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QUALITY AND SPECIFICATION OF SOLID BIOFUELS IN EUROPE

Summary

Ukraine has rather big potential of biomass available for energy production. Biomass (excluding the share that is used by other sectors of economy) can cover up to 9% of the total primary energy demand. Technologies of biomass utilization are mostly at the beginning of their development in Ukraine, but they have good prospects for commercialization in the near future.

The quality classification is interesting for both small and big consumers. The quality classification is focused to the most important commercial biofuels as briquettes, pellets, wood chips, crushed wooden fuel, wooden logs, sawdust, bark, straw bales. That classification is flexible and thus manufacturer or customer can choose any properties class corresponding with produced or required fuel quality. That free classification does not bind mutually different properties of individual fuels. Its advantage is in fact that manufacturer and customer can agree with a certain characteristics for each simple case. In the paper are presented European examples of specification of properties for briquettes, pellets, straw bales and for classes of high-quality solid biofuels for household. Development of bioenergy technologies would reduce Ukraine dependence on imported energy carriers, enhance its energy security at the expense of organizing energy supply based on local renewable sources, create a lot of new jobs (mostly in rural area), contribute greatly to the improvement of ecological situation.

Україна має значительний потенціал біомаси, доступної для виробництва енергії. Біомаса дозволяє покрити в цілому до 9% загальної первинної потреби в енергії. Технології утилізації біомаси знаходяться в початку їх розвитку в Україні, але мають хороші перспективи для комерціалізації в найближчому майбутньому.

В оцінці якості та класифікації твердих біопалив зацікавлені як невеликі, так і промислові споживачі. Представлена класифікація торкається найголовніших видів біопалив, до яких відносять брикети, гранули, дерев'яні срубки, колоди, тирса, кора і солом'яні тюки. Дана класифікація є гнучкою і тому виготовник або клієнт може вибрати будь-який клас за властивостями, що відповідають виробленій або потрібній споживачу якості палива. Класифікація не пов'язує взаємно різні властивості окремих палив. Її перевага у тому, що виготовник і клієнт можуть знайти згоду за певними характеристиками для кожного конкретного випадку. У статті представлені європейські підходи до визначення властивостей брикетів, гранул (пелет), солом'яних тюків у вигляді окремих класів високоякісних твердих біопалив. Розвиток технологій біоенергетики сприяє скороченню залежності України від імпортованих носіїв енергії, збільшує безпеку за рахунок організації енергопостачання, заснованого на місцевих поновлюваних джерелах, створює нові робочі місця (здебільшого в сільській місцевості), сприяє поліпшенню екологічної ситуації.

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Introduction

Total energy potential of biomass in Ukraine is estimated as 9% of the total primary energy consumption. The most promising technologies are direct combustion of biomass for heat production, production of biogas from manure on large farms, extraction and utilization of landfill

gas, co-combustion of biomass and fossil fuel for power production. Technologies of direct combustion of wood, first of all for heat and process steam production, require prior development in Ukraine. It is due to rather low electricity price existing in Ukraine (0.03 \$/kWh) and the same time quite high heat and fuel price. Implementation of small-scale power plants and CHP plants operating on solid

biomass (wood, straw and husk) will be profitable if electricity price rises significantly or in the case of subsidies. Heat production from biomass is profitable now even with the use of foreign equipment. Besides, Ukraine has opportunity to launch its own production of wood and straw fired boilers.

Technologies of straw combustion are very promising for Ukraine as well. To implement them widely it is necessary to solve a number of problems connected with arrangements on collection, baling, transportation and storage of straw. First of all 0.1-1 MW farm and neighbor heating boilers for implementation at agricultural enterprises has the best prospects. After demonstration of their advantages large-scale district heating plants also have good opportunities for commercialization. As for 1-10 MW_e biomass-based CHP plants, we restrict their position in the conception of bioenergy development in Ukraine only by two demonstrational plants (one wood-based and one straw-based) until electricity price rises greatly.

