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Tables and Figures to the Final Publishable Report

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Project Partners involved ASSOCIATION EUROPEENNE POUR LA BIOMASSE,
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Publishable Report - Figures and Tables

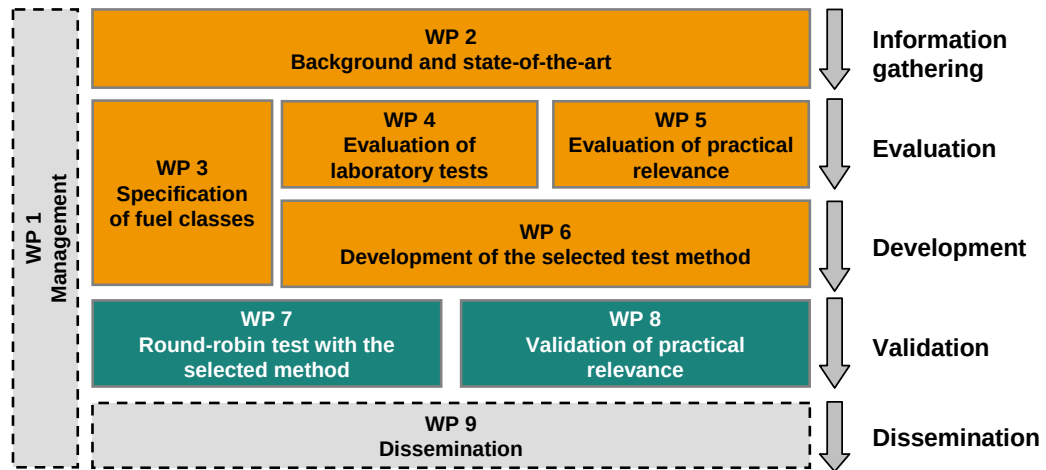


Figure 1: Objectives & Concept - AshMeIT project concept and approach



Figure 2: S&T results, Evaluation of laboratory tests - Fuels for laboratory tests (all pellets) and for boiler tests (pellets in red box) (source: TFZ)

