Considerations for Grading Agricultural Residue

July 24, 2013

Dr. Staffan Melin

Table of Contents

continued on next page

Table of Contents (continued)

Preface

In 2010, the Ontario Federation of Agriculture (OFA) received Agriculture and Agri-Food Canada (AAFC) funding through the Canadian Agricultural Adaptation Council (CAAP) to conduct producer level research and value chain determination, including this report on “Considerations for Grading Agricultural Biomass”. This report is available on the OFA website along with other biomass studies. Please visit www.ofa.on.ca/issues/overview/biomass to access these previous studies including this report.

Based on an Ontario Government Directive to the Ontario Power Generator requesting that the use of coal to generate electricity be stopped by 2014, four power stations were affected. Two stations in Southern Ontario were identified for use of alternative fuels such as those originating from agricultural biomass. The most northern stations would focus on the use of woody biomass.

The OPG had estimated a need for more than 2 million tonnes annually of biomass to co-fire with natural gas at its facilities. In preparation for the production and marketing of biomass, this study was initiated to bring together all the considerations that go into a fuel grade standard for biomass pellets. Delta Research Corporation proceeded to prepare this report based on lessons learned by the forestry sector, already exporting biofuels to Europe for generation of heat and power since 1997.

In earlier studies, the OFA examined a business case for purpose-grown biomass as a fuel and the availability of agricultural crop residues to supplement purpose grown biomass in Ontario. Together agricultural sources create a formidable supply opportunity to support combustion markets at a provincial or local level. These opportunities result in new income for producers. A grading system focused on agricultural materials yet compatible with woody biomass standards would enable an orderly and efficient marketing for agricultural biomass.

In January 2013, the Ontario Government announced it was no longer proceeding with the conversion of its southern Ontario coal facilities as these would be shutdown. Consequently, opportunities for use of biomass are now limited to the Atikokan facility. The agricultural sector in Northern Ontario may be able to participate while Southern Ontario producers will need to find new local combustion markets such as district heating and participate in the rapidly increasing demand for biofuels in Europe and USA.

Hence, this study is not only timely but also provides insights to issues that need to be addressed as agricultural biomass supplies are to be aggregated for fuel consumption purposes.

The OFA wishes to thank Delta Research Corporation for the preparation of this comprehensive report which has provided us with many insights on the development of standards and marketing issues based on experience and knowledge of the domestic and export sector. Delta Research has leading expertise in development of the new international fuel standards soon to be published under ISO for woody as well as agricultural solid biofuels. Delta Research is also engaged in many of the leading research projects for the next generation biofuels on federal and university level in Europe as well as in Canada.

Investment in this project has been provided by Agriculture and Agri-Food Canada through the Canadian Agricultural Adaptation Program (CAAP). In Ontario, this program is delivered by the Agricultural Adaptation Council.

AAC
agricultural adaptation council

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Executive Summary

This document is reporting on a study conducted by Delta Research Corporation (DRC) with the objective to explore the standards established in the market for biomass and to define considerations for how to grade agricultural residue to be compatible with current applications, primarily in the energy sector. The intent is to increase the revenue for members of the Ontario Federation of Agriculture using materials which today are not used or in some cases represent a cost for disposal for farmers.

The study has identified the ISO Solid Biofuels Standards as a well developed product quality classification system for woody as well as agricultural biomass with supporting testing procedures. These Standards currently are the basis for the rapidly escalating wood pellets industry in Europe and North America feeding large amounts of biofuels to the power utilities in Europe. The trade does not include agricultural feedstock at this time. Advanced research in Canada as well as in Europe on developing pre-treatment and processing technology for upgrading the agricultural material to a similar quality as the woody materials is well underway. Several processes such as extraction of nutrients by means of washing and thermal treatment for enrichment of carbon content are highly interesting for agricultural feedstock in order to reach desired characteristics. Leading edge research has been identified in Canada as well as in Europe and is described in the report.

There are other than energy application areas for developing agricultural residue materials such as bio-refining to produce chemicals, bio-materials and pharmaceuticals but standards for quality or grading feedstock have not yet emerged from those markets. However, practically all applications require densification of the raw materials as well as the deliverable product in order to be economically viable due to the low density of biomass. Non-energy applications will benefit from quality standards very similar to those already in place for biofuels. Specification of chemical composition, physical attributes such as particle size and thermo-kinetic characteristics are essential for practically all applications.

Quality and sustainability certification systems are also in place applicable to woody as well as to agricultural feedstock materials.

A strategic techno-economic plan may be developed for the Province of Ontario with the following building blocks:

- Availability data for agricultural crop and price modelling
- Selected ISO Standards for agricultural biomass
- Results from pre-treatment research such as the CEATI and SECTOR projects
- Environmental and climate change objectives for the Province of Ontario

The ISO Standards could be the reference framework or filter for sourcing of materials, determination of pre-treatment required and determination of suitability for energy conversion or other selected applications. Since the use of biomass in energy applications is well developed with a substantial commercial demand, it seems like the use of agricultural biomass for production of power is a logical choice to start development.

1 - Introduction

The establishment of standards is vital for today's trade, safety and public well-being. Without standards the economic development we have experienced for the last 100 years would not have been possible. The energy sector is a prime example of success, at least on a continental basis with standards for voltage, AC frequency, plugs and receptacle, transmission lines, equipment safety certification, etc.

Since the 1960's, with the introduction of renewable energy and fuels in Europe, the need for quality and testing standards has gradually become a pressing issue, not only for suppliers and users but also for stakeholders up-stream such as forest owners and more recently farmers. Without standards we would not have large scale trade of biofuels and combustion equipment among continents today. Neither would we be able to implement regulatory systems for monitoring the environment and climate change. There is still much work on standards to be done and there is an estimated 6,000 experts worldwide engaged in the International Standards Organization (ISO), just to mention one of the many organizations involved. All standards development in Canada is governed by the National Standards System (NSS) and is done on a voluntary basis under the auspices of Standards Council of Canada (SCC), including quality and testing standards for bioenergy and biofuels. SCC overseas more than 350 organizations with more than 15,000 volunteers and SCC is a member of ISO. SCC is supporting the effort under way for implementation of ISO standards for biofuels in Canada. The effort also includes harmonization with locally established standards across Canada.

The objective of this study has been to provide a global perspective on agricultural biofuels and develop an understanding of what options exist for grading agricultural residue material to match specifications required for various applications in Canada as well as internationally. The project is part of the Grow The Margin (GTM) effort under way by OFA for its members with the overall objective to identify new opportunities for revenue from crop residue or alternative crop currently not grown.

The study has focused primarily on current market opportunities where quality specifications already exist but agricultural residue is not yet used to any significant degree. Besides the identification of standards, specifications and certification systems already in existence or in the planning stage, the report also provides a general overview of issues related to sourcing, manufacturing, handling, storage and related safety issues to consider. The study also touches on the domestic as well as the international market opportunities and therefore is covering the entire scope of grading requirements in an international setting.

The most significant short term market opportunity for agricultural biomass is for energy production since it is already a highly structured market with well established material classification and product quality specifications for a large variety of feedstock materials, including agricultural residue and purposely grown crop. Selection of solid biofuels has traditionally been governed by economics and characteristics of the material in terms of combustability. The availability has become more of an issue as the industrial use has rapidly increased and the solid biofuels have been commoditized as pellets or briquettes. Since biomass for the most part is not located where the majority of the end users are located, there is a demand for densification of the material and extensive and sophisticated logistics to bring the products to where they need to be. Product standards and generally accepted testing standards have become crucial for quality assurance. Obviously this is nothing new for the agricultural industry as it applies also to food production. However, the link from agricultural feedstock to other uses than food production still needs to be developed. This study is primarily an inventory of quality and testing standards developed for energy applications. These standards would also be applicable to a large extent for use of agricultural feedstock as raw material for extraction or conversion to bio-chemicals and bio-materials. The selection of material for a particular application is determined by the chemical composition, level of contamination and the physical characteristics. Much of the report is focusing on various quality and testing standards and certification systems in place for conformity with established high volume applications.

A number of conversion technologies are also described to provide a perspective on pre-treatments available for conversion to higher value commodities.

2 – Availability of Biomass in Canada

Traditionally the woody biomass is used for production of commodities such as lumber, pulp, paper and board products. Residue from saw mills, planer mills and hogging operations has been the primary feedstock for energy applications. Gradually, the use of the woody resource has changed in the last 5 years. Today a substantial portion of the feedstock used for pellets and briquettes production comes from harvested trees of lower quality or harvest residue from quality timber logging operations. Also, purposely grown crops like willow and hybrid poplar are subject to intense evaluation since they would provide a very predictable crop cycle and could be cultivated on marginal land.

Agricultural biomass has traditionally been used as a source for food production and has not been used extensively as an industrial fuel product even though the fibre volume is plentiful in many parts of Canada. There are other large scale uses for agricultural biomass such as bio-refining for production of chemicals, pharmaceuticals and biomaterials although it will take time before the demand for feedstock will be significant in those sectors.

Peat biomass is another resource of significance as a potential industrial fuel in Canada although it does not have the same environmental approval as woody biomass and agricultural biomass since it has a cycle time of approximately 50,000 years. International movements are however under way to upgrade peat to partially renewable.

2.1 Woody Biomass

Much has been written about the availability of woody biomass in Canada. The statistics are traditionally sourced from the forest industry operators and used for positioning when bargaining for more fibre at lowest possible price in return for creating jobs. Typically only the stems of the trees are counted for production of dimension lumber and pulp. The stems represent only about 50% of the biomass volume of a tree. In addition, government revenue policy has an impact on how much of the forest is made available and allowed to be harvested. Purposely grown trees such as hybrid poplar and willow are sources of biomass not usually counted as a potential resource. The bottom line is that the price the end user is prepared to pay for a product determines how much biomass can be sourced and therefore most availability evaluations are misleading.

The actual pellets production rate in Canada reached 2,035,000 metric tonne per year in 2012 and is expected to double within the next 3 years. The products are 95% fuel pellets and the remainder animal bedding and other absorbents. The consumption of Canadian wood pellets in 2012 and the projected consumption in 2015 are summarized in the Table 2.1.1.

Table 2.1.1 Production Capacity Annual Rate for Fuel Pellets in December 2012

Region	# of Plants	Average Plant Size in Metric Tonne	Largest Plant Size in Metric Tonne	Total Production Capacity Rate in Metric Tonne	%
Western Canada	16	118,750	400,000	1,900,000	59
Eastern Canada	23	58,000	139,000	1,334,000	41
All of Canada	39	82,923	400,000	3,234,000	100

Table 2.1.2 illustrates the importance of having access to the foreign markets.

Table 2.1.2 Actual Fuel Pellets Shipments 2012 and Projection for 2015

Market	2012		2015 (Forecast)	
Europe	1,750,000	86%	3,200,000	82.2%
North America	120,000	6%	200,000	5.2%
Japan	65,000	3.1%	200,000	5.2%
South Korea	0	0%	200,000	5.2%
Canada	100,000	4.9%	200,000	5.2%
Total Worldwide	2,035,000	100%	3,900,000	100%

Wood Pellet Association of Canada (WPAC) had 24 producing and 36 associate members as of December 31, 2012. The producing members represent about 87% of the total manufacturing capacity of Canada. The Canadian pellets industry currently is estimated to employ 1,800 direct and indirect full time employees. This number would increase to approximately 3,000 if the forecast for 2015 is realized.

However, with incentives in place on a federal level and provincial level, the direction of sale could shift dramatically in favour of the local Canadian market. A potential new federal policy forcing the power companies to close old coal burning plants or start co-firing coal and biomass would generate a huge domestic market. At the present time the carbon credits generated by the Canadian pellets industry are effectively "donated" free of charge to the users of the wood pellets in the European market. If a new domestic market becomes a reality, there would be a surge for not only woody but also for agricultural biofuels. Significant research is currently conducted to prepare for such transition.

2.2 Agricultural Biomass

In much of the literature agricultural material is called "non-woody material" or sometimes "agri-materials" or "agro-materials", which mean the same thing.

Determination of the agricultural biomass potentially economically available for new applications is difficult at best due to a number of factors:

- Fluctuation from one year to the next due to natural cycles caused by weather and other factors
- Effect of climate change on crop yield
- Un-predictable attacks by pests
- Changes in selection of crop by farmers due to market economics
- Lack of quality standards
- Level of contamination as a result of harvesting techniques vary widely
- Chemical composition vary widely from one species to another of agricultural feedstock

Canada has 68 million ha of farmland and USA in comparison has 377 million ha. The Biomass Inventory Mapping and Analysis Tool (BIMAT) developed by Agriculture and AgriFood Canada (AAFC) estimate approximately 68 million ha of farmland in Canada with an average crop yield of 6 tonne/ha/year. If 10% of this area would be used for growing crop for energy purposes, the available biomass would be 40.8 million tonne, which corresponds to approximately 180,000 GWh of heat energy using an average conversion factor of 4.445 GJ/tonne.

Canada has a mix of agriculture crop adapted to the climatic conditions from east to west. Table 2.2.1 estimates the crop residue based on a 50% removal from the fields and also translates

Table 2.2.1 Estimate of Available Agricultural Crop Residue by Species in Canada 2007 (CanmetEnergy)

Canadian 2007 Crop Residue	Removable Residue (50% Removal)		
	1,000 Tonne	% of Total	Energy GWh
Wheat	8,423	32.67	37,440
Oats	1,972	7.65	8,766
Barley	4,613	17.89	20,505
Grain corn	4,892	18.97	21,745
Mixed grain	110	0.43	489
Canola	3,675	14.25	16,335
Soybeans	1,132	4.39	5,032
Flaxseed	266	1.03	1,182
Rye	98	0.38	436
Tame hay	541	2.10	2,405
Fodder corn	64	0.25	284
Total	25,786	100.00	114,619

Energy in calorific heat value
Tonne in dry metric tonne
Average 4.445 MWh/tonne biomass

the amount to a corresponding calorific energy (heat) value.

Table 2.2.2 estimates the agricultural residue per province and identifies which species of crop the majority of the residue comes from. This table also includes the estimated milling residue available for energy purposes per province and also translates the amount to a corresponding calorific energy (heat) value.

The following criteria are essential when evaluating the viability of agricultural biomass for production of industrial products such as biofuels

- Chemical characteristics (low ash melting temperature - risk for fouling, slagging, corrosion), potential for washing of alkali-minerals over winter

Table 2.2.2 Estimate of Available Agricultural Crop Residue by Species in Canada 2007 (CanmetEnergy)

Canadian 2007 Crop Residue	Removable Residue (50% Removal)			Milling Residue		Total	
	1,000 Tonne	% of Total	Energy GWh	1,000 Tonne	Energy GWh	1,000 Tonne	Energy GWh
Newfoundland and Labrador	0	0.00	tame hay				
Prince Edward Island	72	0.28	54 % barley				
			19 % wheat				
Nova Scotia	26	0.10	46 % grain				
			26 % tame hay				
New Brunswick	47	0.18	41 % barley				
			21 % oats				
Quebec	2,364	9.17	73 % grain corn	733	3,258	3,097	13,768
			26 % soybeans				
Ontario	4,725	18.32	62 % grain corn	1,661	7,383	6,386	28,384
			18 % soybeans				
Manitoba	3,512	13.62	38 % wheat	1,409	6,263	4,921	21,873
			21 % canola				
Saskatchewan	8,486	32.91	45 % wheat	3,158	14,037	11,644	51,758
			20 % canola				
Alberta	6,435	24.96	39 % wheat	1,880	8,357	8,315	36,962
			33 % braley				
British Columbia	119	0.46	24 % tame hay				
			20 % barley				
Total	25,786	100.00		8,841	39,298	34,363	152,744

Energy in calorific heat value
Tonne in dry metric tonne
Average 4.445 MWh/tonne biomass

- Moisture content (need for drying)
- Demand for water during cultivation
- Harvesting technique, yield and risk for contamination
- Pelletization characteristics (binding characteristics, abration)
- Availablility on annual basis and over several seasons
- Potential for conflict with food and animal feed production

Appendix F is a Canmet database for agricultural materials as well as peat and lignite. The values are averages of a number of representative samples.

2.3 Peat Biomass

Peatland covers approximately 3% of the earth's land area and about 12% of the Canadian land base. The global inventory of peatland is summarized in Table 2.3.1 and estimated to over 3 million km^2.

Table 2.3.1 Global Inventory of Peatlands

Country	Total Peatland Area in km^2
Canada	1,114,000
Europe (incl. Russia)	893,000
USA	611,000
China	10,000
Asia (tropical)	227,000
Other (mainly tropical)	150,000
World total	3,005,000

Peatland or bog is typically defined as areas with deposits deeper than 40 cm. Peatlands is an integral part of what is called wetlands which also include fen, marsh and shallow open water. The above numbers only include peatlands. The wetlands would include an additional 25% of the global land area.

The total volume of peat in the world is estimated at 3,500-4,000 billion m^3 or 420-480 billion tonne using an estimated bulk density of 120 kg/m^3 for bone dry peat. Only about 17 million tonne per annum is harvested and used for commercial purposes and is harvested from small areas of peatlands.

It is estimated that about 50% of the organic carbon in the earth biosphere is contained in the peatlands and for Canada the equivalent number is estimated to about 56%. The biomass contained in the forest constitute about half as much as is contained in the peatlands. The peatlands have been sequestering enormous amount of carbon but as the climate changes to a drier and warmer regime, particularly in the northern polar regions, peat gradually becomes exposed to air which starts an aerobic decomposition which generates primarily CO_2 as well as CH_4 (methane). The radiative effectiveness of methane trapping heat is 21 times higher than CO_2. The climate change in combination with industrial land use (for example the mining of tar sands in Alberta) is expected over time to have a profound effect on the peatlands in Canada and eventually turn the peatlands in to net GHG emitters.

There are essentially two different types of peat traded in North America. The Sphagnum Peat produced primarily in Canada has the highest quality and consists of weakly decomposed sphagnum moss. The Hypnum Peat produced primarily in USA consists of reed-sedge and is considered to be of lower quality.

An estimated 10 million m^3 or 1.2 million tonne per year is mined and sold as soil improvement and for horticultural applications in Canada. The generation rate in Canada is about 60 times the amount harvested which is the major argument for trying to classify peat as renewable. An estimated 70 million tonne of peat is estimated to be generated in Canada per annum. The argument is however challenged by the fact that significant peatland is destroyed by land development and climate change, factors that are difficult to accurately quantify. In order to assess the total impact of harvesting peat, a project was conducted in 1991 by the Canadian Sphagnum Peat Moss Association (CSPMA), the Department of Natural Resources and Energy and the Secretariat to the North American Wetlands Conservation Council (Canada).

Significant restoration research has been conducted by University of Laval (Quebec) with a special Chair (Dr. Line Rochefort) has been instituted in the Peatland Management discipline. The Peatland Ecology Research Group (PERG) was formed in 1992 to conduct applied research.

The oxidation of only 1% of the peatland carbon in Canada would correspond to 10 times the entire emission of anthropogenic CO_2 in Canada during the year 2000.

The distribution of the peatland in Canada can be viewed at the following website: http://tsdmaps.gsc.nrcan.gc.ca/website/_peatland/peatland_e.htm The province in Canada with the largest area of peatland is Ontario as can be seen in Table 2.3.2. (see the following table).

The harvesting season for peat is limited to the period between mid May to mid September in Canada.

The International Peat Society has initiated a project to establish a certification system for production of peat product to address among other things concern related to aerobic decomposition as a result of ditching during harvesting of sod peat as well as draining of peatlands for land development. The International Panel on Climate Change (IPCC) declared in 1996 that peat was a fossil fuel, but in the 2006 report it is no longer classified as a fossil fuel.

The NT ENVIR 009 Quality Guidelines for Fuel Peat (2005-11) includes quality classification standards for peat in pellet and briquette form.

Peat is a highly explosive material when handled in non-densified form.

Table 2.3.2 Distribution of Peatlands in Canada

Province or Territory	Peatland Area		Wetland Area	
	ha x 000,000	% of Total Area	ha x 000,000	% of Total Area
Alberta	18.0	27.2	23.3	35.2
British Columbia	4.9	5.1	5.3	5.6
Manitoba	19.2	29.5	23.3	35.9
New Brunswick	0.2	4.4	0.3	5.6
Newfoundland-Labrador	5.4	13.4	6.8	16.8
Northwest Territories & Nunavut	16.9	4.9	27.8	8.1
Nova Scotia	0.4	6.3	0.6	10.5
Ontario	31.3	29.3	33.5	31.3
Prince Edward Island	<0.01	<1	0.07	<1
Quebec	11.2	7.2	15.8	7.9
Saskatchewan	4.9	7.5	9.7	14.8
Yukon Territory	1.1	2.3	1.5	3.4
Canada	113.4	11.4	147.9	14.4

3 – Challenges with Agricultural Biomass for Energy Applications

For thermal applications whereby the biomass material is heated or combusted, there are several challenges. The amount of water and ash as well as the melting temperature of ash are critical for the performance of the energy conversion. Also, the balance of the fundamental components carbon, oxygen, nitrogen and hydrogen impacts the calorific yield and the emission spectrum of the conversion process. Biomass generally consists of 50% carbon, 40-43% oxygen and the balance hydrogen, nitrogen, sulphur and trace elements. Some mitigating measures can be taken to change the behaviour of the biomass during the conversion process. These measures may change the classification (grading) of the biomass and are important to consider when producing biofuels to specified standards.

3.1 Ash-melting Temperature

Table 3.1.1 is an excerpt from Mixbiopells Report (switchgrass data is from various other sources) and is listing the main ash components of significance for ash melting behaviour in a selection of biomass materials.

Appendix F is a Canmet database for agricultural materials as well as peat and lignite. The values are averages of a number of representative samples.

Table 3.1.1 Ash Related Parameters of Raw Agricultural Biomass in mg/kg Dry Basis

Raw Agricultural Biomass Composition in mg/kg Dry Basis								
Species	Al	Ca	Fe	K	Mg	Na	Si	Ti
Miscanthus	791	1600–1790	92–120	3410–7200	300–600	31.51	39301	4–40
Switchgrass	700	5100	500	3900	1400	100	17900	10
Reed canary grass	200–600	900–2000	13849	2300–4330	600–730	200–350	22280–22800	360
Hemp	111	13400	120	15400	2000	130	2100	0
Straw	60–130	2950–3300	120	7120–10000	630–1030	100–120	9000–19300	0
Vine pruning	140–774	4240–10900	390–625	2940–7660	820–840	180–415	4500–5350	64–66
Corn cobs	601	4001	701	85001	2901	<501	11001	2501
Corn stalks	140	7390	680	8190	500	800	14200	70
Cereal spilling	700	2050–5000	500	5380–1340	1170–1400	300	26100	10
Hay	200	5600	60	14000	1740	1000	15000	0
Rape straw	n.a.	n.a.	n.a.	58001	n.a.	1701	n.a.	n.a.
Rape press cake	13	3640–6500	0	8890–14100	220–4700	68	750	0
Grape marc	1330	200–6460	1140	7710–18160	60–1100	50–400	720–5260	90
Olive residue	868	7390	670	17000	353–500	46–500	2270–16620	11–80
Olive stones	410–1210	2640–7110	240–800	2550–19340	860	550	6240	90
Almond shells	2931	46501	2271	78701	6871	6421	22901	25.7
Shea waste	7101	30201	5701	381001	32001	1001	46301	500001
Carragenan waste	11401	199401	4401	47101	40001	17001	54701	1100001
Mash from breweries	20–100	4600–5530	4401	700–1340	2500–4780	2001	830–15990	0
Digestate	1940–5300	5800–28900	200–3600	3540–15000	1140–3000	3000–6550	7200–30600	1970
Peat	8000	4600	n.a.	8000–58000	1200	2207000–0	7900	0

Table 3.1.2 Melting Temperature of Salts (from DRC CANFOR Report 2004)

Elemental Component	Ash Compound	CAS	Chemical Formula	Melting Temp. °C	Boiling Temp. °C
Phosphorus	Phosphorous oxide	1314-24-5	P_2O_3	23.8	173
	Phosphorous oxide	1314-56-3	P_2O_5	562	605
	Phosphorous chloride	10026-13-8	PCl_5	167	
	Phosphorous sulfide	12165-69-4	P_2S_3	290	490
		1314-80-3	P_2S_5	285	515
Sodium	Sodium superoxide	12034-12-7	NaO_2	552	
	Sodium chloride	7647-14-5	NaCl	801	
	Sodium carbonate	497-19-8	Na_2CO_3	858	
	Sodium sulphate	7757-82-6	Na_2SO_4	884	
	Sodium oxide	1313-59-3	Na_2O	1,132	
	Sodium metasilicate	6834-92-0	Na_2SiO_3	1,089	
Potassium	Potassium oxide	12136-45-7	K_2O	350	
	Potassium superoxide	12030-88-5	KO_2	380	
	Potassium chloride	7447-40-7	KCl	770	
	Potassium carbonate	584-08-7	K_2CO_3	891	
	Potassium sulfide	1312-73-8	K_2S	948	
	Potassium sulphate	7778-80-5	K_2SO_4	1,069	
Magnesium	Magnesium carbonate	546-93-0	$MgCO_3$	350	
	Magnesium chloride	7786-30-3	$MgCl_2$	714	
	Magnesium sulphate	7487-88-9	$MgSO_4$	1,124	
	Magnesium oxide	130948-4	MgO	2,582	
Barium	Barium oxide	1304-28-5	BaO	1,973	
	Barium chloride	10361-37-2	$BaCl_2$	962	
	Barium sulfide	21109-95-5	BaS	2,230	
Calcium	Calcium oxide	1305-78-8	CaO	2,899	
	Calcium chloride	10043-52-4	$CaCl_2$	775	
	Calcium sulphate	7778-18-9	$CaSO_4$	1,460	
	Calcium sulfide	20548-54-3	CaS	2,525	
Titanium	Titanium dioxide	13463-67-7	TiO_2	1,843	
	Titanium chloride	7550-45-0	$TiCl_4$	-25	
		10049-06-6	$TiCl_2$	1,035	
	Titanium sulfide	12039-07-5	TiS	1,780	
Iron	Iron oxide	1309-37-1	Fe_2O_3	1,565	
	Iron chloride	7758-94-3	$FeCl_2$	677	
	Iron sulfide	1317-37-9	FeS	1,188	
Aluminum	Aluminum oxide	1344-28-1	Al_2O_3	3,000	
	Aluminum chloride	7446-70-0	$AlCl_3$	192.6	
	Aluminum sulfide	1302-81-4	Al_2S_3	1,100	
	Aluminum sulphate	10043-01-3	$Al_2(SO_4)_3$	1,040	
Manganese	Manganese oxide	1344-43-0	MnO	1,840	
	Manganese chloride	7773-01-5	$MnCl_1$	650	
	Manganese sulphate	7785-87-7	$MnSO_4$	700	
	Manganese sulphide α	18820-29-6	MnS	1,610	
Silicon	Silicon dioxide α	14808-60-7	SiO_2	573	
	β	14808-60-7	SiO_2	867	
	γ	15468-32-3	SiO_2	1,470	
	Silicon monosulfide	50927-81-6	SiS	900	
	Silicon disulfide	13759-10-9	SiS_2	1,090	

Table 3.1.2 is listing the melting temperatures for salts contained in ash. Of particular importance is the percentage of salts with very low melting temperature such as potassium oxide and superoxide, phosphorous oxide, magnesium carbonate, sodium superoxide and silicon dioxide. The agglomeration of ash during combustion is a complex process with interaction between many different mineral components and is subject to experimentation with slag inhibiters or additives to find optimum blending ratio (see Section 3.1.2).

The ISO FDIS 17225-1 (excerpt is found in Appendix B) is another source of information for biomass categorization and chemical characteristics of non-woody biomass which indicates the relative presence of the minerals established as typical based on a large number of data from around the world.

Ash-melting temperatures less than +900°C is often problematic since some of the ash components become soft and sticky and adhere easily to colder surfaces in the furnace below that temperature. The ash molecules have electro-negative polarity and are reacting with the metal surface causing transport of ions, which essentially is migration of molecules away from the metal surface. This migration is called corrosion. Depending on the quality of the metal used in furnaces, the corrosion can be quite severe in a short period of time. Milder steel is the most sensitive to corrosion. Fouling and scaling are other phenomena caused by agglomeration of salts on the surface of tubes and surfaces in furnaces or boilers. The higher quality fuels have higher ash melting temperature, often in the range of +1,200 to 1,350°C.

The EN 15370-1 Standard for Determination of Ash Melting Behaviour has been found to be flawed and is currently amended and will be published as an ISO Standard during 2014. Canada is chairing this development and will release information when the new text has been released.

3.1.1 Additives and Binders in Feedstock

Certain additives can be blended with feedstock to increase the ash melting temperature and improve the mechanical durability of pellets and briquettes. The international ISO biofuels standards do allow a certain amount of additives or binders. According to the ISO FDIS 17225 Standards, the allowable amount of additives of binders for graded wood pellets and wood briquettes is 2% of weight and for graded non-woody (agricultural) pellets or briquettes the number is 5% of weight.

At the same time the ISO FDIS 17225 Standards stipulate maximum allowable ash content which means that there has to be careful consideration which additive or binder to use to make sure the maximum ash content is not exceeded. Some additives or binders have a significant mineral content which will add to the ash content after combustion and others are biogenic and are consumed as part of the combustion.

Some of the biogenic additives or binders are bio-degradable and will add to the natural decomposition of fuel and may cause rancidity and generation of carbon-monoxide and unpleasant malodorous gases during storage which shortens the shelf-life of the fuel.

The research conducted on the efficacy of additives and binders has so far only been limited exploration of a number of different compounds. The research has recently become very active in an effort to increase the mechanical durability of torrefied pellets or briquettes and also to increase the ash melting temperature for non-woody (agricultural) pellets and briquettes. Some of the findings are discussed in the following sections. However, no clear guidelines have been developed and the experiments have not always been conducted under controlled and comparable conditions.

For estimation purposes Table 3.1.1.1 summarizes typical elemental compositions for pellets with some common binders. Typical values for wood pellets are included for reference. Some of the salts of the elements vaporizes long before combustion has been completed which accounts for the discrepancy in total ash content when adding up the elements. Table 3.1.2 provides a perspective on which elemental components (salts) are likely to vaporize.

3.1.1.1 Binders to Improve Mechanical Durability

The most common binders tested so far are ligno-sulfonates, starches (potato peel, potato flour, maize starch, corn starch, wheat starch, vegetable and mineral oils, sodium carbonate, urea, glycerol and various forms of lignin).
It appears as if potato flour is the most cost effective and contains a relatively small amount of alkali-minerals such as potassium. Durability improvements of 1 percent or more (measured in accordance with ISO/EN 17831-1) have been recorded for wood pellets (Diagram 3.1.1.1.1) depending on type of binder and ratio of blending with the feedstock. Very limited research has been found relating to non-woody (agricultural) pellets.

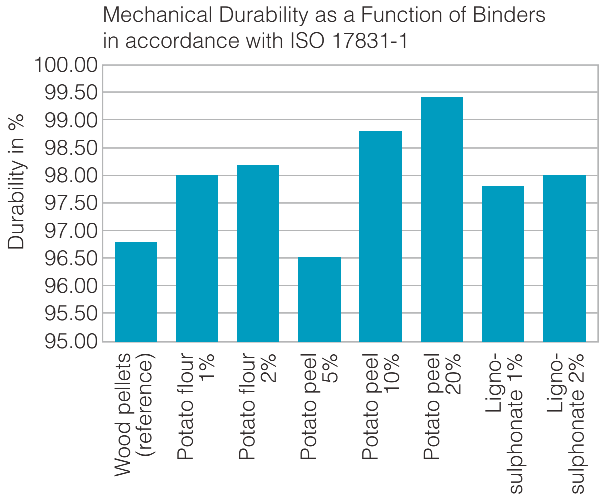


Diagram 3.1.1.1.1 Mechanical Durability of Wood Pellets

(M. Kuokkanen, Bioresources, Additives in Wood Pellets Production – A Pilot-scale Study of Binding Agent Usage).

Table 3.1.1.1 Elemental Composition of Wood Pellets with Typical Binders

Elemental Composition of Wood Pellets with Additives in g/kg of Dry Weight								
	Na	K	Ca	Fe	P	N	S	Ash (%)
Wood pellets (no additive)	0.03	0.32	0.63	0.06	0.05	0.06	0.06	0.50
Wood pellets with 1% potato flour	0.03	0.33	0.65	0.07	0.05	0.05	0.05	0.50
Wood pellets with 2% potato flour	0.03	0.33	0.65	0.07	0.06	0.03	0.05	0.60
Potato peel residue (additive)	0.07	17.47	0.69	0.33	1.81	1.59	1.04	6.90
Potato peel residue 5%	0.03	0.59	0.63	0.11	0.07	0.11	0.07	0.60
Potato peel residue 10%	0.03	1.12	0.64	0.11	0.13	0.11	0.10	0.80
Potato peel residue 20%	0.03	1.73	0.65	0.18	0.20	0.15	0.13	0.90
Lignosulfonate 1%	0.10	0.36	1.13	0.07	0.06	0.17	0.57	0.60
Lignosulfonate 2%	0.12	0.33	1.50	0.06	0.05	0.07	0.99	0.80
ISO FDIS 17225-2 limits						30.00	0.50	0.70
Typical Values	0.02	0.04	0.90	0.03	0.06	10.00	0.20	0.30

Densification of agri-materials is nothing new in the agriculture industry since alfalfa pellets/cubes/briquettes and grain screening pellets have been produced for many years using similar equipment as the biofuels industry. It has been found that feedstock with a wide particle size spectrum are more difficult to densify. Also, biomass with lesser amount of lignin tends to be more difficult to compress to pellets or briquettes since the lignin acts as binding agent. The following Tables 3.1.1.1.2 and 3.1.1.1.3 illustrate typical structural composition of wood materials.

Table 3.1.1.1.4 provides typical structural composition of some common agricultural materials.

Table 3.1.1.1.2 Typical Composition of Wood Members (% of Bone Dry Material)

Species	Cellulose	Hemi-cellulose	Lignin	Extractives	Ash
Pine (70 years old)					
Trunk	41	27	28	3	1
Bark, inner	36	26	29	5	4
Bark, outer	25	20	48	3	4
Branches	32	32	31	4	1
Needles	29	25	28	13	5
Spruce (110 years old)					
Trunk	43	27	28	1	1
Bark	36	20	36	4	4
Branches	29	30	37	2	2
Needles	28	25	35	7	5

Table 3.1.1.1.3 Typical Average Composition of Wood (% of Bone Dry Material)

Species	Cellulose	Hemi-cellulose	Lignin	Extractives
Aspen	40	30	19	2
Birch	41	32	22	3
Spruce	42	28	27	2
Pine	40	28	28	4

Table 3.1.1.1.4 Typical Average Composition of Agricultural Species (% of Bone Dry Material)

Species	Cellulose	Hemi-cellulose	Lignin	Ash	Extractives
Switchgrass	36	28	26	3.5	6.5
Wheat Straw	42	20	20	6.5	11.5
Miscanthus	41	24	25	2.5	7.5
Sunflower Husks	27	15	24	5.0	29.0
Sorghum Seeds	75	5	5	1.5	13.5
Willow	28	18	36	1.5	6.5
Corn Stover	40	31	14	4.5	10.5
Canola Straw	38	23	20	6.5	12.5
Bagasse	40	23	24	3.5	9.5
Olive Residue	25	20	40	4.0	11

Moisture content and particle size distribution are the most important parameters determining the mechanical durability of pellets. A narrow size distribution in a top size range of 0.5-2 mm in combination with a feedstock of approximately 10% moisture prior to extrusion to pellets has been found to be the optimum.

Research indicates that torrefied wood with up to a carbon content corresponding to 22 GJ/tonne dry weight can be densified to acceptable durability (97.5% of higher in accordance with ISO/EN 17831-1) using only moisture as a binder. At higher carbon content other binders are required.

Some of the binders listed above acts as lubricants during the extrusion, some increases the calorific value and some have an impact on the off-gassing characteristics of the pellets or briquettes.

There is some concern regarding contamination of handling equipment if oil is used as binder since residual oil may leave behind a coating on conveyor belts, storage equipment and the inside of ocean vessel holds when pellets are handled in large quantities. Since equipment is often used for other commodities (for example ship loaders, rail cars, trucks, ocean vessels etc.) the cost for cleaning may become prohibitive.

3.1.1.2 Additives to Improve Ash Melting Temperature

Slagging inhibitor may be used to decrease the tendency of slagging, scaling, fouling and corrosion. Calcium in various forms such as lime, dolomite, kaolin, talcum and clay has successfully been used and are known to lift the melting temperature 100-200°C but are also adding to the ash content as well as to the cost. Additives may also increase the abrasion on production equipment such as pressing dies when blended in to the feedstock.

Very limited experimental data are available for comparing the effect on the ash melting temperature of the ash when blending additives to the feedstock. Diagram 3.1.1.2.1 provides some relative numbers for wood pellets and is indicating an increase of close to 150°C when using dolomite.

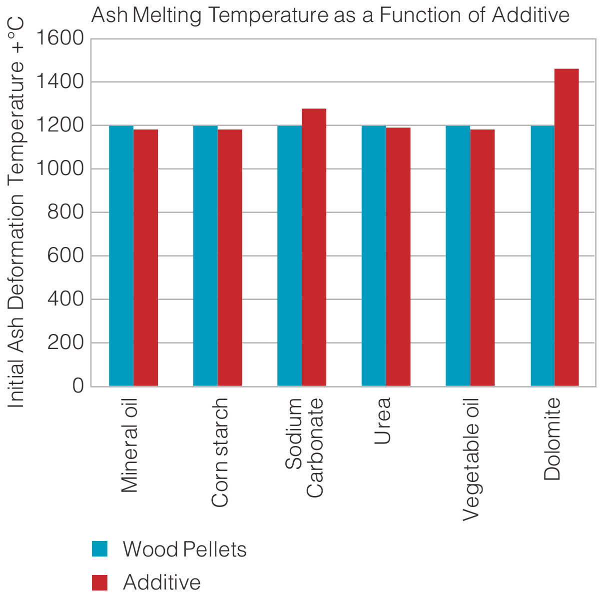


Diagram 3.1.1.2.1 Ash Melting Temperature for Wood Pellets with Different Additives

(R. Nosek, J Jandacka, University of Zilina, Slovakia)

As pointed out in Section 3.1.1.1 the mineral additives increase the ash content and have to be administrated with care in order to stay within the limits of the ISO FDIS 17225 Standards. For non-woody pellets the situation is not as critical since the Standard allows for a 5% ash content.

3.1.2 Additives During Combustion

A method called Chlorout developed by the power company Vattenfall is used in large industrial furnaces. Sulphur or ammonium-sulphate is injected in the hot combustion zone of the furnaces and converts the potassium oxides and chlorides to sulphates which have much higher ash melting temperature. The increased sulphur content is scrubbed from the flue gases. The ammonium portion reacts with the NO_x in the exhaust gas and converts it to inert nitrogen (N_2) as an added benefit and water. The sulphur in the flue gas is scrubbed. (see www.chlorout.com)

Table 3.1.2.1 is an excerpt from the Mixbiopells Report and is listing the main components of significance for combustibility of various agricultural biomass.

3.2 Heavy (Trace) Elements

Table 3.2.1 is an excerpt from Mixbiopells Report and is listing the most common trace elements (heavy metals) for the various biomass materials. ISO FDIS 17225-1 is also listing similar numbers intended as limit values as a standard. The concentration of trace elements is very much dependent on the soil condition where the biomass is growing and can very considerably. Trace mineral tests (so called minor element chemical analysis) are done to establish the level of trace metals in a biomass material. Washing of the feedstock can be done to minimize the content of trace elements (see Section 4.4).

3.3 Radio-active (Trace) Elements

A reference value for radiation from soil is estimated to be 100-700 Becqerel per kg (Bq/kg) in Canada. The radionuclides reach the human body via water and food from plants and animals. The most important nuclide is Potassium 40 (^{40}K). The radiation from an adult is 100 Bq/kg of which 60% comes from ^{40}K. As a consequence of

Table 3.1.2.1 Combustion Related Parameters of Agricultural Biomass

Species	Net calorific value MJ/kg db	Ash Content % db	Moisture Content %	Ash Melting Temperature (ID) °C	N % db	S % db	Cl % db
Miscanthus	17.5-17.9	1.6-3.0	7.5-14.0	820-1172	0.20-0.43	0.02-0.09	0.02-0.13
Switchgrass	17.7-18.5	2.0-10.0	5.0-10.0		0.30-0.50	0.03-0.09	0.01-0.19
Reed canary	17.5-19.0	4.5-6.0	10.0-15.0	1150-1650	0.30-0.6	0.07-0.08	0.03-0.04
Hemp	19.1-19.6	1.6-2.3	56.6	1200-1250	0.30-0.04	0.06-0.1	0.02-0.3
Straw	17.0-19.0	4.4-7.0	9.0-15.0	800-900	0.30-0.8	0.06-0.12	0.03-0.05
Vine pruning	17.5-18.2	2.2-3.5	15	795-1200	0.50-0.75	0.02	0.05-0.07
Corn cobs	16.5	1.0-3.0	6.0-7.0	1100	0.40-0.9	0.03	0.02
Corn stalks	16.6-.17.5	11.0-17.0	15.0-18.0	1250	0.70-0.9	0.08-0.1	n.a.
Cereal spilling	16.5	9.8-10.0	10.0-12.0	1055	1.20-1.7	0.2	0.16-0.3
Hay	18.3	5.5	15	820-1150	1.6	0.04	0.09
Rape straw	18.5	3.4	15.0-25.0	n.a.	1.48	0.2	n.a.
Rape press cake	20.8	6.5	9	860-1115	5.39	0.36	0.01
Grape marc	18.4-20.8	3.5-11.0	50.0-60.0	1300	1.80-2.2	0.09-0.13	0.02-0.03
Olive residue	17.9-18.3	9.0-12.0	35.0-45.0	1310	2.5	0.15	0.06
Olive stones	16.0-19.0	<1	10.0-12.0	n.a.	<0.01	n.a.	n.a.
Almond shells	17.9-18.6	9.0-12.0	35.0-45.0	1395	0.45-2.5	0.09-0.15	0.02-0.06
Shea waste	18.51	6.01	13.01	n.a.	2.601	0.301	0.101
Carragenan waste	16.61	10.01	80.01	n.a.	0.301	0.701	0.301
Mash from breweries	20	4	80	n.a.	3.3	0.2	0
Digestate	15.4	16.5	15.0-20.0	n.a.	2.2	0.6	0.56
Peat	16.5	4	10.0-17.0	n.a.	1.2	0.12	0.03

nuclear bomb tests the concentration of cesium 137 (^{137}Cs) has increased and accumulate in the upper layer of soil and is therefore entering the human body through the food chain. The addition of the ^{137}Cs is of particular concern since it is a contaminant primarily generated by human activity. During combustion of biomass there are three ash fractions generated, bottom ash, fly ash and aerosol ash (very fine fly ash). The bottom ash stays in the furnace until removed as part of the operational procedure. The fly ash contains the more volatile elements of the ash, including cadmium and zink. One of the most volatile elements is cesium which is enriched in the aerosols generated during combustion of biomass contaminated by ^{137}C.