The basic aim of specification of solid biofuels classification is to promote the trade of biofuels, so that the customer and the seller can unanimously define the quality [1, 2, 3]. Solid biofuels are fuel produced directly or indirectly from biomass. Among basic biomass resources which are defined as a material of biological origin excluding material embedded in geological formations and transformed to fossil belong:

- products from agriculture and forestry,
- vegetable waste from agriculture and forestry,
- vegetable waste from the food processing industry,
- wood waste, with the exception of wood waste which may contain halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coating, and which includes in particular such wood waste from construction- and demolition waste,
- cork waste,

- fibrous vegetable waste from virgin pulp production and from production of paper from pulp, if it is co-incinerated at the place of production and heat generated is recovered.

Classification of origin and sources of solid biofuels

The classification is based on the biofuel origin and source. In the hierarchical classification system (Table 1) the main origin-based solid biofuel groups are [5]:

- woody biomass;
- herbaceous biomass;
- fruit biomass;
- blends and mixtures.

Woody biomass is biomass from trees, bushes and shrubs. Herbaceous biomass is from plants that have a non-woody stem and which die back at the end of the growing season. Fruit biomass is the biomass from the parts of a plant which hold seeds. The term “Blends and mixtures” in Table 1 refers to material of various origin within the given box in the classification table and appears on four levels. Blends are intentionally mixed biofuels, whereas mixtures are unintentionally mixed biofuels. The origin of the mixture or blend has to be described using Table 1. If solid biofuel blend or mixture may contain chemically treated material it has to be stated. A blend or a mixture of e.g. chemically treated wood and chemically untreated wood has to be classified as chemically treated wood.

The second level of classification in Table 1 describes fuels from different sources within the main groups, primarily stating whether the biomass is a by-product or a residue from the industry or if it is virgin material.

Groups in Table 1 are further divided into third and fourth level sub-groups.

The purpose of Table 1 is to allow the possibility to differentiate and specify biofuel material based on origin with as much detail as needed.

Table 1. Classification of origin and sources of solid biofuels [5]

1. Woody biomass	1.1 Forest and plantation wood	1.1.1 Whole trees	1.1.1.1 Deciduous
			1.1.1.2 Coniferous
			1.1.1.3 Short rotation coppice
			1.1.1.4 Bushes
			1.1.1.5 Blends and mixtures
		1.1.2 Stemwood	1.1.2.1 Deciduous
			1.1.2.2 Coniferous
			1.1.2.3 Blends and mixtures
		1.1.3 Logging residues	1.1.3.1 Fresh/Green (including leaves/needles)
			1.1.3.2 Stored
	1.1.3.3 Blends and mixtures		
	1.1.4 Stumps	1.1.4.1 Deciduous	
		1.1.4.2 Coniferous	
		1.1.4.3 Short rotation coppice	
		1.1.4.4 Bushes	
1.1.4.5 Blends and mixtures			
1.1.5 Bark (from forestry operations)			
1.1.6 Landscape management woody biomass			
1.2 Wood processing industry, by-products and residues	1.2.1 Chemically untreated wood residues	1.2.1.1 Without bark	
		1.2.1.2 With bark	

