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Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction

Deliverable No. D4.1

Report on requirements of end users on densified and torrefied materials

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Summary

This report describes the required product characteristics for torrefied biomass pellets. The product requirements are compared with existing specifications for wood pellets from the Initiative Wood Pellet Buyers (IWPB) and ENplus, based on the specification for wood pellets defined in the European standard EN 14961-1 “Solid biofuels fuel specifications and classes”. This deliverable was prepared by ECN, and reviewed by partners in the associated task (DTI, SLU, CENER, Topell, VTT and OFI). In addition the deliverable has been discussed within the Dutch Torrefaction Association (DTA).

1 Description of Deliverable no. D4.1

Deliverable 4.1 is a report describing the requirements of end users on torrefied and densified materials. These requirements are comparable with the requirements for wood pellets in many aspects. The latter ones have been classified within the European standard EN 14961-1 called “Solid biofuels fuel specifications and classes” and in the Initiative wood pellet buyers (IWPB) and ENplus specifications.

However, the existing wood pellet specifications cannot be applied directly for torrefied wood pellets, since some product specifications have no or reduced relevance for torrefied pellets, whereas other product specifications should be valuated differently in order to take into account the potential benefits of torrefied wood pellets over conventional wood pellets.

The drafting of the specification of torrefied wood pellets has been initiated within the Dutch Torrefaction Association (DTA) in which SECTOR partners ECN and Topell participate. This report on requirements of end users on densified and torrefied materials also takes into account the comments from industrial end users in the SECTOR project that have been reported in Deliverable D6.1 “Description of existing handling and storage facilities and the associated issues,” as well as individual interviews with utilities.

2 Reference standards for conventional wood pellets

Why are standards so important? Trade, requirements by end users

2.1 Sustainable Biomass Partnership/Initiative Wood Pellet Buyers

The IWPB was launched by GDF SUEZ and unites utilities that (co-)fire substantial quantities of white wood pellets. The original objective is to enable the trading of industrial wood pellets among the partnering companies. The IWPB consist of GDF SUEZ, RWE Essent, E.On, Vattenfall, Drax Plc, Dong and Eggborough, as well as certifying companies SGS and Control Union. The IWPB was renamed to the Sustainable Biomass Partnership (SBP) to emphasize that a sustainability standard will be developed, besides being a trading platform. The specifications for industrial wood pellets as drafted by the IWPB/SBP are provided in Table 1.

Table 1 Industrial wood pellet specifications (IWPB, 2013)

