



GA no 282826

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

Deliverable No. D2.1

Profiles of the selected raw materials part 1

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Nature		
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1 Summary

A collection of 21 raw materials profiles is presented in this Del. 2.1, which include information on biomass properties and suitability for torrefaction tests. Within task 2.1 (Market assessment of biomass feedstock available for torrefaction and demands of end users) this work is complemented by the potential, price and application related information which will be discussed in Deliverable 2.2 (Market assessment of biomass feedstock available for torrefaction), due in month 12. The selected materials involve different biomass types, such as stem wood, agricultural biomass, industrial residues, logging residues and energy crops. Imported biomass has been taken into account due to an increasing sustainable import of biomass from outside Europe (including non-EU countries and East-European countries).

2 Description of Deliverable 2.1

In this work, a set of raw materials for the experimental work in the project has been selected. This preliminary selection is made at an early stage enabling experimental activities to start without delays. Final selection or modifications of this one, for pilot and demo activities will be detailed in Deliverable 2.3 "Profiles of the selected raw materials part 2". As a result, 21 materials were selected. All materials are intended to be used for laboratory tests in task 3.1 and task 4.1 while a smaller number will initially be used for pilot testing. The profiles have been filled with information available in the partners facilities, also with data available in literature, databases (Phyllis, BIODAT, IEA, NREL, EERE etc.) and public documents from biomass research projects which have been completed (IEA Bioenergy, PHYDADES, BioNorm II, PANITAO etc.). It is important to note that some of the profiles presented in this work are not completely filled since there was no information available in literature. All profiles will be revised and completed during the project after the respective laboratory analyses in different Work Packages have been completed. Filled profiles are available in the Annex of this document.

3 Description and criteria of selected raw materials - part 1

Raw materials have been selected in agreement with the partners involved in Work Package 2 (VTT, DBFZ, CENER, EON, RWE, ECN, UmU, Topell, DTI, and Vattenfall), based on the available information of partners, giving higher priority to most potential solutions on short term.

Selected raw materials cover the whole range available based on classification of origin and sources of solid biofuels according to EN 14961-1 standard. It has been a very open choice to try to include forestry biomass, agricultural biomass, industrial woody residues etc. Wood chips from coniferous stem wood without bark have been taken as a reference material for all experimental activities (Spruce as one possible example). Wood chips from broadleaf small sized stem wood with bark (Beech as one possible example) has been taken as second reference material. While laboratory testing is expected to include all materials, pilot testing is expected to be initiated concentrated mainly on these two reference materials.

4 Preliminary selection of feedstocks

Table 1 shows the selected feedstock at this stage of project and partners involved in the preparation of the profiles.

Table 1: Preliminary selection of feedstock and involved partners to fill in the Biomass Profile sheets

No.	Partner	Preselected feedstock
1	VTT	Delimbed coniferous stem wood (without bark), as one possible example spruce (Reference raw material 1)
2	VTT	Logging residue, coniferous
3	VTT	Straw, wheat (Nordic conditions)
4	VTT	Used wood – post consumer wood, recycled wood, chemically untreated
5	VTT	Bark
6	CENER	Delimbed broadleaves stem wood (with bark), as one possible example beech (Reference raw material 2)
7	CENER	Poplar
8	CENER	Straw (Oat and wheat, Southern conditions)
90	CENER	Prunings from olive trees –woody biomass
10	CENER	Eucalyptus
11	CENER	Paulownia
12	ECN	Bamboo
13	ECN	Palm oil residues (e.g. Oil palm fruit bunch, palm kernel or shell)
14	ECN	Bagasse
15	ECN	Corn cobs
16	ECN	Miscanthus
17	ECN	Sun flower residues
18	UmU	Willow (Salix)
19	UmU	Reed canary grass
20	UmU	Straw, barley (Nordic conditions)
21	UmU	Rape straw

This selection aims to cover the entire classification of origin and sources of solid biofuels according EN 14961-1:2010, as Table 2 summarizes.

Table 2: SECTOR's preselected feedstock according to EN 14961-1 raw material classification