Table 2. continued

		1.2.2 Chemically treated wood residues	1.2.1.3 Bark (from industry operations)	
			1.2.1.4 Blends and mixtures	
			1.2.2.1 Without bark	
			1.2.2.2 With bark	
		1.2.3 Fibrous waste from the pulp and paper industry	1.2.2.3 Bark (from industry operations)	
			1.2.2.4 Blends and mixtures	
			1.2.3.1 Chemically untreated fibrous waste	
			1.2.3.2 Chemically treated fibrous waste	
		1.3 Used wood	1.3.1 Chemically untreated wood	1.3.1.1 Without bark
				1.3.1.2 Bark
1.3.1.3 Blends and mixtures				
1.3.2 Chemically treated wood	1.3.2.1 Without bark			
	1.3.2.2 Bark			
	1.3.2.3 Blends and mixtures			
1.4 Blends and mixtures				
2. Herbaceous biomass	2.1 Agriculture and Horticulture herb	2.1.1 Cereal crops	2.1.1.1 Whole plant	
			2.1.1.2 Straw parts	
			2.1.1.3 Grains or seeds	
			2.1.1.4 Husks or shells	
			2.1.1.5 Blends and mixtures	
		2.1.2 Grasses	2.1.2.1 Whole plant	
			2.1.2.2 Straw parts	
			2.1.2.3 Seeds	
			2.1.2.4 Shells	
			2.1.2.5 Blends and mixtures	
		2.1.3 Oil seed crops	2.1.3.1 Whole plant	
			2.1.3.2 Stalks and leaves	
			2.1.3.3 Seeds	
			2.1.3.4 Husks or shells	
			2.1.3.5 Blends and mixtures	
		2.1.4 Root crops	2.1.4.1 Whole plant	
			2.1.4.2 Stalks and leaves	
			2.1.4.3 Root	
			2.1.4.4 Blends and mixtures	
		2.1.5 Legume crops	2.1.5.1 Whole plant	
2.1.5.2 Stalks and leaves				
2.1.5.3 Fruit				
2.1.5.4 Pods				
2.1.5.5 Blends and mixtures				
			2.1.6 Flowers	2.1.6.1 Whole plant
		2.1.6.2 Stalks and leaves		
		2.1.6.3 Seeds		
		2.1.6.4 Blends and mixtures		
		2.1.7 Landscape management herbaceous biomass		
		2.2 Herb processing industry, by-products and residues	2.2.1 Chemically untreated herb residues	2.2.1.1 Cereal crops and grasses
				2.2.1.2 Oil seed crops
				2.2.1.3 Root crops
				2.2.1.4 Legume crops and flowers
				2.2.1.5 Blends and mixtures
2.2.2 Chemically treated herb residues	2.2.2.1 Cereal crops and grasses			
	2.2.2.2 Oil seed crops			
	2.2.2.3 Root crops			
	2.2.2.4 Legume crops and flowers			
	2.2.2.5 Blends and mixtures			
2.3 Blends and mixtures				

Specification of solid biofuels based on traded forms and properties

Solid biofuels are traded in many different sizes and shapes. The size and shape influence the handling of the fuel as well as its combustion properties. Biofuels may be delivered for example in the forms shown in Table 2.

At the standardized symbols:

- d dry (dry basis),
- daf dry, ash-free,
- ar as received,
- A designation for ash content (w-%, dry basis),
- ρ density [kg/m^3],
- BD designation for bulk density,
- DE designation for particle density as received [kg/dm^3],
- D designation for diameter,
- DU designation for mechanical durability,
- E_{ar} energy density as received [MWh/m^3 loose, solid or stacked volume (amount of energy/volume unit)],
- E designation for energy density as received [kWh/m^3 or kWh/kg , unit is to be stated in brackets],
- F designation for amount of fines (< 3,15 mm, w-%),
- L designation for length,
- M_{ar} total moisture content as received [w-%] on wet basis,
- M designation for moisture content as received,
- P designation for particle size distribution,
- $q_{v,gr}$ gross calorific value [MJ/kg] at constant volume,
- $q_{p,net}$ net calorific value [MJ/kg] at constant pressure

Table 2. Major traded forms of solid biofuels [5]

Fuel name	Typical particle size	Common preparation method
Briquettes	$\varnothing > 25 \text{ mm}$	Mechanical compression
Pellets	$\varnothing < 25 \text{ mm}$	Mechanical compression
Fuel powder	< 1 mm	Milling
Sawdust	1 mm to 5 mm	Cutting with sharp tools
Wood chips	5 mm to 100 mm	Cutting with sharp tools
Hog fuel	Varying	Crushing with blunt tools
Logs	100 mm to 1000 mm	Cutting with sharp tools
Whole wood	> 500 mm	Cutting with sharp tools
Small straw bales	0,1 m ³	Compressed and bound to squares
Big straw bales	3,7 m ³	Compressed and bound to squares
Round straw bales	2,1 m ³	Compressed and bound to cylinders
Bundle	Varying	Lengthways oriented & bound
Bark	Varying	Debarking residue from trees Can be shredded or unshredded
Chopped straw	10 mm to 200 mm	Chopped during harvesting
Grain or seed	Varying	No preparation or drying
Shells and fruit stones	5 mm to 15 mm	No preparation
Fibre cake	Varying	Prepared from fibrous waste by dewatering

NOTE: Also other forms may be used.

Examples of various forms and differences of solid biofuels present Fig. 1 and 2.