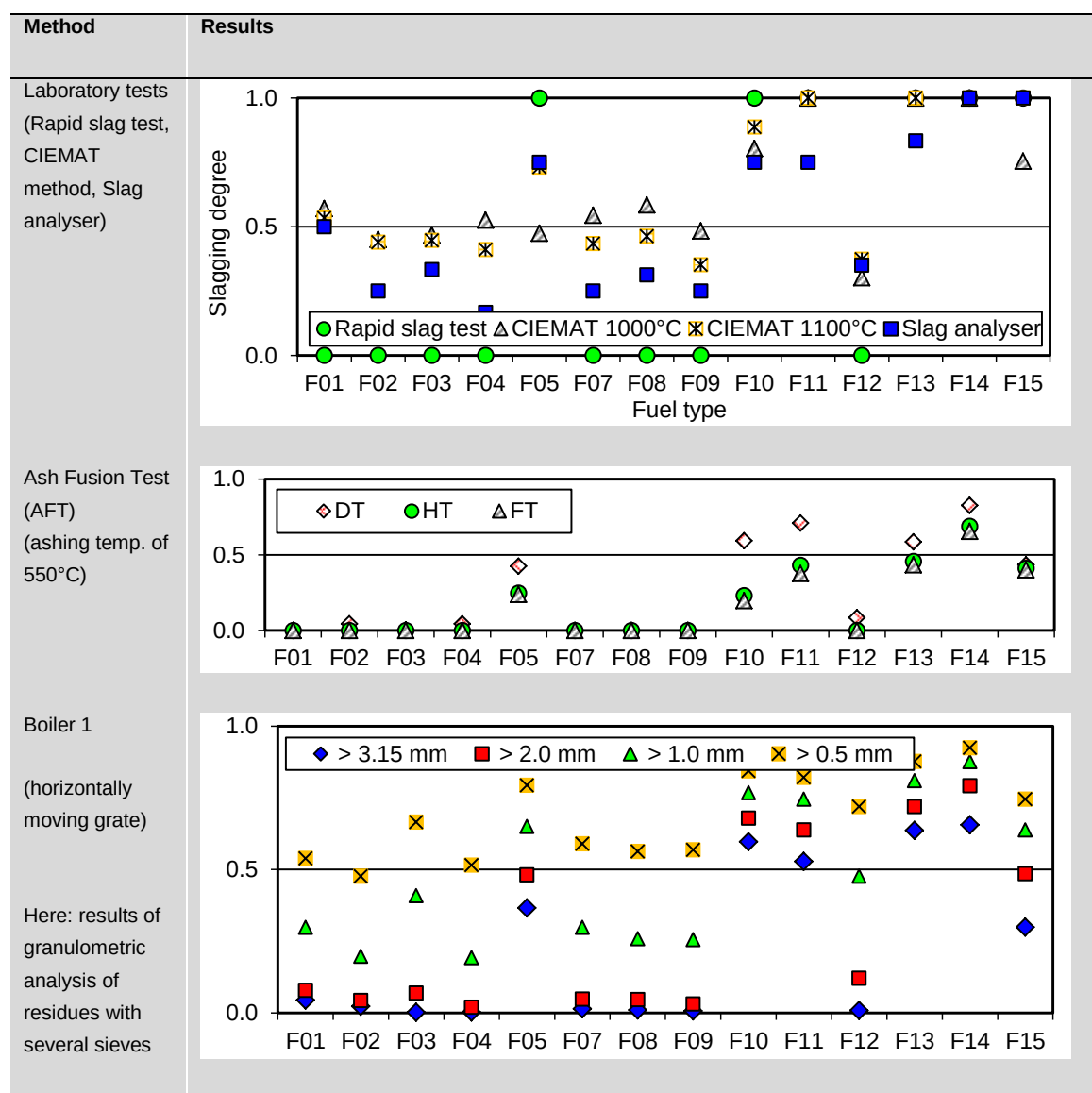


Table 1: S&T results, Evaluation of laboratory tests - Overall comparison of laboratory test methods with results from the combustion tests in one of the selected pellet boilers. All results were normalized to a scale between 0 and 1. Legend: DT = deformation temperature, HT = hemisphere temperature, FT = flow temperature

Criteria	Weighting factor (min: 1 - max: 5)	AFT (550°C)	Rapid slag test	CIEMAT Method	Slag analyser
1. Implementation aspects	3				
Availability/procureability of method	2	3	3	3	2
Easy standardisation possible	4	3	2	2	2
Independant application	4	3	3	3	3
Weighted average		9,0	7,8	7,8	7,2
2. Economic aspects	2				
Investment costs	3	1	3	2	2
Laboratory infrastructure costs	1	2	3	1	2
Cost for consumables per fuel	1	3	3	2	3
Number of staff during test performance	1	3	3	3	3
Sample processing time requirement	3	2	2	1	3
Weighted average		3,8	5,3	3,3	5,1
3. Handling and safety aspects	2				
Apparative complexity	4	2	3	2	2
Requirements concerning operating materials	1	2	3	2	2
Requirements concerning laboratory instrumentation	1	3	3	3	3
Training requirement for laboratory staff	3	1	2	1	1
Weighted average		3,6	5,3	3,6	3,6
4. Accuracy and differentiation aspects	4				
Sample size	4	1	1	2	3
Differentiation range	4	2	1	3	3
Avoidance of error by subjective judgement	5	3	1	2	2
Repeatability	5	3	3	2	2
Reproducibility of results	5	3	3	2	2
Weighted average		9,9	7,5	8,7	9,4
5. Slag prediction capacity	5				
Predictability of slagging in fixed bed combustion	5	2	2	3	3
Weighted average		10,0	10,0	15,0	15,0
Total score		36,2	35,9	38,4	40,3