Raw material classification according to EN 14961-1				Selected feedstock in SECTOR	No.	Partner
1. Woody biomass	1.1 Forest, plantation and other virgin wood	1.1.3 Stem wood	1.1.3.2 Coniferous	Delimbed coniferous stem wood (without bark), as one possible example spruce (Reference raw material 1)	1	VTT
			1.1.3.1 Broad - leaf	Delimbed broadleaves stem wood (with bark), as one possible example beech (Reference raw material 2)	6	CENER
				Willow (Salix)	18	UmU
				Eucalyptus (fast growing plantation)	10	CENER
				Poplar (fast growing plantation)	7	CENER
				Paulownia (fast growing plantation)	11	CENER
			1.1.4 Logging residues	1.1.4.3 Stored, Broad-leaf	Prunings from olive trees – woody biomass	9
	1.1.4.4 Stored, Coniferous	Logging residue, coniferous		2	VTT	
	1.2 By-products and residues from wood processing industry	1.2.1 Chemically untreated wood residues	1.2.1.5 Bark (from industry operations)	Bark	5	VTT
	1.3 Used wood	1.3.1 Chemically untreated wood	1.3.1.1 Without bark	Used wood – post consumer wood, recycled wood, chemically untreated	4	VTT
2. Herbaceous biomass	2.1 Herbaceous biomass from agriculture and horticulture	2.1.1 Cereal crops	2.1.1.2 Straw parts	Straw, wheat (Nordic conditions)	3	VTT
				Straw, barley (Nordic conditions)	20	UmU
				Straw (Oat and wheat, Southern conditions)	8	CENER
				Rape straw	21	UmU
				Corn cobs	15	ECN
		2.1.2 Grasses	2.1.2.1 Whole plant	Miscanthus	16	ECN
				Reed canary grass	19	UmU
			2.1.2.2 Straw parts	Bamboo	12	ECN

Raw material classification according to EN 14961-1				Selected feedstock in SECTOR	No.	Partner
		2.1.6 Flowers	2.1.6.2 Stalks and leaves	Sun flower residues	17	ECN
	2.2 By-products and residues from herbaceous processing industry	2.2.1 Chemically untreated herbaceous residues	2.2.1.1 Cereal crops and grasses	Bagasse	14	ECN
3. Fruit biomass	3.2 By-products and residues from fruit processing industry	3.2.1 Chemically untreated fruit residues	3.2.1.2 Stone/kernel fruits	Empty palm fruit bunches	13	ECN

5 Feedstock profile data sheet description

Feedstock profile is a data sheet to be filled by partners with respective biomass information and consists of different parts as described below.

5.1 Identification and general information

Biomass name: It is the name which describes the feedstock e.g. Stem wood, coniferous. It is important to note that reference fuels shall be marked separately.

Description of feedstock: Describe shortly biomass e.g. text of production method or other information.

Raw material: According EN 14961-1. Examples: Wine prunings, 1.1.7, Stem wood, spruce 1.1.3.2

Traded form: Form of material for torrefaction or other end-use according EN 14961-1, e.g. wood chips, hog fuel, chopped straw.

Selection criteria for feedstock profile: Inform why this biomass is selected for data collection, e.g. high potential (rough estimation), availability, low price, unused potential.

Selected for laboratory and/or pilot tests: Make a proposal should this raw material be selected for laboratory test and/or pilot test. It is important to note that both reference fuels and agrobiomass raw material are needed.

5.2 Quality information for raw material and torrefaction



This part is covered with multiple tables to be filled with EN standards for analysis. If EN standards are not used, analysis method is added in the same place as EN standard is currently written.

5.3 Life cycle assessment

This part consists of a table with the main Life cycle assessment (LCA) indicators of biomass, which information is currently not available. This issue will be filled when WP9 results are available.

6 ANNEX

The annex consists on the 21 raw materials profiles pre-selected for the project SECTOR in this deliverable, as shown below.

	PROFILE No. 1	
	CONIFEROUS STEM WOOD	
Description of feedstock	Stem wood, coniferous without bark (Reference raw material 1)	
Raw material according to EN 14961-1 Table 1	Forest, plantation and other virgin wood 1.1.3.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips, saw dust	
Selection criteria for feedstock profile (e.g. high potential, availability)	High potential, total forest wood in EU-27 is about 678 million solid m ³ (Mantau et al 2009)	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, yes	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,1	<0,02	0,01
Variation (min-max)	< 0,1	<0,01	< 0,01
	0,5	0,02	0,03

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation	0,4 0,3- 0,6	1150	1180	1200	1225

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti				
	Unit	mg/kg (DB)													
	Range	30	500	10	100	50	200	<0,1	100	10					
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn		
	Unit	mg/kg (DB)													
	Range	<0,05	0 -7	0,2	0,5	<0,02	40		<0,1	<0,5			5		
	0,5		10	10	0,05	200		10	10		<2	50			

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Wood chips, saw dust	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		P45 or P65(wood chips) 1 – 5 mm (sawdust)
Bulk density (BD), kg/m ³ EN 15103	330	310 – 350
Moisture as received, M (w-%), EN 14774-1 or 3	< 50	35 – 55
Amount of fines, F, w-% (≤ 3,15 mm) EN 15149-1		1 -19,6
Hemicelluloses content, w-% dry *)		25 – 28
Cellulose content, w-% dry *)	40	40- 45
Lignin content, w-% dry *)	30	24 -33
C (w-% dry), EN 15104	51	48 – 50
H (w-% dry) EN 15104	6,0	6 – 6,5
O (w-% dry) calculated	40	38 – 42
Volatile content, VM (w-% dry) EN 15148		80 – 90
Net calorific value, dry MJ/kg EN 14918	19,1	18,5 – 19,8
Add other properties, S, w-% dry	0,05	
Chlorine, Cl, w-% dry	< 0,01	

Source: Alakangas, E. Wood fuel properties in Finland, PRO2/P2030/05, Biosouth project. Jyväskylä 2005, 89 p. + app. 10 p.