The radionuclides in coal ashes in USA and Canada are reported to radiate on average 1,050 Bq/kg with most of it coming from uranium (^{238}U), thorium (^{232}Th) and their daughter nuclides. Ash from lignite has the highest radioactivity with somewhat lower activity in sub-bituminous and bituminous coal. Measurements of the radiation from pellets (not ash) produced from material sourced in geographic regions such as the interior of Western Canada indicated a very low level of radiation in the range of of 50-100 Bq/kg in ash from pellets. This would translate in to 200-400 Bq/kg total ash based on an ash content of 0.5% by weight of woody biomass. The corresponding number will be higher as the ash content increases in materials such as agricultural biomass unless the ash content can be decreased by washing. In comparison, the allowable limit of radiation from milk and baby food may be 370 Bq/kg and 600 Bq/kg for all other food, somewhat depending on jurisdiction. Deposition of ash is an issue requiring management for the coal burning industry as well as the biomass energy industry.

Table 3.2.1 Heavy Elements in mg/kg Dry Basis

Species	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Miscanthus	<0.17	0.03-0.09	0.81-6.85	1.4-2.0	<0.03	2.0-3.3	0.16-0.95	1.0-25.5
Switchgrass								
Reed canary grass	2.1	0.3	3.4	9.1	0.03-0.1	1	0.1	11.7
Hemp	0.86	0.11	1.21	4.9	0.03	n.a.	n.a.	2.5
Straw	0.31	0.17	6.56	2.1	0.02	2.2	0.18	1.4
Vine pruning	0.30-0.67	0.05-0.2	0.70-6.8	6.2-28.0	0.1	1.1-1.5	1.901	n.a.
Corn cobs	n.a.	<11	4.001	<41	n.a.	2.01	<11	11.01
Corn stalks	n.a.	0.8	8	10	0.1	3.3	n.a.	n.a.
Cereal spilling	0.1	0.1	4.6	2.2	0.02	7	0	1.7
Hay	5.4	0.9	6.4	6.2	0.2	1.2	2	6
Rape straw	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Rape press cake	0.5	0.4	3.8	4.5	0.03	0.7	0.34	6.4
Grape marc	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Olive residue	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Olive stones	0.09	0.12	7.7	3.9	0	3.7	1.3	5.8
Almond shells	0.2	0.02	7.17	4.5	0.01	3.9	1.18	9.71
Shea waste	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Carragenan waste	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Mash from breweries	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.06	n.a.
Digestate	<0.70	0.22-1.10	15.00-17.35	38.5	0.05	n.a.	0.04	n.a.
Peat	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

4 - Pre-treatment Technologies

The rapidly increasing demand for biofuels and the search for inexpensive feedstock is turning the interest to agricultural biomass. Significant differences in chemical composition of biomass from various species of materials have therefore initiated research and development of pre-treatment of the feedstock with the objective to harmonize different feedstock materials to allow production of biofuels to specification. The effects of higher ash in agricultural biomass compared to woody biomass have focused the attention to techniques to eliminate or transform the characteristics of the ash to minimize fouling/scaling/slagging/corrosion in combustors and to manage emissions during energy conversion. Most of these techniques are thermal processes and means heating the raw material in order to separate some components and enrich the content of others. Other processes are cold (low temperature) and can be categorized as "washing" with the objective to clean out contaminants and to dissolve water soluble mineral components. The following sections describe the most prominent pre-treatment processes under development (see Section 13). It is early to quantify the benefits with any certainty in terms of economics. However, they hold significant promise for upgrading agricultural materials to a high quality grade.

4.1 Torrefaction

Torrefaction is a thermal process whereby biomass is held in a reactor, dried and depolymerized for a period of time in the near absence of air (oxygen). Table 4.1.1 summarizes some of the historical milestones in the use of torrefaction

Torrefaction is currently considered the primary candidate for pre-treatment of the large variety of biomass types potentially available, including agricultural biomass. The fact that many of the volatile components of the biomass are vaporized when thermally treated generates a product higher in carbon and with lesser content of other elements such as nitrogen, oxygen, hydrogen, chlorine and sulphur although the relative ash content increases as a percent of retained biomass. Torrefied material is hydrophobic which means that the absorption of water or moisture from the air is limited. For biofuel this would be a significant benefit since such material could be stored outdoors like coal and save major capital investment when building or upgrading power or heating plants for co-firing. However, when the material is compressed during pelletization or briquetization, the torrefied particles break up and the interior is exposed which decreases the hydrophobic characteristics of the material. Experimentation is under way to explore the use of binders or additives to restore the hydrophobicity of the torrefied material. Densification to briquettes may cause less breakage of the particles and generate a more hydrophobic densified fuel product.

Table 4.1.1 Historical Milestones in the Use of Torrefaction

Commodities	Temperature, °C	Started
Beans (coffee), nuts, seeds	hot air +190 to 280	around 1000 A.D. in Ethiopia
Thermo-wood (outdoor furniture, decks)	Steam, hot air, oil +180	1980 in Finland
High calorific biofuels (wood, agro-materials)	Steam, nitrogen +250 to 290	1987 in France

Torrefied material has significantly higher calorific value compared to un-treated biomass. ISO/TC238 has recently released tentative specifications for torrefied wood pellets (see Appendix H) and briquettes (see Appendix I). It is also expected that ISO will eventually release tentative specifications for torrefied non-woody (agricultural) pellets and briquettes as the pre-treatment technology and market develop. The current work schedule for ISO indicates a potential publication of a Standard by ISO during spring of 2015. However, there may be a Draft International Standard (DIS) by mid 2014. The DIS version is normally not released to the public.

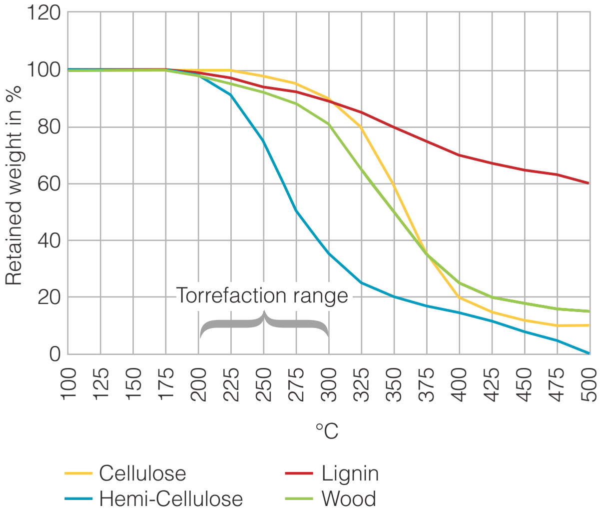


Diagram 4.1.1 Thermal Breakdown of Wood Components

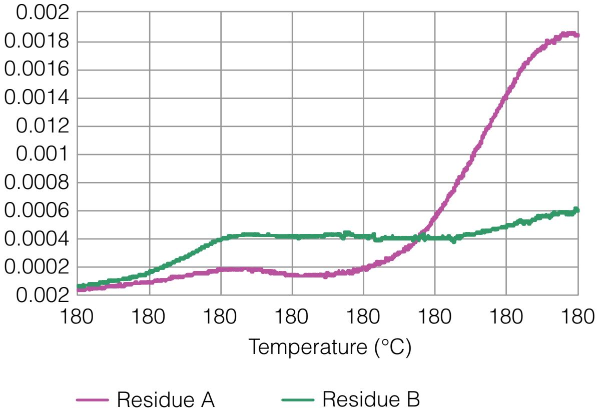


Diagram 4.1.2 Heating of Various Agricultural Residues at 10°C/min

During the torrefaction process some components (in wood it is primarily the hemi-cellulose) of the biomass decompose (depolymerise) and partly vapour off as condensable and non-condensable gases. Diagram 4.1.1 illustrates the decomposition process in the torrefaction temperature range. If oxygen were present, the process would become exothermic and the material would burn.

The depolymerisation for agricultural biomass is more complex and is currently subject to intense research, for example within the CEATI Project (see Section 14). Diagram 4.1.2 illustrates an example of thermo-gravimetric analysis of agricultural material. The significant difference in terms of reactivity dictates the control strategy (temperature and time) for how to run a torrefaction reactor depending on the feedstock characteristics.

Diagram 4.1.3 summarizes the products coming out of the torrefaction process.

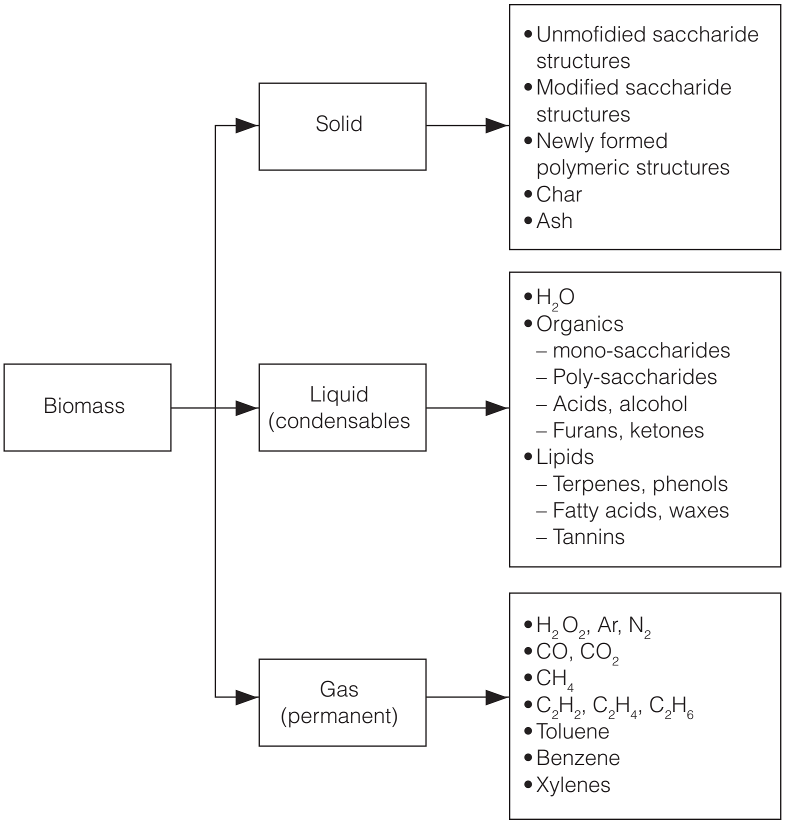


Diagram 4.1.3 Products Generated from Biomass when Torrefied

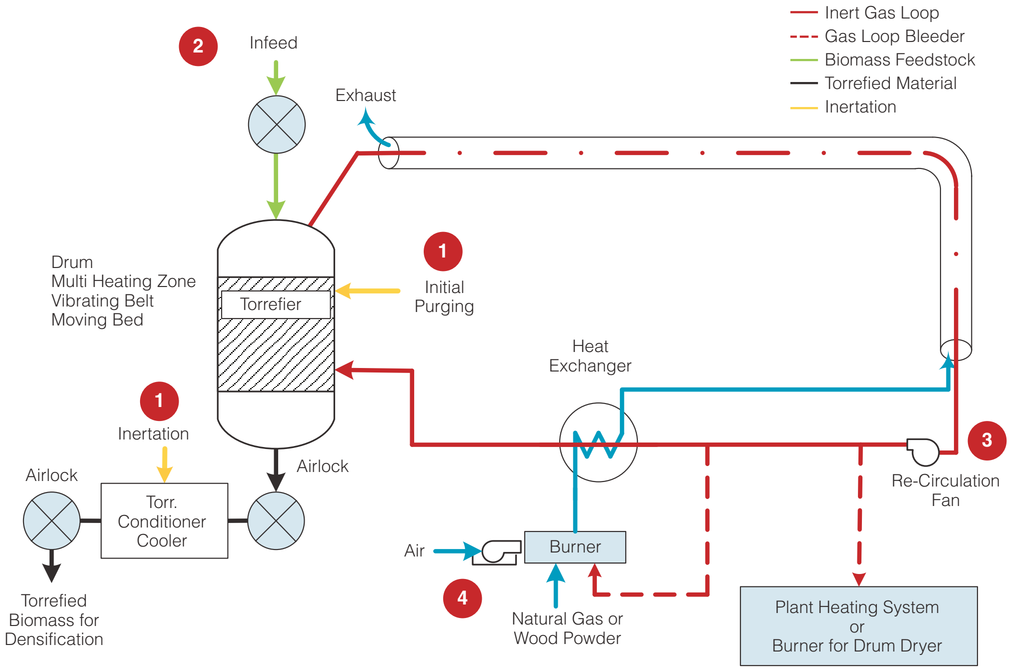


Diagram 4.1.4 Torrefaction – Generic Process Diagram

There are several technologies developed for achieving torrefaction. Some are using nitrogen for inertation and others use steam or oxygen deprived flue-gas. Others are using a very low level of air mixed with inertation gas which in fact is speeding up the torrefaction process but in some aspects makes the control somewhat more challenging. In some systems, the process gases generated in the reactor are sufficiently energetic to be combusted and used to augment the heating of the reactor. The primary heat is in some cases generated by burning biomass as a side-stream of raw material and in other cases natural gas is used. Diagram 4.1.4 is a generic configuration of a torrefaction process.

A generic temperature profile for a torrefaction process is illustrated in Diagram 4.1.5.

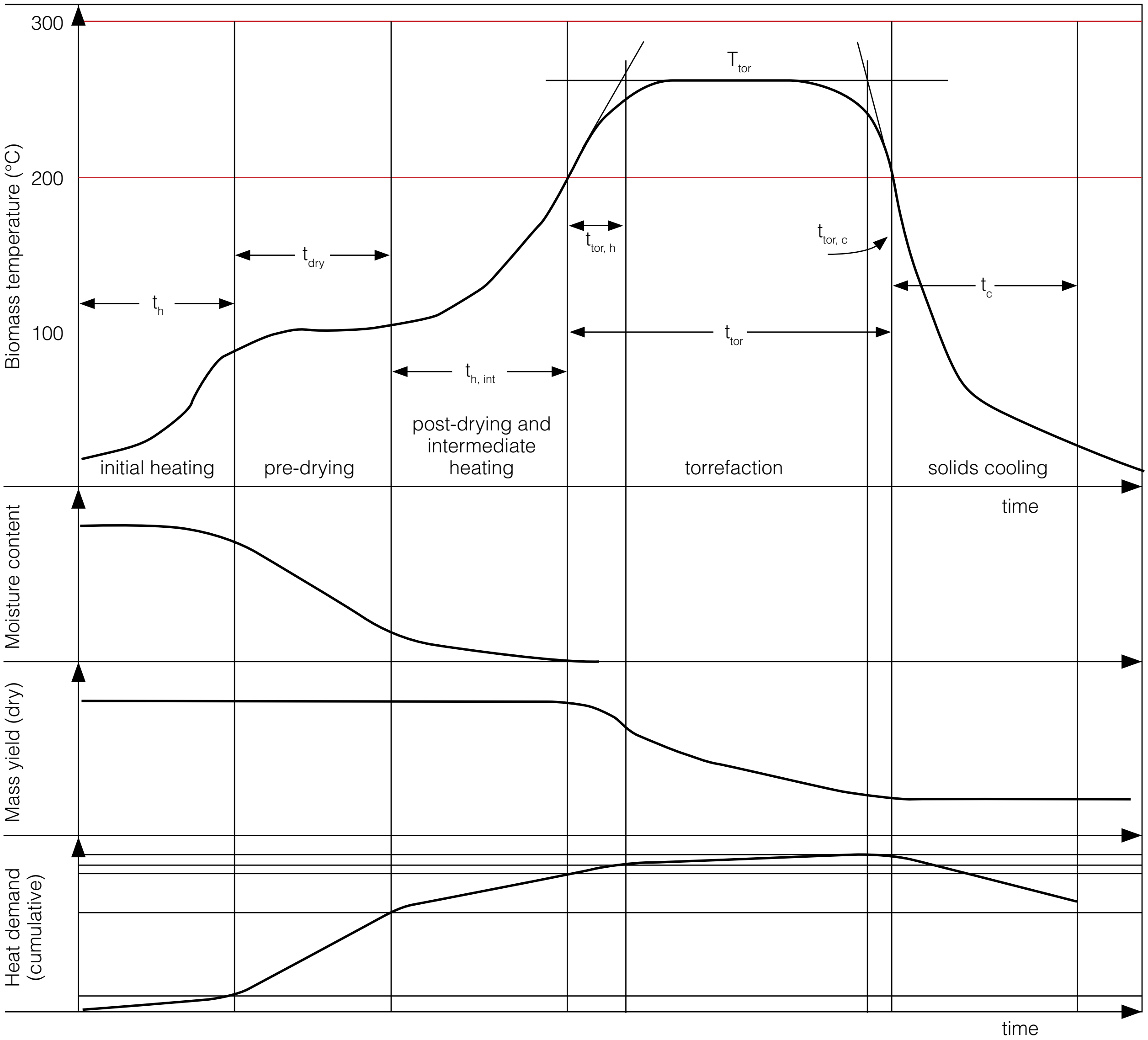


Diagram 4.1.5 Generic Temperature Profile for a Torrefaction Process

The 10 steps of the process can be summarized as follows:

A Processes before the actual torrefaction
  1 Fractionation to size
  2 Conventional drying (in many cases <15% moisture is required)

B Processes inside the torrefaction reactor (inert condition)
  3 Evaporation of residual moisture
  4 Heating of feedstock to +250 to 300°C
  5 De-polymerization of hemicellulose

C Post torrefaction reactor
  6 Re-polymerization
  7 Crushing to size
  8 Conditioning with binder/additive

D Densification
  9 Pelletization or briqueteization
  10 Cooling and screening (dust removal)

The many challenges in torrefaction can be summarized as follows:

- Particle size
  - Mass flow limitation

- Consistency of feedstock particle size
  - Heat transfer variations (= uneven carbonization)
  - Clogging or channelling (vertical tunnels) in mass flow
- Closing of gas-loop
  - Inefficient use of volatile calorific content
  - Condensation of ductwork

- Reactor vessel
  - Control strategy (time& temperature) impacted by moisture variations, particle size variations and volatile content
  - Fouling (condensation in cold spots)

- Densification
  - High Temperature of processed material
  - High reactivity of dust (risk for explosions and fires)

Several market studies have been conducted of the highly diversified development of torrefaction technologies and indicate there are currently over 70 projects under way around the world, primarily in Europe and North America, working on developing the torrefaction technology. The different technologies can be categorized in accordance with Diagram 4.1.6. One of the most important criteria for selecting the best technology is the particle size of the raw feedstock material. Many of the systems can not process small particles like sawdust without getting clogged and other systems can not process large particles without getting clogged. Very few technologies can cover the entire range

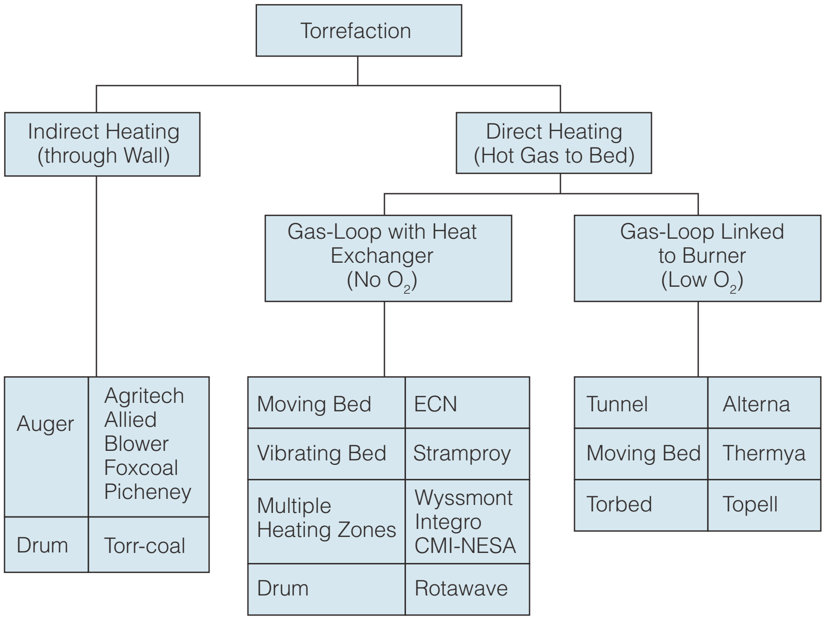


Diagram 4.1.6 Example of Torrefaction Technologies under Development

of particle sizes and still produce a torrefied product which is neither over- nor under-treated.

At this point only two or three technology developers are able to manufacture torrefied pellets in reasonably large volumes (>40,000 tonne per year) based on woody biomass. Several test burns of torrefied hardwood pellets in the range of 1,500 to 4,000 tonne have been conducted in large coal burning stations, so far with encouraging results. Additional test burns with torrefied softwood pellets will be conducted during 2013. The power industry is also looking for sufficient torrefied agricultural pellets for experimental test burning.

4.2 Steam Explosion Pulping

During the steam explosion process biomass is impregnated with steam under pressure (150 to 500 psi or 1,034 to 3,447 MPa) and temperature (+180 to 240°C) in a pressure vessel. The impregnation is followed by an explosive decompression causing the fibre clusters to rupture resulting in a pulp. The process is sometimes called the Masonite technology. The hydrolysis rate of the hemicellulose can be increased by using e.g. SO_2, H_2SO_4 or acidic gas as catalyst during the pressurized phase. The steam explosion technology is also used for increasing the accessible sites in the cellulose molecules for improving the enzymatic hydrolysis which is followed by fermentation during ethanol production.

Several patents have been granted for batch reactors. Arbaflame Technology AS in Norway and Zilkha Biomass Inc in Texas, USA are both producing what is called black pellets which have been successfully tested in co-firing applications in power plants.

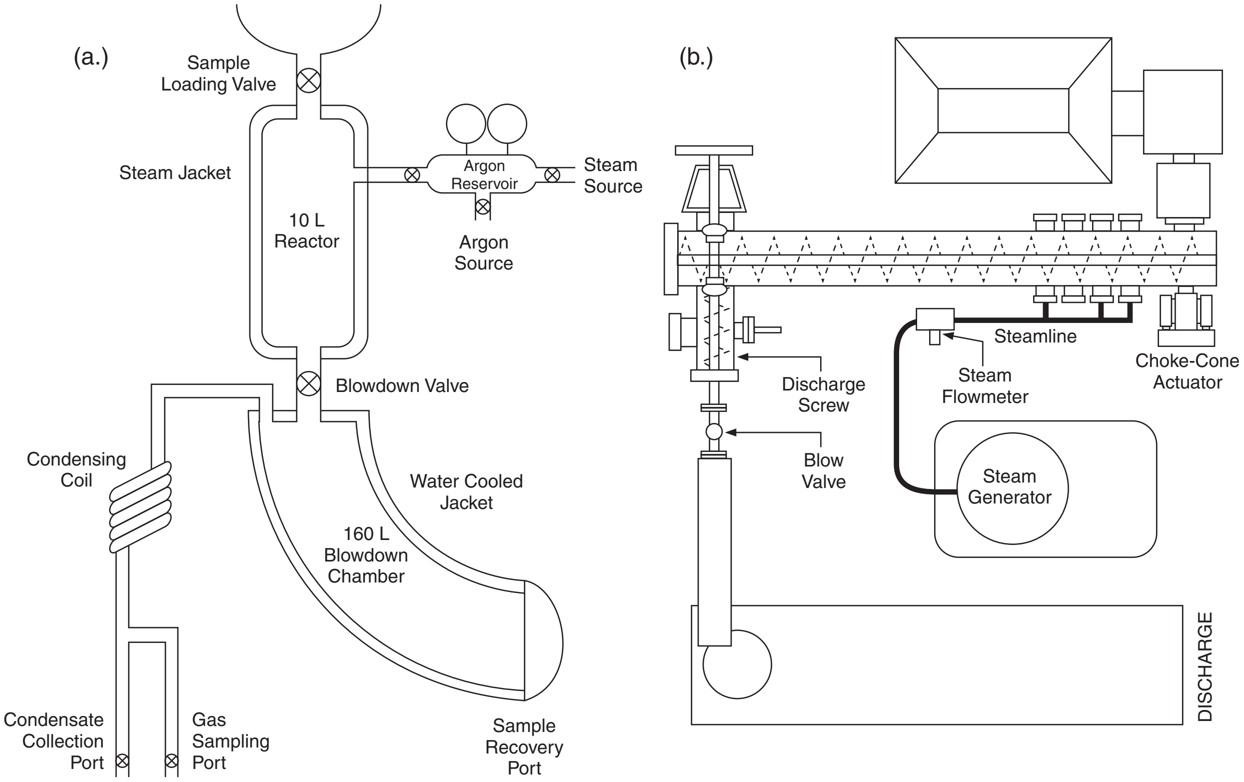


Diagram 4.2.1 Generic Diagram of Explosion Pulping Technology Developed by StakeTech Ltd.

Diagram (a.) illustrates a batch process with the typical blowdown chamber and (b.) a continuous process using a screw with injectors for steam.

Early on SunOpta Bioprocess Inc (formerly StakeTech Ltd.) in Toronto, Canada developed a continuous screw reactor (Diagram 4.2.1) primarily intended for pre-treatment of agricultural materials to be used as animal feed. Stake also developed a batch version used for experimental purposes at several research locations such as the University of British Columbia, Vancouver, University of Sherbrooke, Quebec in Canada, National Renewable Energy Laboratory, NREL, Golden, CO, USA and Virginia Tech, Blacksburg, VA, USA.

The explosion pulp pellets are hydrophobic and can be stored outdoors for a limited period of time without decomposing. However, the material has a strong odour and starts leaching after long exposure to water. The explosion pulp pellets made from woody biomass has a 3-5 % higher calorific value compared to regular white pellets and generates substantially less dust during handling and transportation. Experimentation is under way with agricultural biomass.

4.3 Hydro-Thermal Carbonization (HTC)

The hydrothermal carbonization (HTC) has recently attracted attention since the product generated has some unique characteristics. The HTC process is using water for impregnation of the raw material in a process vessel heated to +200 to 260°C at an equilibrium pressure of 200 to 700 psi for 5-10 minutes. Diagram 4.3.1 illustrates the HTC process.

The oxygen and hydrogen in the material is reduced while the carbon is reduced much less resulting in a material with considerably higher net carbon content compared to the raw material. The mass of the material (sometimes called HTC-biochar) is reduced with up to 37% and the High Heat Value (HHV) increases with up to 36%. The material becomes soft and hydrophobic and can easily be crushed. Besides the HTC-biochar, the process generates non-condensable gases such as CO, H_2 and CH_4 as well as a condensed liquid. The liquid portion is a product of hemi-cellulose and the cellulose both converting to furan resins and the lignin to phenolic polymers during the pre-treatment. These products have industrial applications.

Experimentation indicates that the HTC-biochar can be mixed with pulverized fossil coal and extruded to durable pellets without the use of binder. Table 4.3.1 is a direct comparison of the results of HTC and torrefaction treatment of Loblolly Pine and indicate an efficient extraction of nutrients (ash) and oxygen (and thereby volatiles) at a temperature of +260°C or more while at the same time conserving much of the heavier carbon molecules, which in turn increases both the net calorific value (at 12.1% moisture) and the dramatically higher calorific value on a dry basis. This calorific value is about the same as for bituminous coal. Both torrefaction and HTC treatments are eliminating practically all

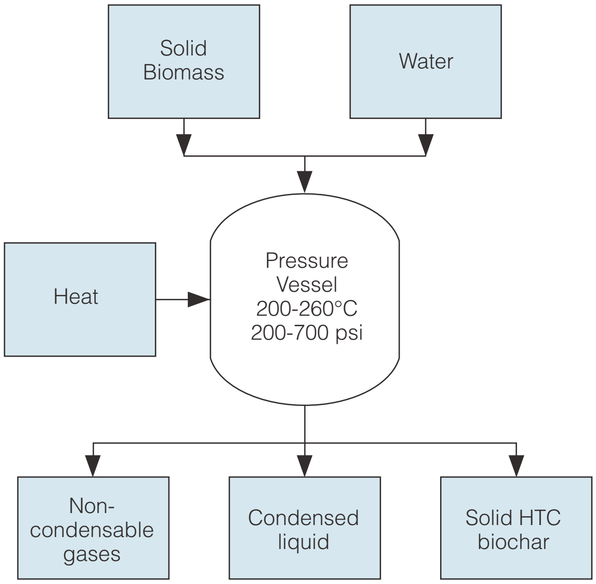


Diagram 4.3.1 Generic Illustration of the HTC Process Involving Impregnation with Water and Heating under Pressure Resulting in Gases, Effluents and Biochar

chlorine (see also Diagram 4.4.1.2) and may also be considered as a washing method.

High temperature HTC-treated ligno-cellulosic material has low Equilibrium Moisture Content (EMC) and if pelletized reaches a very high energy density as illustrated in Table 4.3.1. Diagram 4.3.2 is a comparison of the hydrophobic characteristic of torrefied and HTC treated material.

Extensive research is currently on-going with HTC pre-treatment of a variety of feedstock materials, including agricultural residue, municipal waste and animal waste. Increasing the impregnation efficiency with steam instead of water is also explored. However, the use of steam would decrease the amount of effluent compared to using water and thereby decrease the washing effect of nutrients. Comparative results from HTC treatment for agricultural residue are expected to be published within the next year or so from the research at the Gas Technology Institute in USA.

4.4 Washing

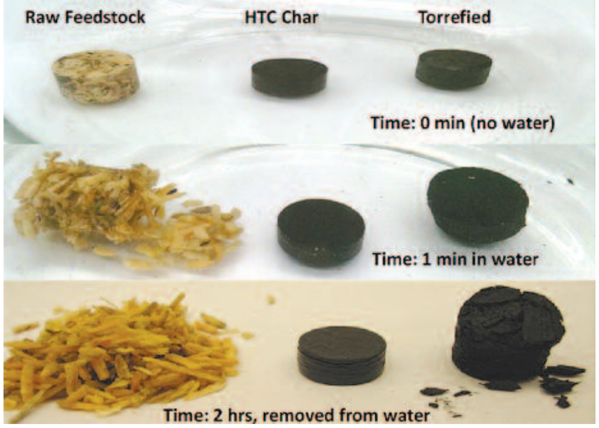
Extensive research is under way to homogenize the agricultural feedstock to and allow utilization of variations in raw material qualities.

Several methodologies have been or are under development for decreasing the content of alkali minerals as well as chlorine and sulphur in agricultural biomass in order to improve the combustible characteristics and ash melting temperature. Some of the methods include various methods of washing or blending the feedstock or the biofuel in order to decrease the ratio of alkali minerals to an acceptable level.

Table 4.3.1 Elemental Composition of Loblolly Pine after Torrefaction versus HTC Treatment

Ultimate & Proximate Analysis (%)	Loblolly Pine	HTC		Torrefied	
	As Received	200°C ~20 min	260°C ~20 min	250°C 80 min.	300°C 80 min
C	50.25	54.7	68.3	50.7	54.8
H	5.97	6.0	5.1	6.2	5.9
N	0.0	0.14	0.37	0.12	0.14
S	0.0	0.0	0.03	0.0	0.0
O	43.34	39.1	25.9	42.9	39.1
Ash	0.4	0.5	0.3	0.5	0.7
Cl	–	–	0.02	–	–
Moisture	3.6	1.3	12.1	0.0	0.0
Volatile Matter	83.7	87.1	60.0	87.7	82.3
Fixed Carbon	12.3	12.4	39.6	11.8	17.0
Mass Yield (%)	–	88.7	63.0	83.8	60.5
As Received (MJ/Kg)	19.46	21.1	25.3	20.9	23.6
Dry (MJ/Kg)	19.54	21.1	27.4	20.9	23.6

Diagram 4.3.2 Hydrophobic Comparison of Torrefied and HTC Treated Material



Pellet Sample	Equilibrium Moisture Content, %	HHV, MJ/kg	Pellet Density, kg/m³	Fuel Density, GJ/m³
Raw wood	8.3	20.65	1102	22.76
HTC-200°C	6.5	21.59	1126	24.31
HTC-230°C	5.6	22.56	1331	30.04
HTC-260°C	4.2	26.42	1492	38.79
Coal (Bit.)	2.2-15.9	25.0	1346	32.30

Washing of agricultural biomass is not only intended to extract acquired contaminants from the harvesting operation but also to extract certain water soluble minerals naturally contained in the biomass. Several washing methods have been experimentally tested with surprisingly good results. Everything from cold water, hot water, acidic, high pressure and high temperature washing are currently being tested in pilot projects. Diagram 4.4.1 provides a perspective on the ash content of various species of biotic materials, including perennial grass after wiltering (in-field leaching) prior to and after washing. As a reference, the softwood material has about 0.3-0.4% ash and the hardwood has about 0.5-0.8%. Grasses may have an ash content of 5-11% of which 1-4% may consist of silica as a combination of silica in the plant material and contamination picked up from the soil during harvesting. The total alkali minerals and trace elements content in grass is usually 0.2-2.0% of weight.

4.4.1 High Temperature Washing

The TORWASH technology has been developed by ECN in The Netherlands and is a complete concept starting with mechanical size reduction, cold water pre-wash, followed by processing in a high temperature reactor, de-watering followed by pressing and water reduction. The effluent is separated and treated in a digester for production of biogas. Diagram 4.4.1.1 illustrates the entire process.

The TORWASH reactor is similar to HTC (see Section 4.3) under pressure and at temperatures from +150 to 260°C whereby the water soluble components of the biomass is dissolved and extracted as an effluent, which by itself has a commercial application as fertilizer or feedstock for biogas production directly to CH4 and CO2 rather than going through an aerobic digestion cycle. Diagram 4.4.1.2 illustrates results achieved with the TORWASH method. The TORWASH reactor cycle is only about 10 minutes while the HTC may be an hour or more.

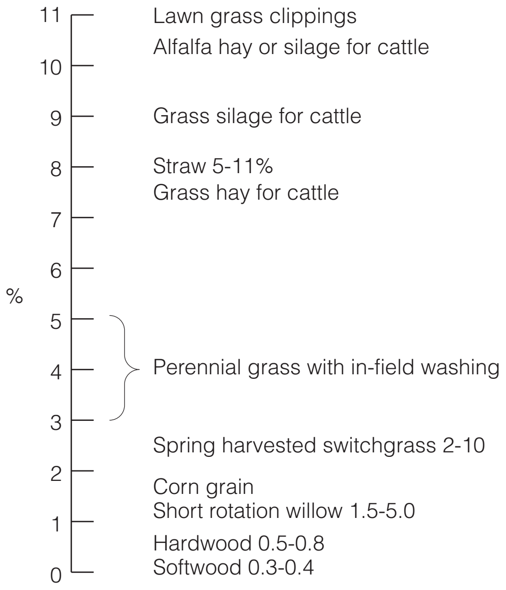


Diagram 4.4.1 Perspective on Ash Content of Common Types of Biomass

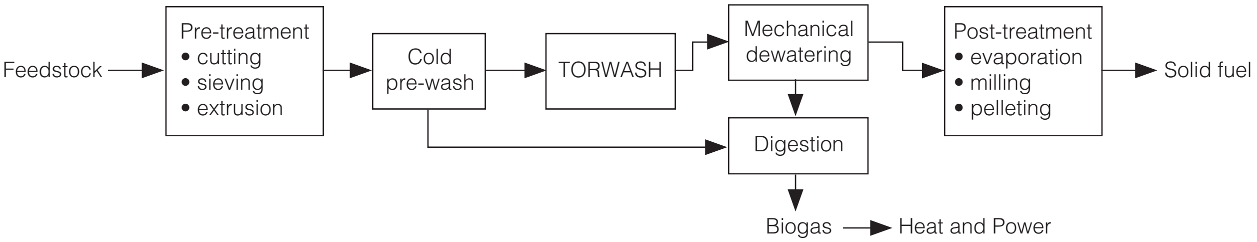


Diagram 4.4.1.1 Illustration of Typical Unit Operations of the TORWASH Concept

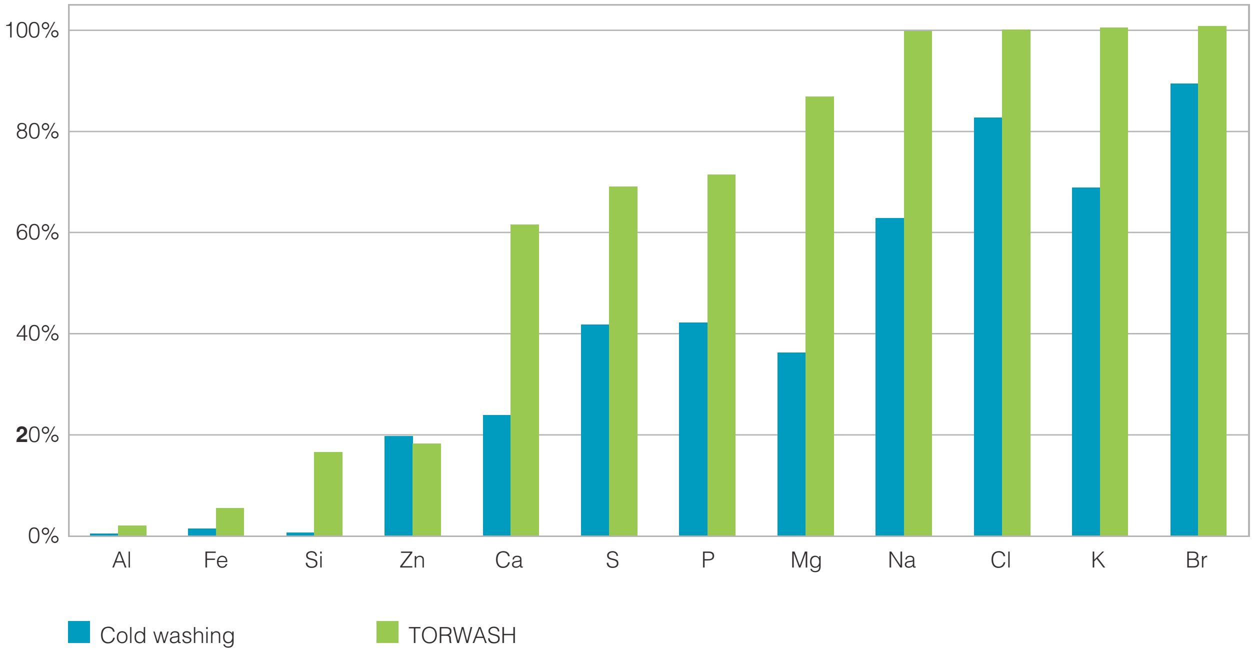


Diagram 4.4.1.2 Removal of Minerals from Hay Biomass by Means of Cold Washing in Water Compared to the TORWASH Technology

The cold water washing at room temperature for less than an hour may extract up to 70% of the ash (average of the minerals illustrated in the diagram on a per weight basis) in the biomass while the TORWASH brings the average number up to 90% (average). TORWASH is sometimes referred to as a wet torrefaction process with water providing the oxygen depleting condition and resulting in an organic rich effluent. The digestion phase takes only about 8 hours instead of 30 days for conventional aerobic processes. The effluent can also be used as fertilizer although the conversion technique is currently confidential awaiting patent protection.

The concept is based on de-watering by means of a mechanical press. Interestingly enough TORWASH claims to be able to take out practically 100% of the chlorine, sodium and potassium, which are the most critical mineral components in terms of slagging, fouling and corrosion.

Flame modelling at ECN indicates a very rapid and nearly complete burn-out characteristic of the TORWASH bio-coal from hay compared to fossil coal as illustrated in Diagram 4.4.1.3 due to the low ash content.

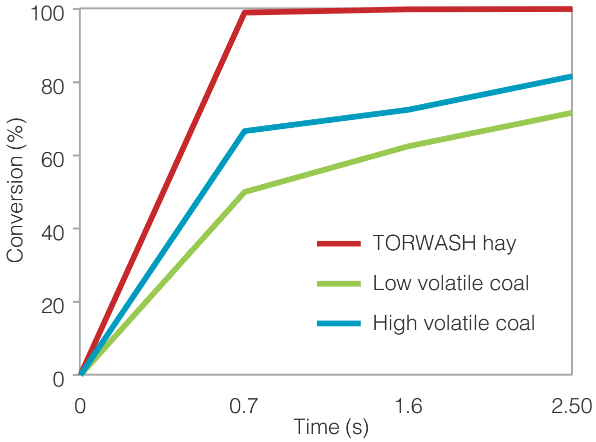


Diagram 4.4.1.3 Burn-out Characteristics of Hay Biomass Treated in TORWASH Reactor Compared to Two Different Qualities of Fossil Coal

Diagram 4.4.1.4 Biomass Treated at Different Temperatures in TORWASH Reactor, Dewatered and Compressed into Pucks Without Binder

Diagram 4.4.1.4 illustrates mechanically compressed pucks of TORWASH material after processing at temperatures ranging from +150 to 230°C. ECN is indicating that binder may be necessary for the bio-coal produced above +230°C, much like torrefied wood.

A consortium has been formed to commercialize the TORWASH technology, including expertise for membrane technology. The project is currently in the pilot-scale phase testing a reactor for 100 kg/hour before the end of 2014 and a planned demonstration plant towards the end of 2016 for 10-30,000 tonne per year.

4.4.2 Low Temperature Washing

There are a number of variables impacting the efficiency of washing which make it difficult to quantify in simple terms. The variables can be summarized as follows:

- Species of crop
  - Maturity of crop at the time of harvest
- Soil conditions
  - Chemical composition
  - Type of soil (USDA soil classification system, including clay, silt, sand and gravel)
- Fertilization of crop
- Water irrigation versus natural rain
  - During growing season
  - After harvesting if material is left on the ground
- Harvesting technique and storage
  - Fall harvesting and storage under cover
  - Spring harvest
- Harvesting time during the year
  - Fall crop and collection during spring
  - Spring crop with sprouts

The results of field washing over winter, or at least part of the fall and winter season, are documented primarily from research in Scandinavia and North America and consistently show significant extraction of a number of major elements as well as nutrients (see Table 4.4.2.1) with the exception of silica which typically increases due to contamination from the soil. Research has been conducted to determine the degree of contamination in grain straw during field wilting and found 3.5 to 5% sand (sometimes even more), primarily silica, was accumulated in the material. The sampling of material was done by hand which means that the contamination is primarily caused during the storage and not as a result of machine harvesting.