WOOD PELLETS SPECIFICATIONS	27/04/2012	EN	Initiative Wood Pellets Buyers: Industrial wood pellets specifications							
PARAMETERS AND REJECTION LIMITS [4]	Units	Standard	I1 industrial		I2 industrial		I3 industrial		Check performed by	Remarks
Origin and source	Only accepted	EN 14961-1	1.1 Forest, plantation and other virgin wood, 1.2.1 chemically untreated wood residues		1.1 Forest, plantation and other virgin wood, 1.2.1 chemically untreated wood residues		1.1 Forest, plantation and other virgin wood, 1.2.1 chemically untreated wood residues		insp & lab	
Sampling		EN 14778							insp	
Quality check									insp	
Sample preparation		EN 14780							insp	
No water damage			None		None		None		insp	
No burned/charred pellets			None		None		None		insp	
Additives (composition, mass)	weight% ar	EN 14961	< 3% additives		< 3% additives		< 3% additives		declared by seller	type and quantity to be stated
		OFGEM	sustainability proven for UK		sustainability proven for UK		sustainability proven for UK		seller	
Physical parameters			Limit	Tolerance	Limit	Tolerance	Limit	Tolerance		
Diameter	mm	EN16127	6 to 8	within range	6 to 10	within range	6 to 12	within range	insp & lab	
Length ≤50 mm	weight %	EN16127	99,9%	within range	99,9%	within range	99,9%	within range	insp & lab	
Length ≤40 mm	weight %	EN16127	99%	within range	99%	within range	99%	within range	insp & lab	
Water content	weight% ar	EN 14774	≤ 10 %	0,5% absolute	≤ 10 %	0,5% absolute	≤ 10 %	0,5% absolute	insp & lab	
Bulk (apparent) density	kg/m3	EN 15103	≥ 600	2% of limit	≥ 600	2% of limit	≥ 600	2% of limit	insp & lab	
Maximum bulk temperature	°C	EN15234-2	≤ 60	1°C	≤ 60	1°C	≤ 60	1°C	insp	Bulk maximal temperature to be checked when the pellets leave the final point of loading for delivery to the end-user. i.e leaving the final storage point or the factory. This is the maximum temperature measured at any spot.
Net calorific value at constant pressure	GJ/ton ar	EN 14918	≥ 16,5	0,3 GJ/ton	≥ 16,5	0,3 GJ/ton	≥ 16,5	0,3 GJ/ton	lab	
Ash content	weight% DM	EN 14775	≤ 1,0%	10% of limit	≤ 1,5%	10% of limit	≤ 3%	10% of limit	lab	
Elementary composition										
Cl	weight% DM	EN 15289	≤ 0,03%	0,01% absolute	≤ 0,05 %	0,01% absolute	≤ 0,1 %	20% of limit	lab	
N	weight% DM	EN 15104	≤ 0,3%	0,05% absolute	≤ 0,3 %	10% of limit	≤ 0,6 %	10% of limit	lab	
S	weight% DM	EN 15289	≤ 0,15 %	0,01% absolute	≤ 0,2 %	20% of limit	≤ 0,4 %	20% of limit	lab	
Trace elements										
As	mg/kg DM	EN 15297	≤ 2	0,064 absolute	≤ 2	0,064 absolute	≤ 2	0,064 absolute	lab	
Cd	mg/kg DM	EN 15297	≤ 1	0,06 absolute	≤ 1	0,06 absolute	≤ 1	0,06 absolute	lab	
Cr	mg/kg DM	EN 15297	≤ 15	0,032 absolute	≤ 15	0,032 absolute	≤ 15	0,032 absolute	lab	
Cu	mg/kg DM	EN 15297	≤ 20	0,043 absolute	≤ 20	0,043 absolute	≤ 20	0,043 absolute	lab	
Pb	mg/kg DM	EN 15297	≤ 20	0,033 absolute	≤ 20	0,033 absolute	≤ 20	0,033 absolute	lab	
Hg	mg/kg DM	EN 15297	≤ 0,1	0,0046 absolute	≤ 0,1	0,0046 absolute	≤ 0,1	0,0046 absolute	lab	
Zn	mg/kg DM	EN 15297	≤ 200	5,43 absolute	≤ 200	5,43 absolute	≤ 200	5,43 absolute	lab	
Fines ≤ 3.15 mm (round hole sieves)	weight% ar	EN15210-1	≤ 4 %	1% absolute	≤ 5 %	1% absolute	≤ 6 %	1% absolute	insp & lab	
Durability	weight% ar	EN 15210	97,5-99%	0,5% absolute	97,0%-99%	0,5% absolute	96,5%-99%	0,5% absolute	lab	
									lab	
Particle size distribution (square hole sieves)		EN15149-2								
% < 3.15 mm	weight %	EN 16126	>99%	1% absolute	>98%	1% absolute	>97%	1% absolute	lab	
% < 2.0 mm	weight %	EN 16126	>95%	2% absolute	>90%	2% absolute	>85%	2% absolute	lab	
% < 1.0 mm	weight %	EN 16126	>60%	5% absolute	>50%	5% absolute	>40%	5% absolute	lab	

Tolerance: instances where ISO doesn't have a tolerance

Notes:
Generic wording to be included to cover water damage and burned pellets

Performed by: -Lab: analyses will be performed by the independent laboratory; - Insp: test will be performed by the inspection company;
-Insp & lab: means a field test will be performed by the inspection company, the final value will be analyzed by the lab

2.2 ENplus

Parallel to the industrial initiative described in the previous Paragraph the ENplus certificating system for wood pellets for heating purposes exists. ENplus pellets have been introduced in Germany in 2010 and the certification has been adopted in various other countries afterwards. Pellet producers from Austria, Belgium, Canada, Croatia, Czech Republic, Denmark, France, Germany, Italy, Lithuania, Portugal, Romania, Spain, Switzerland, United Kingdom and USA are producing ENplus pellets (ENplus, 2013), with a total production of 3.2 Mton in 2012. The requirements for the wood pellets are based on the EN 14961-2 standard for wood pellets for non-industrial use. Specifications within this standard, leading to the A1, A2 or B qualification, are selected from the EN 14961-1 standard on solid biofuels.