Source: Alakangas, E. Analysis of particle size of wood chips and hog fuel – ISO/TC 238, VTT-R-02834-12. 28 p.

2.2 Reactivity of feedstock

Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	~15% (a 270°C)

Source: ² David Agar, Margareta Wihersaari, Torrefiointiprosessi biomassan jalostamiseen ”biohiili” University of Jyväskylä. Sustainable bioenergy (Torrefaction process for refining biomass ”biocoal”, presentation slides in Finnish)



http://users.jyu.fi/~daagar/agar_torrefiointi_fi.pdf

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 2		
	LOGGING RESIDUES CONIFEROUS		
Description of feedstock	Logging residues, coniferous		
Raw material according to EN 14961-1 Table 1	Forest, plantation and other virgin wood 1.1.4.2 / 1.1.4.4		
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips		
Selection criteria for feedstock profile (e.g. high potential, availability)	High potential in some countries, Theoretical annual forest fuel potential 785 million m ³ and the technically harvestable volume of 187 million m ³ (36 Mtoe/a, 411 TWh) Source: Metla		
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)			
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined		

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,5	< 0,02	0,01
Variation (min-max)	0,3 0,8	< 0,02 0,06	< 0,01 0,06

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1) oxidizing conditions			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	3				
variation	1 – 10	1175	1205	1230	1250

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
Range			2000	500	400		1000	0,2	200	75				
			8000	2000	2000	500	5000	1	10000	300				
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)												
	Range		0,1		0,7	10		80		0,4	0,4		0,1	8
			0,8		1,2	200	0,03	170		3	4		1	30

Source: VTT

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	wood chips	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		5 – 100 (P45 or P63)
Bulk density (BD), kg/m ³ EN 15103	300	270 – 360
Moisture as received, M (w-%), EN 14774-1 or 3	< 50	35 – 55
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1	19,5 – 33,7	Varies greatly
Hemicelluloses content, w-% dry		25 – 28
Cellulose content, w-% dry	40	40-45
Lignin content, w-% dry	30	24 -33
C (w-% dry), EN 15104	51	48 – 52
H (w-% dry) EN 15104	6,1	5,7 – 6,2
O (w-% dry) calculated	40	38 – 44
Volatile content, VM (w-% dry) EN 15148		84 – 86
Net calorific value, dry MJ/kg EN 14918	19,2	18,5 – 20,5
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 3	
	WHEAT STRAW	
Description of feedstock	Straw, wheat (Nordic conditions)	
Raw material according to EN 14961-1 Table 1	Herbaceous biomass from agriculture 2.1.1.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Bales	
Selection criteria for feedstock profile (e.g. high potential, availability)	Moderate potential in Nordic countries	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,5	0,1	0,4
Variation (min-max)	0,2 1,5	< 0,05 0,2	< 0,1 1,2

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	5		1050	1200	1210
variation	2- 10		1080	1350	1400

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti				
	Unit	mg/kg (DB)													
	Range	50	2000	100	400	300	2000	0,1	1000	500	5				
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn		
	Unit	mg/kg (DB)													
	Range	<0,05		1	1	<0,02	20		0,2	0,1		1	3		
	0,3		60	10	0,05	100		4	3		6	60			

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Bales	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		10 – 200
Bulk density (BD), kg/m ³ EN 15103		160 - 200
Moisture as received, M (w-%), EN 14774-1 or 3	15	10 -30
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		23 -30
Cellulose content, w-% dry	37	
Lignin content, w-% dry	20	
C (w-% dry), EN 15104	47	41 – 50
H (w-% dry) EN 15104	6,0	5,4 – 6,5
O (w-% dry) calculated	41	36 – 45
Volatile content, VM (w-% dry) EN 15148	77	75 – 81
Net calorific value, dry MJ/kg EN 14918	17,6	16,6 – 20,1
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 4	
	USED WOOD	
Description of feedstock	Used wood – Post consumer wood, recycled wood chemically untreated	
Raw material according to EN 14961-1 Table 1	Chemically untreated wood 1.3.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Hog fuel	
Selection criteria for feedstock profile (e.g. high potential, availability)	Moderate potential	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value			
Variation (min-max)	0,25 1,0	< 0,02 0,08	0,02 0,12

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	0,7		1150	1200	1210
variation	4,0		1220	1260	1265

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti				
	Unit	mg/kg (DB)													
	Range	130		490		5,4	630	<2		200					
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn		
	Unit	mg/kg(DB)													
	Range	0,12		5,2	5,5	49	72		3,2	200		0,5	79		
	0,5		60	80		115		10	630		2,2	300			