Fig. 1: Examples of various forms of solid biofuels

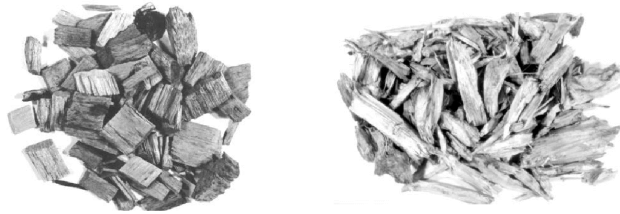


Fig. 2: Difference between wood chips (left) and crushed wood fuel (right) [5]

Presents on example of the specification of properties for briquettes - Table 3, pellets - Table 4, straw bales - Table 5.

Table 3. Specification of properties for briquettes [5]

		Master table		
		Origin: According to Table 1	Woody biomass (1) Herbaceous biomass (2) Blends and mixtures (4)	
		Traded Form (see Table 2)	Briquette	
Normative	Dimensions (mm) Diameter (D) or equivalent (diagonal or cross cut), mm			
	D40	$25 \leq D \leq 40$		
	D50	≤ 50		
	D60	≤ 60		
	D80	≤ 80		
	D100	≤ 100		
	D125	≤ 125		
	D125+	≥ 125 actual value to be stated		
	Length (L)			
	L50	≤ 50		
	L100	≤ 100		
	L200	≤ 200		
	L300	≤ 300		
	L400	≤ 400		
	L400+	≥ 400 actual value to be stated		
	Moisture (w-% as received)			
	M10	$\leq 10\%$		
	M15	$\leq 15\%$		
	M20	$\leq 20\%$		
	Ash (w-% of dry basis)			
A0.7	$\leq 0,7\%$			
A1.5	$\leq 1,5\%$			
A3.0	$\leq 3,0\%$			
A6.0	$\leq 6,0\%$			
A10.0	$\leq 10,0\%$			
Sulphur (w-% of dry basis)				
S0.05	$\leq 0,05\%$	Sulphur is normative only for chemically treated biomass or if sulphur containing additives have been used		
S0.08	$\leq 0,08\%$			
S0.10	$\leq 0,10\%$			
S0.20	$\leq 0,20\%$			
S0.20+	$> 0,20\%$ (actual value to be stated)			
Particle density (kg/dm^3)				
DE0.8	0,80 to 0,99			
DE1.0	1,00 to 1,09			
DE1.1	1,10 to 1,19			
DE1.2	$\geq 1,20$			
Additives (w-% of pressing mass)				
Type and content of pressing aids, slagging inhibitors or any other additives have to be stated				
Nitrogen, N (w-% of dry basis)				
N0.3	$\leq 0,3\%$	Nitrogen is normative only for chemically treated biomass		
N0.5	$\leq 0,5\%$			

Table 3. continued

	N1.0	≤ 1,0%	
	N3.0	≤ 3,0%	
	N3.0+	>3,0% (actual value to be stated)	
Informative	Net calorific value, $q_{p,net,ar}$ (MJ/kg as received) or energy density, E_{ar} (kWh/m ³ loose)		Recommended to be stated at the retail level
	Bulk density as received (kg/m ³ loose)		Recommended to be stated if traded by volume basis
	Chlorine, Cl (w-% of dry basis, %)		Recommended categories Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10+ (if Cl > 0,10% the actual value to be stated)

Table 4. Specification of properties for pellets [5]