Table 4 in the latter standard contains a collection of typical parameters and values for the qualification of pellets from selected biomass origins.

2.3 DTA and other initiatives

All previously described standards and initiatives are based on raw biomass and as such cannot be integrally applied for torrefied materials. Efforts to come to an international standard for thermally treated densified biomass are on-going, although this standard is not expected to come into place in the near future. The Dutch Torrefaction Association (DTA) drafted specifications for torrefied biomass pellets. For this purpose Table 4 from the EN 14961-1 standard on solid biofuels has been adapted for torrefied materials, i.e. parameter values adapted and parameters added. The resulting classes are drafted for each individual material characteristic, while the previously mentioned standards classify wood pellets in a certain class based on a range of specifications. The most important DTA specifications are displayed below; these were obtained from Chapter 4 of the DTA specifications for industrial biocoal (DTA, 2013).

2.3.1 Origin

The origin of the feedstock for torrefaction can be specified using the EN 14961-1 standard. The DTA specification is using the classification 1.1 Forest, plantation and other virgin wood.

2.3.2 Additives and binders

This parameter is given as a w-% of pressing mass. Type and content of pressing aids, slagging inhibitors or any other additives have to be stated. The maximum allowed amount of additive is 20 w-%. If the amount is greater, then the raw material for the pellet is a blend.

2.3.3 Dimensions

The dimensions Diameter (D) and Length (L) are determined according to EN 16127 and the following classes are given:

D 06: D = 6 mm. ± 1.0 mm.; 3.15 mm. ≤ L ≤ 40 mm.
D 08: D = 8 mm. ± 1.0 mm.; 3.15 mm. ≤ L ≤ 40 mm.
D 10: D = 10 mm. ± 1.0 mm.; 3.15 mm. ≤ L ≤ 40 mm.
D 12: D = 12 mm. ± 1.0 mm.; 3.15 mm. ≤ L ≤ 50 mm.

The amount of pellets longer than 40 mm (or 50 mm) can be 5 w-%. The maximum length for classes D 06, D 08 and D 10 shall be < 45 mm. The D 25 class from the wood pellets specifications has been omitted.

2.3.4 Moisture content

The moisture content M is given in w-% as received and determined according to EN 14774-1; EN 14774-2. The classes are:

M 05: M ≤ 5 %
M 10: M ≤ 10 %
M 15: M ≤ 15 %

M 15+: M > 15 % (max. value to be stated).

The M 05 and M 15+ classes have been added compared to wood pellets.

2.3.5 Ash content

The ash content A is given in w-% of dry basis and determined according to EN 14775. The available classes are:

A 1.0: A ≤ 1.0 %
A 2.0: A ≤ 2.0 %
A 3.0: A ≤ 3.0 %
A 4.0: A ≤ 4.0 %
A 5.0: A ≤ 5.0 %
A 7.0: A ≤ 7.0 %
A 10.0: A ≤ 10.0 %
A 10.0+: A > 10.0 % (max. value to be stated).

The smallest amount of ash, compared to wood, has been increased from 0.5 to 1 %.

2.3.6 Mechanical Durability

The mechanical durability DU is given in w-% of the pellets after testing according to EN 15210-1. The available classes are:

DU 98.5: DU ≥ 98.5 %
DU 97.5: DU ≥ 97.5 %
DU 96.5: DU ≥ 96.5 %
DU 95.0: DU ≥ 95.0 %
DU 95.0-: DU < 95.0 % (min. value to be stated).

The DU 98.5 has been added to express excellent quality pellets.

2.3.7 Amount of Fines

The amount of fines F is given in w-% < 3.15 mm after loading or packing and is determined according to EN 15149-1. The available classes are:

F 1.0: F ≤ 1.0 %
F 2.0: F ≤ 2.0 %
F 3.0: F ≤ 3.0 %
F 5.0: F ≤ 5.0 %
F 5.0+: F > 5.0 % (max. value to be stated).

2.3.8 Bulk density

The bulk density BD is given in kg/m³ as received and determined according to EN 15103. The available classes are:

BD 550: BD ≤ 550 kg/m³
BD 600: BD ≤ 600 kg/m³

BD 650: BD ≤ 650 kg/m³
BD 700: BD ≤ 700 kg/m³
BD 750: BD ≤ 750 kg/m³
BD 750+: BD > 750 kg/m³ (min. value to be stated).

The BD 750+ has been added because of the higher bulk density for pellets from torrefied biomass.