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Hog fuel	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	varying	
Bulk density (BD), kg/m ³ EN 15103	200	140 - 260
Moisture as received, M (w-%), EN 14774-1 or 3	20	15 - 30
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		25 - 35
Cellulose content, w-% dry	40	
Lignin content, w-% dry		20 -30
C (w-% dry), EN 15104		49,1 -52,3
H (w-% dry) EN 15104		5,9 – 6,4
O (w-% dry) calculated		N.A
Volatile content, VM (w-% dry) EN 15148		84 - 86
Net calorific value, dry MJ/kg EN 14918		18,6 – 18,9
Add other properties, if needed		

Source: ¹ Alakangas& Wiik: Käytöstä poistetun puun luokittelu ja hyvien käytäntöjen kuvaus. VTT – R-04989-08. 1.9.2008 (Classification and good practices for used wood, in Finnish)

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 5	
	BARK	
Description of feedstock	Bark, coniferous	
Raw material according to EN 14961-1 Table 1	Bark from industry operations 1.2.1.5	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Debarking residues from trees. Can be shredded or unshredded.	
Selection criteria for feedstock profile (e.g. high potential, availability)	Moderate potential, availability from mechanical wood industry, mainly utilized	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,05	0,03	0,02
Variation (min-max)	0,3 0,9	< 0,02 0,05	< 0,01 0,05

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	1,5	1405	1550	1650	1650
variation	1 -5				

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti				
	Unit	mg/kg (DB)													
	Range	400	1000	100	400	20	1000	0,1	500	70					
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn		
	Unit	mg/kg (DB)													
	Range	0,2		1	3	0,01	9		2	1		0,7	70		
	1		10	30	0,1	840		20	30		2	200			

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Debarking residues from trees	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	varying	
Bulk density (BD), kg/m ³ EN 15103		240 – 360
Moisture as received, M (w-%), EN 14774-1 or 3	55	50 – 65
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		10 -15
Cellulose content, w-% dry		20 – 30
Lignin content, w-% dry		10 – 25
C (w-% dry), EN 15104	52	48 – 55
H (w-% dry) EN 15104	5,9	5,5 – 6,4
O (w-% dry) calculated	38	34 – 42
Volatile content, VM (w-% dry) EN 15148		70 – 80
Net calorific value, dry MJ/kg EN 14918	19,2	17,5 – 20,5
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 6	
	BROADLEAVES STEM WOOD	
Description of feedstock	Delimbed broadleaves stem wood with bark (Reference raw material 2)	
Raw material according to EN 14961-1 Table 1	1.1.3.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips	
Selection criteria for feedstock profile (e.g. high potential, availability)	Representative reference material	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test: yes Pilot test: yes	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,3	0,01	0,007
Variation (min-max)	0,08 1,44	0,00 0,1	0,004 0,011

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	0,7	1000	1320	1350	1370
variation	0,3- 1,5	970-1080	1200-1370	1340-1390	1360-1450

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	Si	Na	Ti					
	Unit	% (DB)													
	Range	0,5	55,0	0,7	5,0	1,0	17,0	2,5	0,1	0,05					
		1,0	65,0	1,1	8,0	3,0	25,0	4,0	1,5	0,9					
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)													
	Range	0,8	0,1	0,5	0,5	1,6		51	0,7	0,9	0,2	0,8	0,1	2,8	
		1		24	2,5	1,4		56	0,8	4,1	0,6	26		11	

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Wood chips	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	30	20-30
Bulk density (BD), kg/m ³ EN 15103	240 (~10% moisture)	220 – 260
Moisture as received, M (w-%), EN 14774-1 or 3	20	10 - 50
Amount of fines, F, w-% (≤ 3,15 mm) EN 15149-1	15	7 - 30
Hemicelluloses content, w-% dry	25,7	21,1 – 31,8
Cellulose content, w-% dry	42,6	27,7 – 49,0
Lignin content, w-% dry	30,2	29,5 – 31,5
C (w-% dry), EN 15104	48,7	42,6 – 52,0
H (w-% dry) EN 15104	6,03	5,7– 6,4
O (w-% dry) calculated	44,9	41,4 – 51,1
Volatile content, VM (w-% dry) EN 15148	83,1	75,6 – 85,8
Net calorific value, dry MJ/kg EN 14918	17,8	15,0 – 19,2
Add other properties, if needed		

Source: ¹ <http://www.ecn.nl/phyllis>. ²CENER.