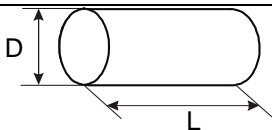
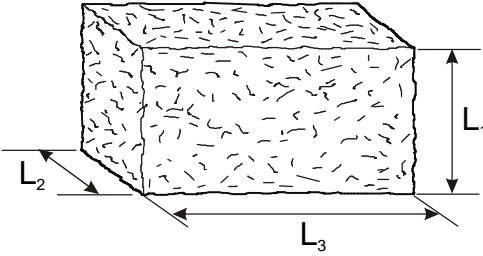
	Master table		
	Origin: According to Table 1		Woody biomass (1), Herbaceous biomass (2), Fruit biomass (3), Blends and mixtures (4)
	Traded Form (see Table 2)		Pellets
Normative	Dimensions (mm)		
	Diameter (D) and Length (L) ^a		
	D06	≤ 6 mm ± 0,5 mm and L ≤ 5 x Diameter	
	D08	≤ 8 mm ± 0,5 mm, and L ≤ 4 x Diameter	
	D10	≤ 10 mm ± 0,5 mm, and L ≤ 4 x Diameter	
	D12	≤ 12 mm ± 1,0 mm, and L ≤ 4 x Diameter	
	D25	≤ 25 mm ± 1,0 mm, and L ≤ 4 x Diameter	
	Moisture (w-% as received)		
	M10	≤ 10%	
	M15	≤ 15%	
	M20	≤ 20%	
	Ash(w-% of dry basis)		
	A0.7	≤ 0,7%	
	A1.5	≤ 1,5%	
	A3.0	≤ 3,0%	
	A6.0	≤ 6,0%	
	A6.0+	> 6,0% (actual value to be stated)	
	Sulphur (w-% of dry basis)		
	S0.05	≤ 0,05%	
	S0.08	≤ 0,08%	
	S0.10	≤ 0,10%	
	S0.20+	> 0,20% (actual value to be stated)	
	Mechanical durability ^a (w-% of pellets after testing)		
	DU97.5	≥ 97,5%	
	DU95.0	≥ 95,0%	
	DU90.0	≥ 90,0%	
	Amount of fines (w-%, < 3,15 mm) after production at factory gate		
	F1.0	≤ 1,0%	
	F2.0	≤ 2,0%	
	F2.0+	> 2,0% (actual value to be stated)	
	Additives (w-% of pressing mass)		
	Type and content of pressing aids, slagging inhibitors or any other additives have to be stated		
Nitrogen, N (w-% of dry basis)			
N0.3	≤ 0,3 %		
N0.5	≤ 0,5 %		
N1.0	≤ 1,0 %		
N3.0	≤ 3,0 %		
N3.0+	> 3,0 % (actual value to be stated)		

Table 4. continued

Informative	Net calorific value, $q_{p,net,ar}$ (MJ/kg as received) or energy density, E_{ar} (kWh/ m ³ loose)	Recommended to be informed by retailer.
	Bulk density as received (kg/m ³ loose)	Recommended to be stated if traded by volume basis
	Chlorine, Cl (weight of dry basis, w-%)	Recommended to be stated as a category Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10+ (if Cl > 0,10 % the actual value to be stated)
^a Maximum 20 w-% of the pellets may have a length of 7,5 x Diameter.		

Table 5. Specification of properties for straw bales [5]

	Master table			
	Origin: According to Table 1.		2.1.1.2 Cereal crop straw 2.1.2.2 Grass straw 2.1.3.2 Oil seed crops stalks and leaves	
	Traded Form		Big Bale	
Normative	Dimensions (mm), height (L_1), width (L_2) and length (L_3)			
				
		Height (L_1)	Width (L_2)	Length (L_3)
	P1	1 300	1 200	2 200
	P2	1 300	1 200	2 400
	P3	600 to 900	1 200	2 400
	P4	1 300	1 200	1 100 to 2 750
	Bale density (kg/m ³)			
	BD130	≤ 135		
	BD150	≤ 150		
	BD165	≤ 165		
	BD165+	> 165		
	Moisture (w-% as received)			
	M16	≤ 16 %	No part over 23 %	
	M16+	≤ 16 %	Parts over 23 % acceptable	
	M23	≤ 23 %	no part over 30 %	
	M23+	≤ 23 %	one or more parts over 30 %	
M30	≤ 30 %	no part over 35 %		
M30+	≤ 30 %	one or more parts over 35 %		
Ash (w-% of dry basis)				
A05	≤ 5 %			
A10	≤ 10 %			
A10+	> 10 %			
Species of biomass				
Has to be stated				
Informative	Net calorific value, $q_{p,net,ar}$ (MJ/kg as received or energy density, E_{ar} (kWh/m ³ loose)		Recommended to be specified.	
	Particle size distribution or structure		It is recommended to declare production methods that influence the size of the straw particles. That is for instance whether the crop has been trashed by rotation or oscillation or whether it has been chopped.	