2.3.9 Net Calorific Value

The net caloric value LHV is given in MJ/kg on dry and ash free basis and is determined according to EN 14918. The available classes are:

LHV 20: LHV ≤ 20 MJ/kg (pending)
LHV 22: LHV ≤ 22 MJ/kg
LHV 24: LHV ≤ 24 MJ/kg
LHV 26: LHV ≤ 26 MJ/kg
LHV 28: LHV ≤ 28 MJ/kg
LHV 28+: LHV > 28 MJ/kg (max. value to be stated).

These classes are specified because these are important values for torrefied materials, compared to the specifications for wood pellets where this parameter is not classified. Within the DTA a discussion is on-going about the classes to be used. It is suggested by member parties to include the LHV 20 class (LHV ≤ 20 MJ/kg) and to reduce the maximum class to LHV 26+ (> 26 MJ/kg). These values should be more in line with the requirements of e-producers and be more realistic for torrefied wood, i.e. still higher than raw wood and lower than charcoal.

2.3.10 Fixed Carbon

The amount of fixed carbon FC is given in w-% on dry and ash free basis and is determined according to EN 15148. The available classes are:

FC 30: FC ≤ 30 %
FC 40: FC ≤ 40 %
FC 55: FC ≤ 55 %
FC 70: FC ≤ 70 %
FC 70+: FC > 70 % (max. value to be stated).

This parameter has been added as being important in the qualification of torrefied materials.

2.3.11 Hardgrove Grindability Index

The Hardgrove grindability index (HGI) value is determined according to ISO 5074. The available classes are:

HGI 30: HGI ≤ 30
HGI 40: HGI ≤ 40
HGI 50: HGI ≤ 50
HGI 60: HGI ≤ 60

HGI 70: HGI ≤ 70
HGI 70+: HGI > 70 (max. value to be stated).

This parameter is to determine the grindability of coal, and the resulting mill capacity. It was added because a reliable method for the determination of the grindability of torrefied biomass is currently lacking.

2.3.12 Sulphur content

The sulphur content S is given in w-% of dry basis and determined according to EN 15289. The available classes are:

S 0.02: S ≤ 0.02 %
S 0.05: S ≤ 0.05 %
S 0.08: S ≤ 0.08 %
S 0.10: S ≤ 0.10 %
S 0.20: S ≤ 0.20 %
S 0.20+: S > 0.20 % (max. value to be stated).

2.3.13 Nitrogen content

The nitrogen content N is given in w-% of dry basis and determined according to EN 15104. The available classes are:

N 0.3: N ≤ 0.3 %
N 0.5: N ≤ 0.5 %
N 1.0: N ≤ 1.0 %
N 2.0: N ≤ 2.0 %
N 3.0: N ≤ 3.0 %
N 3.0+: N > 3.0 % (max. value to be stated).

2.3.14 Chlorine content

The chlorine content Cl is given in w-% of dry basis and determined according to EN 15289. The available classes are:

Cl 0.02: Cl ≤ 0.02 %
Cl 0.03: Cl ≤ 0.03 %
Cl 0.07: Cl ≤ 0.07 %
Cl 0.10: Cl ≤ 0.10 %
Cl 0.10+: Cl > 0.10 % (max. value to be stated).

2.3.15 Ash Melting behaviour

From the ash melting behaviour the fluid temperature FT (Fluid Temperature in an oxidizing atmosphere) is chosen and given in °C. The value is determined according to EN 15370-1. The available classes are:

FT 1200: FT ≤ 1200°C
FT 1300: FT ≤ 1300°C

FT 1400: FT ≤ 1400°C
FT 1400+: FT > 1400°C (max. value to be stated).

The fluid temperature is chosen instead of the deformation temperature in the wood pellet specification because the deformation temperature can lead to misinterpretations too easily, whereas the fluid temperature gives the real value of interest.

3 End use requirements

The compilation of end use requirements is based on the information provided by the work package leaders of WP6 (transportation and storage properties) and WP7 (milling, co-firing and co-gasification, utilization as resource, small-scale combustion), as well as individual interviews with end users. Requirements from large-scale users on logistics and storage properties were to a large extend available from Deliverable 6.1 “Description of existing handling and storage facilities and the associated issues“ that has already been published. Requirements for handling and storage on small-scale were derived from the DBFZ experience with alternative and mixed biomass pellets. Information on the requirements of large-scale users on milling properties as well as on co-firing and co-gasification behaviour of torrefied pellets were acquired by direct contact with industry partners involved in the SECTOR project. For small-scale combustion, requirements of end users were derived from the experiences of BE2020, TFZ and DBFZ on biomass combustion both for woody pellets and for alternative and mixed biomass pellets.