2.2 Reactivity of feedstock

Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T > 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	30%



Source: ²CENER

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 7	
	POPLAR	
Description of feedstock	Poplar, with bark	
Raw material according to EN 14961-1 Table 1	1.1.3.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips	
Selection criteria for feedstock profile (e.g. high potential, availability)	High potential energy crop	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test: yes Pilot test: to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,3	0,03	0,034
Variation (min-max)	0,10 0,1	0,00 0,05	0,008 0,1

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	1,2	1010	1340	1360	1390
variation	0,2 – 2,7	1000 - 1080	1320 - 1370	1350 - 1390	1370 - 1450

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	Si	Na	Ti				
	Unit	% (DB)												
Range		0,10	59,50		5,30	8,50	25,50		1,05					
		2,00	67,00		8,00	10,00	35,00		2,30					
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn
	Unit	mg/kg (DB)												
Range			0,3	30		13		17			1,4			36

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Wood chips	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	16	10 - 50
Bulk density (BD), kg/m ³ EN 15103	240	220 – 260
Moisture as received, M (w-%), EN 14774-1 or 3	8,2	4,8 - 15
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1	13	7 – 30
Hemicelluloses content, w-% dry	25,3	12,7 – 39,8
Cellulose content, w-% dry	44,4	35,2 – 50,8
Lignin content, w-% dry	22,9	15,5 – 31,9
C (w-% dry), EN 15104	49,7	44,8 – 52,0
H (w-% dry) EN 15104	6,06	5,6 – 6,3
O (w-% dry) calculated	43,9	41,6 – 48,6
Volatile content, VM (w-% dry) EN 15148	82,6	71,8 – 87,5
Net calorific value, dry MJ/kg EN 14918	18,5	17,3 – 20,9
Add other properties, if needed		

Source: ¹ <http://www.ecn.nl/phyllis>. ²Smeenk,J.; Brown,R.C.; Eckels,D.: Determination of vapor phase alkali content during biomass gasification; Proc. 4th biomass conference of the Americas, p.961-967. ³Poulomi Sannigrahi, Arthur J. Ragauskas, Gerald A. Tuskan. Poplar as a feedstock for biofuels: A review of compositional characteristics. Biofuels, Bioprod, Bioref. 4:209–226 (2010).

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 8	
	STRAW OF CEREAL	
Description of feedstock	Straw, cereal (oat and wheat, southern conditions)	
Raw material according to EN 14961-1 Table 1	2.1.1.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Big square bales, 3,7 m ³ , compressed and bound to squares	
Selection criteria for feedstock profile (e.g. high potential, availability)	High potential	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test: yes Pilot test: to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,7	0,16	0,5
Variation (min-max)	0,3 2,77	0,00 0,46	0,02 2,3

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	6,7			1200	1220
variation	1,3 – 13,5			1100-1350	1190-1400

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	Si	Na	Ti				
	Unit	% (DB)												
Range		0,8	15,7	1,5	6,2	4,7	15,4	46,4	7,8	0,08				
		1,8	18,3	1,7	8,4	7,6	16,8	52,3	7,8	0,5				
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn
	Unit	mg/kg (DB)												
Range		0,1	0,0	1	2,7	10	0,02	0,3	0,5	1	0,1	0,3	0,9	12
		2,6	0,6	2,3	81,2	1.777	0,05	112	2,3	423	8,4	7,7	6,7	33,8

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Big square bales	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	40	8-60
Bulk density (BD), kg/m ³ EN 15103	50 (chopped)	30-80
Moisture as received, M (w-%), EN 14774-1 or 3	15	8 -25
Amount of fines, F, w-% (≤ 3,15 mm) EN 15149-1		
Hemicelluloses content, w-% dry	25,0	7,2 – 39,1
Cellulose content, w-% dry	37,0	14,8 – 51,5
Lignin content, w-% dry	17,5	5,0 – 30,0
C (w-% dry), EN 15104	48,9	43,7 – 52,6
H (w-% dry) EN 15104	5,9	3,2 – 6,6
O (w-% dry) calculated	43,9	39,4 – 50,1
Volatile content, VM (w-% dry) EN 15148	81	73 – 87
Net calorific value, dry MJ/kg EN 14918	17,8	14,8 – 20,5
Add other properties, if needed		

Source: ¹ <http://www.ecn.nl/phyllis>. ²E.Kurkela, et al: CFB gasification of biomass residues for co-combustion in large utility boilers - studies on ash control and gas cleaning. In: VTT Symposium 192: Power production from biomass III, pp. 213-227, Espoo (Finland) (1999).