Table 2: S&T results, Evaluation of laboratory tests - Summary table of assessment matrix for method assessments with final result (score-points) achieved per method and criteria during a common evaluation with all partners involved. Score point definition 1= negative evaluation, 2= medium evaluation or undecided, 3= positive evaluation

Figure 3: S&T results, method development – The slag analyser equipment

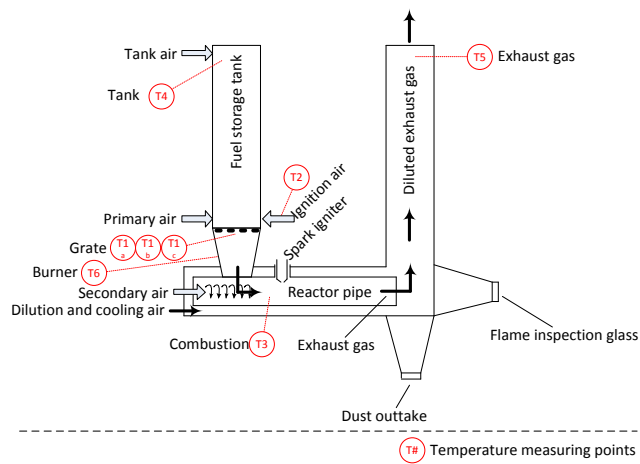


Figure 4: S&T results, method development – Experimental validation- Particle size distribution of all boilers tested in WP5 compared with the average particle size distribution of the slag analyser using the granulometric sieving