4.4.2.1 Industrial Washing by Agitation

Field washing has been researched particularly for reed canary grass, miscanthus grass, wheat

Table 4.4.2.1 Example of Extraction Efficiency of Major Elements and Nutrients Using Low-temperature Washing

Nutrient	Average % Nutrient Reduction After Field Leaching	Typical % Nutrient Reduction After Cennatek Liquid Nutrient Extraction
Chlorine	87.3	95.2
Potassium	79.0	86.5
Sodium	54.7	87.8
Phosphorous	53.8	87.5
Magnesium	38.8	76.9
Nitrogen	4.25	16.6
Calcium	None	57.7

straw, willow and hybrid poplar. Most exhibit similar results in terms of extraction ratio for spring harvest. Cennatek Bioanalytical Services conducted research (Reports to OFA in 2011 and 2012) on washing in water using different water/biomass ratios, residence time and agitation patterns. Table 4.4.2.1 indicates the order magnitude of leaching in the fields of various agricultural crop as reported by other sources versus liquid nutrient extraction in water developed by Cennatek tested on miscanthus materials. It can be concluded that much of the chlorine and potassium is extracted in both scenarios but also that the liquid nutrient extraction is substantially more efficient. The liquid nutrient extraction is on the other hand generating effluent which needs to be taken care of. The effluent can be reduced and used as a nutrient for re-circulation to the soil.

The data on field washing is not consistently documented and the absolute numbers are in most cases not directly comparable due to the many variables listed above. For example, Table 4.4.2.2 illustrates the impact on ash content of soil conditions for miscanthus grown on sandy versus clay rich soil. Table 4.4.2.2 also indicates the extraction ratio for crop harvested during the spring (April-May) versus December.

An accurate determination of field leaching is very difficult to make, particularly from one season to the next since weather conditions have such a significant impact on the crop. It appears though from the research that field leaching of the nutrient most harmful when using the biomass for energy production like chlorine, sodium and potassium is significant. However, the nutrient washing tested by Cennatek is much more predictable and does not add silica as a contaminant. On the other hand, it adds complexity and cost in terms of handling of the washing effluent which might be possible to recover if the nutrient extract can be commercialized.

Table 4.4.2.2 Example of the Difference in Moisture and Nutrient Content Depending on the Time of Harvesting Miscanthus

	Harvesting April-May		Harvesting December
Soil type	Sandy Soil	Clay	Sandy Soil
Moisture content, %	15.0	9.6	56.0
Ash content, %	1.0	2.7	3.1
Chlorine content, g/kg	0.2	8.0	3.3
Potassium content, g/kg	1.65	3.2	10.1

There are two different types of lignin in agricultural biomass, acid-soluble and acid-insoluble. Acidic washing is an optional pre-treatment which has been researched but due to the fact that 25-30% of the lignin may be lost in the process and the reagent may leave behind traces, acidic washing is not considered viable for biomass used as biofuel.

Another conclusion drawn consistently in all published papers is that spring harvest is better for practically all crops since the material has such high moisture content when harvested during summer. High moisture content means that baling is not recommended unless most of the moisture has been driven off to avoid moulding and microbial degradation. Moulding also causes hygienic risk for workers.

Dry matter loss during field wilting vary substantially from one crop to the next and with weather condition, including rain fall, wind and temperature.

Washing can have a dramatic effect on the ash melting temperature as was proven by research done by Cennatek. Table 4.4.2.3 summarizes the effect of water to biomass ratio on ash fusion temperature.

Table 4.4.2.3 The Effect on Ash Fusion Temperature of Water to Biomass Ratio During Washing

Ash Fusion Temperature +°C	Untreated Miscanthus	Treated Miscanthus Ratio 15:1	Treated Miscanthus Ratio 8:1
Initial Deformation	481	1394	1031
Softening	989	1538	1473
Hemispherical	1165	1551	1536
Fluid	1218	1551	1551

4.4.2.2 Industrial Washing by Mechanical Dehydration

The EU funded PROGRASS Project using the IFBB (Integrated Generation of Solid Fuel and Biogas from Biomass) technology using a mechanical press from Anhydro Ltd. in Germany has tested a method for conditioning grass in water at temperatures +5/60/80°C and subsequently pressing the material to separate the liquid and the solids (cakes). The results indicate substantial reduction in alkali and chlorine in the solids resulting in an increase of the ash melting temperature with nearly 150°C (from +1120 to 1260°C) (see Diagram 4.4.2.2.1). The liquid is said to be easily fermented to biogas.

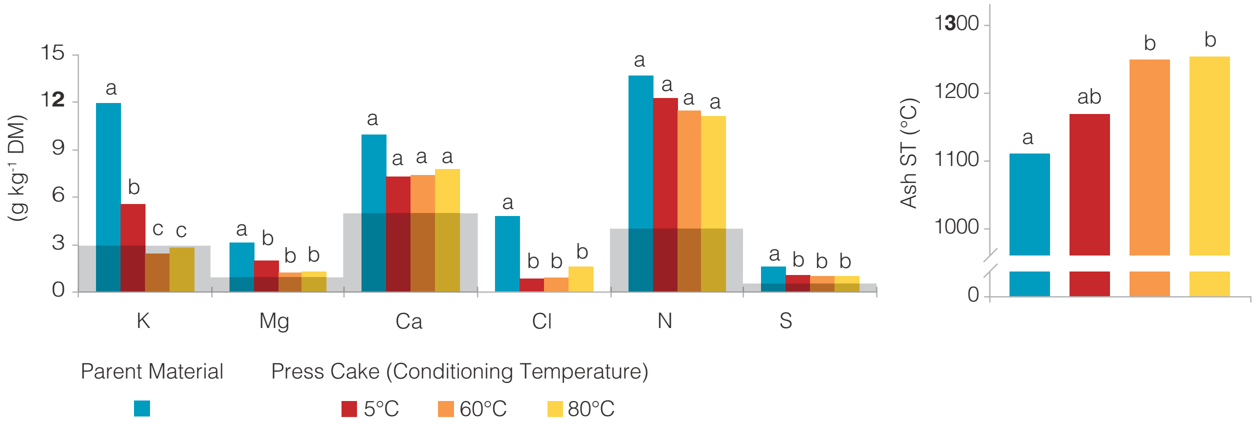


Diagram 4.4.2.2.1 Decrease of the Alkali Content Using Washing and Mechanical Dehydration

5 - Safety and Health Issues Related to Biomass and Biofuels

With an increasing volume of biofuels being manufactured, transported and kept in storage the number of accidents has increased. The wake-up call came on May 9, 2002 during discharge of wood pellets from an ocean vessel in the Port of Rotterdam. One person died from being subjected to a combination of carbon-monoxide emission and oxygen depletion and several others were severely injured. Since then, an additional 9 people have died from off-gassing from wood pellets and an equal number are permanently injured. A Material Safety Data Sheet (MSDS) was developed by WPAC and has since become accepted as an international standard (see Appendix J). The emission factors for off-gassing from wood pellets have been studied in detail at UBC. However, the off-gassing from agricultural pellets have not been studied in any great detail to date although it is part of the objective by the CEATI and SECTOR projects described in Chapter 13. Safety declaration and certification for agricultural materials are also dealt with in Section 11.7.

While woody biofuels such as pellets and chips from fresh or recycled wood dominate the market in terms of volumes, other solid biofuels such as straw, biodegradable fuels used for anaerobic digestion and municipal solid waste, pose specific health and safety challenges that also needs to be addressed.

5.1 Off-gassing

Off-gassing is a sign of reactivity in the biomass material. Woody biofuels with a moisture content of less than 9% emit substantial volumes of carbon monoxide (CO) and carbon dioxide (CO_2). Biofuels with higher moisture emit comparatively limited amount of CO and very large amounts of CO_2. In both cases the emission of methane (CH_4) is very small. There is also some emission of hydrogen (H_2). Diagram 5.1.1 illustrates the emission of CO and CO_2 from wood pellets at various temperatures. The WPAC MSDS provides a formula for calculating concentrations in storage spaces.

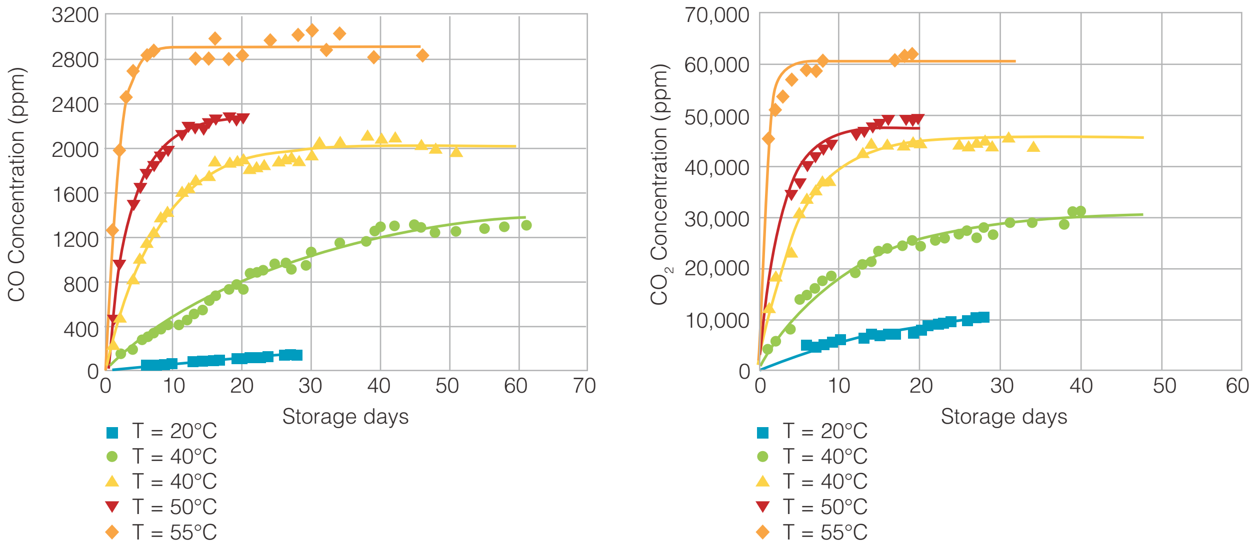


Diagram 5.1.1 Generation of Carbon Monoxide and Carbon Dioxide in Wood Pellets as a Function of Time and Temperature

The CEATI and SECTOR research will provide additional information related to agricultural biofuels (Chapter 14).

5.2 Self-heating

Self-heating results from the three processes and can cause serious problems during large scale storage of biofuels.

Microbial decomposition:

- Some heat is generated during microbial decomposition of all biotic materials to varying degree. Microbes are generally classified according to their thermal survival range as illustrated in Diagram 5.2.1.

- Research shows very little content of microbes (fungi, bacteria, virus etc.) in woody feedstock used for making pellets such as sawdust, clean chips or in commercially traded wood pellets. Also, research of the heat release from wood pellets under oxygen deprived conditions indicates a very low level of activity which means that heat release from anaerobic microbe activity is very low. There is in fact no proven record that microbes are involved to any significant degree in self-heating of wood pellets.

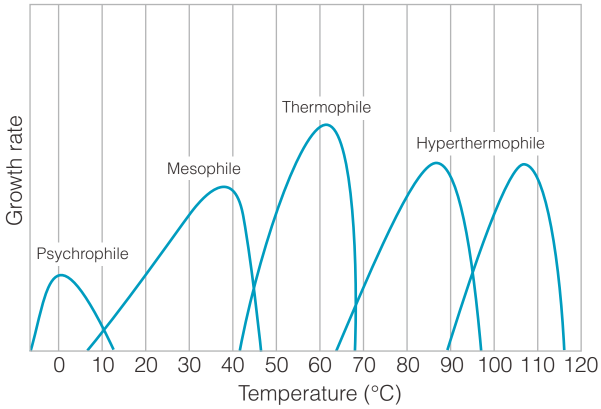


Diagram 5.2.1 Survival Temperature Range for Classes of Microbes

- Wood pellets exported from Canada were classified as “pest free” (pest meaning vectors of insects and bacteria) according to a ruling by EU Directorate General Health and Consumer Protection in 1999 thanks to the harsh thermal treatment and extreme pressure the material is exposed to during the drying of feedstock and extrusion to pellets.

Chemical oxidation:

- All indications from research conducted indicate that chemical oxidation is the main cause of off-gassing and subsequent self-heating observed in non-pelletized materials such as wood chips and in wood pellets. Ample access to air (oxygen) is however a prerequisite for oxidation to happen. If the storage space is deprived of oxygen, the process results in off-gassing with very little self-heating as is the case with ocean transportation with sealed hatch covers.

Hydro-thermal moisture migration:

- In a pile of bulk pellets there is a continuous cyclical vaporization followed by condensation on a micro-level between individual pellets as a result of the variation in the temperature and humidity gradient between the surface layer of the pile and the ambient environment. This process results in moisture migration towards the top of the pile as the internal convection is driving the vapour upward. This hydro-thermal process generates heat which results in increased temperature in the center-top of a pile with wood pellets. In case of ocean transportation, there is no exchange of ambient humidity and therefore there is very little hydro-thermal moisture migration resulting in heating in a cargo hold.

Industrial scale silos are in many cases today equipped with multiple vertical temperature sensing cables with sensing devices located for example every 30 cm and the cables are spaced approximately 3 meters apart. Self-heating is very much dependant on availability of air (oxygen). Large scale silos are ventilated from the bottom and the air flow needs to be high enough to produce a cooling effect. The rate of self-heating may in extreme cases reach 1.5 to 2°C/hour and it is therefore critical to have an efficient ventilation system. The maximum recommended temperature in woody pellets during storage is +60°C. Typical cross-over temperature for woody pellets depends on the size of the stored volume and the cooling capacity of the wall but can be in the range of +130°C and with a runaway temperature of +160°C. The new ISO standards stipulate that woody pellets with a temperature of >+60°C at delivery will not be accepted in overseas ports.

It is expected that the experience with off-gassing from wood pellets will also apply for agricultural pellets and briquettes. The CEATI and SECTOR research will provide additional information related to agricultural biofuels (Chapter 14).

5.3 Dust Explosibility

Dust is a major cause of accidents in the bioenergy sector. The combination of relatively small particle sizes and low Minimum Ignition Energy (MIE) results in high ignition sensitivity. Significant amounts of factory dust may stay suspended in the air, so that the Minimum Explosible Concentration (MEC) is easily exceeded under practical conditions if cleaning and ventilation are not done sufficiently. It is important to minimize the risk of dust explosions by minimizing the risk of sparks. Proper electrical grounding and diligent dust housekeeping in combination with dust prevention and dust collection are extremely important. Once an explosion takes place, it needs to be properly contained, suppressed or vented. Compliance with ATEX Directives and NFPA guidelines is essential. Table 5.3.1 summarizes the parameters which are usually tested for dust in industrial applications in order to provide sufficient data for proper design of explosion prevention measure

Table 5.3.1 Results from Testing Dust from White Pellets and Bark Pellets

Test Mode	Test Parameter (dust <75 µm)		Measure	White Dust	Bark Dust	SYP Dust	Coal Dust	Testing Standards
Dust Cloud	Auto-ignition Temp (Godbert-Greenwald)	Tc	°C	450	450	455	585	ASTM E1491
	Min Ignition Energy	MIE	mJoule	17	17	20	110	ASTM E2019
	Max Explosion Pressure	P_{max}	bar	8.1	8.4	7.7	7.3	ASTM E1226
	Max Explosion Pressure Rate (Rmax)	dP/dt_{max}	bar/sec	537	595	360	426	ASTM E1226
	Deflagration Index	K_{St}	bar.m/sec	146	162	98	124	ASTM E1226
	Min Explosible Concentration	MEC	g/m^3	70	70	25	65	ASTM E1515
	Limiting Oxygen Concentration	LOC	%	10.5	10.5	13.5	12.5	ASTM E1515 mod
Dust Layer	Hot Surface Ignition Temp (5 mm)	T_s	°C	300	310	320		ASTM E2021
	Hot Surface Ignition Temp (19 mm)	T_s	°C	260	250	270		ASTM E2021
	Auto-ignition Temp	T_L	°C	225	215	220		USBM (Bureau of Mines) RI 5624
	Dust Class (>0 to 200 bar.m/sec)			St 1	St 1	St 1	St 1	ASTM E1226
	Dust Class (Explosion Severity (ES > 0.5)			Class II	Class II	Class II	Class II	OSHA CPL 03-00-06

such as dust collection, dust suppression, explosion suppression and explosion venting. The actual numbers in the table are for dust from white pellets manufactured in BC and the bark pellets manufactured in Nova Scotia. The SYP stands for Southern Yellow Pine and the dust material was sourced in SE USA. Limit values for dust generated during handling of agricultural materials are similar as for woody dust materials.

Dust is also a major health and environmental concern during large scale bulk handling such as loading or discharging ocean vessels. Also, large amount of dust is generated during dumping of trucks in receiving hoppers. Dust is of particular concern when handled inside enclosures if oxygen is present since the Minimum Explosion Concentration (MEC) may be exceeded. High dust concentration in combination with an electrostatic discharge will likely initiate a primary explosion which in turn may trigger an even larger secondary explosion. In some places very large vacuum systems are used for discharge of wood pellets from ocean vessels and the pellets may be crushed when directed through bends in the pipe system resulting in very high concentration of dust. Keeping the ratio of dust to air in the pipe is important. Various mitigation procedures should be taken, including elimination of sources of electrostatic charge by making sure that all surfaces in contact with the dust are made of electrically conducting material. The following reference provides recommendations for mitigation procedures and further more detailed reading related to rules and regulations.

http://www.ieabcc.nl/publications/IEA_Bioenergy_Health_and_Safety_Report_(final).pdf

5.4 Health Risks

The health risks posed by biomass fuels in the form of dusts and bio-aerosols come from the physical particle size. As particles become smaller, they pose a greater hazard. As a result, limits on PM10 and PM2.5 (10 µm or 2.5 µm respectively) are becoming more prevalent in national regulations. Diagram 5.4.1 illustrates typical sizes of particles found in the industrial environment.

Diagram 5.4.2 illustrates the sedimentation time for small particles. For example, a particle with a size of PM2.5 micron may stay aloft in still air for a couple of hours and be carried a long distance before settling if there is the slightest air movement.

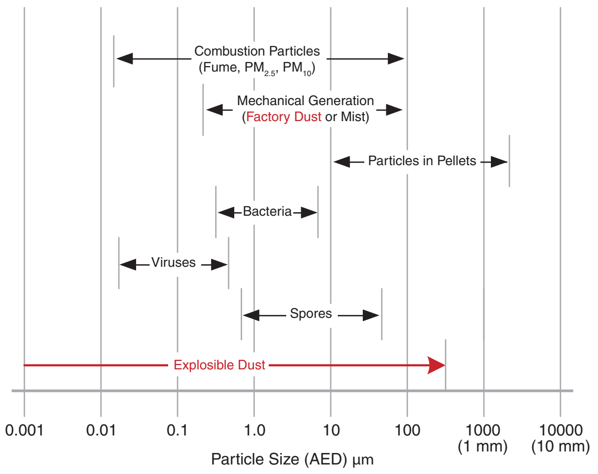
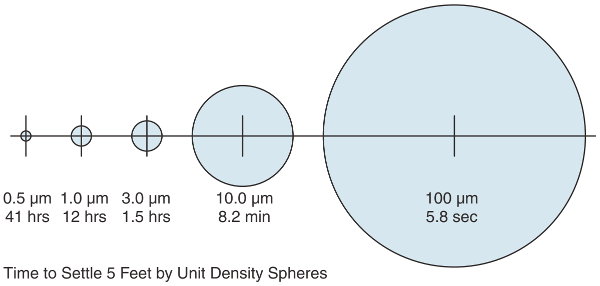


Diagram 5.4.1 Typical Size of Common Particles



Time to Settle 5 Feet by Unit Density Spheres

Source: NIOSH

Diagram 5.4.2 Particle Sedimentation Time in Still Air

In addition, the organic nature of biofuels may result in additional impacts through either allergenic or pathogenic routes. The most prevalent feature will be the allergenic responses but the majority of the effects will be minor and short lived. In the same way pathogenic responses will be a rare occurrence, but potentially result in severe hazards.

The biological substances released from biofuels are similar to the naturally occurring background levels and the human population is equipped with bodily responses to deal with this natural environmental exposure. This natural bodily response and the degree of variation in individual sensitivity make the determination of dose response relationships particularly difficult. Without this level of understanding, it is difficult to ascribe definite limits and regulations that are "safe" for the population at large. Thus this area is generally governed by guideline values and recommendations to minimise exposure rather than definitive limits that are derived from hard scientific data.

Inhalation of dust in the work place is a significant issue in many manufacturing plants and is highly regulated in most jurisdictions. Table 5.4.1 summarizes the acceptable concentration as recommended by OSHA and other agencies in North America for wood working facilities.

Besides inhalation of physical dust particles there is also the risk for exposure to chemicals in form of vapours such as hexanal causing allergic reactions. Some species of biomass contain high levels of volatile resins which escape during handling and storage and therefore require dilution by vigorous ventilation before entry be permitted.

Table 5.4.1 Acceptable Concentration of Wood Particles and Toxicity Classification

Feedstock	PEL (OSHA)	REL (NIOSH)	TLV (ACGIH)	Health Effects
Softwood such as fir, pine, spruce and hemlock.	15 mg/m^3 Total Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 5 mg/m^3 for 8 hours @ 40 hours week	Acute or chonic dermatitis, asthma, erythema, blistering, scaling and itching (ACGIH).
	5 mg/m^3 Respirable Dust		STEL = 10 mg/m^3 for 15 minutes, max 4 times/day, each episode max 60 minutes	
Hardwood such as alder, aspen, cottonwood, hickory, maple and poplar.	15 mg/m^3 Total Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 5 mg/m^3 for 8 hours @ 40 hours week	Acute or chronic dermatitis, asthma, erythema, blistering, scaling and itching (ACGIH). Suspected tumorigenic at site of penetration (IARC).
	5 mg/m^3 Respirable Dust		STEL = 10 mg/m^3 for 15 minutes, max 4 times/day, each episode max 60 minutes	
Oak, walnut and beech.	15 mg/m^3 Total Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 1 mg/m^3 for 8 hours @ 40 hours week	Suspected tumorigenic at site of penetration (ACGIH).
	5 mg/m^3 Respirable Dust			
Western Red Cedar.	15 mg/m^3 Total Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 5 mg/m^3 for 8 hours @ 40 hours week	Acute or chronic rhinitis, dermatitis, asthma (ACGHI).
	5 mg/m^3 Respirable Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	STEL = 10 mg/m^3 for 15 minutes, max 4 times/day, each episode max 60 minutes	

There is also the risk of inhalation of pathogens such as moulds, which may propagate and cause allergic reactions and serious infections.

To keep the moisture level of the material as well as the environment in which the material is stored as low as possible is of paramount importance. Storage of materials with different moisture concentration should be avoided since it causes hydro-thermal moisture migration which is known to generate heat and the potential for fires.

The report Health and Safety Aspects of Solid Biomass Storage, Transportation and Feeding published by the International Energy Agency (IEA) Task 32, May 2013 (see link below) is a good source of information aerosols (physical, chemical and biological) and mitigation techniques to consider such as ventilation, aeration of overheated product and temperature monitoring.

http://www.ieabcc.nl/publications/IEA_Bioenergy_Health_and_Safety_Report_(final).pdf

5.5 Safety Certification

In 2011 the Wood Pellet Association of Canada (WPAC) together with the British Columbia Forest Safety Council (BCFSC) developed a safety certification scheme for the pellets industry in Canada. The scheme consists of annual on-site audits of production facilities with review of safety based on a rigorous protocol for all handling and processing facilities and the building fire codes. A similar scheme is also under development by SafeBC for the saw milling industry in British Columbia after a series of disastrous explosions during the last 18 month causing 4 fatalities and dozens of badly injured workers. Dust was determined to be the cause of the incidents. Facilities qualifying for the certification receive a discount on insurance premiums.

(see (http://www.bcforestsafe.org/other/Base.htm)

6 - Market Development

The demand for certification of wood pellets for the industrial large scale market has emerged as a consequence of increased intra-trading of biofuels between large power companies as well as the increased demand for environmental accountability in order to enjoy the benefits of climate change mitigation subsidies in Europe. Certification will become even more important when agricultural biofuels enter the market made from so many different feedstock materials.

The demand for biofuels has primarily been in Europe and has been driven by the adoption of the Kyoto Agreement by the EU and the related subsidy system. The stringent carbon accountability imposed on suppliers as well as buyers under the international system in combination with national and pan-European subsidy schemes has changed the trade dramatically in a short period of time and is almost impossible to trade pellets which do not comply with quality and sustainability standards.

Pellets is currently the most transportable of all fuels and is delivered in consumer bags, jumbo bags, tank cars, trucks, rail cars and ocean vessels without adaptation of the transportation modality. Briquettes are also entering the market but generally have a lower bulk density and are not as easy to handle in large bulk and generally used in local applications.

6.1 Supply and Demand

At the end of 2011 the world consumption of wood pellets was 14 million metric tonne on an annual basis and by 2020 the consumption is projected to reach 48-60 million tonne. Some projections are twice as high. Diagram 6.1.1

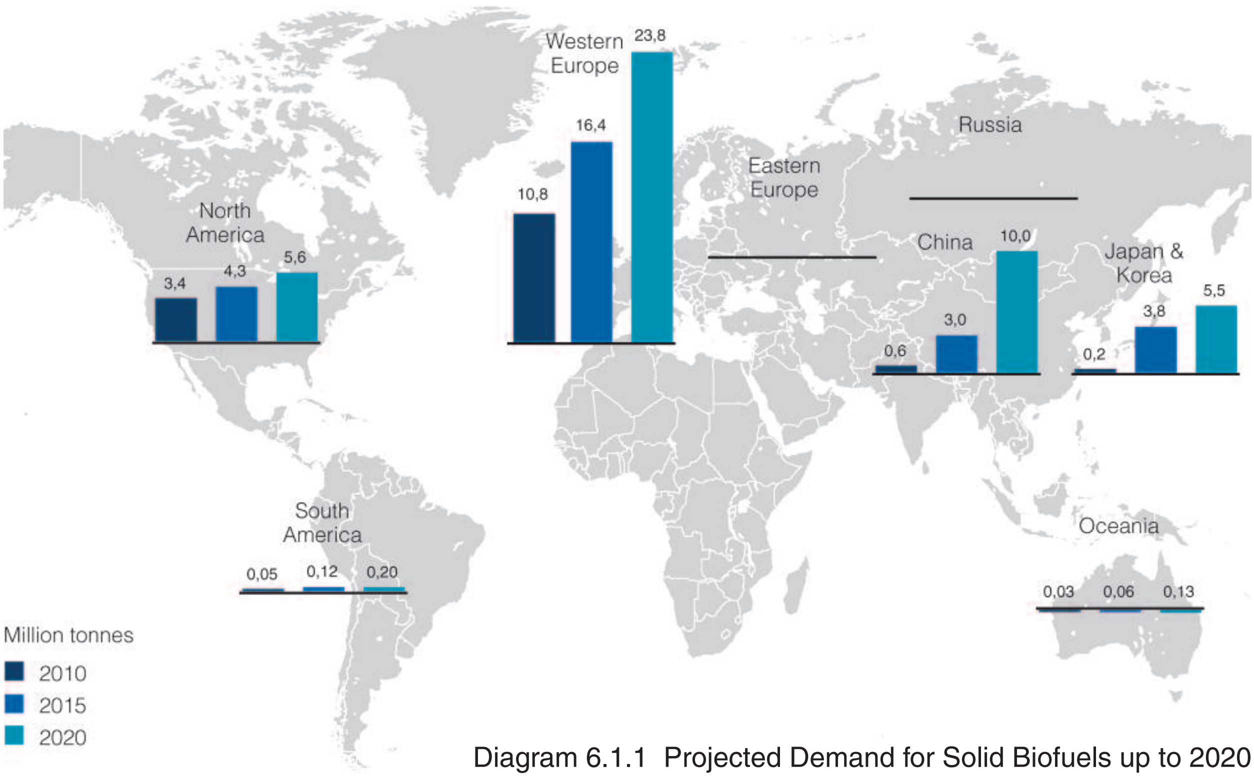


Diagram 6.1.1 Projected Demand for Solid Biofuels up to 2020

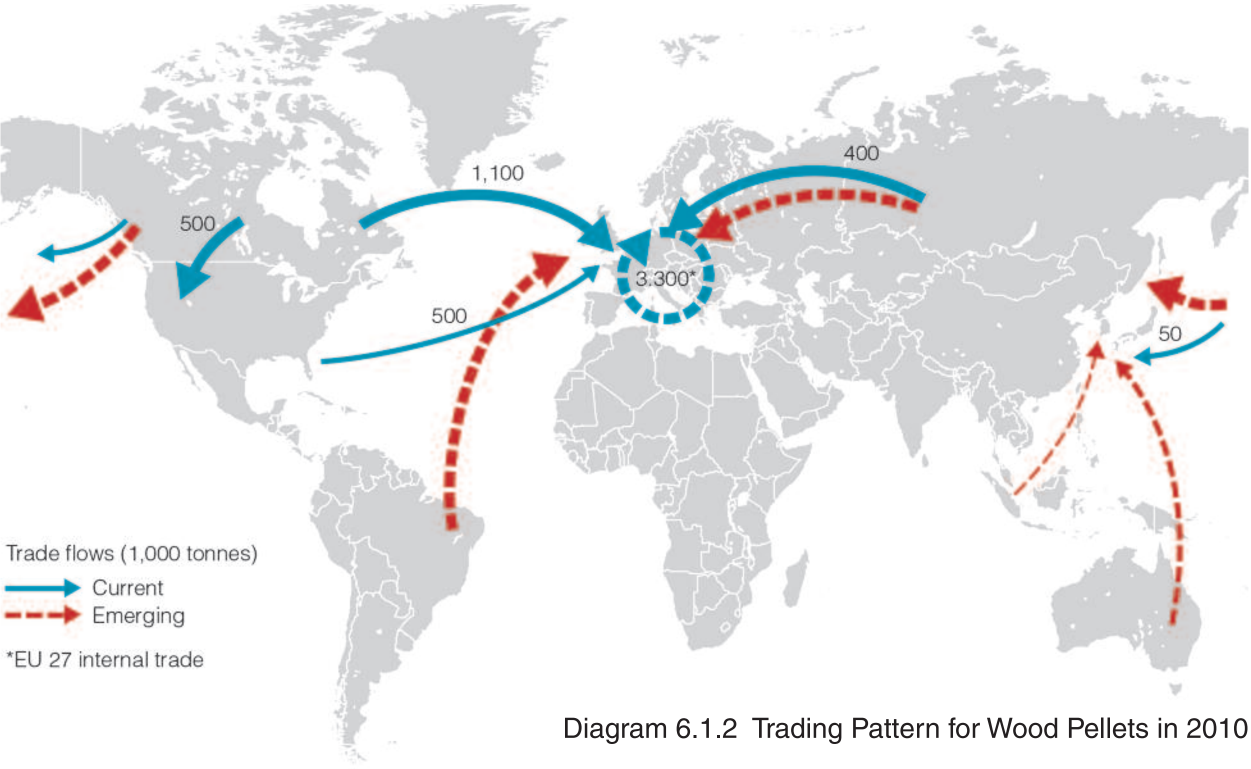


Diagram 6.1.2 Trading Pattern for Wood Pellets in 2010

provides a perspective of the market development forward to the year 2020 according to Pöyry.

Diagram 6.1.2 illustrates the trading pattern for wood pellets in 2010.

The market for solid biofuels can be divided in to three segments:

- bagged pellets for residential use
- bulk pellets for heat generation (district heating)
- bulk pellets for electrical power production

Wood pellets for the production of power are without comparison the largest market and will become dominant in the future. As the large power stations gradually are reaching the end of their life (about 45-50 years) the power companies are faced with converting their plants to other fuel or ways of generating renewable energy or shutting down the plants since regulations in most jurisdiction do not allow continued emission of carbon-dioxide (CO2) from fossil fuels and other pollutants. Most of the old coal burning plants lend themselves for conversion to co-firing or total conversion to other fuels. The practical optional fuels are fossil gas or powder made from biomass. Biomass is considered near carbon-neutral while fossil gas emits about 50% of the CO_2 compared to coal. A variety of incentive policies are in place for promotion of biomass as a fuel in large volumes for power production. Pellets can be economically transported long distances and be converted to powder at the power station before being injected in the furnaces for combustion or may in some cases be used without conversion to powder and burned as in stoker furnaces or in fluidized bed furnaces. To the extent fossil gas is available in the general area of a power plant, the cost of building pipelines to feed a power station with fossil gas is often much higher than conversion to biomass as a fuel. In many cases fossil gas is not even available within economic range.

The federal policy in Canada is to phase out the coal burning power plants or to have them converted to renewable fuels or at least start co-firing with biomass. A 100% conversion to fossil gas will not meet the new federal guidelines for conversion. This upcoming demand for biofuels will increase the market for pellets dramatically. The three dominating potential sources of biomass in Canada are wood, agricultural materials and peat. The woody biomass will not be sufficient to meet the demand which means that there will be a sizable demand for agricultural biofuels. Today,Canada has 21 coal burning power plants with 53 generating units consuming about 60 million tonne of coal per year. If the decommissioning is done in accordance with recent projections and expected extensions, there may be a demand for 25 to 35 million tonne of solid biofuels per year in Canada in the year 2020 provided a progressive incentive program is put in place. This volume could partly be supplied by agricultural biomass. The research described in Chapter 13 is an indication of where the technology is going.

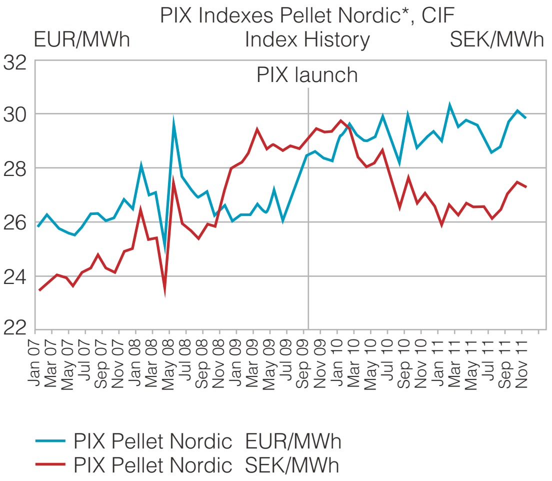
6.2 Market Prices

Diagram 6.2.1 illustrates the market price projection up to the end of 2011. Most of the biomass is available in Western Canada as coniferous trees although substantial volumes of deciduous trees are also available in Eastern Canada, primarily in Ontario and Quebec. Experts are predicting price for pellets in bulk may reach EUR 33-36/MWh (use 4.8 MWh/metric tonne for conversion to price per tonne) or higher in the year 2020 provided the European (including UK), South Korea and North American markets are expanding as currently projected.

A 15 to 20% higher end user price will triple the available woody biomass for biofuels production. Wood Pellet Association of Canada is estimating that 15-20 million tonne of wood pellets per year could be economically produced by 2020 per year in Canada if this price prediction is realized. The demand for agricultural pellets may reach 10 million tonne by 2020 provided quality specified by the ISO FDIS 17225-6 can be achieved and test burning can prove acceptable results if the federal policy is implemented to decrease the use of fossil fuels for power generation.

Diagram 6.2.1 PIX Pellet Nordic Index

Grade	Index Value		Change	Confidence Interval
Pellet Nordic CIF	EUR/MWh	29.89	-0.26	29.22-30.56
	SEK/MWh	273.16	-1.62	



By FOEX Indexes Ltd. *For industrial use

Index is based on previous month's data.

For price conversion between price per ton and price per MWh, a coefficient of 4.8 is used, if not otherwise informed by the price provider.

7- Trade Barriers

The rapidly developing demand and persistent undersupply of biofuels have put a damper on the early signs of trade barriers appearing during mid 1990s when the first shipments of wood pellets to Europe were made from Canada. The market demand has been larger then the supply. Nevertheless, there are trade barriers evolving as the demand for proof of sustainability is becoming better defined, widespread and enforced.

7.1 Phytosanitary Certification

During the nematode scare in the mid 1990s a requirement was enforced to stop importation of woody materials from North America to EU. WPAC requested a ruling by EU based on the fact that the materials going in to wood pellets were practically "sterilized" after passing through a dryer and a hot and high pressure die in the pelletizer before becoming a pellet. The criterion for acceptance was that the material had to be subject to +56°C for at least 30 minutes to be classified as "pest free" and the Canadian pellets passed criteria in December 1999. The interpretation of pest is somewhat flexible and sometimes refers to insects and sometimes all pathogens, including insects, fungus and bacteria.

Recent requests have come from Europe and Korea to verify specifically that the pellets are free of fungus and bacteria. WPAC is currently conducting a research project to verify the microbial count in wood pellets made from softwood as well as hardwood and entering the export market. The results are expected during spring 2013.

The Canadian Food Inspection Agency (CFIA) is the regulator in Canada for issuing phytosanitary certification if required.

http://www.inspection.gc.ca/eng/1297964599443/1297965645317

Once the agricultural pellets become a traded commodity, there will undoubtedly be similar phytosanitary certification requirements.

7.2 EU Illegally Harvested Wood Embargo

In order to stop the import of illegally harvested wood from outside EU the Forest Law Enforcement, Governance and Trade (FLEGT) was established 2003 and ratified in 2005. The system is administrated under the FLEGT Voluntary Partnership Agreements (VPAs) bilateral agreements between the European Union and timber exporting countries, which aim to guarantee that the wood exported to the EU is from legal sources and to support partner countries in improving their own regulation and governance of the sector. On March 3, 2013 the EU Timber Regulation (EUTR – Regulation (EU) No 995/2010) is enforced and applies also to derived products such as pulp, paper and saw dust (likely also solid biofuels). The EU Directorate General DEVCO (DG Development and Cooperation - Eumetsat) and EU Directorate General Environment are the regulatory bodies for the EUTR system. The practical procedure for declaration and certification is still to be established.

For more information see http://ec.europa.eu/environment/eutr2013/index_en.htm

It is not clear to what extent this regulatory scheme might be implemented for purposely grown woody crop like willow, hybrid poplar, salix etc.

7.3 Import Duties

The major markets for Canadian pellets or briquettes like EU, USA and most markets in Asia do not have any import duty on biofuels.

7.4 Sustainability

Sustainability was potentially going to be a trade barrier for export to EU since they only accepted material from PEFC and FSC certification of forest. However, this has changed and the CSA-SFM certification is now accepted in Europe.

USA currently has no restriction or any demand regarding sustainability for biofuels used in USA.

Sustainability requirement for agricultural biofuels has not been defined at this point but would likely fall under the definitions discussed in Section 9.1.

7.5 Pellet Fuels Institute (PFI) Certification

Wood pellets have to be certified under the PFI Certification scheme if sold and used in USA as a fuel for combustion (see Section 11.2). However, wood pellets can be sold and used as animal bedding without PFI certification.

Agricultural pellets are not identified or regulated in the US market at this time.

7.6 Ocean Freight Rates

The Canadian export of wood pellets has been very dependent on the ocean freight rates. As can be seen from Diagram 7.6.1 (indicating the Baltic Index for Panamax vessels) the rates have been fluctuating dramatically since 2003 and have been a major concern.

The present rates hover around USD 30-35/metric tonne from Vancouver to Rotterdam and about $10/metric tonne less from the East Coast. However, the rates are subject to negotiations and some affreightment agreements cover a period of 5-10 years to match the duration of the supply contract overseas and have adjustment clauses for heat value, exchange rates, consumer price index, shipping index etc. in order to stabilize the cost/revenue ratio for the parties involved. At the peak in 2008, the shipping rate from Vancouver to Rotterdam exceeded $93/metric tonne and was not sustainable for any of the parties involved.

Diagram 7.6.1 Baltic Exchange Panamax Index

8 – Development of Standards for Solid Biofuels

The need for international standards for manufacturing and trading of solid biofuels has become pressing as the use of biofuels has advanced from crude combustion of hog fuel, harvest residue and chips in robust furnaces, boilers and incinerators to sophisticated smaller appliances and power stations with rigid emission requirements and complex and expensive maintenance issues. Introduction of certification has been made possible by development of stringent testing standards for verification of critical parameters. Also, the international trade of combustion equipment has made the standardization of both fuels as well as equipment an increasingly important issue to avoid technical trade barriers. Certification has become a public policy issue in many jurisdictions as a measure to come to grips with stiff regulations and cumbersome permitting procedures in many cases stifling proliferation of bioenergy. Wood pellets have become an internationally traded commodity similar to grain and ore which requires strict quality classifications. If agricultural pellets can be manufactured to ISO FDIS 17225 Part 6 specifications, it is likely it will become a high volume bulk commodity for energy production if the demand projected in Section 6.1 is realized.

Standards are generally copyright protected and sold by the organizations developing the documents or by licensed publishers. Therefore, this report can only be referencing the content and present very limited excerpts for illustration of the essential content for the strict purpose of educating the reader about the purpose of standards, how they came about and where to find specific information. For more details the reader is encouraged to acquire copies of the specific standards.

The American Society of Agricultural and Biological Engineers (ASABE) have developed an extensive family of standards in the area of:

1. General engineering for agriculture
2. Agriculture equipment
3. Turf and landscape equipment
4. Electrical and electronic systems
5. Food and process engineering
6. Structures, livestock and environment
7. Soil and water resource management

Testing standards for specific purposes and crops are found in Section 5 of the published standards from ASABE. However, these standards are not developed for the bioenergy industry,are only partially applicable and are not extensively used outside USA even though the standards use both Imperial and Metric measures. The ASABE standards do not have any classification system for biomass materials.

American Society of testing and Materials (ASTM) have developed an extensive family of standards in the area of:

1. Iron and steel products
2. Non-ferrous metal products
3. Metals test methods and analytical procedures
4. Construction
5. Petroleum product, lubricants and fossil fuels
6. Paints, related coatings and aromatics
7. Textiles
8. Plastics
9. Rubber
10. Electrical insulation and electronics

11. Water and environmental technology
12. Nuclear, solar and geothermal energy
13. Medical devices and medical services
14. General methods and Instrumentation
15. General products, chemical specialties and end use products

The ASTM standards use Metric measure to a large extent but do not have any classification system for biomass materials. Many of the ASTM testing standards were developed for fossil fuels. Before the advent of the CEN and ISO standards for solid biofuels, the industry used some of the ASTM standard with some adaptation to the unique characteristics of biofuels.