2.2 Reactivity of feedstock

Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	45%



Source: ³CENER

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 9	
	PRUNINGS FROM OLIVE TREES	
Description of feedstock	Prunings from olive trees –woody biomass	
Raw material according to EN 14961-1 Table 1	1.1.4.3	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips	
Selection criteria for feedstock profile (e.g. high potential, availability)	Availability in European southern countries	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test: yes Pilot test: to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,6	0,07	0,03
Variation (min-max)	0,5 1,7	0,00 0,2	0,00 0,1

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value		1210	1340	1360	1390
variation		1000 - 1300	1320 - 1370	1350 - 1390	1370 - 1450

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	Si	Na	Ti					
	Unit	% (DB)													
	Range	0,9	13,0	0,7	6,0	1,8	17,0	52,5	0,1	0,05					
		1,5	15,0	1,1	9,0	3,0	25,0	54,0	1,5	0,9					
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)													
	Range		0,08			1,7						0,5			3,0
			0,1			2,5					0,7			15	

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Stem wood, log wood/firewood	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	200	100 - 1000
Bulk density (BD), kg/m ³ EN 15103	250	220 – 270
Moisture as received, M (w-%), EN 14774-1 or 3	25	10 - 50
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1	10	7 – 30
Hemicelluloses content, w-% dry	11,5	10,0 – 12,0
Cellulose content, w-% dry	48,5	47,5 – 49,5
Lignin content, w-% dry	30,5	29,5 – 31,5
C (w-% dry), EN 15104	40,7	39,0 – 45,0
H (w-% dry) EN 15104	5,7	5,0 – 6,0
O (w-% dry) calculated	41,0	40,0 – 42,0
Volatile content, VM (w-% dry) EN 15148	76,2	75,2 – 80,5
Net calorific value, dry MJ/kg EN 14918	16,3	16,0 – 18,5
Add other properties, if needed		

Source: ¹ <http://www.ecn.nl/phyllis>. ²F. Suárez-García, A. Martínez-Alonso, M. Fernández Llorente, J.M.D. Tarascon: Inorganic matter characterization in vegetable biomass feedstocks. Fuel 81 (2002) 1161-1169.

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 10	
	EUCALYPTUS	
Description of feedstock	Eucalyptus	
Raw material according to EN 14961-1 Table 1	1.1.3.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips	
Selection criteria for feedstock profile (e.g. high potential, availability)	High potential energy crop	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test: yes Pilot test: to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,29	0,05	0,035
Variation (min-max)	0,03 1,7	0,00 0,4	0,00 0,2

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	1,2	1025	1330	1370	1390
variation	0,2 – 6,1	995 - 1080	1320 - 1370	1350 - 1390	1370 - 1450

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	Si	Na	Ti					
	Unit	% (DB)													
	Range	11,4	28,6	2,8	11,4	0,5	28,6	0,00	14,3	2,0					
		4,1	51,5	2,7	15,1	8,0	30,3	0,01	17,1	6,8					
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)													
	Range	0,8	0,3	0,1	1,3	4	0	27		0,5	0,3	1	0,5	6	
				2	10	20	2	39		8	30	2		58	

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Wood chips	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	15	10 - 50
Bulk density (BD), kg/m ³ EN 15103	250	220 – 260
Moisture as received, M (w-%), EN 14774-1 or 3	10	5 - 50
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1	14	3 – 50
Hemicelluloses content, w-% dry	25,3	8,4 – 43,5
Cellulose content, w-% dry	43,0	8,8 – 57,5
Lignin content, w-% dry	23,2	9 - 37
C (w-% dry), EN 15104	50,3	46,2 – 55,2
H (w-% dry) EN 15104	6,02	4,9 – 6,9
O (w-% dry) calculated	43,3	38,2 – 47,7
Volatile content, VM (w-% dry) EN 15148	83,4	77,5 – 93,6
Net calorific value, dry MJ/kg EN 14918	18,5	17,0 – 21,6
Add other properties, if needed		

Source: ¹ <http://www.ecn.nl/phyllis>. ²O. Kitani and C. W. Hall: Biomass Handbook, Gordon and Breach science publishers, New York (1989).

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T > 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 11	
	PAULOWNIA	
Description of feedstock	Paulownia	
Raw material according to EN 14961-1 Table 1	1.1.3.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips	
Selection criteria for feedstock profile (e.g. high potential, availability)	High potential energy crop	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test: yes Pilot test: to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,24	0,02	0,01
Variation (min-max)	0,10 0,50	0,00 0,1	0,00 0,1

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	1,1				
variation	0,5 – 3,5				

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	Si	Na	Ti				
	Unit	% (DB)												
Range		0,5	55,0	0,7	5,0	1,0	17,0	2,5	0,1	0,05				
		1,0	65,0	1,1	8,0	3,0	25,0	4,0	1,5	0,9				
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn
	Unit	mg/kg (DB)												
Range		0,12		5,2	5,5	49	72		3,2	200		0,5	79	0,12
		0,5		60	80		115		10	630		2,2	300	0,5

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2	Wood chips	
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310	20	10 - 50
Bulk density (BD), kg/m ³ EN 15103	250	220 – 260
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104	49,5	47,9 – 50,0
H (w-% dry) EN 15104	6,4	5,8 – 6,7
O (w-% dry) calculated	43,8	43,2 – 45,0
Volatile content, VM (w-% dry) EN 15148	82,0	81,5 – 84,0
Net calorific value, dry MJ/kg EN 14918	18,6	18,0 – 20,0
Add other properties, if needed		

Source: ¹ <http://www.vicedex.com>.