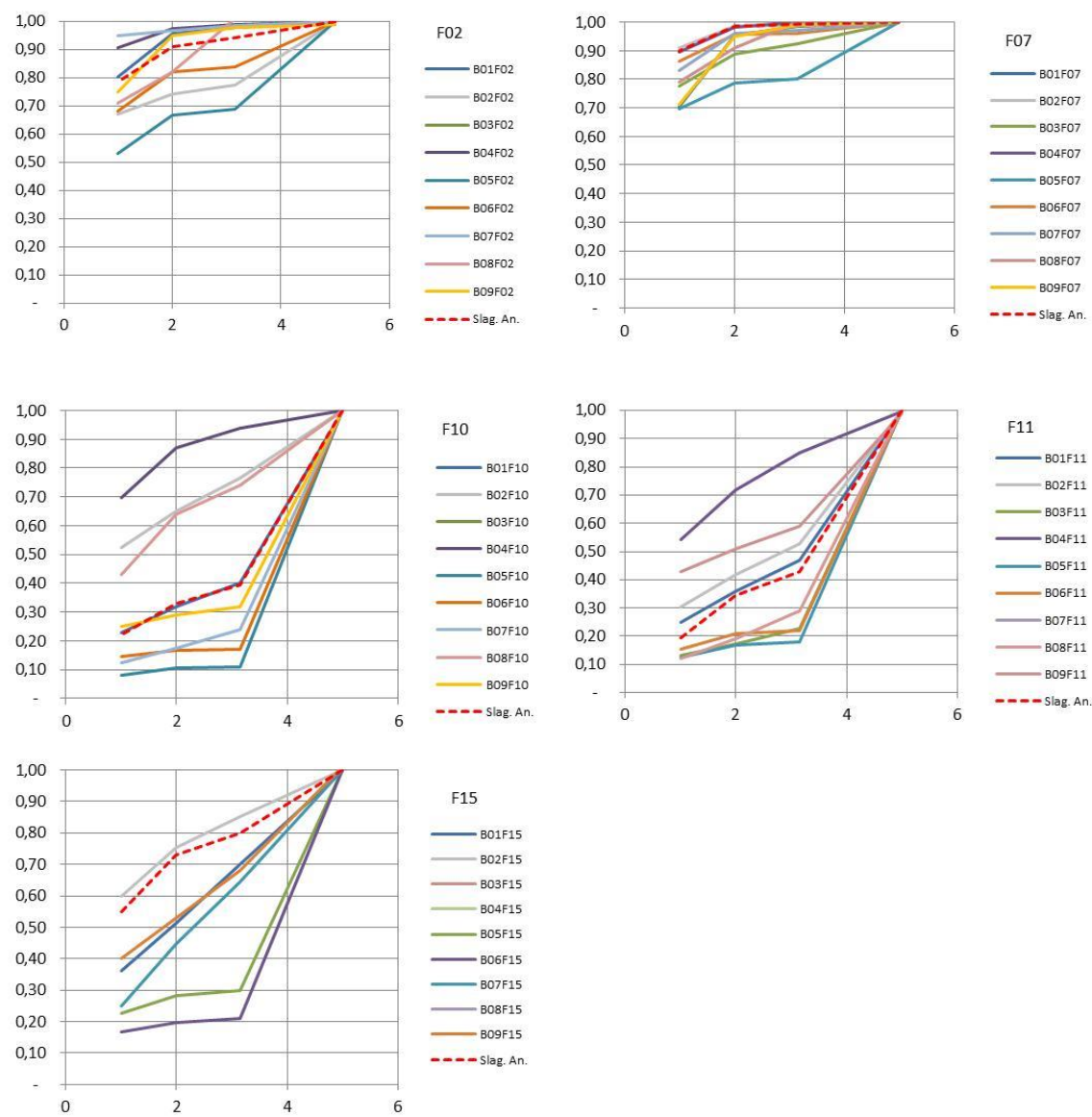
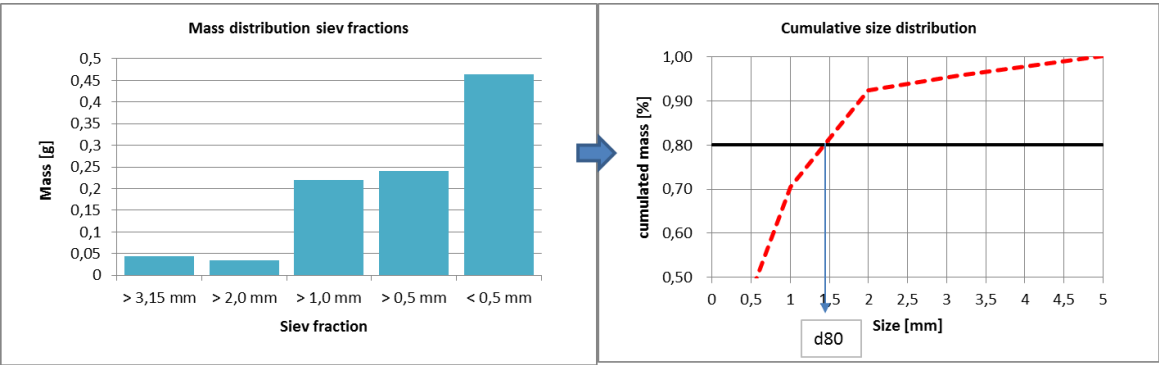


Figure 5: S&T results, method development – illustration of the d80 calculation



Fuel sample	Test unit	d80 [mm]	Std	Rstd [%]
F02 (Stemwood)	DTI (2)	0,79	0,76	96%
	DTI (3)	0,70	0,03	4%
	TFZ	1,14	0,13	11%
F08 (Willow/Spruce 60/40)	DTI (2)	0,81	0,55	68%
	DTI (3)	0,84	0,02	3 %
	TFZ	1,74	0,11	6 %
F18 (Wheat straw)	DTI (2)	-	-	-
	DTI (3)	4,19	0,05	1,2%
	TFZ	4,46	0,02	0,4 %

Table 3: S&T results, method development - Average values and repeatability of d80 expressed as standard deviation (STD) and relative standard deviation (Rstd)