The use of biomass as a substitute for fossil fuels took hold in Europe when the Kyoto Protocol was adopted in 1997. A number of national classification systems for biomass, including wood pellets and briquettes were quickly developed in Sweden, Germany, Italy, The Netherlands and Austria for trade of biofuels. By 1999 it became apparent that a European standard had to be introduced to make trade more effective and also to address serious quality problems when combusting biofuels of many different qualities in small space heaters which are very sensitive to ash agglomeration. Jamming feeder screws, ash sintering, corrosion and fouling as well as excessive emissions caused b y inferior fuel became an issue of survival for the biofuels industry. The large utilities in Scandinavia started using pellets as a replacement for coal. In 1997 the first shipment of wood pellets on a large scale was successfully done from British Columbia to Sweden. The need for more up to date testing standards adapted to biofuels became apparent and starting in 2005 a family of 24 EN testing standards for biofuels were developed providing methodologies for determination of chemical and physical characteristics of biofuels. By 2005 Canada had become the largest exporter of wood pellets in the world and the need for internationally accepted quality as well as testing standards became apparent. In May of 2008 a decision was made to upgrade the EN Standards to ISO level and the ISO Technical Committee 238 for Solid Biofuels (ISO/TC238) was created. The initial work consisted of a review of several hundred testing standards around the globe, including the European, to make sure the best methodologies were selected for the new family of standards under ISO. Figure 8.1 illustrates the massive undertaking to amalgamate the existing standards.

The standards in USA have only partly been integrated into the ISO work. The PFI pellets standards represent a separate group of standards unique for the US market. USA is however participating in the ISO/TC238 work as convenor for Working Group 6.

Upgrading and adjusting the old ISO coal standards to biofuels include sampling, sample preparation, adjustment for thermo-chemical differences between coal and biomass materials, handling characteristics and the development of recommended precision data unique for biofuels. The process has been highly iterative with involvement of the leading experts from world leading labs as well as large users of biomass and leading edge researchers. In 2010 the CEN Technical Committee 335 (CEN/TC335), which had been developing the initial EN standards, ceased further work which since then has been conducted in the ISO Technical Committee 238

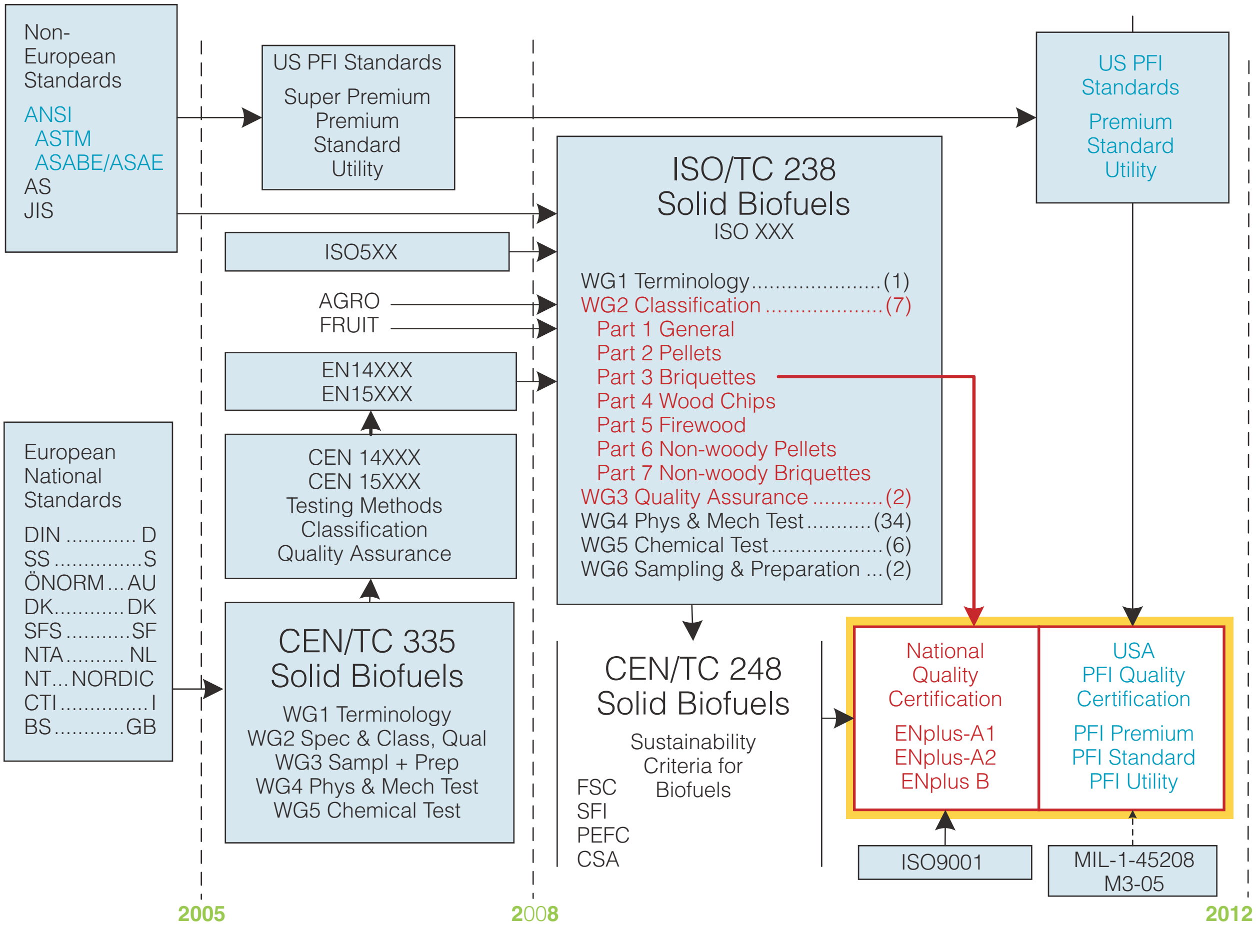


Diagram 8.1 Solid Biofuel Standards & Certification Development

(ISO/TC238) in accordance with the Vienna Agreement. ISO/TC238 today has over 100 expert members representing 34 nations from around the world. ISO/TC238 has the following Working Groups:

WG 1 Terminology/Definitions/Descriptions....................(Convener - Germany)

WG 2 Fuel Specifications and Classes...........................(Convener - Finland)

WG 3 Fuel Quality Assurance...(Convener - UK)

WG 4 Physical and Mechanical Testing Methods ....(Convener - Canada)

WG 5 Chemical Testing Methods ....(Convener - The Netherlands)

WG 6 Sampling and Sample Preparation.......................(Convener - USA)

The publication of ISO standards will be done in accordance with the Vienna Agreement and the national standards organizations. The document designation standard to be used will look like the following examples:

- DIN-CEN-ISO 17225-1 Solid Biofuels – Fuel Specifications and Classes - Part 1- General Requirements. (when published in Germany)
- SIS-CEN-ISO 18134-2 Solid Biofuels – Determination of Moisture Content – Oven Dry Method – Part 2. Total Moisture – Simplified Method. (when published in Sweden)
- The documents will also be issued as for example CEN 17225-1 as well as ISO 17225-1

It is important to notice that standards for solid biofuels are very much subject to upgrades and revisions at this time. Fortunately though there is a convergence to the ISO family of documents which are gradually becoming the international standard for quality classification and testing methodology.

8.1 Testing Standards

The table in Appendix C summarizes the most important testing standards to be published by ISO during 2013/14 as a result of the 6 working groups within ISO. The table also provides a matrix of testing standards under the International Standards Organization (ISO), American Society for Testing and Materials (ASTM), American Society of Agricultural and Biological Engineers (ASABE), the European Committee of Standardization (CEN) plus a few standards developed by the US Bureau of Mines (USBM) and United Nations Recommendation on the Transport of Dangerous Goods, Manual of Tests and Criteria (UN MTC).

It should be mentioned that an attempt was made under CEN to specify a test methodology for ash melting behaviour using visual inspection of the deformation of an ash sample when heated up. However, the method (EN 15370-1) is not reliable and has not been adopted by ISO. New research is under way to devise a new testing methodology to better reflect the internal sintering in an ash sample. The new methodology is currently under evaluation by ISO/TC238.

The ISO testing standards makes no distinction between wood pellets and agricultural pellets and are equally applicable.

8.2. CEN and ISO Classification Standards

The most comprehensive quality classification system developed so far is currently being developed by ISO/TC238 and covers biomass in form of chips, shavings, hog, logs, dust, kernels, seeds, stones, nuts, acorns and compressed materials such as pellets, briquettes, cakes and bales. ISO 17225-1 Fuel Specifications and Classes – Part 1: General Requirements, provides classes of origin and sources of four main groupings of biomass (see Appendix B for more details):

- Woody biomass
- Herbaceous (agricultural) biomass
- Fruit biomass
- Aquatic biomass

The biomass may be by-product or residue from production or harvesting processes, some may be purposely grown, some may be recycled material and some may be harvested and used as fuel in virgin form. There are also classes for mixed as well as purposely blended biomass.

ISO 17225-1 specifies quality classes based on:

- Dimensions
- Moisture content
- Ash content
- Mechanical durability
- Fines content
- Bulk, particle or bale density
- Net calorific value (as received at constant pressure)*
- Nitrogen content
- Sulphur content
- Chlorine content

Ash melting behaviour is not specified as part of the classification under ISO 17225. The EN 15370-1 Standard for Determination of Ash Melting Behaviour has been found to be flawed and is currently amended and will be published as an ISO Standard during 2014. Canada is chairing this development and will release information when the new text has been released.

8.2.1 Binders and Additives

In order to increase the mechanical durability of compressed solid biofuels, the manufacturer may use binders such as starch, corn or potato flour, lignin, vegetable oil etc. during the densification process. In some cases additives are also added as a pressing aid in order to decrease the energy required for making the product. More advanced fuels may even have slagging and fouling inhibitors added to the feedstock during the densification as is discussed in Section 3.1.1 and 3.1.2. The ISO Standards do not limit the amount of binders or additives, with the exception of the graded biofuels which stipulate a limit of 2% additives or binders. If a biofuel has more than 20% by weight of a binder or additive, the biofuel is classified as a blend.

8.2.2 Chemically Treated Feedstock

Any treatment other than air, water or heat of the feedstock of the final solid biofuel product is considered chemical treatment and renders the biofuels chemically treated. The ISO 17225 Standard does not include a classification of chemically treated biofuels but provides examples of what is intended with chemical treatment such as:

- Glue
- Paints
- Plastics
- Laminates
- Preservatives
- Sulphuric acids
- Halogenated organic compounds (chlorine, fluorine, bromine etc.)
- Heavy metals (arsenic, lead etc.)

“Used wood” means pallets, wood packaging, cable reels and construction wood. Demolition wood from buildings is classified as chemically treated wood.

8.2.3 Thermally Treated Biofuels

The ISO 17225-1 Standard specifies two different types of thermally treated biomass – torrefied wood and charcoal. Thermal treatment is described in more detail in Section 4.1. The distinction between treated and un-treated biomass is that thermally treated biomass has a

---

* Noticeable is the absence of gross calorific value (High Heat Value – HHV often used in North America) in the new ISO standards since it is considered to have limited practical significance in the context of energy conversion. Practically all combustion is done at constant pressure (not gross calorific value and not at constant volume as is measured by a bomb calorimeter). International trading of solid biofuels in large scale under commercial contracts is today done at Net Calorific Value at constant pressure as received (often referred to as the net-net value) and the ISO 18125 Standard provides a convenient way of converting.

net calorific value under constant pressure as received of ≥17 MJ/kg and has a much higher carbon content. Torrefied biomass is classified based on the fixed carbon content ranging from 20 to 40% of weight. Charcoal is also classified as a thermally treated biomass but with a carbon content ≥60%. There is currently no calorific value assigned in the Standard as a minimum to qualify as charcoal.

Definition of thermal treatment does not make a distinction between woody and agricultural biomass.

8.2.4 Grading of Biofuels

The ISO FDIS 17225 standard has 7 Parts in total of which common aspects are covered in Part 1. The additional 6 parts are intended for trading purposes with commercialized graded specifications of biofuel characteristics as subsets of the generic classification found in Part 1.

Table 8.2.4.1 summarizes the feedstock materials allowed for production of the biofuels classified as graded for commercial purposes specified in Parts 2 to 7 of ISO FDIS 17225 Part 1. The grading system plays an important role in commercial legal contracts for quality dispute resolution. It can be expected that additional biomass as identified in Appendix B will be graded for trading purposes as more biomass becomes commercially available in sufficient quantities and as we learn how to harvest and prepare these materials for efficient conversion

Table 8.2.4.1 Classification of Biomass and Their Use for Graded Solid Biofuels According to ISO 17225 Standard

		Part 2						Part 3			Part 4				Part 5			Part 6					Part 7	
Feedstock		Wood Pellets						Wood Briquettes			Wood Chips				Firewood			Non-woody Pellets		Cereal Straw Pellets	Miscanthus Pellets	Reed Canary Pellers	Non-woody Briquettes	
Source	ISO Class	A1	A2	B	I1	I2	I3	A1	A2	B	A1	A2	B1	B2	A1	A2	B	A	B				A	B
Woody biomass																								
Forest plantation and other virgin wood	1.1			X	X	X	X			X			X	X										
Whole trees without roots	1.1.1		X						X		X	X				X	X							
Stemwood	1.1.3	X	X					X	X		X	X			X	X	X							
Logging residue	1.1.4		X						X		X	X				X	X							
Logging residue, stored broadleaf	1.1.4.3																							
Logging residue, stored coniferous	1.1.4.4																							
By-products and residues from wood processing industry	1.2			X			X			X				X										
Chemically untreated wood residue	1.2.1	X	X		X	X		X	X		X	X	X		X	X	X							
Bark	1.2.1.5																							
Used wood	1.3																							
Chemically untretaed used wood	1.3.1			X			X			X				X										
Herbaceous biomass																								
Herbaceous biomass	2																	X	X				X	X
Cereal Straw	2.1.1.2																	X	X	X			X	X
Miscanthus (Miscanthus giganteus)	2.1.2.1																	X	X		X		X	X
Reed Canary grass (Phalaris arundinacea L.)	2.1.2.1																	X	X			X	X	X
Non-herbaceous non-woody biomass																								
Fruit biomass	3																	X	X				X	X
Aquatic biomass	4																	X	X				X	X
Blends and mixtures	5																	X	X				X	X

to energy. For example, research is under way to use for example pelletized steam treated biomass as a feedstock for ethanol production.

Annex B of ISO FDIS 17225 Part 1 Standard provides informative data on several other biofuels not graded at this time and may serve as a reference data base (Sections 8.2.5.5 and 8.2.6.4).

8.2.5 Woody Materials

Biofuels made from woody materials is the most common and is traded in densified form as well as non-densified form although the trend is towards densified biofuels since the trade is becoming increasingly international and requires high bulk density to make economic sense.

8.2.5.1 Graded Wood Pellets

The ISO 17225 Solid Biofuels – Fuel Specifications and Classes – Part 2: Graded Wood Pellets, specifies 6 quality classes of wood pellets based on the source of the biomass used as feedstock as summarized in Appendix G.

Pellets quality A1 and A2 are intended for the residential market with A1 being the highest quality in terms of slightly lower ash and nitrogen contents. These qualities are intended for pellets stoves compatible with and tested under EN 14785, pellets burners tested under EN 15270 or burner/boilers tested under EN 303-5.

Pellets quality B is intended for somewhat larger commercial installations which can handle higher contents of ash, nitrogen, sulphur and chlorine.

Pellets Industrial qualities I1/I2/I3 are intended for industrial markets for energy conversion systems which can handle high content of ash, fines, sulphur, chlorine and trace elements.

The demand for certification of wood pellets for the industrial very large scale market has emerged as a consequence of increased intra-trading of biofuels between large power companies as well as the increased demand for environmental accountability in order to enjoy the benefits of climate change mitigation subsidies in Europe. To bring consistency to the large scale biofuels trading the IWPBG established the IWPB product quality standard. The IWPB 1/2/3 quality standard was somewhat different than the I1/I2/I3 classes under ISO but was harmonized in April 2013 and are now called I1/I2/I3 (see Sections 9.2 and 11.3).

8.2.5.2 Graded Torrefied Wood Pellets

Recently, torrefied pellets and briquettes have become graded and commercialized due to a growing demand for high volume deliveries as a replacement for fossil coal. The proposed graded torrefied pellets standard is currently not incorporated in the ISO 17225 standard but is expected to become Part 8 of the ISO FDIS 17225 Standard. Key parameters are still to be added such as hygroscopicity, absorbency and freezing characteristics as soon as testing standards are defined and approved by ISO/TC238 during 2013/14. Appendix H summarizes the allowable feedstock sources for woody torrefied pellets (designated TW1/TW2/TW3).

8.2.5.3 Graded Wood Briquettes

The ISO 17225 Solid Biofuels – Fuel Specifications and Classes – Part 3: Graded Wood Briquettes, specifies 3 quality classes of briquettes based on the source of the biomass used as feedstock.

Briquettes quality A1 and A2 are intended for the residential market with A1 being the highest quality in terms of slightly lower moisture, ash and nitrogen contents. Briquettes quality B is intended for somewhat larger commercial installations which can handle higher contents of ash, nitrogen, sulphur and chlorine.

Briquettes graded under ISO FDIS 17225 Part 3 Standard are intended for pellets stoves, fireplaces, cookers, space and sauna heaters compatible with and tested under EN 13229, EN 12815, EN 12809, EN 13240, EN 15250, EN 15821 or boilers tested under EN 303-5.

Appendix I is summarizing the specification for Graded Wood Briquettes.

8.2.5.4 Graded Torrefied Wood Briquettes

The proposed graded torrefied briquettes standard is currently not incorporated in the ISO FDIS 17225 standard but is expected to become Part 9 of the Standard. Key parameters are still to be added such as hygroscopicity, absorbency and freezing characteristics as soon as testing standards are defined and approved by ISO/TC238 during 2013/14. Appendix I summarizes the allowable source feedstock for woody torrefied briquettes (designated TW1/TW2/TW3.

8.2.5.5 Non-graded Wood Chips

The ISO 17225 Solid Biofuels – Fuel Specifications and Classes – Part 4: Graded Wood Chips, specifies 4 quality classes of firewood based on the source of the biomass used as feedstock.

The significant difference between the quality classes of chips is the moisture and ash contents.

Chips graded under ISO 17225-4 Standards are intended for commercial heating purposes compatible with and tested under EN 303-5.

8.2.5.6 Graded Firewood

The ISO FDIS 17225 Solid Biofuels – Fuel Specifications and Classes – Part 5: Graded Firewood, specifies 3 quality classes of firewood based on the source of the biomass used as feedstock.

The significant difference between the quality classes of firewood is the diameter, length, moisture and the amount of decay.

Firewood graded under ISO FDIS 17225-5 Standards are intended for pellets stoves, fireplaces, cookers, space and sauna heaters compatible with and tested under EN 13229, EN 12815, EN 12809, EN 13240, EN 15250, EN 15821 or boilers tested under EN 303-5.

8.2.5.7 Non-graded Woody Biofuels

The ISO FDIS 17225 Solid Biofuels – Fuel Specifications and Classes – Part 1 General Requirements also includes detailed specifications for an additional group of woody biofuels which are not graded for commercial purposes as follows:

- Table 5 Wood Chips and Hog Fuel
- Table 6 Log Wood and Firewood
- Table 7 Sawdust
- Table 8 Shavings
- Table 9 Bark

8.2.6 Graded Non-woody (Agricultural) Materials

Biofuels made from non-woody or agricultural biofuels are not yet common. However, it is expected that agricultural biomass will be used extensively in the future as a large scale biofuel for heat and power production. It will be traded in densified form as well as non-densified form although the trend is towards densified biofuels since the trade is becoming increasingly international and requires high bulk density to make economic sense.

8.2.6.1 Graded Non-woody (Agricultural) Pellets

The ISO FDIS 17225 Solid Biofuels – Fuel Specifications and Classes – Part 6: Graded Non-woody Pellets, specifies 2 quality classes of non-woody agricultural pellets based on the source of the biomass used as feedstock.

Non-woody pellets quality A and B are intended for residential, commercial and industrial markets, provided the combustion equipment is designed to handle relatively high content of fouling and corrosive agents. Quality A has lower moisture, ash, fines, nitrogen, sulphur and chlorine contents.

Non-woody agricultural pellets may be made from feedstock such as herbaceous, fruit, aquatic as well as blended and mixed biomass. Table 2 in Part 6 (Appendix B) specifies non-woody agricultural pellets made from:

- Cereal Straw
- Miscanthus
- Reed Canary Grass

Non-woody graded pellets under ISO 17225-6 Standards may be used for pellet burners tested in accordance with EN 15270 or boilers tested under EN 303-5. However, due to the chemical characteristics of the agricultural feedstock it is expected that non-woody agricultural pellets will mainly be used for production of power and heat. The more likely scenario is that non-woody or agricultural feedstock will be used for production of torrefied non-woody agricultural pellets (see Section 8.2.6.2).

8.2.6.2 Graded Torrefied Non-woody (Agricultural) Pellets

The proposed graded torrefied pellets standard is currently not incorporated in the ISO FDIS 17225 Part 6 standard but is expected to become Part 10 of the Standard. Key parameters still to be added are hygroscopicity, absorbency and freezing characteristics as soon as testing standards are defined and approved by ISO/TC238 during 2013/14. Appendix H summarizes the allowable source feedstock for non-woody torrefied pellets designated AG1/AG2/AG3. Appendix D also includes the specification for non-torrefied pellets for comparison.

8.2.6.3 Graded Non-woody (Agricultural) Briquettes

The ISO 17225 Solid Biofuels – Fuel Specifications and Classes – Part 7: Graded Non-woody Briquettes, specifies 2 quality classes of non-woody briquettes based on the source of the biomass used as feedstock.

Non-woody briquettes quality A and B are intended for residential, commercial and industrial markets, provided the combustion equipment is designed to handle relatively high content of fouling and corrosive agents. Quality A has lower moisture, ash, fines, nitrogen, sulphur and chlorine contents.

Non-woody briquettes may be made from feedstock such as herbaceous, fruit, aquatic as well as blended and mixed biomass.

Non-woody briquettes graded under ISO 17225-7 Standards are intended for pellets stoves, fireplaces, cookers, room and sauna heaters compatible with and tested under EN 13229, EN 12815, EN 12809, EN 13240, EN 15250, EN 15821 or boilers tested under EN 303-5.

Appendix I also includes the specification for non-woody torrefied briquettes for comparison.

8.2.6.4 Graded Torrefied Non-woody (Agricultural) Briquettes

The proposed graded torrefied briquettes standard is currently not incorporated in the ISO 17225 standard but is expected to become Part 11 of the Standard. Key parameters still to be added are hygroscopicity, absorbency and freezing characteristics as soon as testing standards are defined and approved by ISO/TC238 during 2013/14. Appendix I summarizes the allowable source feedstock for non-woody torrefied briquettes designated AG1/AG2/AG3.

8.2.6.5 Non-graded Non-woody (Agricultural) Biofuels

The ISO FDIS 17225 Part 1 Standard includes a comprehensive classification system of a large number of non-woody biomass materials currently not graded for trading. The classification system provides a rating of the following parameters:

- Dimensions
- Moisture content
- Ash content
- Mechanical durability
- Fines content
- Bulk, particle or bale density
- Net calorific value (as received at constant pressure)*
- Nitrogen content
- Sulphur content
- Chlorine content

The biofuels included are:

- Bales of straw, reed canary grass, miscanthus
- Energy grains
- Olive residues
- Fruit seeds

8.3 Informative Biofuels Databases

Annex B of the ISO 17225-1 Standard provides extensive empirical chemical data (informative average and typical variation data collected and compiled during the development of the Standard) for several selected biofuels which may serve as a reference database. The data includes proximate, ultimate and ash trace elements. Table 8.3.1 summarizes the types of biomass profiles provided in the Standard.

Several databases, all with limited information, have been accumulated to disseminate information about biomass and ashes from biomass (see Section 1).

Table 8.3.1 ISO 17225-1 Selected Chemical Profiling of Biofuels

Source	Biomass Type
Woody Biomass	
Virgin wood without significant amount of bark, leaves and needles	Coniferous wood
	Broadleaf wood
Virgin bark	Bark from coniferous wood
	Bark from broadleaf wood
Virgin logging residue	Coniferous wood
	Broadleaf wood
Virgin short rotation coppice	Willow
	Poplar
Herbaceous Biomass	
Virgin straw without significant of grains	Wheat, rye, barley
	Rape seed
Virgin cereal grain	Wheat, rye, barley
	Rape seed
Virgin canary grass	Summer harvest
	Spring harvest
Virgin grass	Hay
	Miscanthus (China reed)
Fruit Biomass	
Olive and grape cakes	Crude olive cake
	Exhausted olive cake
	Olive kernels
	Crude grape cake
	Exhausted grape cake
Fruit stones and shells	Appricot, peach, cherry
	Almond, hazelnut, pine nut
	Palmoil shell, nut, fibre
Husks, stalks and trash	Rice husks
	Cotton stalks
	Cotton gin trash
	Sunflower husks
	Pensylvanian malva

8.4 Standards for Solid Biofuels in Canada

A movement at the provincial and federal level is currently under way in Canada to adopt the ISO/TC238 Solid Biofuels Standards as a national standard for all solid biomass fuels. At the time of writing this report the effort is just in the early discussion stage. The intent is to avoid having a number of standards developed on a local level which are limited in scope and therefore could become hindrance to trade on a larger scale.

9 - Sustainability of Biofuels

As the implementation of climate change mitigation policies progresses, particularly in Europe, the sustainability of the supply of biofuels is becoming the front line issue. It is getting to the point where without proven and certified sustainability, the generation of bioenergy will not qualify for the vital subsidy system on which the economics of the entire renewable energy concept is based.

An inventory made by Dong Energy in Denmark in 2010 of sustainability systems indicates the existence of 67 different systems worldwide in the sectors listed in Table 9.

Table 9 Illustration of the Many Efforts Under Way to Develop Criteria for Sustainability in a Variety of Sectors

Sector	Number of Sustainability Schemes Developed as of 2010
Biomass and Bioenergy	20
Biofuels	16
Forestry	17
Agriculture	11
Social	3
Total	67

The following sections describe Standards as well as the dominant sustainability schemes in place today related primarily to the trade between North America and Europe and within Europe.

9.1 ISO/TC 248 Sustainability Criteria for Bioenergy

The ISO Project Committee 248 was initiated in 2009 with the objective to develop a global standard for Sustainability Criteria for Bioenergy. The effort has been done by a Project Committee rather than a Technical Committee since it was not clear what the support would be for implementation. The Standard is not a detailed guideline but rather a Process Standard with reference to a number of specific Standards as indicated below. The 248 Project has 4 Working Groups although only three have been active. Working Group 4 (Indirect Effects) has so far been seen as too complex to penetrate.

WG 1 – Terminology and Cross-cutting Issues

- Nomenclature
- Transparency, legality, human rights, working conditions, responsibility, science based approach

WG 2 – GreenHouseGas (GHG) Balance (LCA perspective)

- ISO 14067 Carbon Footprint of Products
  - Requirements and Guidelines for Quantification and Communication (Global Warming Potential -GWP)
- ISO 14040 Environmental Management
  - Life Cycle Assessment – Principles and Framework (steps of LCA and LCIA)
- ISO 14044 Environmental Management
  - Life Cycle Assessment – Requirements and Guidelines (procedure for LCA and LCIA)
- ISO 14064-1/2/3, 14065, 14066,
- IPCC Fourth Assessment 2009
- GHG Emission factors for materials (kg of CO_2eq/MJ)

WG 3 – Social, Economic and Environmental Aspects (LCA perspective)

- Principles, Criteria and Indicators (PCI)
  - Land use rights, water use rights, economic sustainability, food supply, biodiversity,

  - Transparency, legality, human rights, working conditions, local stakeholder involvement
- Local threshold requirements
  - FSC, PEFC, CSA-SFM
  - Contaminations (air, soil, water)
  - Waste handling
  - Energy Efficiency
  - Standard not to be used for certification

WG 4 – Indirect Effects (secondary effects)

- Secondary effects not under direct control of the Economic Operator (EO) not considered
- WG 4 is currently in hold mode

A document numbered ISO CD 13065 is now available for review. It is however not clear if it will be published as an ISO Standard at this point.

9.2 Interpretation of Sustainability Criteria

Guidelines for sustainability of the wood pellets trade have been developed based on the following Directives and Report from the European Commission:

- Directive 2009/28/EC on the promotion of the use of energy from renewable sources (RED)
- Report COM 2010)11 final on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling.
- Impact Assessment (SEC 2010)66 – linked to EC COM(2010)11 final
- Vattenfall Agreement on Sustainability of Procured Biomass between the State of Berlin and Vattenfall Europe AG.
- NTA 8080 (2009) Dutch Technical Agreement, NTA 8080, Sustainability Criteria for biomass for energy purpose.

Sustainability is evaluated based on 9 principals as follows:

- Principle 1. GHG Balance
  - GHG saving (%) = (EF – EB)/EF

    where

    EB = total emissions from the life cycle of the biomass used

    EF = total emissions from the fossil fuel comparator

    For electricity production EF=198 g CO_2eq/MJ electricity (713 kgCO_2/MWh)

    For heating production EF= 87 g CO_2eq/MJ electricity (313 kgCO_2/MWh)

    For heat pump cooling EF= 57 g CO_2eq/MJ electricity (205 kgCO_2/MWh)

- Principle 2. Carbon Stock Change
  - Limitation guidelines regarding Wetlands, Peatlands and Primary Forests

- Principle 3. Biodiversity
  - Limitation guidelines for Primary Forests, Grasslands, Soil Quality,
  - Water Quality and Use, Air Quality, Waste Management, agro-chemicals, Fertilizers,
  - Hazardous Substances and Environmental Impact Assessment

- Principle 4. Protection of Soil Quality
  - Soil Erosion, Nutrients Balance, Soil Salination

- Principle 5. Protection of Water
  - Irrigation Water Use, Biological Oxygen Demand (BOD)

- Principle 6. Protection of Air Quality
  - Emissions to Air, Fire Fighting

- Principle 7. Competition With Local Biomass Uses

  - Competition for Food and Water and other Subsistence Means

- Principle 8. Local Socio-Economic Performance
  - Property Rights, Local Property and Welfare

- Principle 9. Ethics
  - Human Rights, Health and Safety, Labour Rights, Business Integrity and Corruption

The audit principles for compliance with the above Principles are modelled after the Green Gold Label (GGL Module 5) scheme developed by RWE/Essent and Control Union (converted to a Foundation in 2001). GGL has 8 Modules of which Module 5 is for forest materials and Module 2 is for agricultural materials. Besides the 8 Modules there are an additional 2 modules for clean raw materials (CRM) which are applicable to recycled material intended for pre-treatment such as torrefaction.

http://www.greengoldcertified.org/site/pagina.php?id=11

The calculation of end-use GHG balance, using the RED methodology is achieved by comparing the emissions from biomass use to the relevant fossil fuel comparator factors for electricity generation in Europe using the fossil fuels as described in the COM(2010)11 final document – Annex I and in the Impact Assessment EC SEC(201) 65&66 for solid and gaseous biomass.

Diagram 9.2.1 illustrates the results of GHG savings in % compared to fossil fuels used on the EU market. Wood pellets imported for example from BC has a de-rated GHG performance due to

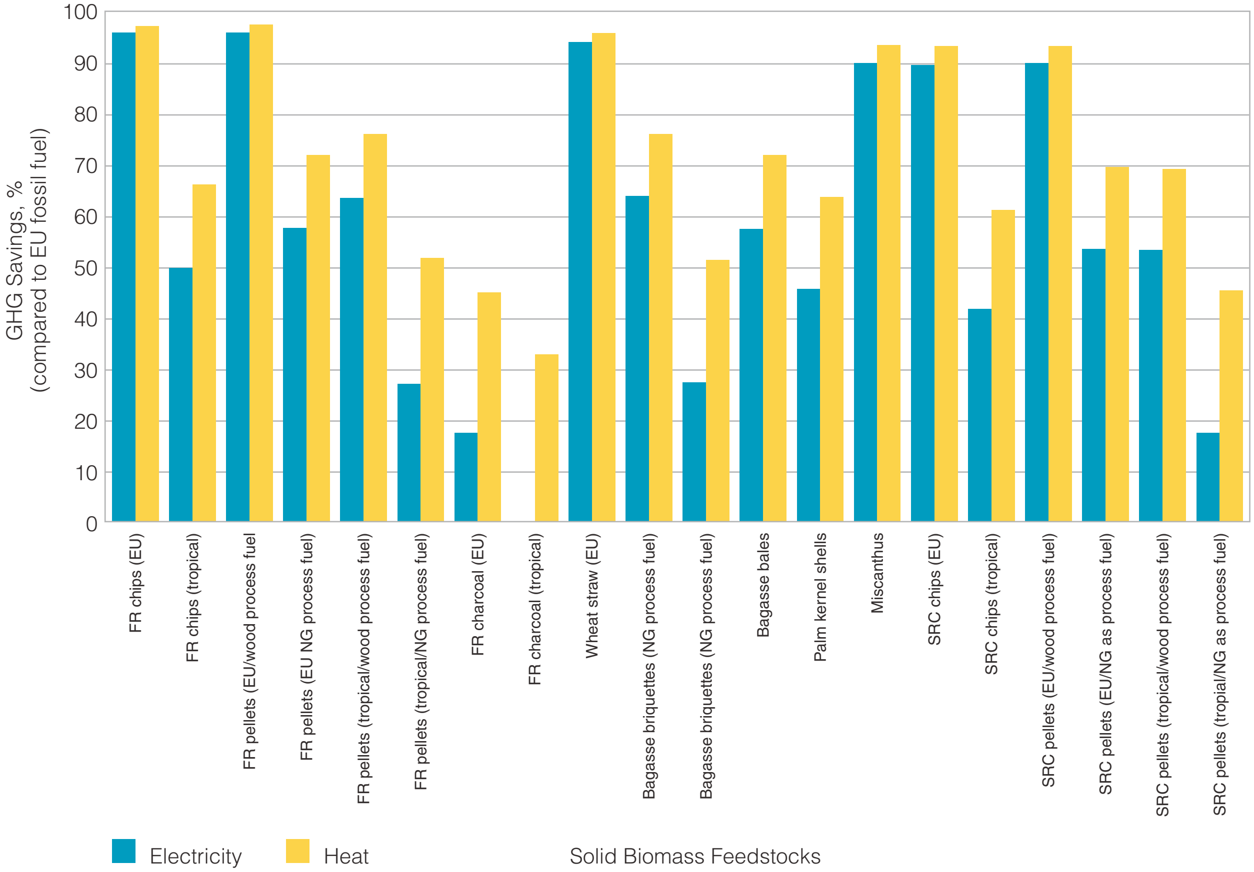


Diagram 9.2.1 Comparison of GHG Savings When Converting to Different Types of Solid Biofuels

the fossil load caused primarily by the long transportation from the interior of BC, across the ocean and to the receiving destination in Europe. The de-rating (called k-factor) corresponds to a GHG saving of about 75 - 78% (not illustrated in the diagram).

9.3 Sustainability of Agricultural Materials for Energy Applications

At EU level, requirements for sustainable agriculture correspond to the ecological cross-compliance requirements (Council Regulation EC No 73/2009) of the Common Agricultural Policy (CAP). For non-EU countries, account is taken both of the national regulations in force and of the guidelines and recommendations on good agricultural practice. The Green Gold Label module GGL 2 (Appendix E) outlines a sustainability certification process, including audit procedures, for agricultural materials and has 10 guiding Principles, each with a given set of Criteria.

For the very limited amount of agricultural material traded for energy purposes today the Green Gold Label (GGL) certification scheme could be used until a commercial size market has been developed at which time agricultural pellets or briquettes may be incorporated, for example, as a schedule in one of the established certification schemes in place. See GGL Source Criteria for agricultural biomass at http://www.greengoldcertified.org/data/docs/ggls2%20-%20agricultural%20source%20criteria%20v.2013.1.pdf

A consideration of the sustainability issue is the nutrient extraction from the soil if agricultural harvest residue is used on a large scalei.e. how much harvest residue should be left behind to sustain a healthy nutrient balance? This issue is also debated by the forest sector and there are differences in opinion among experts. There is likely more research regarding nutrients done in the agriculture industry than in the forest industry. The Environmental Sustainability Attributes of Biomass report November 2012 by CIRAIG concludes that current sustainability criteria need to be established by environmental Life Cycle Assessment (eLCA) and social Life Cycle Assessment (sLCA) although extensive sLCA is not used in North America but is gradually becoming important. The eLCA takes in to consideration carbon footprinting (GHG emissions) as well as soil related specificities. However, the study concludes that only the GHG change impact has to be quantified by means of life cycle assessment while all other environmental issues have to be addressed through qualitative statements and evidence that measures have been implemented on the farm by means of best practices, reduction projects and environmental farm plans. An eLCA is however capable of assessing soil and aquatic eco-toxicity, eutrophication, respiratory effects from ammonia and particulate matter as well as water use.

The recycling of nutrients as part of the washing discussed in Section 4.4 could be an important mitigating factor if agricultural biomass becomes a large scale feedstock for production of solid biofuels.

It is expected that more precise sustainability requirements for use of agriculture biofuels for power production in Ontario will be announced at a later date. The use of agricultural biofuels for energy production in a domestic market like Ontario will be highly beneficial compared to export to Europe since the carbon foot print will be considerably smaller with the elimination of ocean transportation. The carbon credit would also be contributed to Canada rather than to overseas jurisdiction.

9.4 Sustainability of Wood Pellets for the Large Scale Industrial Users

Sustainability criteria are under development for solid biofuels by the large pellets users in Europe. Rather than assessing the sustainability of biofuels from a producer standpoint with emphasize on feedstock related assessment, the approach taken by IWPBG is to look at the sustainability from a user perspective which will assess the entire supply chain with particular focus on supply logistic aspects. This market demand approach provides a better understanding of the overall envelope within which the material characteristics will have to fit to comply with market driven sustainability criteria and will take in to consideration all factors involved in crop generation, harvesting, processing, transporting, storing and converting a particular biofuel to energy and power. Various crops and related characteristics are assessed and qualified into grades based on parameters critical to the use of the material. This way each crop material is immediately classified in accordance with its marketability as soon as the characteristics are known from lab testing and the predetermined handling characteristics.

The potential threat of competing interests between food production and energy production is currently being resolved by means for sustainability criteria being imposed on feedstock for energy production.

Qualities of pellets such as agricultural pellets, explosion pulping pellets and torrefied pellets are not part of the IWPBG procurement concept at this time. The main reason is that there is no market established for these products yet. However, the same sustainability criteria will apply as for regular woody biofuels such as white pellets and briquettes. Table 9.4.1 summarizes the general guidelines for sustainability implemented by the IWPB Group for large scale procurement of woody biofuels and are identical to the Principles listed in Section 9.2.

In order to comply with the above Principles, each operator within the IWPB procurement

Table 9.4.1 Sustainability Principles Guidelines Used by the IWPB Group

IWPB Sustainability Principles
Principle 1: Greenhouse Gas Balance (GHG) The greenhouse gas (GHG) savings along the entire life cycle, taking into account the whole supply chain including production, processing, transport and end-use are at least 60% with respect to reference fossil fuels.
Principle 2: Carbon Stock Production of woody biomass fuels does not take place at the expense of significant carbon reservoirs in vegetation and soil.
Principle 3: Biodiversity Production of wood biomass fuels may not take place in areas with high biodiversity value, unless evidence is provided that the production of that raw material did not interfere with those nature protection purposes.
Principle 4: Protection of Soil Quality Production and processing of woody biomass fuels should maintain or improve the soil quality.
Principle 5: Protection of Water Quality Production and processing of woody biomass fuels should not exhaust ground and surface water and should avoid or significantly limit negative impacts on water.
Principle 6: Protection of Air Quality Production and processing of woody biomass should avoid negative impact or significantly reduce impact on air quality.
Principle 7: Competition with Local Biomass Applications Production of woody biomass should not endanger food, water supply or communities where the use of this specific biomass is essential for subsistence.
Principle 8: Local Socio-Economic Performance Production of woody biomass should respect property rights and contribute to local prosperity and to the welfare of the employees and the local population.
Principle 9: Corporate Responsibility Generic sustainability principles not directly related to woody biomass are covered by the Codes of Conduct or Policies of the members of IWPB covering all types of commodities and should be applied for production and processing of woody biomass.

process is required to fill in forms published by IWPB dated June 5, 2012 Report 2 (see http://www.laborelec.be/ENG/initiative-wood-pellet-buyers-iwpb/).

The documents for the compliance verification process for IWPB certification is available at the following website: http://www.laborelec.be/ENG/biomass-verification-procedure/

9.5 Sustainability of Wood Pellets for the Small Scale Users

The ENplus certification scheme as described in Section 11.1 includes a requirement to comply with “generally acceptable Sustainability principles” with reference to a “statement of Commitment” to be signed by the licensee. However, there are no specific guidelines. EPC however is referring to the same guidelines as are prescribed for the IWPB operators.

The US PFI (see Section 11.2) certification scheme does not include a requirement for sustainability.

10 – Quality Control and Quality Assurance Standards

ISO 9001 Quality Management System includes Quality Planning, Quality Control, Quality Assurance and Quality Improvement modules.

CEN/TC335 has drafted a Fuel Quality Assurance Standard specifically for the solid biofuels market. However, the development is not completed. The scheme includes traceability and control measures from the feedstock through manufacturing and distribution all the way to the end user with proposed forms for control stations along the road. No time schedule is set for completion of the standard at this time. Working Group #3 within ISO/TC238 was working on an upgrade of the CEN/TC335 document but decided in the April 2013 meeting in Bangkok not to proceed until a clear demand has been expressed by the industry. Several other QC/QA systems are already in place.

11 – Product Quality Certification

Many different certification schemes for solid biofuels have been developed over the last 10 years and are still under development. The European ENplus scheme is gaining momentum and is a voluntary system. Currently, over 30% of all pellets in Europe are traded under this certification scheme. Another 30% will be traded under the IWPB certification scheme by the end of 2013 to the large power producers. In USA the PFI certification scheme was introduced as a mandatory system but has not gained wide acceptance yet. Canada is in the process of introducing a version of the voluntary ENplus scheme the Canadian export as well as the domestic market with the potential for adaptation also to the US market. It is important however to notice that all these activities are evolving at this point and it will tae at least another year before the situation stabilizes.