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 12		
	BAMBOO HERBACEOUS		
Description of feedstock	Chipped bamboo stems		
Raw material according to EN 14961-1 Table 1	2.1.2.2		
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	chips		
Selection criteria for feedstock profile (e.g. high potential, availability)	Available in high quantities		
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)			
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, yes		

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value			
Variation (min-max)			

1.2 Ash content, ash melting behavior and ash composition and

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation					

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
	Range													
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)												
	Range													

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% (≤ 3,15 mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104		
H (w-% dry) EN 15104		
O (w-% dry) calculated		
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918		
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 13	
	EMPTY FRUIT BUNCHES	
Description of feedstock	Byproduct from palm oil industry	
Raw material according to EN 14961-1 Table 1	3.2.1.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Bales or small briquettes	
Selection criteria for feedstock profile (e.g. high potential, availability)	Available in large quantities	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value			
Variation (min-max)			

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation					

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
	Range													
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)												
	Range													

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104		
H (w-% dry) EN 15104		
O (w-% dry) calculated		
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918		
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 14	
	BAGASSE HERBACEOUS	
Description of feedstock	Fibrous matter that remains after sugar canes stalks are crushed	
Raw material according to EN 14961-1 Table 1	2.2.1.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Chopped straw	
Selection criteria for feedstock profile (e.g. high potential, availability)	Available in high quantities	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value			
Variation (min-max)			

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation					

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
	Range													
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)												
	Range													

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% (≤ 3,15 mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104		
H (w-% dry) EN 15104		
O (w-% dry) calculated		
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918		
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 15	
	CORN COBS	
Description of feedstock	Central core of a maize ear	
Raw material according to EN 14961-1 Table 1	2.1.1.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Chopped	
Selection criteria for feedstock profile (e.g. high potential, availability)	High availability	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value			
Variation (min-max)			

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation					

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
	Range													
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)												
	Range													

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104		
H (w-% dry) EN 15104		
O (w-% dry) calculated		
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918		
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 16	
	MISCANTHUS	
Description of feedstock	Herbaceous biomass	
Raw material according to EN 14961-1 Table 1	2.1.2.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Chopped or in bales	
Selection criteria for feedstock profile (e.g. high potential, availability)	Available in high quantities	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value			
Variation (min-max)			

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation					

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
	Range													
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)												
	Range													

2. QUALITY INFORMATION FOR TORREFACTION

2.1 2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104		
H (w-% dry) EN 15104		
O (w-% dry) calculated		
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918		
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 17	
	SUNFLOWER RESIDUE	
Description of feedstock	Stalks and leaves from sun flowers	
Raw material according to EN 14961-1 Table 1	2.1.6.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Chopped straw	
Selection criteria for feedstock profile (e.g. high potential, availability)	High availability	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value			
Variation (min-max)			

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation					

Macro elements CEN/TS 15290	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
	Range													
Micro elements CEN/TS 15297	Composition	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)												
	Range													

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104		
H (w-% dry) EN 15104		
O (w-% dry) calculated		
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918		
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 18		
	WILLOW		
Description of feedstock	Willow (Salix)		
Raw material according to EN 14961-1 Table 1	1.1.1.3		
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Wood chips		
Selection criteria for feedstock profile (e.g. high potential, availability)			
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)			
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined		

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,5	0,04	
Variation (min-max)	0,3-0,96	0,02-0,12	0,018-0,03

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation	2,2	1100	1363	1523	1528

Macro elements CEN/TS 15290 Oxides, %	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti				
	Unit	mg/kg (DB)													
	Range	0,13	29,36	0,24	1,38	9,41	13,95		0,81	0,35					
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)													
	Range														

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104	49	47,1-50,3
H (w-% dry) EN 15104	6	5,82-6,2
O (w-% dry) calculated	43	41,3-45,3
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918	19,5	
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	39 (Data at 300°C at time >200°C=12.5 min)

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 19	
	REED CANARY GRASS	
Description of feedstock	Reed canary grass	
Raw material according to EN 14961-1 Table 1	2.1.2.1	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Bales, chopped	
Selection criteria for feedstock profile (e.g. high potential, availability)	Perennial crop from Nordic countries	
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,6	0,08	
Variation (min-max)	0,3-1,4	0,07-0,20	0,04

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value	8	1040-1390	1000-1200	1100-1400	1160-1500
variation	3-10				

Macro elements CEN/TS 15290 Oxides, %	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
Range		0,21	1,87	0,27	0,93	1,79	2,01	<0,1	45,14	0,04				
		5,79	16,74	1,65	5,55	14,49	19,0		93,05	2,46				
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn
	Unit	mg/kg (DB)												
Range			>0,03	0,16	1,73	5,56	0,02		0,43	1,06	0,87		0,63	51,45