3.1 Experience and requirements of large-scale end users

3.1.1 Logistics and storage properties

In total, five existing plants, i.e. the Reuter West plant in Germany and the Willem Alexander Centrale (WAC) in the Netherlands (both operated by Vattenfall, the latter plant was closed mid-2013), the Ibbenbüren and Niederaußem plants in Germany (both operated by RWE) and the Ironbridge B power plant in England (operated by E.On) provided information on their plant specifications and requirements for transportation and storage properties of torrefied pellets. All plants either plan to use torrefied pellets or have conducted trials with batches of torrefied material. The plants are operated on different fuels (both lignite and hard coal) and have different thermal conversion technologies (combustion and entrained-flow gasification).

Table 2 Specifications for transportation and storage provided by power plant operators

	Reuter West plant	Willem Alexander Centrale (WAC)	Ibbenbüren plant	Niederaußem plant	Ironbridge B power plant
Owner / Operator	Vattenfall Europe AG	NUON Vattenfall	RWE power AG	RWE power AG	E.ON
Fuel	Hard coal	Hard coal	Hard coal, some lignite dust, animal bone meal and sewage sludge	Lignite	Hard coal
Fuel demand	3300 t/d	2000 t/d	1.5 Mio. t/a	26 Mio t/a	3000 – 6000 t/d
Boiler / burner type	Pulverized coal combustion	Pulverized coal gasification	Pulverized coal combustion	Pulverized coal combustion	Pulverized coal combustion
Experiences with biomass	Yes, large-scale tests with thermally treated biomass and biomass co-firing	Yes, large-scale tests with thermally treated biomass	No experience with torrefied biomass	No experience with torrefied biomass, some experience with biomass co-firing at small on-site test plant	Yes, biomass co-firing
Current fuel storage	Outdoor coal storage yard for 200.000 t	Outdoor coal storage yard	Outdoor bunker	Ditch outside bunker	Outdoor coal storage
Availability of indoor fuel storage	Not yet, but attempted for biomass utilization	Not yet, but attempted for biomass utilization	Small silos for lignite dust, animal bone meal and sewage sludge	Not yet, attempted to use ditch bunker or underground slot bunkers	Yes, large silo and large shed
Transportation on-site	Ship grab un-loader and conveyor belts	Grab crane and conveyor belts	Conveyor belts	Bucket excavator and conveyor belts	Conveyor belts

Table 3 Potential issues for handling and storage of torrefied pellets identified by power plant operators

Process step	**Reuter West plant**	**Willem Alexander Centrale (WAC)**	**Ibbenbüren plant**	**Niederaußem plant**	**Ironbridge B power plant**
Delivery	Risk of dust explosion. In case of relatively low pellet durability: adapt unloading equipment based for high amount of fines (water dispersion system, dust evacuation system, reduced height from which the crane drops the fuel. Durability of torrefied pellets if water dispersion is used for dust reduction.		Risk of fires and explosion. Dust emission during unloading.	Dust emission during unloading.	High levels of dust in the conveyor system particularly around chutes and transfer towers.
On-site storage and transportation	Outdoor storage: Potential odour problems at plant sites with nearby residential areas. Weather resistance properties. Limited height of piles to ensure front loader safety. Biological activity. Monitor temperature during storage to minimize self-heating and self-ignition risks. Indoor storage: Install de-dusting system. Reduce angle of inclination of conveyor belts based on flowability of pellets. Insulated / tight transition stations.		Stability of torrefied material in outside storage bunkers. Dust emission during transportation and at transition sites. Risk of fires and explosion. Suitability of scrap to move biomass.	Stability of torrefied material in outside storage ditch bunkers. Dust emission during transportation and at transition sites. Risk of fires and explosion. Suitability of excavators to move biomass.	No issues specifically mentioned for storage and transportation.