11.1 ENplus Product Quality Certification

With a product quality scheme based on two DIN Quality Standard for wood pellets (DIN 51731 and DIN plus) in Germany established in mid 2000 and the new set of EN Standards produced by CEN/TC 335, not only for product quality classification like EN 14918, but also for testing methodology, the German Pellet Institute (DEPI www.depi.de) started to develop a Product Quality Certification system due to widespread complaints from the residential use of pellets in small space heaters related to clinkering and quality of bagged pellets. Some pellets were produced in Germany and some outside the country. This called for an international approach and DEPI decided to offer the certification system to the European Biomass Association (AEBIOM www.aebiom.org) on a license basis with the hope that the certification scheme would spread throughout the market. In Europe the ENplus certification of wood pellets is voluntary but has become de facto requirement for producers to become successful in the market. The ENplus certification system is applicable to all parties starting with the manufacturers all the way to the party delivering the product to the end-user and includes traders, transportation companies, retailers and other parties having custody of the actual product. In December 2010 the European Pellet Council (EPC www.pelletcouncil.eu) was created to be the custodian of what is now called the ENplus certification scheme. EPC is part of AEBIOM and was given the authority to “sub-contract” the scheme to any national organization, in Europe or outside Europe, interested in adopting, administrating and enforcing the certification scheme. A the end of 2012 the following countries have adopted the ENplus certification system;

- Austria
- Belgium
- Croatia
- Czech Republic
- Denmark
- France
- Germany
- Italy
- Lithuania
- Portugal
- Romania
- Spain
- Switzerland
- United Kingdom

ENplus is now developing towards a true pan-European certification system with 13 of the EU25 already signed up. More members are however in the process of applying for participation. Over 30% of the pellets trade in Europe today are certified under ENplus less than 2 years after introduction of the certification scheme.

11.1.1 ENplus Certification in Canada

WPAC (www.pellet.org) is an Associated Member of EPC (www.pelletcouncil.eu) since December of 2010 and has been granted a license for use of the ENplus certification system in Canada which means that certification of Canadian organizations from now on will be done under the auspices of WPAC. The final agreement between WPAC and AEBIOM will be signed in spring of 2013. Diagram 11.1.1.1 illustrates the contractual relations with the parties of the Canadian ENplus certification system.

WPAC has established an agreement with Control Union Certifications (CUC) as the sole Certification Body in Canada in order to fulfill the role of Certifying Body and Registrar. WPAC is the holder of the ENplus license and sublicensing to producers and traders is issued by WPAC. The ENplus Trade Mark is protected by EPC.

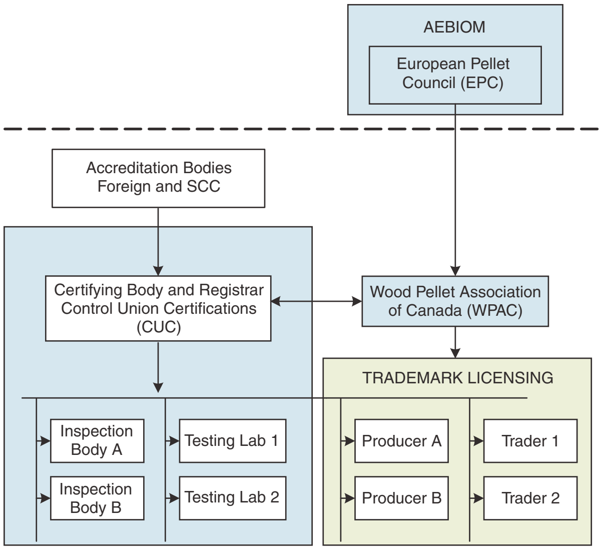


Diagram 11.1.1.1 Contractual Relation Between Parties of the Canadian ENplus Certification Scheme

CUC is EN 45011 accredited by the Dutch Board of Accreditation [RvA] member of the European Co-Operation for Accreditation [EA] and will perform the following duties in Canada:

- administrate the licensee registry
  - producers
  - traders
- track the performance of licensees in terms of production and conformity
- keep a current registry of
  - traders of non-certified pellets
  - traders with non physical contact with pellets
  - modalities such as vehicles and storage facilities as part of the certified logistical chain
- collect fees from licensees
- report to WPAC on a regular basis, including
  - recommendation and reports received from inspection bodies, auditors and testing laboratories
  - financial status of the ENplus system in Canada
  - inspection and auditing activities

The application process for producers and traders follow a strict process as outlined in the ENplus Handbook and is illustrated in Diagram 11.1.1.2.

The ENplus certification scheme has regulations on how to handle non-conformity by licensees. There are special rules on how to calculate fees for multiple products as well as multiple production sites. Diagram 11.1.1.3 illustrates trade mark branding of product packaging and

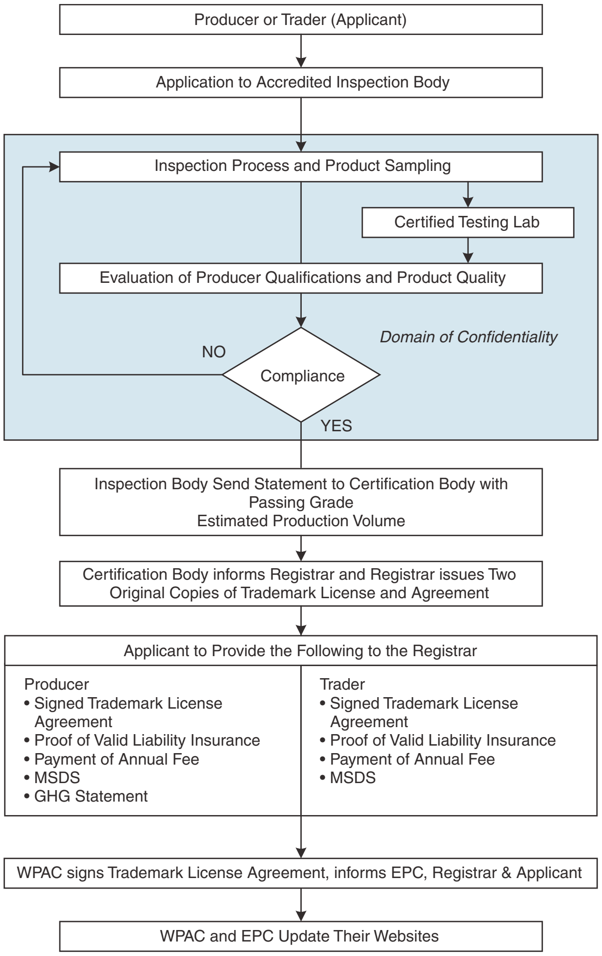


Diagram 11.1.1.2 Application Process for Certification Under ENplus

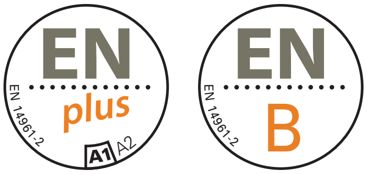


Diagram 11.1.1.3 Trademark Branding of Product Packaging Under ENplus

documentation, promotional materials etc. used for certified products.

Establishing ENplus as a Canadian standard will facilitate a simplification of the otherwise extremely complicated permitting of systems for bioenergy production currently in place in most Canadian jurisdictions. A certified known fuel quality in combination with certified performance tested combustor equipment would be the cornerstones of a streamlined process where most of the unknowns are removed (Section 13.5). Introduction of such a simplification is likely to have significant impact upon the use of Canadian pellets in Canada and contribute significantly to the national carbon credit balance.

WPAC members will pay a fee for having the right to use the ENplus logo of CAD 0.15/mt, non-WPAC members will be charged CAD 0.20/mt of which 50% of the projected annual fee shall be paid when the ENplus license agreement is signed and thereafter upon annual renewal.

Same WPAC fees will apply for producers and traders with the following exceptions:

- A producer that sells his own product directly to end consumers or trades product from 3rd parties requires a certification as producer and trader. License fees need to be paid for both activities. (ENplus Handbook 4.13)
- A trader that solely trades the ENplus certified material, without physical contact/movement, will not need to be certified. However, he needs to be registered with WPAC. (ENplus Handbook 4.3)
- A trader that solely trades bagged ENplus pellets will not need to be certified however needs to be registered with WPAC. (ENplus Handbook 4.3) In case the product will be transported by a non-certified 3rd party, the trader will need to be certified in accordance with ENplus.

The certified producer and trader also shall pay the following fees:

- Fixed annual fee to cover certification costs [to be paid to Certification Body] , license rights and contribution to litigation fund
- Audit fee [to be paid to Inspection Body]
- Testing fee [to be paid to Testing Body]

Sustainability criteria was added to the ENplus certification scheme as of January 2012. CSA-SFM, FSC, PEFC, SFI, FFCS and GGLS5.

11.1.1.1 Accreditation of Inspection Bodies and Auditors

Inspections can be executed by any Inspection Body registered with the EPC irrespective where they are based. Qualified auditors conducting inspections and audits for Inspections Bodies must have at least 2 years of experience with inspection of pellet production plants and have to attend a auditor's workshop at least every second year.

11.1.1.2 Accreditation of Testing Laboratories

Analysis can be executed by any Testing Body registered with the EPC irrespective of where they are based.

11.2 Pellet Fuels Institute (PFI) Product Quality Certification

In USA the manufacturers of wood pellets have had quality standards established by Pellet Fuels Institute (PFI www.pelletheat.org) based on ASTM testing standards for some years. In early March 2010 the US Environmental Protection Agency (EPA) announced that the quality of pellets marketed in USA would have to be certified as part of the upgrade of the EPA 1988 New Source Performance Standard (NSPS) for wood heaters. The objective was to regulate the emissions from small space heaters which consequently would require tighter quality specifications for the fuel. The option for PFI was to accept an EPA imposed standard of wood pellets or develop their own industry standard and certification system for review by EPA before November 2010. PFI acted quickly and developed a new product quality standard and a certification procedure. The PFI certification scheme is now in force since October 7, 2010 but very few manufacturers have so far applied for certification. The US certification system is a regulatory requirement and non-compliant manufacturers would face stiff penalties if EPA were to enforce compliance with the PFI certification standard. The PFI certification system may be used by Canadian manufacturers selling in to the US market. However, the PFI certification system covers only the manufacturing stage and does not have provisions for chain of custody certification.

The new PFI Product Quality Standard Specification is summarized in Appendix G and includes only three grades (the previous Super Premium grade has been deleted and the remaining grades have been adjusted accordingly). The new Standard is the basis for a certification scheme which has similarities with the ENplus in Europe with a third party enforcer and an outside auditing process as indicated in Diagram 11.2.1.

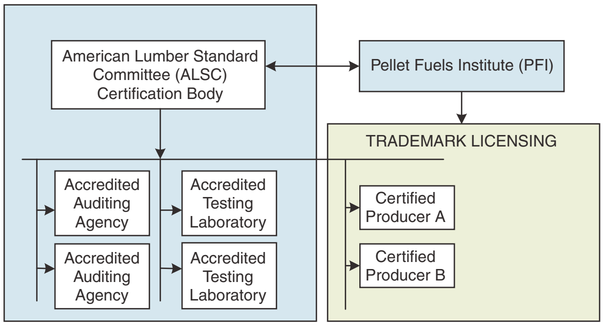


Diagram 11.2.1 Contractual Relations Between Parties of the PFI Certification Scheme

The PFI certification scheme, which is subject to additional modification and approvals, is described in detail in the following documents which can be downloaded from the PFI website (www.pelletheat.org):

- PFI North American Certification of Residential/Commercial Densified Fuel
- PFI Residential/Commercial Densified Fuel Quality Assurance and Quality Control Handbook
- PFI Standard Specifications for Residential/Commercial Densified Fuel
- Much of the Quality Management procedures used in the PFI certification scheme is modeled after the ENplus Handbook. PFI's old program was modeled after MIL-I-45208 however that system was replaced by the new program.
- PFI Residential/Commercial Densified Fuel Enforcement Regulations, October 25, 2010.

The specifications for the three PFI product quality classes are identical with the exception of small differences in:

- Bulk density
- Mechanical Durability
- Fines content
- Ash content
- Moisture

There are however significant differences in the specification under the certification scheme compared to the ENplus. The High Heating Value (HHV) and the Ash Melting Temperature are stated as received on the packaging label but are not graded under the certification. The Low (Net) Heating Value (LHV) is not stated.

The PFI scheme is offered on a per company basis:

- PFI issues certification Standards and supervise the implementation
- An appointed Certification Body implements the certification and enforces the compliance. The American Lumber Standard Committee (ALSC) is the chosen as the Certification Body for the PFI certification system.
- Audit agencies are accredited by the Certification Body and the Audit Agencies pay a fee for initial audit by Certification Body and subsequent audits of manufacturers. The Audit Agencies (corresponding to Inspection Bodies under ENplus) collect cost for audits from manufacturers
- Test Labs are accredited by the Certification Body and the Test Labs pay an application fee and a fee for the initial audit by Certification Body

There is no requirement for traders of pellets in USA to be certified as is the case in Europe. This may be because most wood pellets manufactured in USA are also packed at the manufacturing facility. The wood pellets exported from US are not subject to the PFI certification since they have to be compatible with the standards in the receiving markets (at the present time the European market).

The PFI certification scheme does not at this time stipulate any requirement for sustainability of the feedstock.

The ASTM and NIST (National Institute of Standards and Technology) Standards are used as the basis for the quality testing under the PFI certification scheme.

There is a mandatory audit per month per plant required.

A minimum of 40 lbs per sample per 1,000 short ton of product produced is required for lab test purposes. The collected monthly sampled volume is used for preparation of a test sample which is used for the monthly analysis of the quality.

There is no time limited validity of the certification under the PFI certification scheme. If the certificate holder defaults on obligations, the Certification Mark may be revoked or suspended.

The aggregate cost for certification is estimated to USD 0.30 – 0.45/short tonne depending on annual production volume. The manufacturer pays the following:

- Application fee
- Initial audit fee
- Fee for each subsequent production audit

The PFI Certification Mark for certified product depicted in Diagram 11.2.2 includes a brief product specification as opposed to the ENplus which is strictly a logo with reference to the quality classes A1/A2/B.

The USA is participating, together with 34 other nations, in the further development of the ISO standards for biofuels and there is a sentiment among experts in USA to introduce the ENplus as a parallel certification system to the PFI system. Even though the ENplus is considerably more stringent, the main driver towards ENplus is the more practical quality verification system under ENplus.

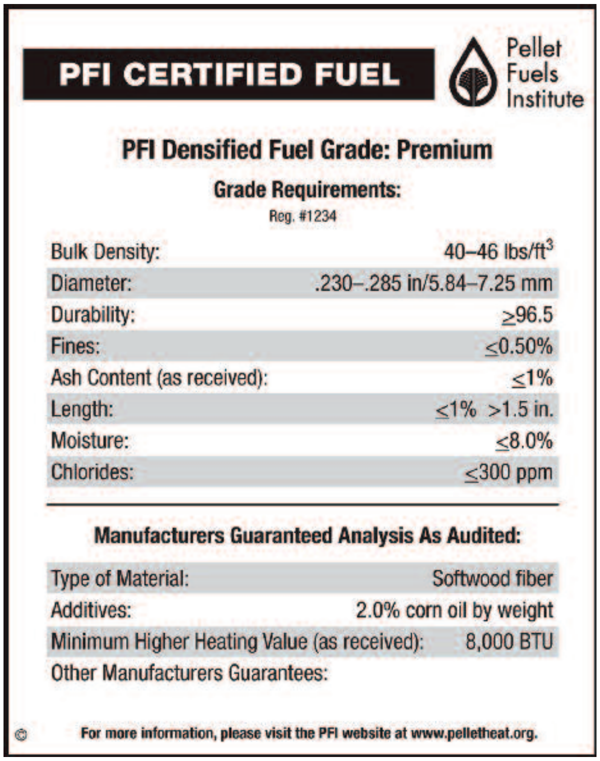
11.2.1 PFI Certification Status in Canada

Canadian producers have the same right to be certified as US producers under the PFI certification system. So far none of the Canadian producers has applied for PFI certification.

Scott Smith of Shaw Resources, a Canadian pellet producer servicing both the European and US markets, was co-chair of the PFI standards committee throughout the development of the PFI standards, Jeff Thiessen of Dansons (former president of WPAC) was President/Vice President of the PFI during this period, Mike Albright of UNB (a Canadian lab) actively participated on the PFI Standards Committee and Jim Cronin of Energex (a pellet producer with plants in both the US and Canada) also served on the PFI Standards Committee throughout this time period.

11.3 Industrial Wood Pellet Buyers (IWPB) Group Certification

The Industrial Wood Pellet Buyers Group (IWPBG) represents the most powerful buyers of wood pellets in the world. The organization was set up in 2010 as a result of several years of difficulty in sourcing biofuels from reliable



PFI CERTIFIED FUEL

Pellet Fuels Institute

PFI Densified Fuel Grade: Premium

Grade Requirements:

Reg. #1234

Bulk Density:	40–46 lbs/ft^3
Diameter:	.230–.285 in/5.84–7.25 mm
Durability:	≥96.5
Fines:	≤0.50%
Ash Content (as received):	≤1%
Length:	≤1% >1.5 in.
Moisture:	≤8.0%
Chlorides:	≤300 ppm

Manufacturers Guaranteed Analysis As Audited:

Type of Material:	Softwood fiber
Additives:	2.0% corn oil by weight
Minimum Higher Heating Value (as received):	8,000 BTU
Other Manufacturers Guarantees:	

© For more information, please visit the PFI website at www.pelletheat.org.

Diagram 11.2.2 PFI Product Certification Mark sources in combination with a closer cooperation to manage short term shortages and limitation in storage capacity during maintenance shutdowns. In order to avoid the perception of collusion, the major suppliers represented by Wood Pellet Association of Canada (WPAC) and US Industrial Pellets Association (USIPA) as well as European Industrial Pellet Suppliers (EIPS) now participate in the IWPBG meetings to make sure the interests of the supply side is also heard. The main drivers for development of the IWPB standard were initially the following companies:

• GDFSUEZ	www.gdfsuez.com
• RWE	www.rwe.com
• EON	www.eon.com
• Fortum	www.fortum.com
• Drax	www.draxgroup.plc.uk
• Vattenfall	www.vattenfall.com
• Dong	www.dongenergy.com

The original IWPB product quality class standard has been merged with the ISO Standards (see Sections 8.2.5.1 and 9.2). The IWPB standard has evolved to become a certification including sustainability criteria similar to what ENplus has incorporated.

The European Pellet Council (EPC) initiated the PellCert Project with the intent to implement a version of the ENplus for industrial pellets. However, the IWPB Group has developed their own trading scheme based on the European Federation of Energy Traders (EFET) model, including:

- Procurement contract templates (Individual Biomass Contract)
- Wood Pellet Specification
- CIF Delivery Terms
- Quantity Measurement and Weighing Procedure
- Sampling and Testing Procedures
- Sustainability Requirements
- Credit Terms and Conditions
- Loading/Unloading Requirements
- Seller's Code of Conduct.

11.4 ENagro Certification

The Mixbiopells Project funded by the Intelligent Energy Europe (IEE) Program has developed a certification scheme called ENagro for pelletized agricultural biofuels modelled after the ENplus for wood pellets. However, this scheme has not been implemented since the market has not been developed yet in Europe. If it is implemented, ENagro will be administered by European Pellet Council (EPC) in a similar manner as ENplus. In fact, the two licensing and inspection schemes are almost identical and the procedures described in Section 11.1 describe the certification procedure in some detail. The EN 14981 (ISO 17225-6) classification is the basis for the agricultural biomass materials which would be certified under ENagro. An inventory of the most suitable non-woody biomass feedstock materials for energy purposes was done in part of Europe from Scandinavia to the Mediterranean region illustrates (Diagram 11.4.1) the finding and may serve as indicator also for parts of Canada although there is also significant potential for

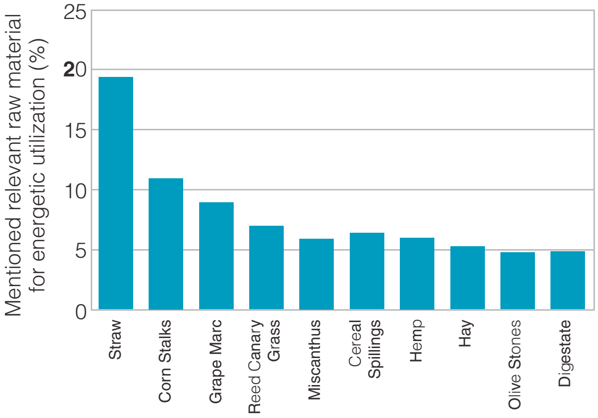


Diagram 11.4.1 Inventory in Europe of Crop Suitable for Energetic Applications

switchgrass and short rotation crop such as hybrid poplar and willow in Canada due to a much larger acreage available.

The classes of agricultural biomass in the EN14981-1 (ISO 17225-1) summarized in Table 11.4.2 was selected for certification under ENagro.

Table 11.4.2 Classes of Agricultural Materials Selected from the ISO 17225 Standards for Potential Certification Under the Proposed ENagro Certification Scheme

ENagro-straw pellets	ENagro-miscanthus pellet	ENagro-reed canary grass pellets	ENagro-blended pellets (A and B class)
2.1.1.2 Straw parts	2.1.2.1 Grasses, whole plant	2.1.2.1 Grasses, whole plant	2 Herbaceous biomass
			3 Fruit Biomass
			5 Blends and mixtures

Appendix D provides specifications for the biomass classes and related pelletized material under ENagro if it were to be implemented. Based on the extensive research under way for the use of agricultural biomass for energy purposes, it is highly likely that ENagro will be activated within the next few years.

The MixBioPells Project has developed logos to be used for certified products as illustrated in Diagram 11.4.3 for straw, miscanthus and reed canary grass.

Diagram 11.4.3 Proposed Logos for Certified Agricultural Pelletized Materials such as Straw, Miscanthus and Reed Canary Grass

11.5 USDA Bio Preferred Program

BioPreferred® program was created by the US Farm Security and Rural Investment Act of 2002 (2002 Farm Bill), and expanded by the Food, Conservation, and Energy Act of 2008 (2008 Farm Bill). The purpose is to increase the purchase and use of biobased products. It is not a sustainability certification program. The United States Department of Agriculture manages the program. BioPreferred includes:

- a preferred procurement program for Federal agencies and their contractors,
- and a voluntary labeling program for the broad scale consumer marketing of biobased products.

Under the procurement program, BioPreferred designates categories of biobased products that are required for purchase by US federal agencies and their contractors. As a part of this process, the minimum biobased content is specified. Going forward, biobased intermediate ingredients and feedstocks will be included in the designation process.

Under the voluntary labeling program, biobased products that meet the BioPreferred Program requirements carry a distinctive label for easier identification by the consumer.

FP Products indicated by this symbol are eligible for preferred Federal procurement. These are products within categories that USDA has designated for the Federal Procurement Preference. Products within these categories are afforded preference by Federal agencies and their contractors when making purchasing decisions. Products indicated by this symbol are USDA Certified Biobased Products and have earned the UDSA Certified Biobased Product Label.

Defined by the 2002 Farm Bill, biobased products are commercial or industrial products (other than food or feed) that are composed in whole, or in significant part, of biological products, renewable agricultural materials (including plant, animal, and marine materials), or forestry materials. The 2008 Farm Bill extended the definition of biobased products to include biobased intermediate ingredients or feedstocks. USDA has established minimum biobased content standards for many product categories (http://www.biopreferred.gov/ProductCategories.aspx). A product or package must meet or exceed the minimum biobased content percentage in its given category in order to use the Certified Biobased Product label. Where USDA has not established minimum biobased content standards for a product category, companies may apply for the Certified Biobased Product label if the product or package contains a minimum of 25% biobased content. Applicants are required to submit an application to USDA, one application for certification and one application for use of the label. Applicants will bear the cost of having products tested for biobased content. At this time, there is no cost for manufacturers or distributors to participate in the USDA application process.

Product testing is done using ASTM D6866 Standard. The amount of biobased carbon in the material or product expressed as a percent of weight (mass) of the total organic carbon in the material or product. For products within designated items, the biobased content shall be defined and determined as specified in the applicable section of subpart B of part 2902. For all other products, the biobased content is to be determined using ASTM Method D6866, Standard Test Methods for Determining the Biobased Content of Natural Range Materials Using Radiocarbon and Isotope Ratio Mass Spectrometry Analysis.

Processing of an application for certification is about 60 days. Due to the absence of funding in the Farm Bill extension legislation (i.e., the "American Taxpayer Relief Act of 2012"), USDA has suspended the processing of applications for voluntary certification of biobased products. USDA will continue limited activities related to the Federal procurement preference program, such as adding products to the BioPreferred catalog, as staff resources allow. All existing biobased product label certifications (900 'USDA Certified Biobased Products' as of December 31, 2012) are and will remain valid. Only by choosing biobased products labeled "USDA Certified Biobased Products" can the consumer be assured that the USDA and the Federal government stand behind the accuracy of the claim that the product contains biological ingredients in the amounts stated on the label. Manufacturers and vendors who have obtained the rights to use the BioPreferred® label on a product have submitted to USDA test evidence of the biobased content of the product or package.

The USDA BioPreferred Program Audit sets in place the audit procedures for both the Procurement side of the program as well as the Labeling side of the program. The purpose is to monitor the validity of the participants' designated and certified biobased content claims; and, for the Labeling initiative, monitor the proper usage of the label in the marketplace. The audit consists of three (3) stages:

- **Stage 1** of the audit will be conducted bi-annually and completed in the first half of the year for both programs.

- **Stage 2** auditing is tentatively slated to be conducted in 2014, unless other issues impact alteration of dates.

- **Stage 3** auditing is only for the Labeling Program and the audit for this stage is slated to begin in 2016. This stage involves random sampling and retesting of certified products only that have been certified for a specified period of time.

All appeals from participants/companies must be made in writing to USDA with supporting documentation for their appeal.

If a biobased product falls within a category for which there is a federal procurement preference, the company may list that product in the BioPreferred® catalog. The catalog is used by the Department of Defense, Federal government Agencies and Federal contractor personnel seeking information on biobased products for potential purchase. It is also used by the general consumer and commercial sector seeking biobased products. In order for a product to be listed in the catalogue, it must meet the minimum biobased content standard for the product category. Products that receive the BioPreferred label are automatically listed in the BioPreferred catalog, so there is no need to submit product information for labeled products. To see a list of product categories, access the following link: http://www.biopreferred.gov/files/BioPreferred%20Product%20Categories%20Jan%202013.pdf

The US congress mandated the BioPreferred program to promote the increased purchase and use of biobased products that provide opportunities to boost domestic demand for renewable commodities and to create jobs and investment income. Imported products are eligible for certification, but they have to meet the same minimum content, verification standards and test, and program requirements as U.S. products. They are subject to disclose ingredients and country of origin to the extent U.S. law requires. For more information: http://www.biopreferred.gov/AboutUs.aspx

11.6 Organic Certification

The Canadian Government has implemented the Organic Products Regulation for organic products sold in the open market. Organic Certification of biogenic fertilizers as a bi-product of nutrient washing of agricultural biomass as discussed in Chapter 4 can be obtained through Accredited Certification bodies. The process is administrated by the Canadian Food Inspection Agency (CFIA).

11.7 Safety Declaration and Certification

This report has indicated several safety aspects common for all bionic materials. Depending on the extent workers, the public or the environment are exposed to risk directly related to the product, the Material Safety Data Sheet (MSDS) needs to reflect and quantify those risks and provide mitigating measures to mitigate the risks. Appendix J is provides a generic example of the comprehensive nature of an MSDS for a biofuel product, in this case wood pellets. The producer of an agricultural biofuel product needs to consider development something similar in order to meet international safety standards for handling and storing agricultural products in large quantities. A proposal is to have a template document(s) developed under the auspices of OFA for generic categories of agricultural biofuels or feedstock materials for bio-refining. However, each producer has to issue his own version of the MSDS since it is a legally binding document. The process can be done in a similar fashion as WPAC has done. The more important characteristics required for an MSDS would be:

- Off-gassing
- Explosibility and Flammability
- Self-heating
- Bio-degradability
- Toxicological Data
- Content of Radio-nuclides
- Harmonized Systems (HS) Code
- IMO Safety Classification
  - MARPOL Classification
  - Material Incompatibility

12 – Proposed OFA Classification of Agricultural Biomass

In view of the progress being made in the research summarized in Chapter 13 and considering the challenges identified in Chapter 3 and opportunities discussed through the document, it is obvious that agricultural biomass not used for food production has a place as a high volume source of fibre for a number of applications. Determination of the suitability of agricultural material for each particular application needs to be done and involves chemical characterization of the raw material in accordance with Chapter 3. For energy applications as an example, probably the largest and most immediate application area, the ISO FDIS 17225 Part 6 Table 2 in Appendix D summarizes the limit values required for using Cereal Straw, Miscanthus and Reed Canary Grass to be acceptable as solid biofuels.

In order to bring parametric values within stipulated limits, the material may need to be pre-treated prior to densification and ultimate use to bring characteristic values within range. The feasibility and economics of pre-treatments such as torrefaction, washing and hydrothermal carbonization as outlined in Chapter 4 should be evaluated. The CEATI Project (see Section 13.1) is intended to result in prescriptions for how to thermally convert various agricultural materials to specified qualities. These prescriptions would apply to torrefaction of materials to reach a certain carbonization level and chemical and physical characteristics. The prescription under development is relatively independent of torrefaction reactor technology used.

Another option would be to blend the agricultural material with other materials such as woody biomass with much lower content of alkali metals, sulphur, chlorine and nitrogen (see Section 12.1) to bring the characteristics of the agricultural material within range.

For certified biofuels there may be a requirement for selective sourcing of the feedstock as outlined in Appendix B and in some cases also compatibility with sustainability criteria outlined in Chapter 9.

12.1 Blending of Feedstock

Since many of the agricultural biomasses exceed the limit values set in the ISO FDIS 17225 Part 6 Standard a blend of agricultural and woody feedstock may be used to reach acceptable values. The benefit would be that no pre-treatment would be necessary. Three approaches may be considered:

1. Blending of primary feedstock. In case pellets or briquettes are produced, the different feedstock materials may be metered at a ratio to a product stream before the densification process.
2. Blending of pellets manufactured from different feedstock materials at a ratio before being combusted or hammer milled before being combusted depending on the application.
3. Blending of different biofuels at the point of combustion by means of multi-fuel suspension burner. This is quite common for incineration purposes for example when burning municipal sludge.

Controlled blending of raw materials is always a challenge unless the materials have similar flow characteristics. Agricultural and woody feedstock materials quite often are very different unless they are ground to fine particle of similar size. Even so, some materials are fibrous, some are spherical and some are two dimensional (flat). Blending of woody feedstock and bark or different qualities of wood is quite common in the pellets industry. However, there are very few examples of blending woody and agricultural feedstock. A project conducted in Vermont, USA in 2011 experimented with mixing Switchgrass, Reed Canary Grass and Mulch Hay in ratios of 25 and 12 and 6% respectively with woody biomass with the objective to evaluate the burning characteristics and emission spectrum. Each biomass, including the woody biomass, was also examined without blending in order to have reference data. The results are summarized as follows;

- None of the agricultural feedstock materials had been subject to washing
- The feedstock was ground to size, blended and pelletized. A 5% corn starch additive had to be used to produce durable pellets. The reason may be related to die temperature in the pelletizer All three grasses had significantly higher content of nitrogen, sulphur and chlorine which resulted in increased emission of NO_x and SO_x as well as generation of clinker. Table 12.1.1 summarizes the chlorine and sulphur content of the blended fuels used in the experiment
- The alkali content such as potassium and sodium were not measured, nor were the trace metal contents
- The above table provides an idea how the ash, chlorine and sulphur content are impacted by the blending ratios. It is quite obvious that critical content parameters can be corrected by blending at various ratios. Unfortunately, the potassium, phosphorous and silica content were not analyzed which somewhat limits the value of the experiment from a perspective blending.
- Combustion testing was conducted on the 100% composition of the four qualities. The “filterable” particles and the “condensable” particle concentration of the exhaust at about 7% oxygen were measured as a function of

Table 12.1.1 Burning and Emission Characteristics of Blended Agricultural and Woody Materials

Blend %	Moisture %	Additive %	Ash %	Ash Fusion Temp + °C	Sulphur %	Chlorine ppm	S/Cl Ratio	HHV MJ/kg
100 Wood	5.07	–	0.70	1,477.00	0.01	32.00	3.13	20.37
100 Swch	7.21	5.00	4.32	1,146.00	0.09	279.00	3.23	20.72
25 Swch	3.06	5.00	1.31	1,160.00	0.02	75.00	2.67	20.07
12 Swch	2.81	5.00	0.91	1,043.00	0.01	36.00	2.78	19.84
6 Swch	3.89	5.00	0.55	1,093.00	0.01	33.00	3.03	20.50
100 Reed	9.37	5.00	6.67	1,482.00	0.10	562.00	1.78	18.38
25 Reed	6.22	5.00	1.69	1,199.00	0.02	90.00	2.22	19.61
12 Reed	4.83	5.00	0.90	1,171.00	0.02	81.00	2.47	19.91
6 Reed	4.82	5.00	0.56	1,143.00	0.01	33.00	3.03	19.83
100 Mul	8.90	5.00	5.12	1,091.00	0.12	1,752.00	0.68	18.87
25 Mul	5.22	5.00	1.63	1,143.00	0.05	649.00	0.77	19.55
12 Mul	5.17	5.00	0.90	1,054.00	0.02	228.00	0.88	20.43
6 Mul	3.85	5.00	0.56	1,104.00	0.01	126.00	0.79	20.05

heat input (calorific value of the fuel). Filterable particles are defined as particles larger than 2.5 micron (PM2.5). The so called PM10 particles are part of the filterable range of particles but PM2.5 is usually what is regulated. The condensable particles are smaller than 2.5 micron and are collected in a water filter. The generation of particles is partly reflecting the amount of size reduction done of the feedstock in combination with the chemical composition of the nutrients (ash) in the material, and as such is also part of the quality factor of biofuels. It is not clear how consistent the particle size within the pellets was in the Vermont experiment but some conclusions may be drawn from the exhaust stack testing as illustrated in Diagram 12.1.1. The NO_x was also measured as part of the project. Exhaust tests were not done for the 25/12/6% blends.

Much more research is needed to develop blending ratios with predictable results in terms of combustability and the resulting emission spectrum.

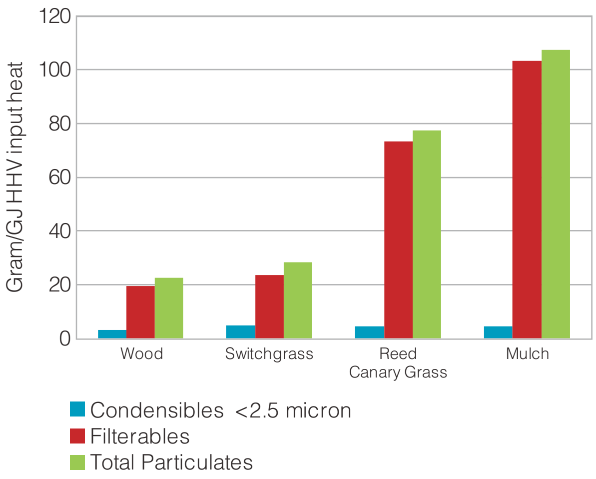


Diagram 12.1.1 Emission Spectrum for the Four Feedstock Materials Used in the Vermont Project

Short Rotation Crop (SRC) such as willow may be harvested anytime during the year for blending purposes while grasses are seasonal. In addition, willow may be grown on marginal soil such as Class 3 or lower while grasses require typically higher grade soil to grow.

12.2 Agricultural Biomass for Other Than Energy Conversion

The market for agricultural biomass residue product qualities not suitable for energy conversion may find a market elsewhere as raw material for conversion to chemicals. The USDA BioPreferred Program may be applicable since there are no stipulated limits to qualify under this scheme other than the 25% minimum limit bio-based content (see Section 11.5). The application for listing a product should follow the procedure, including the biocarbon test, set up by USDA and is available for Canadian producers. The following are examples of applications other than for energy conversion:

- Feedstock for conversion to ethanol
- Bio-refining
  - Chemicals
  - Pharmaceuticals
  - Bio-materials (e.g. carbon fibre)
- Animal bedding
- Industrial absorbents;etc.

12.3 OFA Biomass Grading System

The recommended steps to establish a biomass grading system for OFA members is:

- Quantitatively verify how large portions of the agricultural biomass not used for food purposes (or could be grown in Ontario) would qualify as biofuels versus non-biofuels. This will establish a basis for integration with economically viable applications such as large scale power production. It is recommended that the ISO FDIS 17225 classification system is selected as the basis since OPG is already oriented towards ISO

- Systematic field washing should be conducted to build a reliable multi-year database on the efficiency of nutrient extraction
- Research should be conducted to build a reliable database for blending the most interesting feedstock materials to specification
- Pre-commercial development following the results generated by the CEATI Project on torrefaction and a close tracking of the further development of the Hydro-thermal Carbonization technology as it develops
- WPAC currently is establishing the ENplus certification system for wood pellets for export to Europe. There is also a proposal to introduce the ISO/TC238 classification, grading system and testing procedures for all biomass in Canada although this may take time to put in place and is driven by efforts in various provinces to streamline the permitting procedures for combustors up to approximately 3 MW of thermal heat. The ENplus is currently migrating to the ISO standards but is likely to retain the ENplus name even if based on ISO. There is currently no effort to incorporate agriculture based pellets in the ENplus certification system. If agricultural pellets become available in large volumes in the market and the issues with ash melting temperature is resolved, it is conceivable that the large buyers in Europe as well as for example OPG like to buy such pellets in large qualities based on the ISO 17225-6 Standard (ash melting temperature currently not specified under ISO) and it is likely a quality certification system will be established (may be called ENagro certification or may become a subgroup under ENplus).
- There is currently no effort to incorporate torrefied pellets under ENplus. It is however conceivable that torrefied agricultural pellets will become an attractive biofuel for the world market. The CEATI and SECTOR Projects are indicating a path forward from a quality standpoint. Both projects will over time also look at the economics of such product.

Development of a Grading System for other applications than energy may be difficult as long as well accepted product quality specifications are not established.

13 – Research and Development Related to Solid Biofuels

Research and development of how to use agriculture material for energy production has been going on for several decades around the world addressing primarily related to deal with significant volumes of ash, particularly ash with relatively low ash melting temperature. The research has been focused on improving our understanding of which raw materials would be most suitable to use and how to economically harvest such materials. Not only waste streams from the agricultural industry but also purposely grown crop have been the focal point. Various pre-processes intended to alter the original characteristics of the raw material are under development as discussed in Chapter 4. In the short to medium term, uses for agricultural materials outside the food and feed market are limited to research projects that are focused on commoditizing agricultural biofuels, including technical specifications, safety guidelines, sustainability criteria and quality certification.

13.1 The CEATI Project

The CEATI (sometimes referred to as the ABITORR-CEATI) Project was initiated in July 2012 and is running for 2 years with the intent to evaluate up to 10 different agricultural feedstock materials with regards to suitability for production of torrefied agricultural pellets to be used for energy production. The project is conducting the research as a network with researchers from CanmetEnergy/NRCan, University of British Columbia, Western University, FPInnovations and Delta Research Corporation. The research involves selection of feedstock based on chemical characteristics and suitability for thermal treatment using torrefaction. The project is evaluating the chemical composition of the feedstock materials. The energy used for initial size reduction is determined using a grinder with different screens and throughput as well as tendency of clogging due to the fibrous structure of the materials. The research includes torrefaction of the agricultural materials using a special large size thermo-gravimetric analyzer (BTGA) for developing kinetic models for each of the feedstock materials. These models are the basis for development of control strategies unique for each feedstock. The BTGA has a gas impinger for collection of the hydro-carbons emitted during the torrefaction treatment, which allows determination of mass and energy balance for the torrefaction. The project is also looking at washing of alkali from the feedstock in order to eliminate most of the salts found in agricultural biomass which have a negative impact on combustability of the biomass resulting in fouling, scaling, slagging and corrosion. The torrefied material will be densified to pellets or briquettes and experimentation will be done to see if durable agricultural pellets can be made without adding binders. The research also includes performance evaluation of the pelletized final product in terms of calorific value, ash content, ash melting temperature, mechanical durability and hydrophobic characteristics. Also, an understanding of the reactivity of the material such as off-gassing, self-heating and dust explosibility will be explored. At the end of the project which will run for more than 2 years, the economics of agricultural pellets as a high volume biofuel will be evaluated.

For more details on the research conducted by CEATI, see http://www.ceati.com/.

13.2 The SECTOR Project

The EU Framework Programme for research and demonstration was set up under the Amsterdam Treaty in 1997 and is complementary to the nationally supported research and demonstration programs across Europe. Allocation of funds under the Programme is done for periods of 5 to 7 years at a time in order to support longer term project of certain complexities and potential to have a pan-European impact on the social and economic structure. The current framework called the Seventh Framework Programme (FP7) is covering the period 2007-2013 with a budget of EUR 50.52 billion (+EUR 2.7 billion for EURATOM). FP8 will soon kick in for the period 2014-2020 with an estimated budget of EUR 80 billion. Within the budget for FP7 the energy sector is allocated EUR 2.3 billion to be used for research and demonstration projects. To qualify for funding a minimum of 3 partners coming from 3 different countries from associated states has to collaborate to qualify for FP7 funding. The typical duration of such projects is 3 to 5 years but there is not a defined upper limit. A project budget granted by the Commission can reach several tens of million euros, paid as a fraction of the actual costs spent by the participants. Torrefaction technology was considered beyond the prototype stage in 2009 when the SECTOR (Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction) Project was proposed to the European Commission as a pre-commercialization project and a potential game changer for the power generation industry in Europe. A consortium of partners had been assembled to apply for funding from FP7 and in 2011 funding for the project under the EC Grant Agreement No 282826 backed by cash contributions from the partners was approved by the European Commission. The SECTOR project is expected to shorten the time-to-market of torrefaction technology and to promote market introduction within stringent sustainability boundary conditions. The actual work started January 1, 2012 and the entire project will be completed within 42 months. There are 21 consortium members participating in the project of which three are suppliers of torrefied pellets for experimental purposes. Wood Pellet Association of Canada (Mr Melin) is one of 9 members on the Advisory Committee and also participates in some of the 10 working groups. The entire project is administrated by Deutsches Biomasse Forschungs Zentrum (DBFZ). The total budget is EUR 10.29 million of which EUR 7.57 million is European grants. This is the largest research project in the world for torrefaction and is strongly supported by the power producers in Europe.

SECTOR is exploring the potential not only for woody biomass but also some agro-biomass and is covering all aspects starting with evaluation of feedstock and examines all the steps to the final product, including sustainability, new testing methodology, specifications and MSDS for handling and transportation.