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% (≤ 3,15 mm) EN 15149-1		
Hemicelluloses content, w-% dry	30	
Cellulose content, w-% dry	46	
Lignin content, w-% dry	22	
C (w-% dry), EN 15104	45,3	44-48
H (w-% dry) EN 15104	5,6	5,2-6,21
O (w-% dry) calculated	41.2	38,9-43,9
Volatile content, VM (w-% dry) EN 15148	77	74-81
Net calorific value, dry MJ/kg EN 14918	16,6	14,6-17,5
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	39,5 (Data at 300°C at time >200°C=12.5 min)

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 20	
	BARLEY STRAW	
Description of feedstock	Barley straw	
Raw material according to EN 14961-1 Table 1	2.1.1.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Bales, chopped	
Selection criteria for feedstock profile (e.g. high potential, availability)		
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,6	0,12	
Variation (min-max)	0,41-1,25	0,09-0,16	0,2-0,7

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1) ASTM D 1857			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation	4-6,5				

Macro elements CEN/TS 15290 Oxides, %	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti			
	Unit	mg/kg (DB)												
	Range	0,23	6,9	0,19	1,08	1,62	7,58		26,99	0,41				
		1,12	14,94	1,69	3,42	5,34	49,45		80,38	2,73				
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn
	Unit	mg/kg (DB)												
	Range													

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104	45,4	39,9-47,5
H (w-% dry) EN 15104	5,6	5,3-5,9
O (w-% dry) calculated	42,1	41,2-43,8
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918	18,9	
Add other properties, if needed		

2.2 Reactivity of feedstock



Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	58 (Data at 300°C at time >200°C=12.5 min)

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.

	PROFILE No. 21	
	RAPE STRAW	
Description of feedstock	Rape straw	
Raw material according to EN 14961-1 Table 1	2.1.1.2	
Traded form (e.g. wood chips) according Table 2 of EN 14961-1 or other	Bales, chopped	
Selection criteria for feedstock profile (e.g. high potential, availability)		
Remarks (e.g. biomass cutting step, place of origin, pretreatment etc.)		
Selected for laboratory and/or pilot tests	Laboratory test, yes Pilot test, to be defined	

1. QUALITY OF RAW MATERIAL

1.1 Emissions/corrosion related compounds (w-% of dry matter, EN 15104 (N, S) and EN 15289 (Cl))

Component	Nitrogen, N	Sulphur, S	Chlorine, Cl
Typical value	0,5	0,2	
Variation (min-max)	0,48-2,3	0,1-0,40	0,2

1.2 Ash content, ash melting behavior and ash composition

Parameter	Ash content EN 14775	Ash melting behavior (CEN/TS 15370-1)			
		SST	DT	HT	FT
Unit	% (DB)	°C	°C	°C	°C
Typical value variation	5,8				

Macro elements CEN/TS 15290 Oxides,	Composition	Al	Ca	Fe	Mg	P	K	As	Si	Na	Ti				
	Unit	mg/kg (DB)													
	Range	0,24	30,77	0,16	1,55	2,23	13,49		5,42	0,44					
Micro elements CEN/TS 15297	Composition	As	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	V	Zn	
	Unit	mg/kg (DB)													
	Range														

2. QUALITY INFORMATION FOR TORREFACTION

2.1 Quality data of biomass for torrefaction

Property	Typical value	Variation (min. – max.)
Traded form (e.g. chips) EN 14961-1, Table 2		
Particle size, P (Dimension /nominal size, mm, use) EN 15149-1, screen size according ISO 3310		
Bulk density (BD), kg/m ³ EN 15104		
Moisture as received, M (w-%), EN 14774-1 or 3		
Amount of fines, F, w-% ($\leq 3,15$ mm) EN 15149-1		
Hemicelluloses content, w-% dry		
Cellulose content, w-% dry		
Lignin content, w-% dry		
C (w-% dry), EN 15104	47,7	46,2-51,1
H (w-% dry) EN 15104	6,2	6-6,4
O (w-% dry) calculated	39,9	34-42,5
Volatile content, VM (w-% dry) EN 15148		
Net calorific value, dry MJ/kg EN 14918		18,2
Add other properties, if needed		

2.2 Reactivity of feedstock

Indicator	Weight loss at 280-290 °C with residence time of 30 minutes at T> 200°C (% AWL)
Torrefaction degree by TGA (Thermogravimetric analysis)	55 (Data at 300°C at time >200°C=12.5 min)

3. LIFE CYCLE ASSESSMENT

3.1 Life cycle assessment (LCA) indicators of biomass

LCA indicator	Units	Value at torrefaction plant gate
Climate change	g CO ₂ eq/MJ	
Primary energy balance	kWh/kWh biomass	

All analysis is on dry basis, moisture content is informed as received. If calculation from dry basis to e.g. ash free basis is needed use formulas from standard EN 15297.