Fuel	Slagg analyser V3		PASSA	
		<i>std</i>		<i>std</i>
F01 (3)	1,39	0,08	1,64	0,07
F02 (3)	1,19	0,02	1,48	0,39
F03 (3)	4,23	0,01	2,01	0,25
F05 (3)	4,18	0,01	3,94	0,22
F07 (3)	1,47	0,17	1,83	0,09
F08 (3)	1,7	0,04	1,87	0,26
F09 (3)	1,76	0,09	2,22	0,15
F10 (3)	3,84	0,15	4,08	0,17
F11 (3)	4,5	0	5,49	0,01
F15 (3)	4,34	0	4,69	0,09
F16 (3)	1,64	0,06	-	-
F18 (3)	4,12	0,02	-	-
F19 (3)	1,98	0,04	-	-
F20 (3)	2,88	0,08	-	-

Table 4: S&T results, method development – Results of the developed slag index from the Slag analyser and the PASSA method

Figure 6: S&T results, practical relevance of AshMeIT methods - Boiler technologies

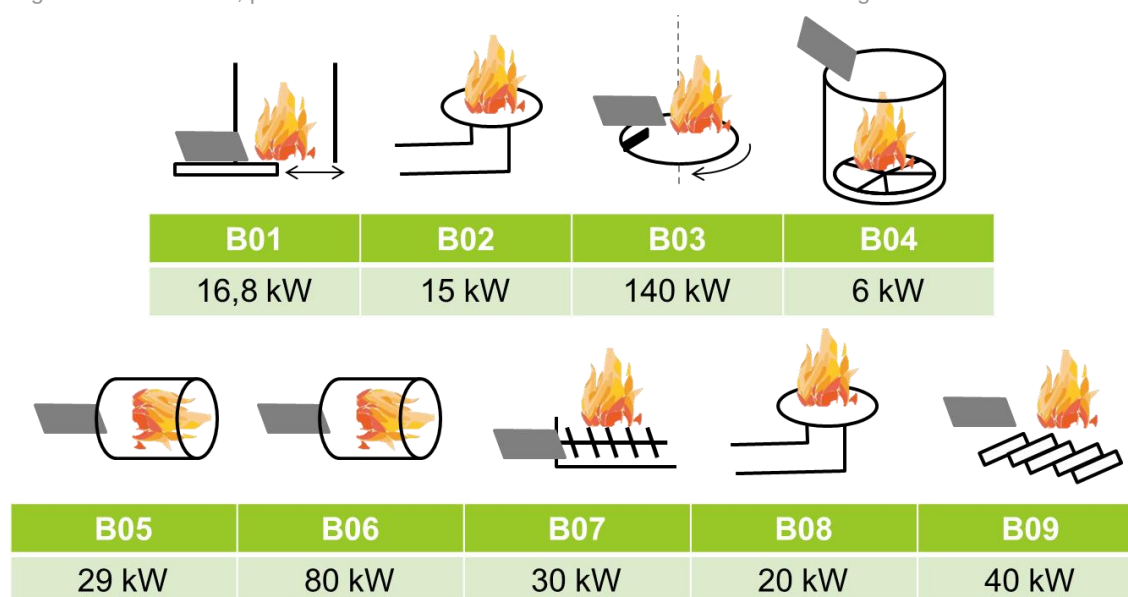


Table 5: S&T results, practical relevance of AshMeIT methods - Test fuels for the combustion tests

No.	Test pellet fuels
f01	Pine and spruce mixture (from saw dust)
f02	Stem wood without bark (spruce and pine mixture)
f03	Hardwood (beech/ash tree) 80% with soft wood (spruce) 20 %
f04	Bark rich (spruce from forest thinning)
f05	Wood (untreated waste wood)
f06	Soft wood 80 % with peat additive 20 %
f07	Willow 30 % with Spruce 70 %
f08	Willow 60 % with Spruce 40 %
f09	Willow 100 %
f10	Miscanthus
f11	Wheat straw
f12	Vineyard pruning
f13	Corn Cobs with hay (20%)
f14	DDGS (dried distiller's grains with solubles)
f15	Rape seed extraction
F16	willow/spruce (40/60)
F18	wheat straw pellets
F19	pure bark pellets
F20	saw dust with 20% peat