For more information on the SECTOR Programme, see http://www.kooperation-international.de/en/detail/info/technology-2007-19th-international-exhibition-for-technological-developments.html

13.3 European Agricultural Biomass Research for Energy Purposes

EU has funded numerous projects for promoting use of agricultural material as a biofuel as well as resolving many of the problems encountered when using agricultural biomass in small scale as well as large scale energy conversion systems. The following excerpt from the MixbioPells reports summarizes the more prominent projects:

1. The “Pellets for Europe”-project aimed to stimulate the European pellet market. The project focused on;
   - new wood pellet markets,
   - new markets for pellets from agricultural residues
   - integration and development of the European pellet market.

   The project was co-funded by the EC Altener programme and ended in May 2005. Project activities were further developed in the framework of the project pellets@las supported by the Intelligent Energy Europe (IEE) programme. A report on the utilisation of alternative pellets was published.

2. The general objective of the pellets@las project was to promote the development of a transparent and stable European pellet market and provide;
   - pellet market data such as prices and production volumes
   - raw material data
   - country reports
   - analyses of international pellet trade
   - updates on recent relevant standards developments

   The project ended in December 2009. A study of mixed pellets markets was published and includes maps and figures for the production and use of mixed biomass pellets.

3. The IEE founded project EUBIONET III ended 2011 and was the continuation of the EUBIONET II project (2005 – 2007). The objective with the EUBIONET III was to increase the use of biofuels within EU by finding ways to overcome market barriers. National biomass programs and biomass fuel potentials were analysed especially for different industrial residues and agro-biomass. International trade of biomass fuel was promoted and price mechanisms were analysed. Certification and sustainability criteria were set developed. Increased use of the CEN standards for biofuels were promoted. Assessment was made of the availability of biomass materials, including agricultural biomass.

4. Agriforenergy I and II projects had the objective to promote the use of biomass from agricultural and forestry sector for heating, electricity and transport purpose and to mobilize the large biomass potential from fragmented privately owned forests and from agricultural land by increasing the cooperation among farmers and forest owners.

5. Several reports of the IEA Task 32 “Biomass Combustion and Co-Firing” and Task 40 “Sustainable Bioenergy Trade” includes information on use and tade with woody as well as agricultural biomass.

6. Within the EU-project “BioagroEnergy” pellets production and use of alternative raw materials was demonstrated in the period 2006-2009.

7. The Interreg IIIA project “Biomischpellets – Ergebnisse des Forschungsprojektes NEBrA”was done as cooperation between Germany and Poland in 2008. Several mixed biomass pellets were produced and tested in small scale boilers.

8. Within the ERA NET Bioenergy project “Development of test methods for non-wood small-scale combustion plants” a study of the driving forces and barriers for the use of non-woody fuels was done in order to evaluate and choose the most promising fuels for small-scale boilers. Furthermore, information

on regulations of the authorities in the participating countries relevant to the project as well as other related European documents were gathered. An overview and further compilation of the current state of technology for small scale non wood fuels appliances in Europe, with focus on the participating countries, was done. Measurement equipment and methods were analyzed and evaluated experimentally at three test stands. The validation was done by applying statistical methods on the experimentally derived results. The overall results are the basis for a proposal (best practice guideline) for a Europe-wide standard for testing non-wood fuels in small-scale boilers.

9. The ERA NET Bioenergy project “Combustion tests of new ash rich biomass” was intended to identify and develop practical and economical combustion technologies for small-scale combustion of new ash rich biomass pellets. An evaluation of present technology regarding CO, NO_x and particle emissions (especially particulate matter) and ash related problems was done by burning several new ash rich biomass pellets.

10. The main objective of the Green Pellets project (supported by Life+) is to demonstrate that new dedicated energy crops for solid biomass provide an effective, sustainable and eco-friendly bioenergy source for heating and significantly reduce the greenhouse gas emissions. Herbaceous crops dedicated to the production of solid biomass fuels have environmental advantages such as purification capacities or soil erosion prevention. Energy crops development must be carefully managed in order to reach an acceptable balance between food and non-food supply while avoiding harm to the environment.

11. The ongoing FP7 project “Safepellets” aims to answer the question, where and under which conditions off-gassing and self-heating from biomass pellets occurs and what measures can be undertaken to reduce these risks. The objective with this project is to draft international safety standard and inspection methods along the whole pellets supply chain.

12. The objectives with the ongoing FP7 project “AshMelT” is to develop a test method for the assessment of the ash melting characteristics of solid biofuels, the specification of ash melting classes for solid biofuels and to work out a proposal for a European standard.

13.4 The Eco-Energy Innovation Initiative (Eco-EII) Project

Environment Canada and Natural Resources Canada jointly initiated the Eco-EII project in October 2012 with the objective to develop Biomass and Biomass-Coal Co-Fire Emission Factors with a budget of $835,000 over 3 years. The driver for the project is the ambition by the Canadian government to reduce total Canadian greenhouse gas emissions by 17% from 2005 levels by 2020 as part of its commitment during the UN Climate Summit (Conference of Parties - COP 15) in Copenhagen in December 2009. The work under the Eco-EII project is intended to generate an emission data base to be used by policy makers and regulators and as a base for further scientific work. The emission factors used to date in Canada have to a large extent been default values extracted from the US AP-42 (Air Pollutant Emission Factors) database published by US Public Health Service first in 1968 and subsequently updated by US EPA in 1972 and 1985 with the fifth edition no longer being maintained. The AP-42 includes point and area sources emission factors as well as mobile source emission factors and provides guidelines for dispersion models. This database is no longer considered reliable for the purpose of setting new policies in Canada and needs to be replaced by emission factors, specifically adapted to co-firing with coal which is considered the most likely scenario for large scale conversion of the Canadian energy supply to make it greener.

The Eco-EII project has he following milestones:

Task		Completion date
1:	Literature review Combustors > 4 MW (Envirochem)	March 31, 2013
2a:	Pilot scale emission sampling (Canmet)	June, 2013
2b:	Industrial scale emission sampling (Atikokan+NSP)	June, 2014
3:	Analysis, conclusion, recommendation	December, 2014
4:	Reporting	March, 2015

The project is focusing on emission performance of woody biomass (softwood and hardwood) but will also include emission data for short rotation crop and agricultural materials. The following parameters of the fuel are of key interest to monitor and relate to emission factors:

- Ash content
- Ash melting temperature
- Moisture content
- Particle size distribution of raw feedstock
- Chlorine content
- Mechanical durability
- Fines content

The conclusion is that these parameters need to be carefully evaluated for agricultural fuels. For agri-fuels to become attractive it is important to have emission factors developed and made available alongside the emission factors for woody fuels.

Canmet has research capability to experimentally determine the emission factors using their Pilot Scale Research Furnace (PSRF). The Eco-EII project includes development of emission factors at 15/30/45/100% co-firing using PRB (Powder River Basin) sub-bituminous (Western Canada) coal as reference fuel.

13.5 Canadian Solid Biofuels Standards Development

As part of the Eco-EII project an Informal Working Group was formed in early 2013 consisting of representatives for the governments of Ontario, BC, Quebec and New Brunswick, Northwest Territories and industry representatives as well as academia. Other provinces, regional governments and industry parties are expected to join the committee during the spring of 2013. The Group has the objective to explore if a biofuels standard and quality certification system can be found which would allow a radically simplified permitting procedure for combustors across Canada. The Province of Ontario for example is planning to develop an internet permitting procedure using a self-declaration method whereby the applicant submits information such as:

- Combustor output power in kW or MW
- Make and model of combustor and related equipment certification
- Location of combustor
- Installation details
- Fuel to be used with reference to approved quality standards

Current process involves preparation of a very time consuming application, including a detailed analytical declaration of the fuel to be used in addition to an exhaustive declaration of the performance of the combustor equipment supported by test reports. The contemplated permitting process may potentially cut the permitting time from several months to a few days. This would facilitate a fast proliferation of bio-energy as a viable alternative to non-renewable forms of energy currently used. It would also promote domestic use of biofuels from the forest as well as the agriculture industry.

The work by the Group is proceeding and is expanding across Canada. Other provinces are now evaluating the Ontario proposed permitting procedure for combustors to determine if it could be made applicable.

WPAC is currently setting up the ENplus quality certification system in Canada for wood pellets. ENplus is based on the ISO Standards which also includes a comprehensive classification of agricultural pellets as well as non-compressed biofuels (see Section 8). It would be logical to extend the certification scheme to other biofuels such as agri-based pellets. Once established the Canadian version of the ENplus may be called CANplus. Establishment of the ENplus in Canada is expected to be done before 2013 for wood pellets.

In addition, the Group is expected to develop recommendations on how pressure vessel certification done under the CEN rules in Europe can be accepted as compatible with the provincial regulations in each of the provinces and territories across Canada. BC already has such a system in place which simplifies the import of high quality biofuels-burning boilers from Europe.

13.6 Ash from Biomass as Soil Amendment

Harvest residue left on the ground has high nitrogen content. The material is leaching nitrogen to the ground in terms of ions causing eutrophication (oversupply of nutrients) in some types of soil. In areas where the soil has nitrogen deficiency, the unharvested residue is beneficial since it helps increase the nitrogen content of the soil. The findings however are generally that the more harvest residue is left on the ground the greater the chance of eutrophication. Also, harvest residue left on the ground is known to generate N_2O, which is a very potent greenhouse gas, as well as methane in spaces with limited access to oxygen (anaerobic oxidation), which is also a very potent greenhouse gas.

In the forest industry the traditional logging of stems only leaving behind substantial harvest debris tends to increase the risk of eutrophication while whole tree logging tends to decrease the risk although it is to some extent related to species. Extensive research in Sweden over a long period of time regarding the effects of leaving forest harvest residue on the ground indicates a higher level of leaching of NO_3^- (nitrate) causing acidification and a lowering of the pH in the soil. This has resulted in migration of nutrients in terms of cations such as calcium, potassium, magnesia as well as the anion alumina in the soil which eventually reaches watersheds and streams. The nutrients lost during leaching can be replaced by recycling the ash generated when biomass (including pellets) is converted to energy. In the Swedish field research the ash has been pelletized (see Picture 13.6.1) and spread on the forest floor with special spreaders. The B/A (Basic/Acidic oxide or ion) ratio is a measure of the level of eutrophication and acidification in the soil.

It would appear as if ash from combustion of agricultural biomass would be a good fertilizer since it will likely contain potassium and phosphorous. Much of the experience in Sweden with ash from combustion of woody materials may be transferable to experiments with ash from combustion of agricultural biomass.

Picture 13.6.1 Example of Pelletized Ash from Combustion of Solid Biofuels Ready for Distribution as a Fertilizer

14 - Biofuels Databases

A large number of biomass databases exist although many are not providing easy access. The following list is intended for identification where to look is further research is required. Most of the databases are incomplete and the definitions and nomenclature is not always compatible.

- Internal DBFZ database
- Internal BE2020+ database
- Internal CTI database
- Canmet biomass database
- Centre for Biomass Technology. Videnblade No: 83, 86, 131, 132
- Fuels for CO_2 reduction in power plants, 2005
- Hartmann et al.: Naturbelassene biogene Festbrennstoffe - Umweltrelevante Eigenschaften und Einflussmöglichkeiten, StMLU, München, 2000 http://www.lfu.bayern.de/energie/biogene_festbrennstoffe/doc/festbrennstoffe.pdf
- Kratzeisen M et al. Applicability of biogas digestate as solid fuel. Fuel (2010), doi:10.1016/j.fuel.2010.02.008 (digestates from biogas plants with wet fermentation technology)
- Bränslehandboken (Handbook of fuels). Birgitta Strömberg, 2008 http://www.varmeforsk.se/rapporter?action=show&id=2943
- PHYLLIS database http://www.ecn.nl/phyllis2/Browse/Standard/ECN-Phyllis
- Biobib database http://www.vt.tuwien.ac.at/biobib/biobib.html
- Pellets@las
- EPC Country reports
- ISO FDIS 17225-1 Annex B Informative Biofuels Databases
- Agricultural utilization Research Institute (AURI) 2001. Agricultural Renewable Solid Fuels Data, Waseca, MN.

15 – Conclusions and Recommendations

International classification standards for quality suitable for energy conversion have been developed for agricultural biomass and will shortly be published by International Standards Organization (ISO). The standards encompass a wide variety of species and have identified a few as particularly suitable such as cereal straw, miscanthus grass and reed canary grass. There is currently a movement to adopt standards developed by the ISO Technical Committee 238 Solid Biofuels as a Canadian Standard. Even though these standards are intended for energy applications, they may also serve a purpose for feedstock definition in areas such as bio-refining for production of chemicals, bio-materials and pharmaceuticals.

Besides the ISO standards which are very specific in terms of chemical composition of the materials, there are less specific standards like the USDA Bio Preferred Program, which provides access to public procurement in USA of agricultural products.

Several quality and sustainability certification systems applicable to agricultural based product, such as the Green Gold Label (GGLS-2) Source Criteria, are already in place. Agricultural bio-fuels could likely merge the already massive flow of woody bio-fuels to power stations with proper pre-treatment and certification in place.

Promising research is currently under way to explore the opportunity for agricultural biomass to become a source of fibre for manufacturing if solid biofuels. Several pre-treatments have been identified as technically feasible to improve the characteristics of the materials to the point where agricultural materials are practically equal in value to woody materials for energy conversion applications. The economics still needs to be proven and some species are likely more suitable than others. The treatments include washing to decrease the content of certain alkali minerals and chlorine and other treatments include thermal breakdown of the structural components of the material in combination with alteration of the ratio of carbon.

The EN 15370-1 Standard for Determination of Ash Melting Behaviour has been found to be flawed and is currently amended and will be published as an ISO Standard during 2014. Canada is chairing this development and will release information when the new text has been released.

The standards could form a basis for a more detailed evaluation of potential added revenue for OFA members by feeding agricultural residue to the energy sector, for example, power production in Ontario.

A strategic techno-economic plan may be developed for the Province of Ontario with the following building blocks;

- Availability data for agricultural crop and price modelling
- Availability statistics for agricultural crop
- Selected ISO Standards for agricultural biomass
- Results for pre-treatment research such as the CEATI and SECTOR projects
- Environmental and climate change objectives for the Province of Ontario

The ISO Standards could be the reference framework or filter for sourcing of materials, determination of pre-treatment required and determination of suitability for energy conversion or other selected application. Since the use of biomass in energy applications is well developed with a substantial commercial demand,the use of agricultural biomass for production of power is a logical next choice.

Appendix A - References

Most of the Standards referenced in this document are copyright protected and therefore not included in this report. However, they can be ordered in electronic form over the internet for a fee from the issuing organization as they become published.

- ISO 17225-1 Solid Biofuels – Fuel Specifications and classes – Part 1: General Requirements
- ISO 17225-2 Solid Biofuels – Fuel Specifications and classes – Part 2: Graded Wood Pellets
- ISO 17225-3 Solid Biofuels – Fuel Specifications and classes – Part 3: Graded wood Briquettes
- ISO 17225-4 Solid Biofuels – Fuel Specifications and classes – Part 4: Graded wood chips
- ISO 17225-5 Solid Biofuels – Fuel Specifications and classes – Part 5: Graded firewood
- ISO 17225-6 Solid Biofuels – Fuel Specifications and classes – Part 6: Graded non-woody pellets
- ISO 17225-7 Solid Biofuels – Fuel Specifications and classes – Part 7: Graded non-woody briquettes

A. Documents providing information of safety and health issues related to handling and storage of biomass

1. Melin, S. Testing of Explosibility and Flammability of Airborne Dust from Wood Pellets. Wood Pellet Association of Canada, November 5, 2008.
2. Melin, S. Material Safety Data Sheet, Wood Pellets in Bulk. Wood Pellet Association of Canada, April 28, 2006.
3. Melin, S. Certification of Canadian Pellets. Wood Pellet Association of Canada, April 7, 2011.
4. Melin, S. Determination of Explosibility of Dust Layers in Pellet Manufacturing Plants. Wood Pellet Association of Canada, August 30, 2012.
5. Melin, S. Nuclear Radiation, Wood Pellets and Thermal Coal. Technical Bulletin, Wood Pellet Association of Canada, Dec 12, 2009.
6. International Energy Agency (IEA), The Pellet Handbook - the production and thermal utilization of biomass pellets, 2010, ISBN 978-1-84407-631-4.
7. International Energy Agency (IEA), Health and Safety Aspects of Solid Biomass Storage, Transportation and Feeding, May 2013.
8. Henry Persson. Silo Fires – Fire extinguishing and preventive and preparatory measures. Swedish Civil Contingencies Agency (MSB), 2013.

B. Documents providing quantitative information of nutrient extraction and efficiency of washing of agricultural biomass

9. Bakker, R. and Jenkins, B.M. (1996): Feasi¬bility of fuel leaching to reduce ash fouling in biomass combustion systems. In: Biomass for Energy and the Environment, Proceedings of the 9th European Conference on Bioenergy in Copenhagen, Elsevier Science, pp. 980-985.
10. Burvall. J., 1997. Influence of harvest time and soil type on fuel quality in reed canary grass. Biomass and Bioenergy vol. 12, No3, pp149-154.
11. Cennentek Bioanalytical Servives: Feasibility of Improving Biomass Combustion through Extraction of Nutrients, prepared for Ontario Federation of Agriculture, June 2011.
12. Jenkins, B.M., R.R. Bakker, L.L. Baxter, J.H. Gilmer, and J.B. Wei. “Combustion Characteristics of Leached Biomass”. Developments in Thermochemical Biomass Conversion 2 (1997): 1316-1330.
13. Landström, S., L. Lomakka, and S. Andersson. “Harvest in spring improves yield and quality of reed canary grass as a bioenergy crop”. Biomass and Bioenergy 11 (1996): 333-341.
14. Adler P.R., M.A. Sanderson, A.A. Boateng, P.J.Weimer and J.G. Hans-Joachim. 2006. Biomass yield and biofuel quality of switchgrass harvested in fall or spring. Agron. J. 98:1518–1525.
15. Jensen, P.A., B. Sander and K. Dam-Johansen. 2001. Removal of K and Cl by leaching of straw char, Biomass and Bioenergy 20(6): 447–457.
16. Knudsen N.O. et al, 1998. Possibilities and evaluation of straw pretreatment, In: Biomass for Energy and Industry, Proceedings of the International Conference, Wurzburg, Germany.
17. Deng, L.; Zhang, T.; Liu, Y-H.; Che, D-F. Effect of washing on fuel properties and combustion characteristics of biomass. J. Eng. Thermophys. 2010, 31(7), 1239-1242.
18. Garland, J.L.; Mackowiak, C.L. Utilization of the Water Soluble Fraction of Wheat Straw as a Plant Nutrient Source. NASA Technical Memorandum 103497, National Aeronautics and Space Administration, John F. Kennedy Space Center, FL, 1992.
19. Hadders, G.; Olsson, R. Harvest of grass for combustion in late summer and in spring. Biomass Bioenergy 1997, 12, 171-175.
20. Vamvuka, D.; Zografos, D. Predicting the behaviour of ash from agricultural wastes during combustion. Fuel 2004, 83, 2051-2057.
21. Banowetz, Gary. Et al. Mineral Content of Grasses grown for Seed in Low Rainfall Areas of the Pacific Northwest and Analysis of Ash from Gasification of Bluegrass Straw. Energy And Fuels 2009, 23, 502-506.

22. Kristensen, Erik Flöjgaard. Harvesting and Handling of Miscanthus, Danish Experiences. Research Centre Bygholm.
23. Samson, Roger. Stephanie Bailey Stamler: Strategies for Improving Yield / Quality in Warm Season Grasses. Resource Efficient Agricultural Production (REAP), Ste Anne de Bellevue, Quebec.
24. Hartmann, H. et. al. Grain and straw combustion in domestic furnaces – influences of types and pre-treatments. : Proceedings of the 15th European Biomass Conference and Exhibition, Berlin, Germany.
25. Hartmann, Hans et al.: Naturbelassene Biogene Festbrennstoffe – umweltrelevante Eigenschaffen und Einflussmöglichkeiten. Bayerischer Staatsministerium Fur Landesentwicklung und Umweltfragen, Report 154, September 2000.
26. Burvall, J., Influence of harvest time and soil type on fuel quality in reed canary grass (Phalaris arundinacea L.). Biomass and Bioenergy, in press, 1996.

C. Documents providing quantitative information on ash composition, additives, binders and combustion characteristics

1. Axenbom, A. (red), Kristensen, D. & Praks, 0., 1991. Halm som bränsle för framtida elproduktion - en sammanfattning av dagslaget. Vattenfall Bioenergi, U(B) 1991/44. Älvkarleby.
2. Dahlin, J., 1991. Halms fyringstekniske egenskaper. dk-TEKNIK, Braendsler og forbrwndningsteknik, Soborg.
3. Christensen, B.T., 1983 a. Nedbrydning af halm. I. Byghalms tab af näringsalte og törstof som fölge af udvaskning med vand. Tidsskrift for planteavl 87 (1983), 477-487.
4. Christensen, B.T., 1983 b. Nedbrydning af halm. II. Vägtab af byghalm placeret på jordoverfladen og ändringer i halmens indhold af plantenäringstoffer. Tidsskrift for planteavl 88 (1983), 37-48.
5. Gardenas, S., 1991. Alkali och klor i biomassa ett problem vid elgenerering. Vattenfall Bioenergi, U(B) 1991/40. Älvkarleby.
6. Hansen, M. W., Hansen, A., Jensen, L. R. & Nielsen, C., 1987. Forundersö-gelse af halmfyrede kraftvarmevärker. dk-teknik, TR-sag nr. 1986-/352¬86.356. Söborg.
7. Ivarsson, E. & Nilsson, C., 1988. Smälttemperaturen hos halmaskor med respektive utan tillsatsmedel. Laboratoriestudier och dataanalyser. Sveriges lantbruksuniversitet, Institutionen for lantbrukets byggnadsteknik, Special-meddelande 153. Lund.
8. Ravn, T., 1986. Brugsvärdi af dansk halm. II Clorinhold i byghalm. Med-delelser fra Bioteknisk institut, A.T.V., 22 årg., nr. 1-4. Kolding.
9. Rexen, F. P., 1970. Undersögelser over dansk halms kemiske sammensätning. Forskningsinstituttet for handels- og industriplanter, Beretning nr. 53. Särtryk af Meddelser fra halmafdelningen 6:1-37. Kolding.
10. Staniforth, A.R., 1979. Cereal Straw. Oxford University Press. Oxford.
11. Svanberg, 0., 1962. De svenska skördeprodukternas innehåll av biogena element. GKS skriftserie nr 3. Gödsel- och kalkindustriernas samarbets-delegation. Stockholm.
12. Thellesen, H., 1988. Halmens egenskaber til fyringsformål. Slaggedannelse. Statens jordbrugstekniske försög, Beretning nr 40. Horsens.
13. Gunnar Hadders. Förändringar under skördeperioden av bränsleegenskaper hos halm. Jordbrukstekniska Institutet, Ultuna-Uppsala, JTI-Rapport 186.
14. Clemens et al. (1996): Auswertungen zum Energiegetreide-Anbauversuch 1994/95 (un-veröffentlicht). Lehr- und Versuchsanstalt Emmenhausen-Borler, Landwirtschaftskam-mer Rheinland-Pfalz.
15. Lewandowski, I. (1996): Einflußmöglichkeiten der Pflanzenproduktion auf die Brennstoffeigenschaften am Beispiel von Gräsern. Proceedings "Eigenschaften fester Bioenergieträger". Fachagentur Nachwachsende Rohstoffe (eds.), Landwirtschaftsverlag, pp. 32-48.
16. Sander, B. (1996): Fuel data for Danish biofuels and improvement of the quality of straw and whole crops. In: Biomass for Energy and the Environment (Vol. 3). Proceedings of the 9th European Conference on Bio-energy in Copenhagen, Elsevier Science, Oxford, pp. 490-495.
17. Pahkala, K. et.al. 1996. Produktion och användning av agrofiber i Finland. rapport nr 3. Maatalouden tutkimuskeskus, jokioinen. Finland.
18. Lewandowski, I. & Kicherer A. 1996. Combustion quality of biomass: practical relevance and experiments to modify biomass quality of Miscanthus x giganteus. Institute Fur Pflazenbau und Grunland, Universität Hohenheim, Stuttgart, Germany.
19. Sander B., T. Reffstrup, T. Ravn, L.B. Jul. 1994. Undersökelser af halms kemiske sammensætning - med relation til forbrændning og forgasning. Foretaget af Bioteknologisk Institut for ELSAM/ELKRAFT.
20. Burvall, J., Hedman B. 1996. Laboratorieundersökningar av smältförlopp och svavelretention i askor hos bränslemixar av stenkol/rörflen/halm. Opublicerad.
21. Axenbom et.al. 1991. Halm som bränsle för framtida elproduktion - en sammanfattning av dagsläget. Vattenfall bioenergi, 1991/44.
22. Öhman, M. 1997. A new method to quatify fluidized bed agglomeration in the combustion of biomass fuels. Energy Technology Centre, Dep. of Inorganic chemistry, Umeå University, Sweden.
23. Kirchmann, H., Ericsson J, 1987. Kisel i mark och gröda. Aktuellt från SLU: 358.
24. Värmeforskseminarium 1998-0319,20. Norrköping. Driftserfarenheter biobränsle.

25. Kiel, Jaap. Biomass co-firing in High Percentages – opportunities in conventional and advanced coal-fired plants. ECN, IEA Bioenergy Task 32 Workshop, Geertruidenberg, The Netherlands October 21, 2008.
26. Werkelin, J., B-J Skrifvars, M. Zevenhoven, B. Holmbom, and M. Hupa. “Chemical forms of ash-forming elements in woody biomass fuels.” Fuel 89 (2010): 481-493.
27. Aronsson, P.G., and L.F. Bergström, 2001. Nitrate leaching from lysimeter-grown short-rotation willow coppice in relation to N-application, irrigation and soil type. Biomass and Bioenergy 21: 155-164.
28. Barkley, B.A. 1983. A silvicultural guide for hybrid poplar in Ontario. Ontario Ministry Natural Resources Publ #5093 35pp.
29. Cherney, J,H; Johnson, K,D; Volence, J,J; Anliker, K,S 1998. Chemical composition of Herbaceous grass and Legume Species grown for maximum biomass Production, 1988, Biomass, 17, 215-238.
30. Christian, D. G., A.B. Riche, and N.E. Yates. 2008. Growth, yield and mineral content of Miscanthus x giganteus grown as a biofuel for 14 successive harvests. Industrial Crops and Products 28: 320–327.
31. Jorgensen U. 1997. Genotypic variation in dry matter accumulation and content of N, K and Cl in Miscanthus in Denmark. Biomass and Bioenergy 12: 155-169.
32. Lewandowski, I. and A. Heinz. 2003. "Delayed harvest of miscanthus-influences on biomass quantity and quality and environmental impacts of energy production." European Journal of Agronomy 19(1): 45-63.
33. Monti, A. N. Di Virgilio and G. Venturi. 2008. Mineral composition and ash content of six major energy crops. Biomass and Bioenergy. 32 (3): 216-223.
34. Reumerman, P.J. 2002. Van den Berg D. Reduction of fouling, slagging and corrosion characteristics of miscanthus (the BIOMIS project) report. EC contract FAIR-98-3571, 2002.
35. Arvelakis, S.; Gehrmann, H.; Beckmann, M.; Koukios, E. G. Agglomeration problems during fluidized bed gasification of olive-oil residue: evaluation of fractionation and leaching as pre-treatments 1. Fuel 2003, 82, 1261-1270.
36. Colyar, K.R. Evaluation of nutrient extraction and membrane processes to facilitate the reuse of water, chemical consumables and macronutrients during lignocellulosic biomass-to-fuel processing in rural communities. M.Sc. Thesis, University of Colorado, Boulder, CO, 2008.
37. Di Iaconi, C. Pagano, M. Ramadori, R. Lopez, A.; Nitrogen recovery from a stabilized municipal landfill leachate. Bioresour. Technol. 2010, 101, 1732-1736.
38. Gilbe, C.; Lindström, E.; Backman, R.; Samuelsson, R.; Burvall, J.; Öhman, M. Predicting Slagging Tendencies for Biomass Pellets Fired in Residential Appliances: A Comparison of Different Prediction Methods. Energy Fuels 2008, 22, 3680-3686.
39. Hanks, D.A. Soil Nutrient Extraction Method Using Pressurized Hot Water. US Patent 5,974,899, November 2, 1999.
40. Landstrom, S.; Lomakka, L.; Andersson, S. Harvest in spring improves yield and quality of reed canary grass as a bioenergy crop. Biomass Bioenergy 1996, 11, 333-341.
41. Lapierre, C.; Jouin, D.; Monties, B. On the molecular origin of the alkali solubility of Gramineae lignins. Phytochem- istry 1989, 28, 1401-1403.
42. Li, X.; Zhao, Q. Recovery of ammonium-nitrogen from landfill leachate as a multi-nutrient fertilizer. Ecol. Eng. 2003, 20, 171-181.
43. Miles, Jr., T.R.; Miles, T.R. Alkali deposits found in biomass power plants – a preliminary investigation of their ex¬tent and nature. Summary report for the National Renewable Energy Laboratory, NREL subcontract TZ-2-11226-1, Golden, Colorado, 1995.
44. Song, Y. H. Qiu, G. L. Yuan, P. Cui, X. Y. Peng, J. F. Zeng, P. Duan, L. Xiang, L. C. Qian, F.; Nutrients removal and recovery from an-aerobically digested swine wastewater by struvite crystallization without chemical additions. J. Hazard. Mater. 2011, 190, 140-149.
45. Turn, S. Q.; Kinoshita, C. M.; Ishimura, D. M. Removal of inorganic constituents of biomass feedstocks by mechanical dewatering and leaching. Biomass Bioenergy 1997, 12, 241-252.
46. Van Voorthuizen, E. M.; Zwijnenburg, A.; Wessling, M. Nutrient removal by NF and RO membranes in a decentralized sanitation system. Water Res. 2005, 39, 3657-3667.
47. Xiao, R.; Chen, X.; Wang, F.; Yu, G. The physicochemical properties of different biomass ashes at different ashing temperature. Renewable Energy 2010.
48. Xiong, S.; Burvall, J.; Örberg, H.; Kalen, G.; Thyrel, M.; Ö hman, M.; Boström, D. Slagging characteristics during com¬bustion of corn stovers with and without kaolin and calcite. Energy Fuels 2008, 22, 3465-3470.
49. Yu, C.; Zheng, Y.; Cheng, Y. S.; Jenkins, B. M.; Zhang, R.; VanderGheynst, J. S. Solid-liquid extraction of alkali metals and organic compounds by leaching of food industry residues. Bioresour. Technol. 2010, 101, 4331-4336.
50. Yuan, Y.; Zhao, L.; Meng, H.; Lin, C.; Tian, Y. Effects of comparison on anti-slagging additives of corn straw biomass pellet fuel. Transactions of the Chinese Society of Agricultural Engineering, 2010, 26(11), 251-255.
51. Andreas Monti, et al. Mineral Composition and Ash Content of Six Major Energy Crops. Biomass and Bioenergy 32, 2008, 216-223.
52. Agricultural utilization Research Institute (AURI) 2001. Agricultural Renewable Solid Fuels Data. Waseca, Mn.
53. D. Salour, B.M. Jenkins, M. Vafei, M. Kayhanian, Control of in-bed agglomeration by fuel blending in a pilot scale straw and wood fueled AFBC, Biomass Bioenergy 4 (2) (1993) 117–133.

54. T.A. Milne, Voluntary standards for biomass for fuels and chemicals, Biomass 22 (1990) 343–351. [3 6] B. McBurney, Wood refuse/biomass fuel specification guidelines, Proceedings TAPPI Engineering Conference, 1993.
55. Matti Kuokkanen, Teemu Vilppo, Toivo Kuokkanen, Tuomas Stoor, Jouko Niinimaäki. Additives in Wood Pellet production – A pilot+scale Study of Binding Agent Usage. Bioresources 6(4), 4331-4355, 2011.
56. Jakob Nygaard Knudsen et al. Corrosion and deposit investigation during large-scale combustion of switchgrass at a coal-fired power station. Elsam Engineering A/S (Dong Energy).
57. L.G Tabil et al. Performance if differet binders during alfalfa pelleting. Canadian Agricultural Engineering, Vol 39, No 1, January/February/March 1997.
58. Radovan Nosek, Jozef Jandacka. Increasing the melting temperature of ash by adding different types of additives in to wood pellets. University of Zilina, Slovakia.
59. Ingwald Obernberger, Christoffer Boman. Fuel additives and blending as primary measures for reduction of fine ash particle emissions – state of the art. ERA-NET Bioenergy, Umeå University.

D. Documents providing information on wet, torrefaction, explosion pulping, hydrothermal carbonization and similar processes

1. International Energy Agency (IEA), Status Overview of Torrefaction Technologies, December 2012.
2. Lam, Pak Sui. Steam Explosion of Biomass to Produce Durable Wood Pellets, PhD Thesis, UBC May 2011.
3. C. Grimm, Fördervorhaben der DBU zur Hydrothermalen Karbonisierung – Ziele und Stand. Gülzower Fachgespräche 33, F achagentur Nachwachsende Rohstoffe (FNR), 2010, pp. 33-41.
4. A. Funke, F. Ziegler, Hydrothermal Carbonization of Biomass: A Literature Survey Focussing on its Technical Application and Prospects, Proc. 17th European Biomass Conference & Exhibition, 2009, Florence, Italy, and Munich, Germany, pp. 1037−1050.
5. B. Erlach, G. Tsatsaronis, ; Upgrading of biomass by hydrothermal carbonisation: Analysis of an industrial-scale plant design. Proc. ECOS – 23rd International Conference. Jun 14¬17, 2010, Lausanne, Switzerland.
6. M. Gerhardt, M. Berg, B. Kamm, Hydrothermal carbonization of lignocellulosic biomass and its precursors. Proc. International Conference on Polygeneration Strategies with special Focus on Integrated Biorefineries, Sep 07-09, 2010, Leipzig, Germany.
7. W. Yan, et al., Thermal Pretreatment of Lignocellullosic Biomass, Environmental Progress & Sustainable Energy 28 (3), 2009, pp. 435−440.
8. H. Ramke, Hydrothermale Carbonisierung organischer Siedlungsabfälle, 22. Abfallwirtschaftsforum, Gießen, 2010.
9. K. Serfass, Hydrothermale Carbonisierung. Eignung und Verarbeitung unterschiedlicher Biomassen zu Biokohle. Presentation at C.A.R.M.E.N Statusseminar Hydrothermale Karbonisierung (HTC), Aschaffenburg, Okt 5, 2010.
10. Erlach Berit, et.al. Co-production of electricity, heat and biocoal pellets from biomass: a techno-economic comparison with wood pelletizing. Technische Universität Berlin, Institute for Energy Engineering, Berlin, Germany. World Renewable Energy Congress 2011, Linköping, Sweden.
11. Pels, J.R., Bergman, P.C.A.: TORWASH - Proof of Principle – Phase 1, ECN-E—06-021, December 2006.
12. TORIPO Project, dewatering technology, Triqua, http://www.triqua.eu/triqua/fs3_site.nsf/htmlViewHomepage/website_6A34E78F71555811C12573CA00343B0D
13. Felix, Larry: Utilizing Hydrothermal Carbonization to Produce Densified, Coal-like Fuels from Ligno-cellulosic Biomass, US Forest Service Products Laboratory, March 26, 2012, Gas Technology Institute, Birmingham, Alabama.

E. Documents providing information on blending and mixing of feedstock and biofuels

1. The Vermont Grass Energy Partnership. Technical Assessment of Grass Pellets as Boiler Fuel in Vermont. Final Report January 2011.
2. Strömberg, Birgitta. Bränslehandboken (Handbook of Fuels), Värmeforsk Servive AB, F4-324, ISSN 0282-3772.
3. Kristöfel, Christa. Wopienka, Elisabeth. Biomass Report, IEE-09-758-SI 2.558286 – MixBioPells
4. Lenz, Volker. Zeng, Thomas. Best Practice Examples ”Production & Combustion Chains”. MixBioPells, DBFZ, Aril 2012.
5. Rönnbäck, Marie. Sager (SP), Anna. Alakangas, Eija (VTT). Report on the Labelling Concept. IEE-09-758-SI 2.558286- MixBioPells, April 2012.
6. Kristöfel, Christa. Wopienka, Elisabeth. Cost Analysis Report, IEE-09-758-SI 2.558286 – MixBioPells
7. Zeng, Thomas (DBFZ). Lallio, Markku. Ovarainen, Heikki.; Critical Review on the pelleting Technology, combustion technology and industrial scale Systems. IEE-09-758-SI 2.558286 – MixBioPells

Appendix B

Excerpt ISO 17225-1

Table 1 – Classification of Origin and Sources of Solid Biofuels

1. Woody biomass	1.1 Forest, plantation and other virgin wood	1.1.1 Whole trees without roots	1.1.1.1 Broad-leaf
			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 Whole trees with roots	1.1.2.1 Broad-leaf
			1.1.2.2 Coniferous
			1.1.2.3 Short rotation coppice
			1.1.2.4 Bushes
			1.1.2.5 Blends and mixtures
		1.1.3 Stemwood	1.1.3.1 Broad-leaf with bark
			1.1.3.2 Coniferous with bark
			1.1.3.3 Broad-leaf without bark
			1.1.3.4 Coniferous without bark
			1.1.3.5 Blends and mixtures
		1.1.4 Logging residues	1.1.4.1 Fresh/Green, Broad-leaf (including leaves)
			1.1.4.2 Fresh/Green, Coniferous (including needles)
			1.1.4.3 Stored, Broad-leaf
			1.1.4.4 Stored, Coniferous
			1.1.4.5 Blends and mixtures
		1.1.5 Stumps/roots	1.1.5.1 Broad-leaf
			1.1.5.2 Coniferous
			1.1.5.3 Short rotation coppice
			1.1.5.4 Bushes
			1.1.5.5 Blends and mixtures
		1.1.6 Bark (from forestry operations)	
		1.1.7 Segregated wood from gardens, parks, roadside maintenance, vineyards, fruit orchards and driftwood from freshwater	
		1.1.8 Blends and mixtures	
	1.2 By-products and residues from wood processing industry	1.2.1 Chemically untreated wood by-products and residues	1.2.1.1 Broad-leaf with bark
			1.2.1.2 Coniferous with bark
			1.2.1.3 Broad-leaf without bark
			1.2.1.4 Coniferous without bark
			1.2.1.5 Bark (from industry operations)
		1.2.2 Chemically treated wood by-products, residues, fibres and wood constituents	1.2.2.1 Without bark
			1.2.2.2 With bark
			1.2.2.3 Bark (from industry operations)
			1.2.2.4 Fibres and wood constituents
		1.2.3 Blends and mixtures	
	1.3 Used wood	1.3.1 Chemically untreated used wood	1.3.1.1 Without bark
			1.3.1.2 With bark
			1.3.1.3 Bark
		1.3.2 Chemically treated used wood	1.3.2.1 Without bark
			1.3.2.2 With bark
			1.3.2.3 Bark
		1.3.3 Blends and mixtures	
	1.4 Blends and mixtures		

NOTE 1 If appropriate, also the actual species (e.g. spruce, wheat) of biomass may be stated according to EN 13556, *Round and sawn timber — Nomenclature of timbers used in Europe*[1].

NOTE 2 Driftwood from saltwater is not recommended as a fuel.

Table 1 – Continued

2. Herbaceous biomass	2.1 Herbaceous biomass from agriculture and horticulture	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 Bamboo
			2.1.2.6 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 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards and fruit orchards	
		2.1.8 Blends and mixtures	
	2.2 By-products and residues from food and herbaceous processing industry	2.2.1 Chemically untreated herbaceous 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
			2.2.1.5 Flowers
			2.2.1.6 Blends and mixtures
		2.2.2 Chemically treated herbaceous 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
			2.2.2.5 Flowers
			2.2.2.6 Blends and mixtures
		2.2.3 Blends and mixtures	
	2.3 Blends and mixtures		

Table 1 – Continued

3. Fruit biomass	3.1 Orchard and horticulture fruit	3.1.1 Berries	3.1.1.1 Whole berries
			3.1.1.2 Flesh
			3.1.1.3 Seeds
			3.1.1.4 Blends and mixtures
		3.1.2 Stone/kernel fruits	3.1.2.1 Whole fruit
			3.1.2.2 Flesh
			3.1.2.3 Stone/kernel/fruit fibre
			3.1.2.4 Blends and mixtures
		3.1.3 Nuts and acorns	3.1.3.1 Whole nuts
			3.1.3.2 Shells/husks
			3.1.3.3 Kernels
			3.1.3.4 Blends and mixtures
		3.1.4 Blends and mixtures	
	3.2 By-products and residues from food and fruit processing industry	3.2.1 Chemically untreated fruit residues	3.2.1.1 Berries
			3.2.1.2 Stone/kernel fruits/fruit fibre
			3.2.1.3 Nuts and acorns
			3.2.1.4 Crude olive cake
			3.2.1.5 Blends and mixtures
		3.2.2 Chemically treated fruit residues	3.2.2.1 Berries
			3.2.2.2 Stone/kernel fruits
			3.2.2.3 Nuts and acorns
			3.2.2.4 Exhausted olive cake
			3.2.2.5 Blends and mixtures
		3.2.3 Blends and mixtures	
	3.3 Blends and mixtures		
4. Aquatic biomass	4.1 Algae	4.1.1 Micro algae (latin name to be stated)	
		4.1.2 Macro algae (latin name to be stated)	
		4.1.3 Blends and mixtures	
	4.2 Water hyacinth		
	4.3 Lake and sea weed	4.3.1 Lake weed (latin name to be stated)	
		4.3.2 Sea weed	4.3.2.1 Blue sea weed (latin name to be stated)
			4.3.2.2 Green sea weed (latin name to be stated)
			4.3.2.3 Blue-green sea weed (latin name to be stated)
			4.3.2.4 Brown sea weed (latin name to be stated)
			4.3.2.5 Red sea weed (latin name to be stated)
		4.3.3 Blends and mixtures	
	4.4 Reeds	4.4.1 Common reed	
		4.4.2 Other reed	
		4.4.3 Blends and mixtures	
	4.5 Blends and mixtures		
5 Blends and mixtures	5.1 Blends		
	5.2 Mixtures		

NOTE 3 Group 5 "Blends and mixtures" include blends and mixtures from the main origin-based solid biofuel groups 1 to 4.