3.1.2 Milling, co-firing and co-gasification

Torrefied and densified biomass is expected to exhibit a similar behaviour during milling, combustion and gasification like coal. Aspects such as the required energy for milling, particle size distribution, mill capacity and pneumatic feeding are expected to have crucial influence on the feasibility of operating coal fired power plants on torrefied and densified biomass. Operators of power plants were interviewed with respect to their requirements for biomass processing, drying, milling, fuel mixing and feeding, which are displayed in Table 4 and summarized earlier in Deliverable 6.1. Similarly, a summary of potential issues was identified by the plant operators based on experience and foreseen behaviour, which is displayed in Table 5.

Several utilities proposed to aim for torrefied pellets with a relatively high net calorific value of 21-22 MJ/kg for use in existing power plants, while new-built facilities could be adapted to co-fire torrefied wood pellets with a net calorific value of 19-20 MJ/kg. This approach would allow increased co-firing shares in existing facilities with minimum modifications and reduced impact on the net output.

Co-milling coal and torrefied wood pellets at high biomass co-firing shares is expected to reduce the mill throughput, and additional or spare capacity would be required. Higher throughputs can be obtained by pulverizing torrefied pellets in a dedicated mill with tailored settings.

The torrefaction process is expected to slightly increase the ash content, as a result of the slight mass loss. However, this slight increase is expected to have no significant effects on slagging and fouling behavior compared to co-firing the same biomass without torrefaction. The particle size distribution of pulverised torrefied wood pellets could be slightly larger than that of pulverised coal, since the increased reactivity of biomass is expected to lead to similar burnout behavior.

The bulk density of the pulverised torrefied pellets is particularly important for co-gasification, since fuel pressurization is a batch process. The volumetric energy content of the pulverised torrefied biomass should be in proximity of that of pulverised coal to be able to maintain the rated output of the power plant.

Table 4 Specifications on milling and feeding of power plants provided by power plant operators

	Reuter West plant	Willem Alexander Centrale (WAC)	Ibbenbüren plant	Niederaußem plant	Ironbridge B power plant
Mixing with torrefied biomass before grinding	Possible, tested during extensive test campaign. Pulverised biomass powder added through dedicated biomass storage downstream of coal milling and drying.		Possible (similar to the mixing with animal bone meal and sludge via direct addition to the coal conveyor belt)	No information provided	No information provided
Feeding of the mill	Covered conveyors	Unknown	From boiler bunkers	Unknown	Drag link type feeders (ribbon conveyor)
Milling technology	Roller mill	Loesche roller mill	Heated bowl mill Babcock MPS 255	Combined drying and milling in fan beater mills with hot flue gases (1050-1200 °C)	Foster Wheeler D9 tube/ball mill with aerodynamic classifier
Number of mills	4/unit	3	8	Unknown	6/unit
Milling capacity	Unknown	Unknown	37 t/h	Unknown	Unknown
Feeding of the burners	Unknown	Lock hopper, pressurization and pneumatic conveying	Unknown	Unknown	Unknown
Particle size (input/output)	Unknown	/ <100 µm	0,5-6,6 mm /	<80 mm / 1 mm <6%	Unknown

Table 5 Potential issues for milling and feeding of torrefied pellets identified by power plants operators

Reuter West plant	Willem Alexander Centrale (WAC)	Ibbenbüren plant	Niederaußem plant	Ironbridge B power plant
• homogeneous blends need to be ensured • best mixing point not defined yet • dust explosion risk • co-milling decreases the capacity of the mills; dedicated milling preferred		• suitability of the mills for torrefied pellets • safety issues	• suitability of the mills for torrefied pellets • premature ignition due to drying with hot flue gas	• fibrous biomass types can interfere with the mill level control system due to high rates of internal recirculation • ball mill might be replaced by hammer mill

3.2 Requirements of small- and medium-scale end users

On small- and medium-scale, there are commercially available boilers both for wood pellets and for coal. Certain boiler manufacturers developed boilers that are able to handle alternative fuels such as straw pellets, miscanthus pellets or cereals. At the moment there are no boilers available that are specifically designed or adapted for torrefied biomass. Therefore torrefied biomass should be used in commercially available wood pellet boilers, boilers designed for alternative fuels or industrial boilers. As such, potential issues could surface that have to be considered and addressed by adapted boiler control.

Table 6 provides an overview of the main fuel characteristics of torrefied wood pellets that are compared with wood pellets, straw pellets and lignite.