Figure 7: S&T results, practical relevance of AshMeT methods - Severity versus Applicability

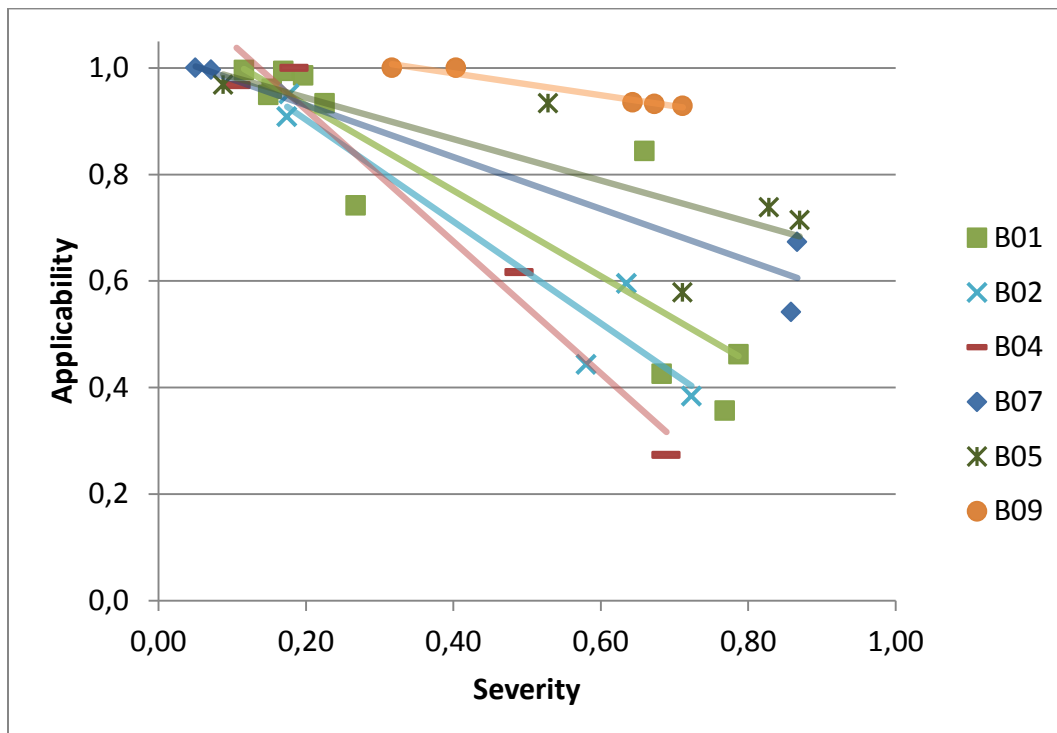


Figure 8: S&T results, practical relevance of AshMeT methods – Severity versus shrinkage starting temperature (SST)