Table 15 – Specification of Properties for Thermally Treated Biomass (e.g. Mild Form Pyrolysis/Torrefaction)

	Master table	
	Origin: According to 6.1 and Table 1	Woody biomass (1); Herbaceous biomass (2); Fruit biomass (3); Aquatic biomass (4); Blends and mixtures (5).
	Traded Form (see Table 2)	Thermally treated biomass
Normative	**Dimensions** (mm)	to be stated
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2	
	M3	≤ 3 %
	M5	≤ 5 %
	M8	≤ 8 %
	M10	≤ 10 %
	M10+	> 10 % (maximum value to be stated)
	Ash, A (w-% of dry basis) ISO 18122	
	A0.5	≤ 0,5 %
	A0.7	≤ 0,7 %
	A1.0	≤ 1,0 %
	A1.5	≤ 1,5 %
	A2.0	≤ 2,0 %
	A3.0	≤ 3,0 %
	A5.0	≤ 5,0 %
	A7.0	≤ 7,0 %
	A10.0	≤ 10,0 %
	A10.0+	> 10,0 % (maximum value to be stated)
	Bulk density (BD) (kg/m^3 as received) ISO 17828	
	BD200	≥ 200 kg/m^3
	BD250	≥ 250 kg/m^3
	BD300	≥ 300 kg/m^3
	Net calorific value, Q (MJ/kg or kWh/kg as received) ISO 18125	≥ 17 MJ/kg (minimum value to be stated)
	Fixed carbon, C (w-% of dry basis) [a]	
	C20	≥ 20 %
	C25	≥ 25 %
	C30	≥ 30 %
	C35	≥ 35 %
	C40	≥ 40 %
	Volatiles, VM, (w-% of dry basis), ISO 18123	Maximum value to be stated

[a] Fixed carbon (%) is calculated by the following: 100 – [moisture (w-%) + ash (w-%) + volatile matter (w-%)]. All percentage are on the same moisture basis.

NOTE 11 Thermally treated biomass briquettes and pellets are specified in Table 3 and Table 4.

Table 15 – Specification of Properties for Thermally Treated Biomass (e.g. Mild Form Pyrolysis/Torrefaction)

	Master table			
	Origin: According to 6.1 and Table 1		Woody biomass (1.1 and 1.2.1); Fruit biomass (3)	
	Traded Form (see Table 2)		Charcoal	
Normative	**Dimensions** (mm)			
		Main fraction (minimum 75 w-%), mm	Fines fraction, w-% (< 10 mm)	Coarse fraction, (w-%), max. length of particle, mm
	P150	16 mm ≤ P ≤ 150 mm	≤ 7 %	≤ 10 % > 100 mm, and all < 150mm
	Moisture, M (w-% as received) ISO 18134-1, ISO 18134-2			
	M8	≤ 8 %		
	M10	≤ 10 %		
	Ash, A (w-% of dry basis) ISO 18122			
	A5.0	≤ 5,0 %		
	A8.0	≤ 8,0 %		
	A8.0+	> 8,0 % (maximum value to be stated)		
	Fixed carbon, C [a] (w-% of dry basis)			
	C60	≥ 60 %		
	C75	≥ 75 %		
	Bulk density (BD) (kg/m^3 as received) ISO 17828			
	BD130	≥ 130 kg/m^3		
	BD150	≥ 150 kg/m^3		
	Net calorific value, Q (MJ/kg or kWh/kg as received) ISO 18125			Minimum value to be stated

[a] Fixed carbon (%) is calculated by the following: 100 – [moisture (w-%) + ash (w-%) + volatile matter (w-%)]. All percentage are on the same moisture basis.

Appendix C

Rosetta Stone of Solid Biofuels Testing Standards					
ISO #	CEN	ASABE	ASTM	Other	Document content
18134-1	14774-1				Moisture - Ref Method
18134-2	14774-2				Moisture - Simplified Method
18157-1	14774-3	S269.4	E 871-82		Moisture - General analysis
18122	14775		D 1102		Ash Content
18125	14918				Calorific Value
17828	15103	S269.4			Bulk Density
18123	15148		E 872-82		Volatile Matter
17827-1	15149-1				Particle Size Distribution (oscillating screen)
17827-2	15149-2				Particle Size Distribution (vibrating screen)
NWI	15150				Particle Density
17831-1	15210-1	S269.4			Mechanical Durability - Pellets
17831-2	15210-2				Mechanical Durability - Briquettes
17830	16126				Particle Size Distribution (Disintegrated Pellets)
5074					Grindability
17829	16127				Length & Diameter of Pellets
NWI		S319.3			Fines Content
NWI					Hygroscopicity
NWI					Absorbicity
NWI					Freezing characteristics
Tech Report					Image analysis - particle classification
NWI					Off-gassing
			E 1491		Auto-ignition temperature (cloud)
	13821		E 2019		Minimum ignition energy (MIE)
6184-1	14034-1		E 1226		Max explosion pressure (Pmax)
	14034-2		E 1226		Max Explosion pressure rate (dP/dt)
	14034-2		E 1226		Deflagration index (Kst)
	14034-3		E 1515		Min Explosible Concentration (MEC)
	14034-4		E 1515 mod		Limiting Oxygen Concentration (LOC)
	50281		E 2021		Hot surface Temp (Ts)
NWI					Dust sampling
				USBM RI5624	Auto-iginition temp (layer)
NWI				UN MTC Test 1	Flammability of solids
				UN MTC Test 4.2	Self-heating
NWI					Explosive dust sampling
NWI					Angle of Repose
NWI					Angle of Drain
NWI					Explosive dust sampling
NWI	15370-1				Ash melting behaviour
16948	15104		D 5373		CHN - instrument method
16994	15289		D 4239		Total content, sulfur and chlorine
16995	15105				Water soluable content, chlorine, sodium, potassium
16967	15290				Major elements
16968	15297		D 4326		Minor elements
16996					Elemental composition by X-ray fluorescence
16993	15296				Conversion of analytical results
18135	14778				Sampling
14780	14780				Sample Preparation

Appendix D

Excerpt ISO 17225-6, Part 6
Graded Non-woody Pellets, Table 2 Specifications

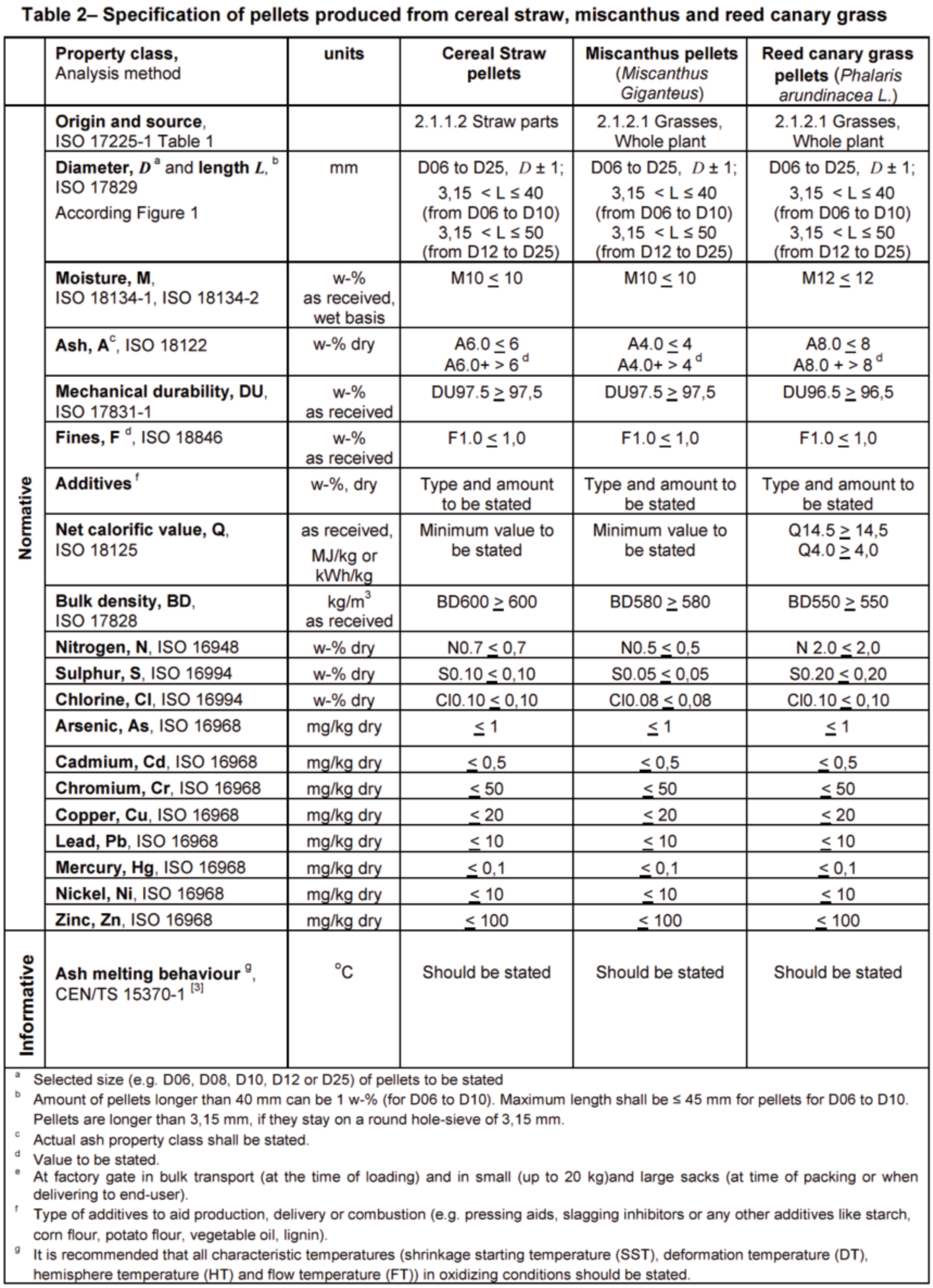


Table 2– Specification of pellets produced from cereal straw, miscanthus and reed canary grass

	Property class, Analysis method	units	Cereal Straw pellets	Miscanthus pellets (*Miscanthus Giganteus*)	Reed canary grass pellets (*Phalaris arundinacea L.*)
Normative	**Origin and source**, ISO 17225-1 Table 1		2.1.1.2 Straw parts	2.1.2.1 Grasses, Whole plant	2.1.2.1 Grasses, Whole plant
	Diameter, *D* [a] **and length *L***, [b] ISO 17829 According Figure 1	mm	D06 to D25, *D* ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, *D* ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, *D* ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)
	Moisture, M, ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M10 ≤ 10	M10 ≤ 10	M12 ≤ 12
	Ash, A[c], ISO 18122	w-% dry	A6.0 ≤ 6 A6.0+ > 6 [d]	A4.0 ≤ 4 A4.0+ > 4 [d]	A8.0 ≤ 8 A8.0 + > 8 [d]
	Mechanical durability, DU, ISO 17831-1	w-% as received	DU97.5 ≥ 97,5	DU97.5 ≥ 97,5	DU96.5 ≥ 96,5
	Fines, F [d], ISO 18846	w-% as received	F1.0 ≤ 1,0	F1.0 ≤ 1,0	F1.0 ≤ 1,0
	Additives [f]	w-%, dry	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated
	Net calorific value, Q, ISO 18125	as received, MJ/kg or kWh/kg	Minimum value to be stated	Minimum value to be stated	Q14.5 ≥ 14,5 Q4.0 ≥ 4,0
	Bulk density, BD, ISO 17828	kg/m^3 as received	BD600 ≥ 600	BD580 ≥ 580	BD550 ≥ 550
	Nitrogen, N, ISO 16948	w-% dry	N0.7 ≤ 0,7	N0.5 ≤ 0,5	N 2.0 ≤ 2,0
	Sulphur, S, ISO 16994	w-% dry	S0.10 ≤ 0,10	S0.05 ≤ 0,05	S0.20 ≤ 0,20
	Chlorine, Cl, ISO 16994	w-% dry	Cl0.10 ≤ 0,10	Cl0.08 ≤ 0,08	Cl0.10 ≤ 0,10
	Arsenic, As, ISO 16968	mg/kg dry	≤ 1	≤ 1	≤ 1
	Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5	≤ 0,5	≤ 0,5
	Chromium, Cr, ISO 16968	mg/kg dry	≤ 50	≤ 50	≤ 50
	Copper, Cu, ISO 16968	mg/kg dry	≤ 20	≤ 20	≤ 20
	Lead, Pb, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1	≤ 0,1	≤ 0,1
	Nickel, Ni, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
	Zinc, Zn, ISO 16968	mg/kg dry	≤ 100	≤ 100	≤ 100
Informative	**Ash melting behaviour** [g], CEN/TS 15370-1 [3]	°C	Should be stated	Should be stated	Should be stated

[a] Selected size (e.g. D06, D08, D10, D12 or D25) of pellets to be stated

[b] Amount of pellets longer than 40 mm can be 1 w-% (for D06 to D10). Maximum length shall be ≤ 45 mm for pellets for D06 to D10. Pellets are longer than 3,15 mm, if they stay on a round hole-sieve of 3,15 mm.

[c] Actual ash property class shall be stated.

[d] Value to be stated.

[e] At factory gate in bulk transport (at the time of loading) and in small (up to 20 kg)and large sacks (at time of packing or when delivering to end-user).

[f] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin).

[g] It is recommended that all characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

Appendix E

GGLS2 - Agricultural Source Criteria
Green Gold Label Program

Version 2013.1 (January 2013)

Introduction & Scope

The GGLS2 is based on the United Nations sustainable development program Agenda 21 and the sustainability criteria from the Renewable Energy Directive (2009/28/EC). This standard is to be used for approval of the agricultural source when no other certification system is available. An audit based on these principles with a positive result will lead to a “testimony of approval” as a GGL approved source (see Annex A for GGL approved agricultural systems other than GGL 2). For these materials, falling under the scope of GGLS2 (Agricultural Sources), each year an audit with a positive result will have to be carried out.

Glossary

See GGL Glossary

Principles

Principle 1 The agriculture management system is part of an integrated long term planning program (either individually or organized in a group), aimed at development and sustainability.

Criteria:
1.1 A long term commitment to adhere to the principles and criteria for sustainable agriculture, expressed in a written and up to date agriculture management plan or other management documents.
1.2 Policy reviews are carried out periodically.
1.3 A policy is implemented to influence tenure and property rights of local small holders positively, with respect to the minimum size of land-holding.
1.4 The management plan is dealing with the policy on improvement of production, harvesting, storage, processing, distribution and marketing of products on local, national and regional level.
1.5 Storage and distribution problems, affecting food availability are identified and dealt with in the management plan.

Principle 2 The agriculture management system is based on land-resource planning.

Criteria:
2.1 Collection and continuous monitoring of utilization of natural resources and living conditions are used for the land resource planning (either individually or on a regional basis). Data about: climate, water and soil, land use, vegetation cover and distribution, animal species, utilization of wild plants, production systems and yields, costs and prices and, social and cultural considerations affecting agriculture and adjacent land use are collected on a regular basis
2.2 Participation in the initiation and maintenance of district and village agricultural land resource planning assisted by management and conservation groups.

Principle 3 The agriculture management is aimed at land conservation and rehabilitation.

Criteria:
3.1 Land degradation is surveyed on a regular basis.

3.2 Land and conservation areas at risk are identified and the policy and management measures are formulated.

3.3 The general planning, management and utilization of land resources and the preservation of soil fertility are defined and executed. GGLS2 - Agricultural Source Criteria

Principle 4 The agriculture management is aimed at the insurance of freshwater supply and quality for sustainable food production and sustainable rural development.

Criteria:
4.1 Efficiency and productivity of agricultural water use for better utilization of limited water resources has to increase.
4.2 Monitoring of the irrigation performance.
4.3 Proper dispose of sewage and waste from the farm and human settlements and of manure produces by intensive life stock breeding.
4.4 Water quality has to be monitored on biological, physical and chemical quality.
4.5 Measures have to be taken to minimize soil run-of and sedimentation.
4.6 Irrigation has to be planned in a long term program.
4.7 Long term strategies and implementation program have to be developed on water use under scarce conditions.
4.8 Waste water re-use has to be part of the agriculture management system.

Principle 5 The agricultural management system has implemented integrated pest management and control.

Criteria:
5.1 The management system is based on an integrated system of pest control.
5.2 The use of banned pesticides is prohibited.
5.3 The use of restricted pesticides is controlled and a administration is kept up to date. Stock is kept in a separate and locked storage.
5.4 Biological control agents and organic pesticides, as well as traditional knowledge and skills regarding alternatively non-chemical pest control have to be identified and implemented in the agricultural management system.

Principle 6 The agricultural management system has implemented sustainable plant nutrition to increase food production.

Criteria:
6.1 The management plan is based on an integrated plant nutrition approach.
6.2 The availability of fertilizer and other plant nutrient resources are optimized.

Principle 7 Raw materials shall not be obtained from land with high biodiversity value[1].

Criteria:
7.1 The raw material is not produced on land that had one of the following statuses in or after January 2008, whether or not the land still have that status:

- Primary forest and other wooded land, namely forest and other wooded land containing native tree species without clearly visible indication of human activity and the ecological processes are not significantly disturbed;
- Areas with the purposes of nature conservation which are designated by law or by the relevant competent authority. In addition, also areas that have been recognized by international agreements or included in lists drawn up by intergovernmental organizations or the International Union for the Conservation of Nature, subject to their recognition in accordance with the second subparagraph of Article 18(4) [Directive 2009/28/EC] for the protection of rare threatened or endangered ecosystems or species. Cultivation of biomass on above mentioned areas is permitted under the condition that evidence is provided that the production did not interfere with those nature protection purposes;
- Areas with highly bio diverse grasslands which divided in Natural grasslands and Non-Natural grasslands[2]:
    - Natural grassland is grassland that would remain grassland in the absence of human intervention and which maintains the natural species composition and ecological characteristics and processes.
    - Non-natural grassland is grassland that would cease to be grassland in the absence of human intervention and which is species-rich and not degraded, unless evidence is provided that the harvesting of the raw materials is necessary to preserve its grassland status.

Principle 8 Raw materials shall not be obtained from land with high carbon stock.

Criteria:
8.1 The raw material is not produced from land with high carbon stock, that is to say land that had one of the following statuses in January 2008 and no longer has this status[3, 4]:

- An aerial photograph of the land, showing it to be planted (positive), or
- A map of all the primary forests in the region, showing the land to fall outside them (negative)
- Wetlands, namely land that is covered with or saturated by water permanently Or for a significant part of the year;
- Continuously forested areas, namely land spanning more than one hectare with trees higher than five meters and a canopy cover of more than 30%, or trees able to reach those thresholds in situ;
- Land spanning more than one hectare with trees higher than five meters and a canopy cover of between 10% and 30%, or trees able to reach those thresholds in situ, unless evidence is provided that the carbon stock of the area before and after conversion is such that, when the methodology laid down in part C of Annex V of the RED is applied, the conditions laid down in subsection 2 of Article 17 of the RED would be fulfilled.

Principle 9 Raw materials shall not be obtained from peatland[3].

Criteria:
9.1 The raw material is not produced on land that was peatland in January 2008, an exception is possible if evidence is provided that5:

- The soil was completely drained in 2008, or
- There has not been draining of the soil since January 2008.

Principle 10 Agricultural raw materials cultivated in the Community shall be obtained in accordance with the European “Cross Compliance” regulations.

Criteria:
10.1 Agricultural raw materials cultivated in the Community must be obtained in accordance with the requirements and standards under the provisions referred to under the heading “Environment” in part A of Annex III to Council Regulation (EC) No 1782/2003 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers and in point 9 of Annex III to that Regulation, and in accordance with the minimum requirements for good agricultural and environmental condition defined pursuant to Article 5(1) of that Regulation.

Organic

GLOBAL GAP

---

[1] Evidence of compliance with the land-related criteria could take many forms, including aerial photographs, satellite images, maps, land register entries/databases and site surveys. Evidence can be “positive” or “negative”. For example, compliance with the criterion on “primary forest” could be shown by:
- An aerial photograph of the land, showing it to be planted (positive), or
- A map of all the primary forests in the region, showing the land to fall outside them (negative)

[2] All further EC Communications regarding the definition of highly bio diverse grasslands will be binding for this scheme and will be communicated to all participants.

[3] Evidence of compliance with the land-related criteria could take many forms, including aerial photographs, satellite images, maps, land register entries/databases and site surveys. Evidence can be “positive” or “negative”. For example, compliance with the criterion on “primary forest” could be shown by:

[4] The provisions of this paragraph shall not apply if, at the time the raw material was obtained, the land had the same status as it had in January 2008.

[5] This means that for peatland that was partially drained in January 2008 a subsequent deeper drainage, affecting soil that was not already fully drained, would constitute a breach of the criterion.

Appendix F

Excerpt Canmet Agricultural Biomass Database

			Biomass Characterization																	
Parameter	Testing Standard		Switch-grass Pellets	Dried Distiller's Grain	Corn Cob	Oat hull pellets	Flax Shives	Canola Seed	Corn Stover 1	Corn Stover 2	Mis-canthus	Oat hulls	White pine	Sask Acute Willow	Sask Willow	Quebec Willow	Canary Grass	Beans	Peat	Lignite
Moisture	ASTM D5142	w.b. wt%	7.85	8.95	7.96	10.10	9.97	5.64	23.70	19.32	5.30	8.66	38.01	5.01	5.66	6.33	13.86	13.38	35.77	30.00
Ash	ASTM D5142	d.b. wt%	3.87	4.88	1.49	7.19	3.13	4.45	14.30	9.59	2.73	5.09	0.44	1.78	1.65	2.14	7.30	4.69	1.99	22.03
Volatiles	ISO 562	d.b. wt%	80.40	79.89	85.08	83.99	86.67	84.22	69.82	73.46	77.93	75.03	84.45	80.00	82.04	79.17	81.36	77.78	68.57	54.04
Fixed Carbon	by difference*	d.b. wt%	15.72	15.23	13.43	8.82	10.20	11.33	15.88	16.95	19.33	19.88	15.11	18.22	16.30	18.69	18.64	17.53	29.44	23.93
Carbon	ASTM D5373	d.b. wt%	48.20	50.37	48.10	51.20	54.95	60.77	37.92	45.31	47.86	46.73	52.49	50.29	50.48	50.13	48.60	45.67	56.14	58.81
Hydrogen	ASTM D5373	d.b. wt%	6.11	6.75	6.02	7.05	6.81	8.32	4.73	4.90	5.84	6.07	6.32	6.10	5.99	5.79	6.03	6.33	5.67	4.17
Nitrogen	ASTM D5373	d.b. wt%	0.42	4.74	0.36	2.40	0.47	4.49	0.93	0.66	0.52	0.91	0.10	0.65	0.35	0.51	0.77	4.25	0.81	0.91
Sulphur	ASTM D4239	d.b. wt%	0.08	0.68	0.05	0.21	0.09	0.53	0.08	0.07	0.07	0.12	<0.05	0.07	0.05	0.05	0.10	0.27	0.23	0.50
Oxygen	by difference	d.b. wt%	41.31	32.58	43.98	31.95	34.56	21.44	42.04	39.47	42.97	41.08	40.60	41.11	41.48	41.38	44.44	38.79	35.16	13.58
Calorific	ISO 1928	Cal/g	4,526.00	5,250.00	4,402.00	4,969.00	4,631.00	6,791.00	3,716.00	3,973.00	4,585.00	4,424.00	4,907.00	4,829.00	4,799.00	4,748.00	4,541.97	4,442.00	5,107.00	5,196.00
Calorific value	ISO 1928	GJ/tonne	18.90	22.00	18.40	20.80	19.40	28.40	15.60	16.60	19.20	18.50	20.60	20.20	20.01	20.01	19.02	18.60	21.40	21.80
Calorific value	ISO 1928	btu/lb	8,148.00	9,450.00	7,927.00	8,929.00	8,339.00	12,224.00	6,685.00	7,147.00	8,253.00	7,963.00	8,833.00	8,692.00	8,638.00	8,546.00	8,086.80	7,996.00	9,192.00	9,352.00
SiO2	ASTM D4326	ash wt%	64.48	0.28.	12.09	28.26	7.74	<0 10	70.37	70.15	33.80	65.67	6.70	3.63	1.87	1.69	68.83	3.29	28.05	49.76
P2O5	ASTM D4327	ash wt%	4.05	35.42	2.77	26.26	2.53	45.00	0.72	0.72	5.24	6.42	3.52	5.56	6.08	4.24	4.72	27.76	1.31	0.30
CaO	ASTM D4328	ash wt%	7.34	0.35	1.38	8.48	18.29	11.00	2.88	2.90	16.27	1.74	31.10	31.98	42.08	42.15	4.92	5.48	12.65	9.91
MgO	ASTM D4329	ash wt%	3.42	9.37	1.68	9.13	7.46	14.00	1.72	1.88	3.06	3.09	4.34	7.76	2.83	4.19	1.98	7.01	17.72	2.11
Na2O	ASTM D4330	ash wt%	0.26	6.67	<0.20	<0.20	2.09	<0.20	1.10	0.90	<0 20	0.97	0.36	4.71	2.53	0.20	0.68	<0.20	2.84	4.20
K2O	ASTM D4331	ash wt%	7.13	21.63	47.20	18.28	28.42	18.00	8.11	8.76	25.89	11.21	15.45	13.59	9.52	11.26	7.05	39.82	1.14	1.04
Total Chlorine		µg/g d.b.	760.00	1,367.00	2,907.00	624.00	757.00	163.00	3,937.00	3,948.00	1,048.00	1,065.00	39.00	798.00	431.00	134.00	1,147.00	193.00	2,008.00	25.00

*Some of the more recent tests cite ASTM D3172

w.b. – wet basis (as received)

d.b. – dry basis

Appendix G

ISO Solid Biofuels Specifications, ENplus and PFI Certification Summary for Pellets

Parameter	ISO Classification of Wood Pellets							Testing Standard		PFI Certification Standard				
	Measure	ENplus Certification Standard			I1	I2	I3	ISO	EN	Measure	Premium	Standard	Utility	Testing Standard
		A1	A2	B										
Origin of material	1.1 Forest plantation and virgin wood			x	x	x		**17225-1**						
	1.1.1 Whole tree		x					**17225-1**						
	1.1.3 Stemwood	x	x					**17225-1**						
	1.1.4 Logging residue		x					**17225-1**						
	1.2 Industrial by-products and residue			x				**17225-1**						
	1.2.1 Chemically untreated wood	x	x		x	x		**17225-1**						
	1.2.1.5 Bark							**17225-1**						
	1.3 Used wood			x				**17225-1**						
	1.3.1 Chemically untreated wood						x							
Diameter / Length	mm	6 ± 1			6 to 8	6 to 10	6 to 12	17829	16127	Inch (mm)	0.23 - 0.285 (5.84 - 7.25)			PFI Spec. / NIST
Length	mm	3.15 ≤ L ≤ 40			6 L ≤ 40	6 L ≤ 40	6 L ≤ 40			Inch, % greater than 1.50 inches	≤ 1.0			
					8 L ≤ 50	8 L ≤ 50	8 L ≤ 50							
Moisture	% of weight, ar	≤ 10						WD XXX-1/2/3	14774-1/2/3	% of weight, ar	≤ 8	≤ 10		ASTM E 871
Total ash	% of weight, dry	≤ 0.7	≤ 1.5	≤ 3.0	≤ 1.0	≤ 1.5	≤ 3.0	18122	14775	% of weight, dry	≤ 1.0	≤ 2.0	≤ 6.0	ASTM D 1102
Ash melting behaviour	°C	as stated						WD XXX	15370	°F	as stated (not mandatory)			ASTM D 1857
Durability	% of weight, ar	≥ 97.5		≥ 96.5	≥ 97.5		≥ 96.5	17831-1	15210-1	% of weight, ar	≥ 96.5	≥ 95.0		PFI Spec. Annex A.1
Fines content	% of weight, ar	≤ 1.0			≤ 4.0	≤ 5.0	≤ 6.0	ISO NXXX Fines		% of weight, ar	≤ 0.5	≤ 1.0		PFI Spec.
Particle size distribution	% of weight				>99% (3.15 mm)	>98% (3.15 mm)	>97% (3.15 mm)	17830	16126					
					>95% (2.0 mm)	>90% (2.0 mm)	>85% (2.0 mm)							
					>60% (0.1 mm)	>50% (0.1 mm)	>40% (0.1 mm)							
Additives	% of weight, ar	≤ 2.0						Max 2% of weight		% of weight, ar	as stated			Max 2% by weight
Net calorific value, constant pressure, ar	MJ/kg GJ/tonne	≥ 16.5	≥ 16.3	≥ 16.0	≥ 16.5			18125	14918	Higher Heat Value (HHV) at constant[1] volume in BTU/lb, ar	minimum as stated			ASTM E 711
Bulk density	kg/m3, ar	≥ 600						17828	15103	lb/cuft, ar	40.0 - 46.0	38.0 - 46.0		ASTM E 873
Bulk temperature	°C				≤ 60.0 ± 1									
Nitrogen	% of weight, dry	≤ 0.3	≤ 0.5	≤ 1.0	≤ 0.3		≤ 0.6	16948	15104					
Sulphur	% of weight, dry	≤ 0.03		≤ 0.04	≤ 0.15	≤ 0.2	≤ 0.4	16994	15289					
Chlorine	% of weight, dry	≤ 0.02		≤ 0.03	≤ 0.03	≤ 0.05	≤ 0.1			ppm	≤ 300			ASTM D 4208
	Elemental components in mg/kg substance of raw biomass material													
Arsenic	mg/kg dry	≤ 1			≤ 2			16968	15297					
Cadmium	mg/kg dry	≤ 0.5			≤ 1									
Chromium	mg/kg dry	≤ 10			≤ 15									
Copper	mg/kg dry	≤ 10			≤ 20									
Lead	mg/kg dry	≤ 10			≤ 20									
Mercury	mg/kg dry	≤ 0.1			≤ 0.1									
Nickel	mg/kg dry	≤ 10												
Zinc	mg/kg dry	≤ 100			≤ 200									

(1) Net calorific value at constant pressure can be calculated according to the following formula as per ASTM E711-87 (2004), formula 5; Net calorific value (constant pressure) = Gross calorific value (constant volume) - 23.96 x H x 9 where H is the hydrogen content in % of weight.
1 BTU/lb = 2.326 J/gram.

Appendix H

ISO Solid Biofuels Specifications, Woody, Non-woody Pellets, Non-woody Torrefied Pellets

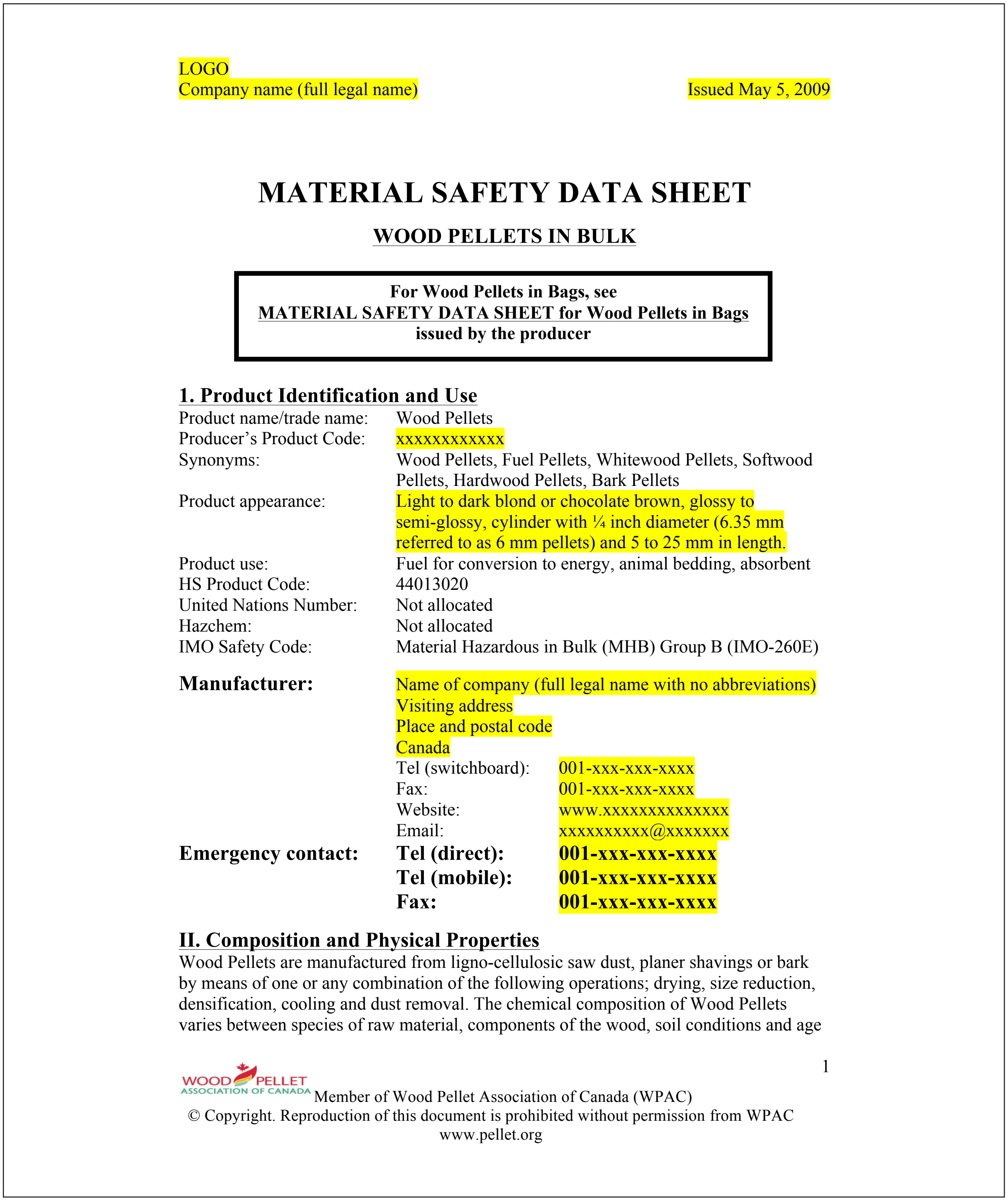
Parameter	Measure	ISO Classification of Briquettes											Testing Standard	
		Wood briquettes			Non-woody briquettes		Torrefied briquettes						ISO	EN
		A1	A2	B	A	B	TW1	TW2	TW3	TA1	TA2	TA3		
Origin of material	1.1 Forest plantation and virgin wood			X				X	X				17225-1	
	1.1.1 Whole tree		X				X						17225-1	
	1.1.3 Stemwood	X	X				X						17225-1	
	1.1.4 Logging residue		X				X						17225-1	
	1.2 Industrial by-products and residue			X				X	X				17225-1	
	1.2.1 Chemically untreated wood	X	X				X						17225-1	
	1.2.1.5 Bark												17225-1	
	1.3 Used wood			X									17225-1	
	2. Herbaceous biomass				X	X					X	X	17225-1	
	2.1 Herbaceous biomass from agriculture and horticulture									X			17225-1	
	2.2.1 By-products and residue from food and herbaceous processing industry, chemically untreated herbaceaous residue									X			17225-1	
	3. Fuit				X	X					X	X	17225-1	
	3.1 Orchard and horticulture fruit									X			17225-1	
	3.2.1 By-products and residues from food and fruit processing industry, chemically untreated fruit residues									X			17225-1	
	4. Aquatic biomass				X	X				X	X	X	17225-1	
	5. Blends and mixtures				X	X								
Diameter / Length	mm	Max to be stated											17829	16127
Length	mm	Max to be stated												
Moisture	% of weight, ar	≤ 12	≤ 15		≤ 12	≤ 15	≤ 10						WD XXX-1/2/3	14774-1/2/3
Total ash	% of weight, dry	≤ 1.0	≤ 1.5	≤ 3.0	≤ 6	≤ 10	≤ 2.0	≤ 5.0	≤ 10.0	≤ 5.0	≤ 10.0	stated	18122	14775
Ash melting behaviour	°C	as stated											WD XXX	15370
Durability	% of weight, ar	≥ 97.5		≥ 96.5	≥ 97.5	≥ 96.5	≥ 97.5	≥ 96.5	≥ 96.5	≥ 97.5	≥ 96.5	≥ 95.5	17831-1	15210-1
Fines content	% of weight, ar	≤ 1.0			≤ 2.0	≤ 3.0	≤ 1.0						ISO NXXX Fines	
Particle density	kg/m3	≥ 1.0		≥ 0.9	0.9	0.6							ISO WD XXXXX	
Additives	% of weight, ar	≤ 2.0			≤ 5	≤ 5	As stated						Max 2% of weight	
Net calorific value, constant pressure, ar	MJ/kg GJ/tonne	≥ 15.5	≥ 15.3	≥ 14.9	≥ 14.5	≥ 14.5	≥ 20		≥ 19	≥ 18	≥ 17	stated	18125	14918
Bulk density	kg/m3, ar				≥ 600	≥ 600	≥ 650			≥ 600			17828	15103
Bulk temperature	°C													
Nitrogen	% of weight, dry	≤ 0.3	≤ 0.5	≤ 1.0	≤ 1.5	≤ 2.0	≤ 0.5		≤ 1.0	≤ 1.5	≤ 2.0	≤ 2.0	16948	15104
Sulphur	% of weight, dry	≤ 0.03		≤ 0.04	≤ 0.2	≤ 0.3	≤ 0.03		≤ 0.05				16994	15289
Chlorine	% of weight, dry	≤ 0.02		≤ 0.03	≤ 0.1	≤ 0.3	≤ 0.03	≤ 0.05	≤ 0.1	≤ 0.2	≤ 0.3			
Volatile matter	% of weight, dry						≤ 75							
	Elemental components in mg/kg substance of raw biomass material													
Arsenic	mg/kg dry	≤ 1			≤ 1.0		≤ 2			≤ 1			16968	15297
Cadmium	mg/kg dry	≤ 0.5			≤ 0.5		≤ 1.0							
Chromium	mg/kg dry	≤ 10			≤ 50		≤ 15			≤ 50				
Copper	mg/kg dry	≤ 10			≤ 20		≤ 20							
Lead	mg/kg dry	≤ 10												
Mercury	mg/kg dry	≤ 0.1												
Nickel	mg/kg dry	≤ 10												
Zinc	mg/kg dry	≤ 100								≤ 200				

ISO Solid Biofuels Specifications for Briquettes

Parameter	Measure	ISO Classification of Briquettes											Testing Standard	
		Wood briquettes			Non-woody briquettes		Torrefied briquettes						ISO	EN
		A1	A2	B	A	B	TW1	TW2	TW3	TA1	TA2	TA3		
Origin of material	1.1 Forest plantation and virgin wood			X				X	X				17225-1	
	1.1.1 Whole tree		X				X						17225-1	
	1.1.3 Stemwood	X	X				X						17225-1	
	1.1.4 Logging residue		X				X						17225-1	
	1.2 Industrial by-products and residue			X				X	X				17225-1	
	1.2.1 Chemically untreated wood	X	X				X						17225-1	
	1.2.1.5 Bark												17225-1	
	1.3 Used wood			X									17225-1	
	2. Herbaceous biomass				X	X					X	X	17225-1	
	2.1 Herbaceous biomass from agriculture and horticulture									X			17225-1	
	2.2.1 By-products and residue from food and herbaceous processing industry, chemically untreated herbaceous residue									X			17225-1	
	3. Fuit				X	X					X	X	17225-1	
	3.1 Orchard and horticulture fruit									X			17225-1	
	3.2.1 By-products and residues from food and fruit processing industry, chemically untreated fruit residues									X			17225-1	
	4. Aquatic biomass				X	X				X	X	X	17225-1	
	5. Blends and mixtures				X	X								
Diameter / Length	mm	Max to be stated											17829	16127
Length	mm	Max to be stated												
Moisture	% of weight, ar	≤ 12	≤ 15		≤ 12	≤ 15	≤ 10						WD XXX-1/2/3	14774-1/2/3
Total ash	% of weight, dry	≤ 1.0	≤ 1.5	≤ 3.0	≤ 6	≤ 10	≤ 2.0	≤ 5.0	≤ 10.0	≤ 5.0	≤ 10.0	stated	18122	14775
Ash melting behaviour	°C	as stated											WD XXX	15370
Durability	% of weight, ar	≥ 97.5		≥ 96.5	≥ 97.5	≥ 96.5	≥ 97.5	≥ 96.5	≥ 96.5	≥ 97.5	≥ 96.5	≥ 95.5	17831-1	15210-1
Fines content	% of weight, ar	≤ 1.0			≤ 2.0	≤ 3.0	≤ 1.0						ISO NXXX Fines	
Particle density	kg/m3	≥ 1.0		≥ 0.9	0.9	0.6							ISO WD XXXXX	
Additives	% of weight, ar	≤ 2.0			≤ 5	≤ 5	As stated						Max 2% of weight	
Net calorific value, constant pressure, ar	MJ/kg GJ/tonne	≥ 15.5	≥ 15.3	≥ 14.9	≥ 14.5	≥ 14.5	≥ 20		≥ 19	≥ 18	≥ 17	stated	18125	14918
Bulk density	kg/m3, ar				≥ 600	≥ 600	≥ 650			≥ 600			17828	15103
Bulk temperature	°C													
Nitrogen	% of weight, dry	≤ 0.3	≤ 0.5	≤ 1.0	≤ 1.5	≤ 2.0	≤ 0.5		≤ 1.0	≤ 1.5	≤ 2.0	≤ 2.0	16948	15104
Sulphur	% of weight, dry	≤ 0.03		≤ 0.04	≤ 0.2	≤ 0.3	≤ 0.03		≤ 0.05				16994	15289
Chlorine	% of weight, dry	≤ 0.02		≤ 0.03	≤ 0.1	≤ 0.3	≤ 0.03	≤ 0.05	≤ 0.1	≤ 0.2	≤ 0.3			
Volatile matter	% of weight, dry						≤ 75							
	Elemental components in mg/kg substance of raw biomass material													
Arsenic	mg/kg dry	≤ 1			≤ 1.0		≤ 2			≤ 1			16968	15297
Cadmium	mg/kg dry	≤ 0.5			≤ 0.5		≤ 1.0							
Chromium	mg/kg dry	≤ 10			≤ 50		≤ 15			≤ 50				
Copper	mg/kg dry	≤ 10			≤ 20		≤ 20							
Lead	mg/kg dry	≤ 10												
Mercury	mg/kg dry	≤ 0.1												
Nickel	mg/kg dry	≤ 10												
Zinc	mg/kg dry	≤ 100								≤ 200				

Appendix J

Areas of the document highlighted in yellow are provided by individual producers. A separate scaled down version of this MSDS is available for pellets traded in small bags.