The physical and chemical properties of torrefied wood indicate that higher co-firing percentages could be possible than with non-torrefied biomass. The increased heating value is the result of the reduced moisture content and the modification of the organic content of the feedstock. In general the heating value, the content of volatiles and the bulk density of torrefied wood pellets are between the values of non-torrefied wood/straw pellets and lignite briquettes. The ash content of torrefied and non-torrefied clean wood pellets is typically very low, in the range of 0.3 to 0.5 %wt (Bourgois and Guyonnet, 1988). This is an important advantage for co-firing since there is no need for any additional downstream de-dusting equipment. The high ash content of straw pellets (approx. 6 to 7 %wt) typically stems from the high concentrations of alkali, chlorine and sulphur; lignite also exhibits a high ash content of approximately 5 wt%.

Table 6 Characteristics of straw pellets (analysis of DBFZ), wood pellets, torrefied wood pellets and lignite (Kiel, 2013)

		Straw pellets	Wood pellets	Torrefied wood pellets	Lignite briquettes
Heating value	MJ/kg	17.0	15 – 17	18 – 24	23 – 28
Volatile matter	% db	75.1	75 – 84	55 – 80	15 – 30
Moisture content	% wt	6.36	7 – 10	1 – 5	10 – 15
Bulk density	kg/m³	592	550 – 650	650 – 800	800 - 850
Dimension	mm	D = 6 - 25 3,15≤L≤50[1]	D = 6 or 8 3,15≤L≤40[2]	No standard	different L>50

The altered fuel properties of torrefied wood pellets could lead to differences during handling, storage, feeding and combustion. An inventory of potential issues was prepared, these are summarized for the application of torrefied wood pellets in a dedicated boiler for wood pellets, alternative fuels and a coal boiler in Table 7.

[1] DIN EN 14961-2
[2] DIN EN 14961-6

Table 7 Potential issues for torrefied wood pellet/briquette[3] usage in different small- and medium-scale boilers

	Wood pellet boiler	Boiler for alternative fuels	Industrial boiler
Handling properties	Torrefied pellets should have comparable handling properties (durability, content of fines, bulk density) and thus, could be handled like untreated biomass pellets. If the durability is lower, dust formation could form an issue. Hydrophobicity is increased for torrefied pellets, although outdoor storage is not recommended for small and medium-scale.		If used as briquettes, handling should be comparable to coal briquettes. If the durability is lower, dust formation could be problematic.
Heating value	Higher heating value compared to untreated biomass pellets could cause higher temperatures in the heating chamber if feeding and air supply is not adapted. This may cause slagging problems, higher flue gas temperatures and lower boiler efficiency.		Lower heating value compared to coal could lead to reduced boiler efficiency and reduced nominal load.
Ash content	Increased ash content compared to untreated biomass pellets could require adapted ash removal systems.		No problems expected.
Content of volatiles	No problems expected.		Higher content of volatiles could lead to incomplete burnout in the gas phase caused by the inappropriate dimensioning of the combustion chamber. Consequently, incomplete combustion has a negative impact on the boiler performance.
Burnout of solids	Low volatile content and associated higher content of fixed carbon could increase the burnout time of solid residues. Thus, grate dimensioning might be inadequate and could lead to deposition of unburned material in the ash hopper.		The burnout of the solid should be quicker than for coal and thus, no problems are expected.

[3] Torrefied wood briquettes could be more suitable for industrial boilers currently firing lignite briquettes or coal

4 Conclusion

The absence of standards for torrefied pellets is particularly problematic for small- and medium-scale use. The characteristics of torrefied pellets are expected to vary depending on the input material, the torrefaction conditions and the kind of production chain (integration of the densification step). Therefore the implementation of standards is of great relevance. In some countries (e.g. Germany), regulations exist for fuels with respect to domestic usage. To enable the utilization of torrefied pellets under such regulatory frameworks, adaption of the regulations would be required. The adaption of the boiler control to the characteristics of torrefied pellets requires a joint effort of on-going research on combustion behaviour of torrefied pellets, standardization bodies and boiler manufacturers.

For large-scale use, the formation of dust upon handling and the associated dust explosion risks surface as potential issues, particularly in case the pellet durability is relatively low. Additional safety issues like self-heating and self-ignition also require further investigation to exclude any risks. Based on limited experience with moisture resistance of torrefied pellets, outdoor storage appears to be less relevant for most of the potential large-scale users. However the effect on milling and feeding, overall plant efficiency and optimal blending to ensure a homogeneous mixture with coal, are highly relevant as well as the associated requirements.

5 References

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