The following European examples are specifications for high quality classes of solid biofuels recommended for household usage. Household usage needs special considerations for the following reasons:

- Small-scale equipment does not usually have advanced control and gas cleaning
- Unprofessional management
- Often located in living and populated districts.

A.1 Wood briquettes

Origin:	1.2.1.1 Chemically untreated wood without bark (Table 1)
Moisture content:	M10 (moisture ≤ 10 w-% as received)
Basic density:	DE1.0 (particle density min. 1 to 1,09 kg/dm ³)
Dimensions:	to be selected from Table 3
Ash content:	A0.7 ($\leq 0,7$ w-% of dry basis)
Additives:	<2 w-% of dry basis. Only products from the primarily agricultural and forest biomass that are not chemically modified are approved to be added as a pressing aids. Type and amount of additive has to be stated.
Net calorific value:	E4.7 [kWh/kg] ($q_{p,net,ar} \geq 4,7$ kWh/kg = 16,9 MJ/kg)

A.2 Wood pellets

Origin:	1.2.1.1 Chemically untreated wood without bark
Moisture content:	M10 (moisture ≤ 10 w-% as received)
Mechanical durability:	DU97.5 (97,5 w-% of a pellet batch of 100 g shall be uncrushed after testing)
Amount of fines:	F1.0 or F2.0 (percentage of fines among pellets sieved through > 3.15 mm sieve shall not exceed 1 or 2 w-% at factory gate)
Dimensions:	D06 or D08 (pellet diameter 6 mm ± 0.5 mm and length <5 x diameter or diameter 8 ± 0.5 mm, and length <4 x diameter, max. 20% of the pellets may have a length of 7.5 x diameter)
Ash content:	A0.7 (< 0.7 w-% of dry matter)
Sulphur content:	S0.05 ($<0,05$ w-% of dry matter)
Additives:	<2 w-% of pressing mass. Only products from the primarily agricultural and forest biomass that are not chemically modified are approved to be added as a pressing aids. Type and amount of additive has to be stated.
Energy density:	E4.7 [kWh/kg] ($q_{p,net,ar} \geq 4,7$ kWh/kg = 16,9 MJ/kg)

A.3 Wood chips

Origin:	1.1.2 Stem wood (Table 1)
Moisture content:	M20 or M30
Dimensions:	P16, P45 or P63
Energy density:	E0.9 [kWh/loose m ³] ($E_{ar} \geq 900$ kWh/loose m ³)

A.4 Log wood (oven-ready) [5]

Origin:	1.1.2 Stem wood (Table 1)
Moisture content:	M20 (moisture ≤ 20 w-% as received)

Dimensions:	P200, P250, P500 or P1000 (length [L] and thickness [D] (maximum diameter of a single chop: $L < 200$ mm and $D < 20$ mm ignition wood, $L = 250$ mm ± 20 mm and 40 mm $\leq D \leq 150$ mm, $L = 500$ mm ± 40 mm and 60 mm $\leq D \leq 250$ mm, $L = 1000$ mm ± 50 mm and 60 mm $\leq D \leq 350$ mm)
Wood:	To be stated if coniferous or deciduous wood is used
Classification:	No significant amount of mould or decay seen, the cut-off surface of the logs are even and smooth.
Energy density:	For deciduous wood E1700 [kWh/stacked m ³] ($E_{ar} \geq 1700$ kWh/stacked m ³) or for coniferous or for mixture of deciduous and coniferous wood E1300 ($E_{ar} \geq 1300$ kWh/stacked m ³)

Technologies of biomass utilization are mostly at the beginning of their development in Ukraine, but they have good prospects for commercialization in the near future [6].

Conclusion

- The purpose of quality classification and specification of solid biofuels is to determinate their quality within whole supply chain from origin until the certificated solid biofuel delivery and to assure corresponding confidence to the qualitative requirements. This is a basis for market preparation and development with solid biofuels. Requirements for production will be met through assurance of quality and its control. Principle of the solid fuel quality assurance is based on its clearly defined determination and limited demands for product.
- Development of bioenergy technologies would reduce Ukraine dependence on imported energy carriers, enhance its energy security at the expense of organizing energy supply based on local renewable sources, create a lot of new jobs (mostly in rural area), contribute greatly to the improvement of ecological situation.

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