue remaining after the combustion of a fuel, typically expressed as a percentage of the mass of dry matter in the solid biofuel.

Woody solid biofuels typically have low ash content. Ash content increases mainly with bark content, contamination with soil and/or sand, and inorganic additives or chemical treatments such as paint or preservatives. The ash minerals are mainly composed of alkali metals (such as calcium, potassium and sodium), magnesium and silica.

Two types of ash are generated during combustion: bottom ash and fly ash. Bottom ash is collected from

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the furnace or boiler grates. Fly ash is the ash carried with the hot flue gas through the exhaust pipe and is very fine and mainly inorganic. Some of the fly ash accumulates on boiler surfaces (causing fouling); finer fly ash is emitted to the atmosphere as particulate matter. In a typical grate-type combustion system, about 98% of the ash is collected as bottom ash and 2% is collected as fly ash.

The presence of alkali minerals lowers the softening and melting temperature of ash (say from 1700°C for pure silica to <800°C). This could cause ash to form clinker and/or slag (fused ash in glassy form). It is therefore important to ensure that the temperature on the grate is kept below 750°C to prevent slag formation and premature shutdown of the boiler or furnace.

Particle Size (P)

Solid biofuels may be uniform in size, as in wood pellets and briquettes, or they may come in a range of sizes from a few centimeters to 50 cm or larger, as in the case of wood chips.

The CAN/CSA-ISO 17225 Part 1 to 8 Standards establish specific values for both acceptable particle size range and minimum allowable amounts of acceptable sized material for each traded form of solid biofuels and their grades. The standard describes the appropriate distribution of the majority of the fuel, termed main fraction, along with the fines (small) and coarse (large) fractions or portions. Fines, defined as particles less than 3.15 mm (less than 1/8 inch), pose issues related to combustion performance, as fines likely go through the boiler or furnace without burning. Very fine particles also pose a risk for dust generation, fires and even explosions (if subjected to an ignition source) during handling and storage. Coarse particles are defined as oversized material, which are long and skinny pieces, which can cause issues in feeding systems (by jamming augers) and will likely be discharged through the ash system without being completely burned.

Biomass heating equipment used in small commercial and institutional applications, such as public buildings, hospitals, schools and warehouses, requires higher quality solid biofuels to ensure reliable and clean operation.

The dimensions and size distribution of a fuel not only determine the appropriate fuel-feeding system, but also influence combustion. Pellets, for instance, are fed automatically, whereas firewood needs to be manually fed. A boiler designed to operate with wood chips may not operate with briquettes properly as the fuel handling system may not be able to handle larger briquettes and the combustion chamber of the furnace may not burn the denser and larger briquettes. It is therefore important to be aware of how particle size interacts with the feeding system and firebox of a boiler or furnace.

Particle size is measured by screening a known volume of fuel (typically 8 liters or 2 gallons) in a mechanical shaker. It is highly recommended to perform a visual inspection of the biomass fuel to confirm that the fuel does not have too many fines or coarse materials.

Glossary

Biomass by-product: A secondary product which is made incidentally during the production of wood products (such as sawdust and shavings).

Biomass residue: Biomass from well-defined side-streams of forestry and related industrial operations (such as logging residue including tops and branches).

Binders and Additives: Materials intentionally introduced in the production of wood pellets and briquettes to make production more efficient, improve durability, improve quality (i.e. combustion properties), and reduce air emissions.

Chemically untreated woody biomass: Residues from debarking, sawing or size reduction, shaping and pressing processes.

Chemically treated woody biomass: Wood residues from production of panels and furniture (glued, painted, coated, lacquered) that contain no heavy metals or halogenated organic compounds at levels higher than those in typical virgin material values.

Contaminants: Impurities in a solid biomass fuel, including substances such as paint, rubber and plastics, and, are most commonly present in the post-consumer derived fuels.

Extraneous substances: Foreign materials which enter the biomass or solid biomass fuel during harvest, logging, processing, transport and storage. Examples include, stones, rocks, glass and metals. Presence of the extraneous substances increases the ash content of solid biofuels.

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Units and Conversions

Metric prefixes

MJ/kg* – MegaJoules per kilogram
BTU/lb – British Thermal Units per pound
kWh/kg – Kilowatt hour per kilogram
* 1 MJ/kg = 1 Gigajoule/tonne (GJ/t)

Kilo (k) = Multiplier of 1,000
Mega (M) = Multiplier of 1,000,000
Giga (G) = Multiplier of 1,000,000,000

Volume

1 full cord = 128 ft^3 (4x4x8 ft) = 3.6 m^3 (stacked firewood)
1 cubic metre = 35.3 cubic feet
1,000 litre (lt) = 1 m^3

Weight

Metric ton (t) = **tonne** = 1000 kilograms = 2205 lb
Imperial or **Long ton (lt)** = 1016 kilograms = 2240 lb
Short (US) ton (st) = 907 kilograms = 2000 lb

From **long ton** to **metric ton** multiply by 1.016
From **short ton** to **metric ton** multiply by 0.9072

Energy and Density

From **MJ/kg** to **kWh/kg** multiply MJ/kg by 0.2778
From **MJ/kg** to **BTU/lb** multiply MJ/kg by 430
From **BTU/lb** to **MJ/kg** multiply Btu/lb by 0.002326
From **MJ/m³** to **BTU/ft³** multiply MJ/m^3 by 26.84
From **BTU/ft³** to **MJ/m³** multiply Btu/ft^3 by 0.0373

Fuel Equivalents

1000 litre (lt) heating oil **equivalent (in energy basis)**
~ **5–8 m³** dry stacked firewood (M 20%)
10–12 m³ wood chips (M 45%, loosely stored)
~2 metric tonne (or ~3 m^3) wood pellet

Example: In Canada, majority of bioheat facilities installed in public buildings such as schools, retirement homes, campuses are less than 1 MWth capacity. To illustrate what amount of woody solid biofuels would be needed annually, a 500 kW boiler (thermal output) is chosen as an example. Table 3 compares calculated annual fuel consumptions for wood pellets and wood chips for two different boiler efficiencies.

Assumptions:

- approximately 1800 operating hours @ full capacity per year.
- Wood Pellets – A2 Grade, Moisture 8%, wet basis; HHV = 16.5 MJ/kg (4.6 kWh/kg) as received.
- Wood Chips – A2 Grade, Moisture 35%, wet basis; HHV = 12 MJ/kg (3.3 kWh/kg) as received.
- Wood Chips – B1 Grade, Moisture 50%, wet basis; HHV = 9.3 MJ/kg (2.6 kWh/kg) as received.

Table 3. Comparison of annual fuel amounts as a function of solid biofuels, moisture content and boiler efficiency

Solid Biofuels	Amount of Fuel (metric tonnes/year)	Amount of Fuel (metric tonnes/year)
Boiler Efficiency	70 %	85%
Wood pellets (A2 – M10)	280	230
Wood chips (A2 – M35)	395	325
Wood chips (B1 – M50)	500	410

References & Links

1. CSA Group – www.csagroup.org for CAN/CSA-ISO 17225 Solid Biofuels – Fuel specifications and classes – Part 1 to 8.
2. Natural Resources Canada – www.nrcan.gc.ca for the Solid Biofuels Bulletin Series.

Acknowledgement

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