LOGO
Company name (full legal name)

Issued May 5, 2009

MATERIAL SAFETY DATA SHEET

WOOD PELLETS IN BULK

For Wood Pellets in Bags, see
MATERIAL SAFETY DATA SHEET for Wood Pellets in Bags
issued by the producer

1. Product Identification and Use

Product name/trade name:	Wood Pellets
Producer's Product Code:	xxxxxxxxxxxx
Synonyms:	Wood Pellets, Fuel Pellets, Whitewood Pellets, Softwood Pellets, Hardwood Pellets, Bark Pellets
Product appearance:	Light to dark blond or chocolate brown, glossy to semi-glossy, cylinder with ¼ inch diameter (6.35 mm referred to as 6 mm pellets) and 5 to 25 mm in length.
Product use:	Fuel for conversion to energy, animal bedding, absorbent
HS Product Code:	44013020
United Nations Number:	Not allocated
Hazchem:	Not allocated
IMO Safety Code:	Material Hazardous in Bulk (MHB) Group B (IMO-260E)

Manufacturer:

Name of company (full legal name with no abbreviations)
Visiting address
Place and postal code
Canada

Tel (switchboard):	001-xxx-xxx-xxxx
Fax:	001-xxx-xxx-xxxx
Website:	www.xxxxxxxxxxxxxx
Email:	xxxxxxxxxx@xxxxxxx

Emergency contact:

Tel (direct):	**001-xxx-xxx-xxxx**
Tel (mobile):	**001-xxx-xxx-xxxx**
Fax:	**001-xxx-xxx-xxxx**

II. Composition and Physical Properties

Wood Pellets are manufactured from ligno-cellulosic saw dust, planer shavings or bark by means of one or any combination of the following operations; drying, size reduction, densification, cooling and dust removal. The chemical composition of Wood Pellets varies between species of raw material, components of the wood, soil conditions and age

1

Member of Wood Pellet Association of Canada (WPAC)

www.pellet.org

of the tree. Wood Pellets are typically manufactured from a blend of feedstock with the following composition;

Feedstock	Oxygenated compounds (indicative composition in % of weight)		
		Cellulose	30 - 40
		Hemi-cellulose	25 - 30
		Lignin	30 - 45
		Extractives (terpene, fatty acids, phenols)	3 - 5
Additives	None except as stated in Wood Pellets Product Specification		
Binders	None except as stated in Wood Pellets Product Specification		

Classification as per CEN/TC 14961 Standard; D06/M10/A0.7/S0.05/DU97.5/F1.0/N0.3

Many pellet products consist of a blend of white wood and bark feedstock which may affect the characteristics of the pellets. For more detailed information about the properties, see the latest version of Wood Pellets Product Specification issued by the manufacturer. This MSDS includes the major differences in the characteristics of the Dust from pure whitewood and pure bark pellets.

III. Health Hazard Data

Wood Pellets emit dust and gaseous invisible substances during handling and storage as part of the normal degradation of all biological materials. Ambient oxygen is typically depleted during such degradation. The sizes of the particulate matter range from crumbs to extremely fine airborne dust. The dust normally settles on surfaces over time. Emitted gases are immediately diluted by the air in the containment and escape with ventilation air. If the Wood Pellets are stored in a containment which is not ventilated (naturally or forced) the concentration of emitted gases, or the oxygen depletion, may pose a health threat for humans present in the containment and the containment should be ventilated and precautions should be taken as specified in this MSDS. Section IX includes a method of estimating the concentration of gases. The gases emitted at normal indoor temperature include carbon-monoxide (CO), carbon-dioxide (CO_2), methane (CH_4) and hydrocarbons with Permissible Exposure Levels (PEL) and symptoms as follows;

Entry	**Substance**	**Permissible Exposure Level and symptom**		**Remedial action**
Swallow	Dust	Dry sensation, see Section IX.		Rinse mouth thoroughly with water. Do not induce vomiting.
Inhale	Dust	Coughing, dry throat. For toxicological data, see Section X.		Rinse mouth thoroughly with water. Do not induce vomiting.
	Carbon monoxide (CO)	Toxic invisible and odorless gas. Living space TLV-TWA 9 ppmv (ASHRAE). Work space TLV-TWA 25 ppmv (OSHA).		If hygiene level is exceeded, evacuate and ventilate thoroughly, see Section IX for estimation of ventilation requirement.
		50 ppmv	Max 15 minutes.	
		200	Mild headache.	Evacuate.
		400	Serious headache.	Evacuate and seek medical attention.
		800	Dizziness, convulsion, unconscious in 2 hours, death in 2-3 hours.	Evacuate and seek medical attention.

		1,600	Dizziness, convulsion, unconscious, death in 1 - 2 hours.	Evacuate and seek medical attention.
		3,200	Dizziness, convulsion, unconscious, death in 1 hour..	Evacuate and seek medical attention.
		6,400	Dizziness, convulsion, unconscious, death in 25 minutes.	Evacuate and seek medical attention.
		12,800	Dizziness, convulsion, unconscious, death in 1 – 3 minutes.	Evacuate and seek medical attention.
	Carbon dioxide (CO_2)	Asphyxiating invisible and odorless gas. Occupational TLV-TWA 5,000 ppmv (OSHA)		If hygiene level is exceeded, ventilate thoroughly, see Section IX for estimation of ventilation requirement.
	Methane (CH_4)	Asphyxiating invisible and odorless gas.		Ventilate
	Hydrocarbons	See Section IX. Odor.		Ventilate
	Oxygen depleted air	Oxygen level is normally 20.9 % at sea level in well ventilated space. Minimum hygiene level is 19.5 % in work space (NIOSH)		If oxygen level is less than hygiene level, evacuate and ventilate thoroughly.
Skin contact	Dust	Itching for some people. For toxicological data, see Section X.		Remove contaminated clothing. Rinse skin thoroughly with water.
Eye contact	Dust	Tearing, burning. For toxicological data, see Section X.		Flush with water and sweep out particles inward towards the nose

IV. First Aid Procedures

Wood Pellets are considered a benign product for most people. However, individuals with a propensity for allergic reactions may experience reactions and should contact their physician to establish the best remedial action to take if reaction occurs.

In case Wood Pellets are not handled or stored in accordance with recommendations in Section VII the risk of harmful exposure increases, particularly exposure to concentration of CO higher than stipulated PEL in Section III. In case of exposure it is important to quickly remove the victim from the contaminated area. Unconscious persons should immediately be given oxygen and artificial respiration. The administration of oxygen at an elevated pressure has shown to be beneficial, as has treatment in a hyperbaric chamber. The physician should be informed that the patient has inhaled toxic quantities of carbon monoxide. Rescue personnel should be equipped with self-contained breathing apparatus when entering enclosed spaces with gas.

Carbon monoxide is highly toxic by means of binding with the hemoglobin in the blood to form carboxyhemoglobin which can not take part in normal oxygen transport, greatly reducing the blood's ability to transport oxygen to vital organs such as the brain.

Asphyxiating gases like carbon dioxide and methane (sometimes called simple asphyxiant) are primarily hazardous by means of replacing the air and thereby depriving the space of oxygen. Person exposed to oxygen depleted conditions should be treated the same as a person exposed to carbon monoxide.

V. Fire and Explosion Measures

Wood Pellets is a fuel and by nature is prone to catch fire when exposed to heat or fire. During handling of Wood Pellets there are three phases with various levels of stability, reactivity (see section IX) and decomposition products:

- solid intact Wood Pellets
- crumbs or dust
- non-condensable (primarily CO, CO_2 and CH_4) and condensable gases (primarily aldehydes, acetone, methanol, formic acid)

Extinguishing a fire in Wood Pellets require special methods to be successful as follows;

State of Wood Pellets	**Extinguishing measures**	**Additional information**
General	Restrict oxygen from entering the space where the Wood Pellets are stored.	
	Cover exposed pellets with foam or sand to limit exposure to air.	
	Be prepared for an extended period of extinguishing work. An industrial size silo may take a week to fully bring under control.	
Storage in enclosed space	Seal openings, slots or cracks where Wood Pellets may be exposed to air.	
	Inject nitrogen (N_2) or carbon dioxide (CO_2) in gaseous form at the bottom or in the middle of the pile of Wood Pellets or as close as possible to the fire if exposed. N_2 is preferred. Dosage of gas depends on the severity of the fire (how early detection is made). Recommended injection speed is 5 – 10 $kg/m^2/hour$ (m^2 refers to the cross section of the storage containment such as a silo) with a total injected volume throughout the extinguishing activity of 5 – 15 kg/m^3 for less severe fires and 30 – 40 kg/m^3 for more advanced fires.	Recommended values developed by SP Technical Research Institute of Sweden Specific volume for N_2 is 0.862 m^3/kg and for CO_2 0.547 m^3/kg (at NTP)
Storage in open flat storage	Cover the pile of Wood Pellets with foam or sand if available or spray water. Dig out the pile to reach the heart of the fire and remove effected material.	
During handling	Restrict oxygen from entering the space where the Wood Pellets are present	
	Cover the Wood Pellets with foam or sand if available or spray water. Dig out the material to reach the heart of the fire and remove effected material.	

VI. Accidental Release Measures

If Wood Pellets are released in a populated area, the material should be removed by sweeping or vacuuming as soon as possible. Wood Pellets are a fuel and should preferably be disposed of by means of burning. Deposition of Wood Pellets or related dust should be such that gas from the material does not accumulate. Wear a protective mask to prevent inhaling of dust during cleanup (see Section VIII).

VII. Safe Handling and Storage

Precautionary measures are recommended to avoid hazardous conditions by the reactivity as outlined in Section IX developing when handling Wood Pellets.

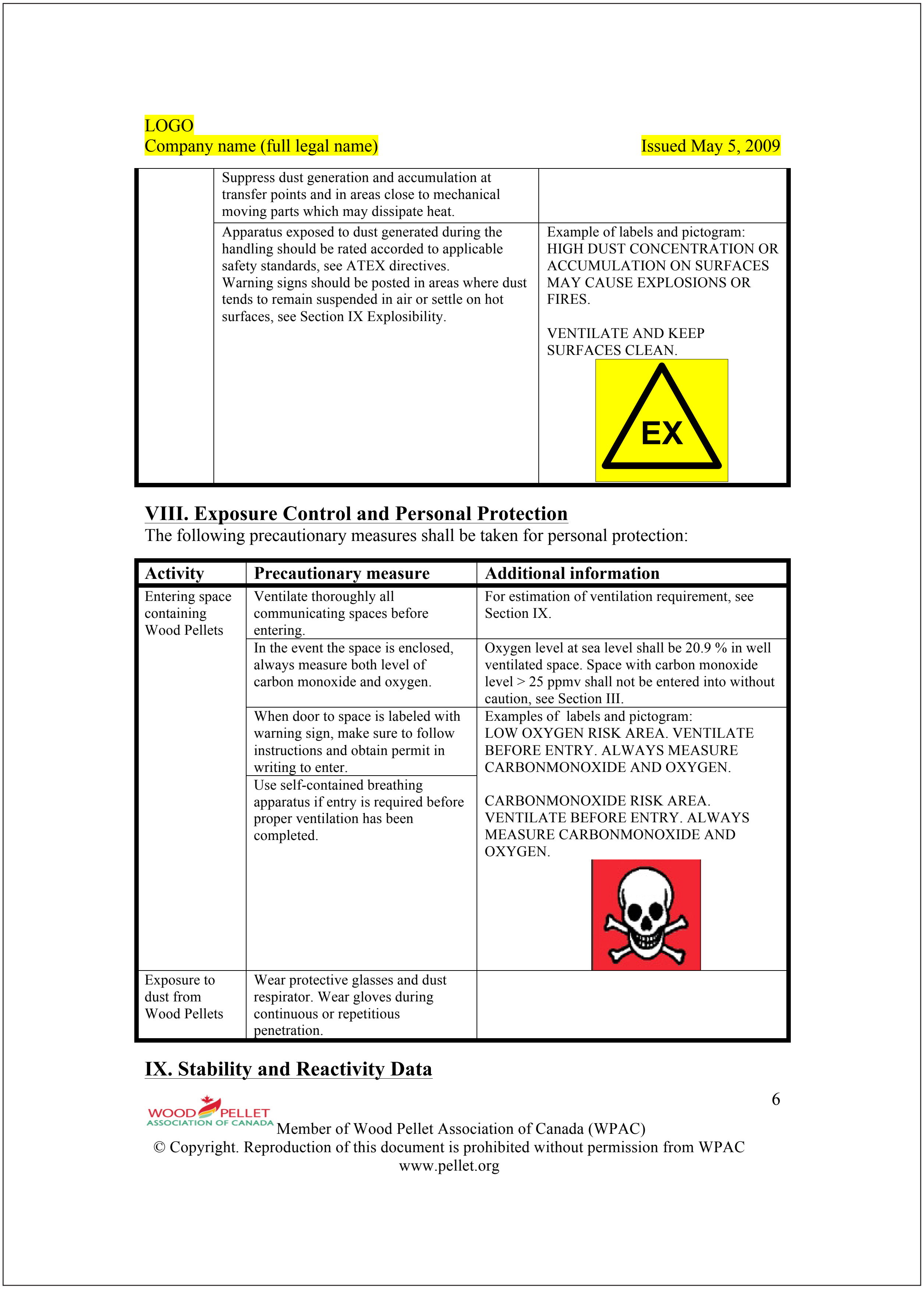
State of Wood	**Precautionary measures**	**Additional information**

LOGO
Company name (full legal name) Issued May 5, 2009

Pellets		
General	Always store Wood Pellets in containment with a minimum of one (1) air exchange per 24 hours at + 20^{o}C and a minimum of two (2) air exchanges per 24 hours at + 30^{o}C and above.	One air exchange corresponds to the volume of the containment.
	For long period storage in large bulk containment shall be as air tight as possible. Fires tend to migrate towards air (oxygen) supply. For shorter period open storage, ventilate to eliminate gas and odor.	Early warning sensors for heat and gas detection enhances the safety of storing Wood Pellets
	Protect the Wood Pellets from contact with water and moisture to avoid swelling, increased off-gassing, increased microbial activity and subsequent self-heating.	For large enclosed storage, label the points of entry to storage containment or communicating spaces containing Wood Pellets with a sign such as “Low Oxygen Risk Area, Ventilate thoroughly before Entry”.
	Always protect Wood Pellets and dust from exposure to heat radiators, halogen lamps and exposed electrical circuitry which may generate ignition energy and set off a fire or explosion.	See Section IX Explosibility and applicable ATEX directives.
	Always segregate the Wood Pellets from oxidizing agents (e.g. poly-oxides capable of transferring oxygen molecules such as permanganate, per-chlorate) or reducing agent (e.g. chemical compounds which includes atoms with low electro-negativity such as ferrous ions (rust), sodium ions (dissolved sea salt)).	Schedule for Wood Pellets, Code of Safe Practice for Solid Bulk Cargoes, 2004, IMO 260E.
	Do not expose Wood Pellets to rain.	
	Do not smoke or extinguish cigarettes in the vicinity of Wood Pellets or wood dust.	Install heat and gas detectors with visible and audible alarm.
Storage in enclosed space	For large enclosed storage entry should be prohibited by means of secured lock and a well established written approval process for entry, only AFTER ventilation has been concluded and measurement with gas meter has confirmed safe atmosphere in the space. Alternatively, use self-contained breathing apparatus when entering space. Always make sure backup personnel are in the immediate vicinity monitoring the entry.	Label points of entry to enclosed storage areas containing Wood Pellets with “Carbon monoxide Risk Area, Ventilate thoroughly before Entry”.
	Install N$_2$ or CO$_2$ sprinklers as per applicable fire regulations.	A Shipper Cargo Information Sheet (SCIS) must be used when shipping Wood Pellets in ocean vessels as per international regulations issued by IMO, see SCIS issued by Producer.
Storage in open space	For large storage spaces install water sprinklers. For smaller storage spaces, contact your local fire department for recommendations.	Sand or foam has proven to be effective to limit access of oxygen in case of fire.
During handling	Avoid breakage caused by dropping the Wood Pellets. Be aware of potential dust generation during high pressure pneumatic handling of pellets.	Monitor temperature at bearings, pulleys, augers or other heat generating machinery.
	Avoid friction generated by rough surfaces such as worn out conveyor belts as much as possible.	

WOOD PELLET ASSOCIATION OF CANADA Member of Wood Pellet Association of Canada (WPAC)

www.pellet.org



	Suppress dust generation and accumulation at transfer points and in areas close to mechanical moving parts which may dissipate heat.	
	Apparatus exposed to dust generated during the handling should be rated accorded to applicable safety standards, see ATEX directives. Warning signs should be posted in areas where dust tends to remain suspended in air or settle on hot surfaces, see Section IX Explosibility.	Example of labels and pictogram: HIGH DUST CONCENTRATION OR ACCUMULATION ON SURFACES MAY CAUSE EXPLOSIONS OR FIRES. VENTILATE AND KEEP SURFACES CLEAN.

VIII. Exposure Control and Personal Protection

The following precautionary measures shall be taken for personal protection:

Activity	Precautionary measure	Additional information
Entering space containing Wood Pellets	Ventilate thoroughly all communicating spaces before entering.	For estimation of ventilation requirement, see Section IX.
	In the event the space is enclosed, always measure both level of carbon monoxide and oxygen.	Oxygen level at sea level shall be 20.9 % in well ventilated space. Space with carbon monoxide level > 25 ppmv shall not be entered into without caution, see Section III.
	When door to space is labeled with warning sign, make sure to follow instructions and obtain permit in writing to enter.	Examples of labels and pictogram: LOW OXYGEN RISK AREA. VENTILATE BEFORE ENTRY. ALWAYS MEASURE CARBONMONOXIDE AND OXYGEN. CARBONMONOXIDE RISK AREA. VENTILATE BEFORE ENTRY. ALWAYS MEASURE CARBONMONOXIDE AND OXYGEN.
	Use self-contained breathing apparatus if entry is required before proper ventilation has been completed.	
Exposure to dust from Wood Pellets	Wear protective glasses and dust respirator. Wear gloves during continuous or repetitious penetration.	

IX. Stability and Reactivity Data

The stability and reactivity properties of Wood Pellets are as follows:

Parameter	Measure	Value
Odor	°C	Above + 5 °C, fresh Wood Pellets in bulk smells like aldehydes in poorly ventilated space and more like fresh softwood in ventilated space.
Off-gassing	Emission Factor (g/tonne)	Emission of CO, CO_2 and CH_4 from Wood Pellets contained in a space is a function of temperature, ambient air pressure, bulk density, void in Wood Pellets, access to oxygen, relative humidity in air (if ventilated) as well as the age and composition of the raw material (unique for the product as specified in the Wood Pellet Product Specification). The emission rate in grams (g) of off-gassing per tonne of stored Wood Pellets given below are from measurements of gas generated within a sealed containment filled with Wood Pellets at approximately constant pressure without ventilation over a period of > 20 days. The emission factors values are only valid for sealed containment without sufficient oxygen available to support oxidation of the Wood Pellets (see Oxidation in this Section). The numbers should not at any time be substituted for actual measurements. The following examples illustrate how the emission factors can be used for estimating a rough order of magnitude of the gas concentration in a non-ventilated as well as a ventilated containment with Wood Pellets, assuming the ambient air pressure is constant.

Non-ventilated (sealed) containment

Gas species	Temperature °C	Emission factor (±10 %) **g/tonne/>20 days**
Carbon-monoxide (CO)	+ 20	12
	+ 30	15
	+ 40	16
	+ 50	17
	+ 55	17
Carbon-dioxide (CO_2)	+ 20	20
	+ 30	54
	+ 40	80
	+ 50	84
	+ 55	106
Methane (CH_4)	+ 20	0.2
	+ 30	1.0
	+ 40	1.3
	+ 50	1.5
	+ 55	1.9

Example A.

- Mass of Wood Pellets = 1000 tonne
- Bulk density of Wood Pellets = 700 kg/m^3 (0.7 $tonne/m^3$)
- Solids in bulk Wood Pellets including 0.5 % fines = 50 %
- Size of containment = 2800 m^3
- Temperature = +20 °C (constant)
- Emission factor for CO (>20 days storage time) = 12 g/tonne (see table above)

Calculation of concentration of CO (g/m^3) in containment;

12 (g/tonne)*1000 (tonne)/[2800 (m^3)-50%*1000 (tonne)/0.7 ($tonne/m^3$)]

= 5.8 g/m^3

Calculation of concentration of CO (ppmv) in containment

- Ambient pressure = 101.325 kPa (1 atm)
- Molecular weight of CO (Mwt) = 28 (g/mol)

(g/m^3)*(20(^{o}C)+273.1(C^o))/Mwt(g/mol)/0.012 = 5.8*293.1/28/0.012 = 5060 ppmv after > 20 days of storage in sealed containment.

PEL (TLV-TWA = 15 minutes, See Section III) = 50 ppmv which means a person shall not be exposed to the atmosphere in the non-ventilated containment.

Ventilated containment

Gas species	Temperature ^{o}C	Emission rate factor (±10 %) **g/tonne/day**
Carbon-monoxide (CO)	+ 20	0.9
	+ 30	2.2
	+ 40	8.0
	+ 50	18.0
	+ 55	25.0
Carbon-dioxide (CO_2)	+ 20	1.3
	+ 30	4.8
	+ 40	17.0
	+ 50	29.0
	+ 55	119.0
Methane (CH_4)	+ 20	0.01
	+ 30	0.04
	+ 40	0.18
	+ 50	0.38
	+ 55	1.10

Example B

- Volume of Wood Pellets = 1000 tonne
- Size of containment = 2800 m^3
- Storage time = 5 days
- Temperature = +20^{o}C (constant)
- Ambient pressure = 101.325 kPa (1 atm)
- Emission of CO = 0.9 g/tonne/day (see Table above)
- Ventilation rate = 1 air exchanges (2800 m^3) /day
- Molecular weight of CO (Mwt) = 28 (g/mol)
- Conversion factor (g/m^3 to ppmv) = 0.012

Calculation of concentration of CO;

0.9 (g/tone/day)*1000 (tonne)/[2800 (m^3/day]*[1-exp(-2800 (m^3/day/2800 (m^3)*5 (days)] = 0.32 g/m^3

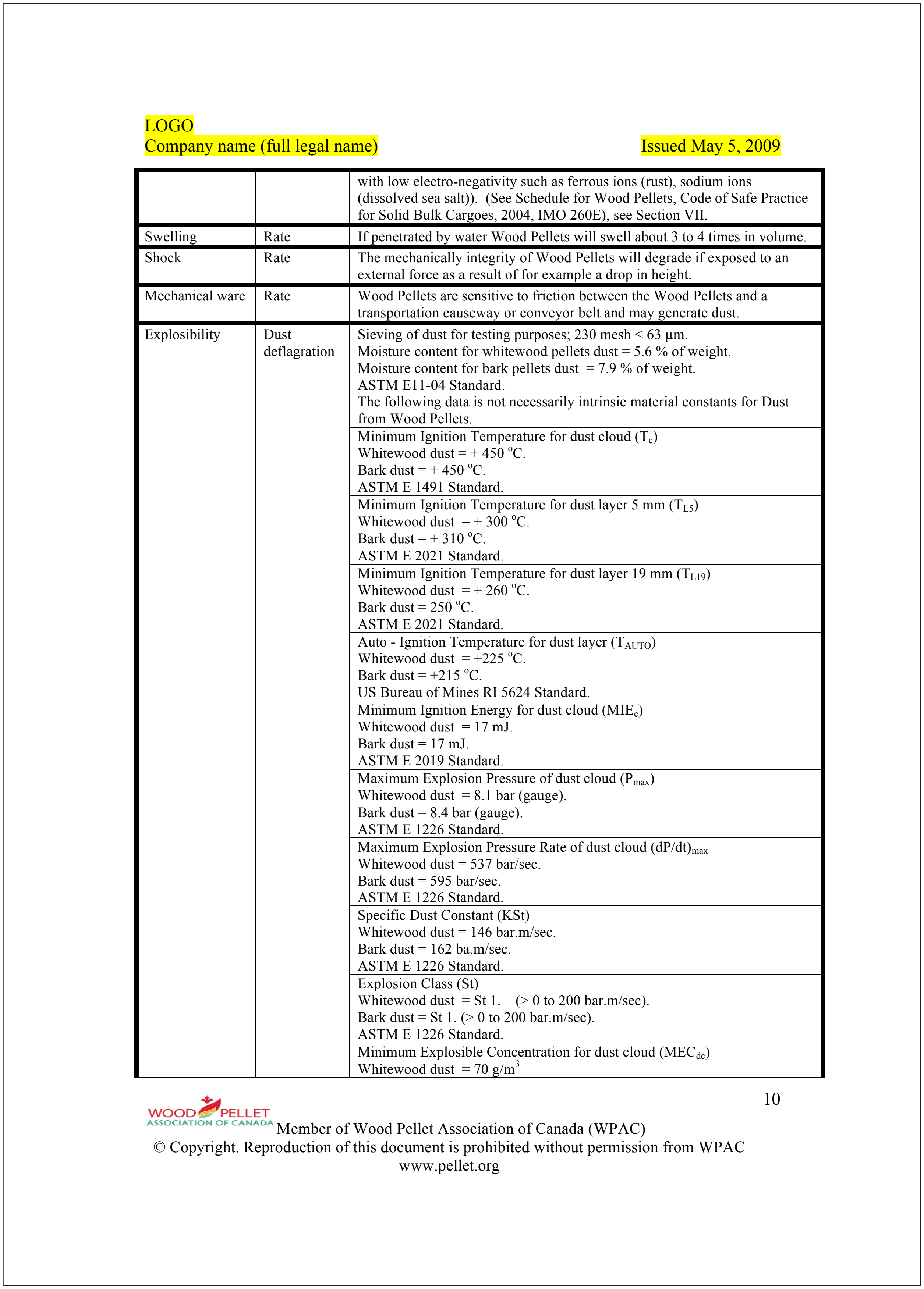
Conversion to ppmv;

(g/tonne)*(T+273.1(C^o))/Mwt(g/mol)/0.012 = 0.32*293.1/28/0.012 = 279 ppmv

To keep the concentration below PEL the containment needs to be ventilated with more than one air exchange per day.

For more accurate estimation of gas concentrations in containment with

<table>
<tr><td></td><td></td><td colspan="2">variations in temperature and pressure, see “Report on Off-gassing from Wood Pellets” to be issued by Wood Pellet Association of Canada (www.pellet.org) when results from on-going research becomes available.</td></tr>
<tr><td rowspan="8">Oxidization</td><td rowspan="8">Rate</td><td colspan="2">It is believed oxidation of fatty acids contained in the woody material is the primary cause for depletion of oxygen and emission of gas species as exemplified above during storage of Wood Pellets or related dust. The depletion ratio is a function of temperature, pressure, bulk density, void in Wood Pellets, relative humidity in air (if ventilated) as well as the age and composition of the raw material (unique for the product as specified in the Wood Pellet Product Specification). The numbers below are from measurements of gas generated within the space of the Wood Pellets at approximately constant pressure. The numbers should not at any time be substituted for actual measurements.</td></tr>
<tr><td>Temperature °C</td><td>(±10 %) Depletion of oxygen in %/24h</td></tr>
<tr><td>+ 20</td><td>0.7 – 1.2</td></tr>
<tr><td>+ 30</td><td></td></tr>
<tr><td>+ 40</td><td>1.5 – 2.5</td></tr>
<tr><td>+ 50</td><td></td></tr>
<tr><td>+ 55</td><td></td></tr>
<tr><td colspan="2">For more accurate estimation of oxygen concentrations in containment with variations in temperature and pressure, see “Report on Off-gassing from Wood Pellets” issued by Wood Pellet Association of Canada (www.pellet.org) when results from on-going research becomes available.</td></tr>
<tr><td>Melting temperature</td><td>-</td><td colspan="2">Not applicable.</td></tr>
<tr><td>Vaporization</td><td>-</td><td colspan="2">Emit hydrocarbons as vapors above + 5 °C.</td></tr>
<tr><td>Boiling temperature</td><td>-</td><td colspan="2">Not applicable.</td></tr>
<tr><td>Flash point temperature</td><td>-</td><td colspan="2">Not applicable.</td></tr>
<tr><td>Auto-ignition temperature</td><td>°C</td><td colspan="2">Auto-ignite of Wood Pellets at temperatures > + 260 °C in the presence of oxygen. For dust, see Section Explosibility Dust deflagration below.</td></tr>
<tr><td>Pyrophorocity</td><td>Rate</td><td colspan="2">Wood Pellets or dust are not classified as pyrophoric solids as defined by UN MTC Rev.3, 2000, Class 4.2 Test N.4.</td></tr>
<tr><td>Flammability</td><td>Rate</td><td colspan="2">Wood Pellets or dust are not classified as flammable solids as defined by UN MTC Rev. 3, 2000, Class 4.1 Test N.1. (Burning rate < 200 mm/2 min.)
Burning rate; Airborne Wood Pellet Dust = 20 mm/2 min.
Airborne Bark Pellet Dust = 22 mm/2 min.</td></tr>
<tr><td>Self-heating</td><td>Rate</td><td colspan="2">Propensity to start self-heating in presence of oxygen.</td></tr>
<tr><td>Bio-degradability</td><td>%</td><td colspan="2">100.</td></tr>
<tr><td>Corrosivity</td><td></td><td colspan="2">Not applicable.</td></tr>
<tr><td>pH</td><td></td><td colspan="2">The potential for Hydrogen ions (pH) varies depending on species of wood.</td></tr>
<tr><td>Solubility</td><td>%</td><td colspan="2">If penetrated by water Wood Pellets will dissolve into its feedstock fractions.</td></tr>
<tr><td>Mechanical stability</td><td>-</td><td colspan="2">If exposed to wear and shock Wood Pellets will disintegrate into smaller fractions and dust.</td></tr>
<tr><td>Incompatibility</td><td>-</td><td colspan="2">Always segregate the Wood Pellets from oxidizing agents (e.g. poly-oxides capable of transferring oxygen molecules such as permanganate, per-chlorate) or reducing agent (e.g. chemical compounds which includes atoms</td></tr>
</table>



LOGO
Company name (full legal name) Issued May 5, 2009

		with low electro-negativity such as ferrous ions (rust), sodium ions (dissolved sea salt)). (See Schedule for Wood Pellets, Code of Safe Practice for Solid Bulk Cargoes, 2004, IMO 260E), see Section VII.
Swelling	Rate	If penetrated by water Wood Pellets will swell about 3 to 4 times in volume.
Shock	Rate	The mechanically integrity of Wood Pellets will degrade if exposed to an external force as a result of for example a drop in height.
Mechanical ware	Rate	Wood Pellets are sensitive to friction between the Wood Pellets and a transportation causeway or conveyor belt and may generate dust.
Explosibility	Dust deflagration	Sieving of dust for testing purposes; 230 mesh < 63 µm. Moisture content for whitewood pellets dust = 5.6 % of weight. Moisture content for bark pellets dust = 7.9 % of weight. ASTM E11-04 Standard. The following data is not necessarily intrinsic material constants for Dust from Wood Pellets.
		Minimum Ignition Temperature for dust cloud (T_c) Whitewood dust = + 450 °C. Bark dust = + 450 °C. ASTM E 1491 Standard.
		Minimum Ignition Temperature for dust layer 5 mm (T_{L5}) Whitewood dust = + 300 °C. Bark dust = + 310 °C. ASTM E 2021 Standard.
		Minimum Ignition Temperature for dust layer 19 mm (T_{L19}) Whitewood dust = + 260 °C. Bark dust = 250 °C. ASTM E 2021 Standard.
		Auto - Ignition Temperature for dust layer (T_{AUTO}) Whitewood dust = +225 °C. Bark dust = +215 °C. US Bureau of Mines RI 5624 Standard.
		Minimum Ignition Energy for dust cloud (MIE_c) Whitewood dust = 17 mJ. Bark dust = 17 mJ. ASTM E 2019 Standard.
		Maximum Explosion Pressure of dust cloud (P_{max}) Whitewood dust = 8.1 bar (gauge). Bark dust = 8.4 bar (gauge). ASTM E 1226 Standard.
		Maximum Explosion Pressure Rate of dust cloud $(dP/dt)_{max}$ Whitewood dust = 537 bar/sec. Bark dust = 595 bar/sec. ASTM E 1226 Standard.
		Specific Dust Constant (KSt) Whitewood dust = 146 bar.m/sec. Bark dust = 162 ba.m/sec. ASTM E 1226 Standard.
		Explosion Class (St) Whitewood dust = St 1. (> 0 to 200 bar.m/sec). Bark dust = St 1. (> 0 to 200 bar.m/sec). ASTM E 1226 Standard.
		Minimum Explosible Concentration for dust cloud (MEC_{dc}) Whitewood dust = 70 g/m^3

Member of Wood Pellet Association of Canada (WPAC)

www.pellet.org

		Bark dust = 70 g/m^3 ASTM E 1515 Standard.
		Limiting Oxygen Concentration for dust cloud (LOC$_c$) Whitewood dust = 10.5 %. Bark dust = 10.5 %. ASTM E 1515 Standard (modified).
	Gas	Carbon monoxide (CO) is potentially explosive in concentration > 12 % by volume (120,000 ppmv) when mixed with air. Wood Pellets are not known to generate this level of concentration.
		Methane (CH$_4$) is flammable in concentration > 20 % (LFL 20) by volume (200,000 ppmv) when mixed with air. Solid Wood Pellets are not known to generate this level of concentration.

X. Exposure and Toxicological Data

The feedstock is the basis of the toxicological characteristics of Wood Pellets. The available data does not make a clear distinction between whitewood and bark material. The toxicological data applies primarily to the material in form of dust.

Feedstock	PEL (OSHA)	REL (NIOSH)	TLV (ACGIH)	Health Effects
Softwood such as fir, pine, spruce and hemlock.	15 mg/m^3 Total Dust 5 mg/m^3 Respirable Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 5 mg/m^3 for 8 hours @ 40 hours week STEL = 10 mg/m^3 for 15 minutes, max 4 times/day, each episode max 60 minutes	Acute or chonic dermatitis, asthma, erythema, blistering, scaling and itching (ACGIH).
Hardwood such as alder, aspen, cottonwood, hickory, maple and poplar.	15 mg/m^3 Total Dust 5 mg/m^3 Respirable Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 5 mg/m^3 for 8 hours @ 40 hours week STEL = 10 mg/m^3 for 15 minutes, max 4 times/day, each episode max 60 minutes	Acute or chronic dermatitis, asthma, erythema, blistering, scaling and itching (ACGIH). Suspected tumorigenic at site of penetration (IARC).
Oak, walnut and beech.	15 mg/m^3 Total Dust 5 mg/m^3 Respirable Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 1 mg/m^3 for 8 hours @ 40 hours week	Suspected tumorigenic at site of penetration (ACGIH).
Western Red Cedar.	15 mg/m^3 Total Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	TWA = 5 mg/m^3 for 8 hours @ 40 hours week	Acute or chronic rhinitis, dermatitis, asthma (ACGHI).
	5 mg/m^3 Respirable Dust	TWA = 1 mg/m^3 for 10 hours @ 40 hours week	STEL = 10 mg/m^3 for 15 minutes, max 4 times/day, each episode max 60 minutes	

Respirable Dust means particles with an AED<10 µm capable of deposition in nasal, thoracic and respiratory regions.

Dust from certain hardwoods has been identified by IARC as a positive human carcinogen. An excess risk of nasal adeno-carcinoma has been reported mainly in those workers in this industry exposed to wood dusts. Some studies suggest workers in the sawmilling, pulp and paper and secondary wood industries may have an increased

incidence of nasal cancers and Hodgkin's disease. However, IARC concludes that the epidemiological data does not permit a definite assessment.
Dust from Western Red Cedar is considered a "Nuisance Dust" (= containing less than 1% silicates (OSHA)) with no documented respiratory cancinogenic health effects (ACGIH). Cedar oil is a skin and respiratory irritant.

XI. Notice to Reader

The information contained in this MSDS is based on consensus by occupational health and safety professionals, manufacturers of Wood Pellets and other sources believed to be accurate or otherwise technically correct. It is the Reader's responsibility to determine if this information is applicable. This MSDS is updated from time to time, and the reader has the responsibility to make sure the latest version is used. We do not have an obligation to immediately update the information in the MSDS.

Product data available from the manufacturer of the Wood Pellets includes;

- MSDS for Wood Pellets Packaged in Bag Smaller than 25 kg
- MSDS for Wood Pellets in Bulk
- Wood Pellet Product Specification
- Shipper Cargo Information Sheet (SCIS)

Contact the manufacturer to order the latest version of these documents.

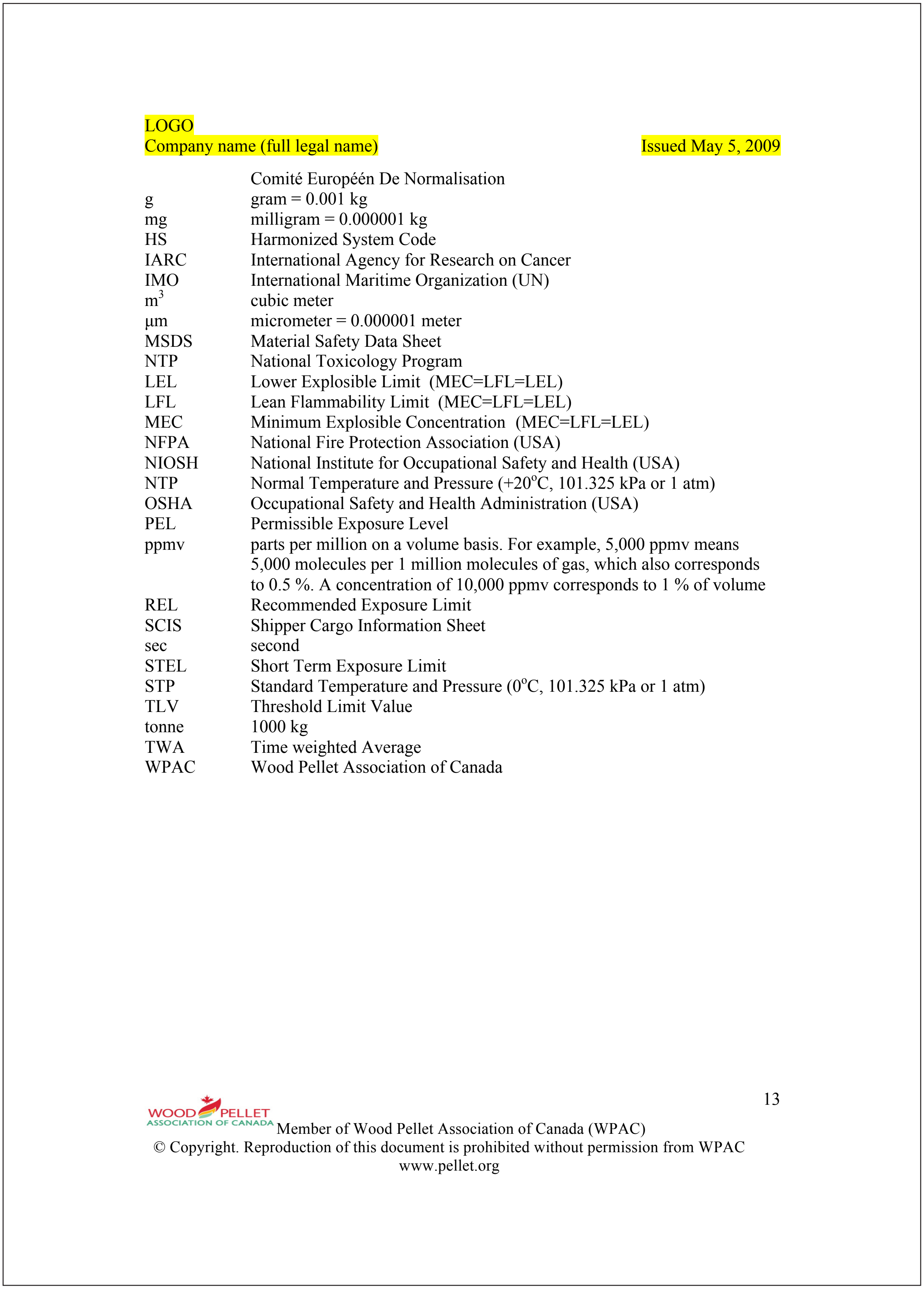
Notice that some of the information in this MSDS applies only to Wood Pellets manufactured by the Manufacturer identified on the first page of this MSDS and may not necessarily be applicable to products manufactured by other producers.

While we have attempted to ensure that the information contained in this MSDS is accurate, we are not responsible for any error or omissions, or for the results obtained from the use of this information.

We are not responsible for any direct, indirect, special, incidental, or consequential damage, or any other damages whatsoever and however caused, arising out of or in connection with the use of the information in this MSDS, or in reliance on that information, whether the action is in contract, tort (including negligence) or other tortious action. We disclaim any liability for unauthorized use or reproduction of any portion of this information in this MSDS.

XII. Abbreviations Used in This Document

ACGIH	American Conference of Governmental Industrial Hygienists
AED	Aerodynamic Equivalent Diameter
ASHRAE	American Society of Heating Refrigerating and Air-conditioning Engineers
ATEX	ATmosphere EXplosible
atm	atmosphere pressure
bar	10^5 Pascal (Pa) or 100 kPa or 0.9869 atm
CCOHS	Canadian Center for Occupational Health and Safety
CEN/TC	European Committee for Standardization/Technical Committee



	Comité Européén De Normalisation
g	gram = 0.001 kg
mg	milligram = 0.000001 kg
HS	Harmonized System Code
IARC	International Agency for Research on Cancer
IMO	International Maritime Organization (UN)
m^3	cubic meter
µm	micrometer = 0.000001 meter
MSDS	Material Safety Data Sheet
NTP	National Toxicology Program
LEL	Lower Explosible Limit (MEC=LFL=LEL)
LFL	Lean Flammability Limit (MEC=LFL=LEL)
MEC	Minimum Explosible Concentration (MEC=LFL=LEL)
NFPA	National Fire Protection Association (USA)
NIOSH	National Institute for Occupational Safety and Health (USA)
NTP	Normal Temperature and Pressure (+20°C, 101.325 kPa or 1 atm)
OSHA	Occupational Safety and Health Administration (USA)
PEL	Permissible Exposure Level
ppmv	parts per million on a volume basis. For example, 5,000 ppmv means 5,000 molecules per 1 million molecules of gas, which also corresponds to 0.5 %. A concentration of 10,000 ppmv corresponds to 1 % of volume
REL	Recommended Exposure Limit
SCIS	Shipper Cargo Information Sheet
sec	second
STEL	Short Term Exposure Limit
STP	Standard Temperature and Pressure (0°C, 101.325 kPa or 1 atm)
TLV	Threshold Limit Value
tonne	1000 kg
TWA	Time weighted Average
WPAC	Wood Pellet Association of Canada

Designed and produced by Grafiks Marketing & Communications, Sarnia, Ontario

www.grafiks.com

Ontario
Federation of
Agriculture

Ontario Federation of Agriculture
Ontario AgriCentre
100 Stone Road West, Suite 206
Guelph, ON N1G 5L3
519-821-8883