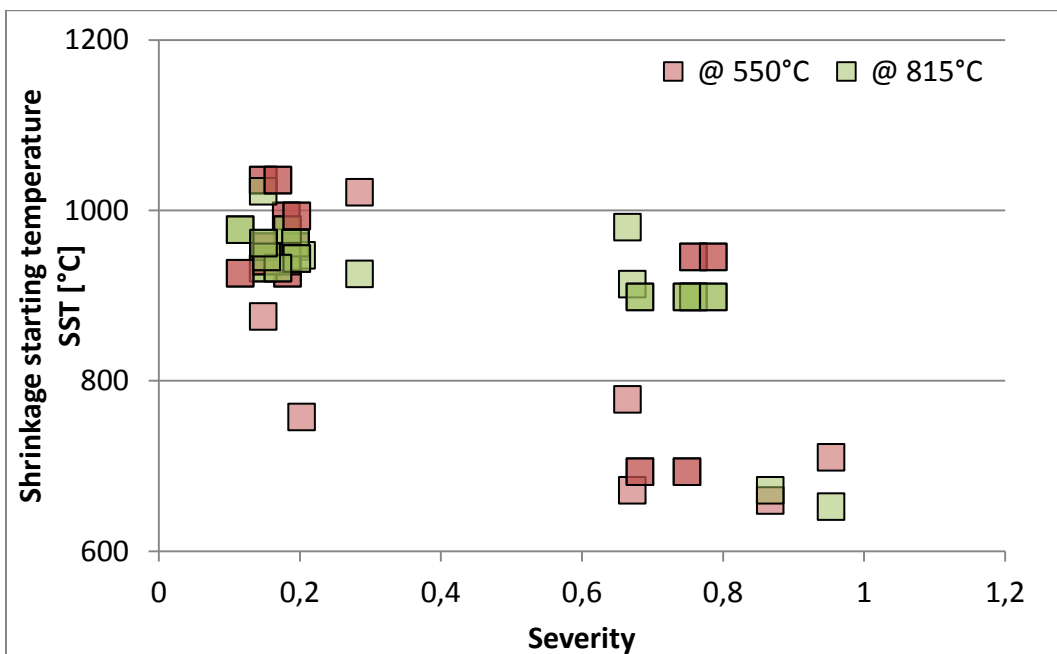


Figure 9: S&T results, practical relevance of AshMeIT methods – Severity versus Slag analyser results

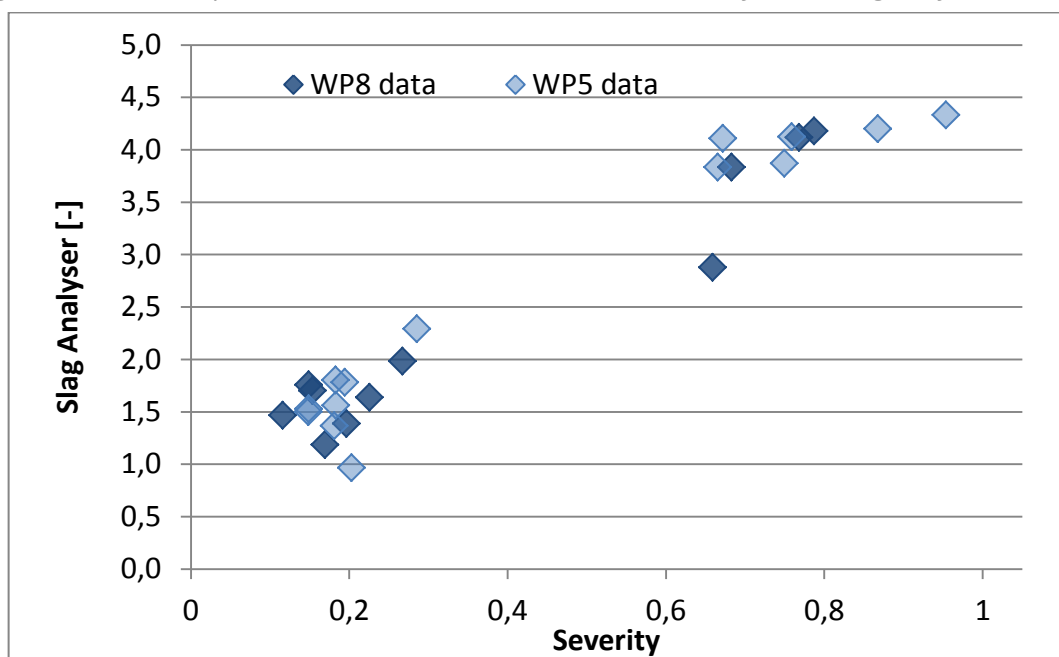
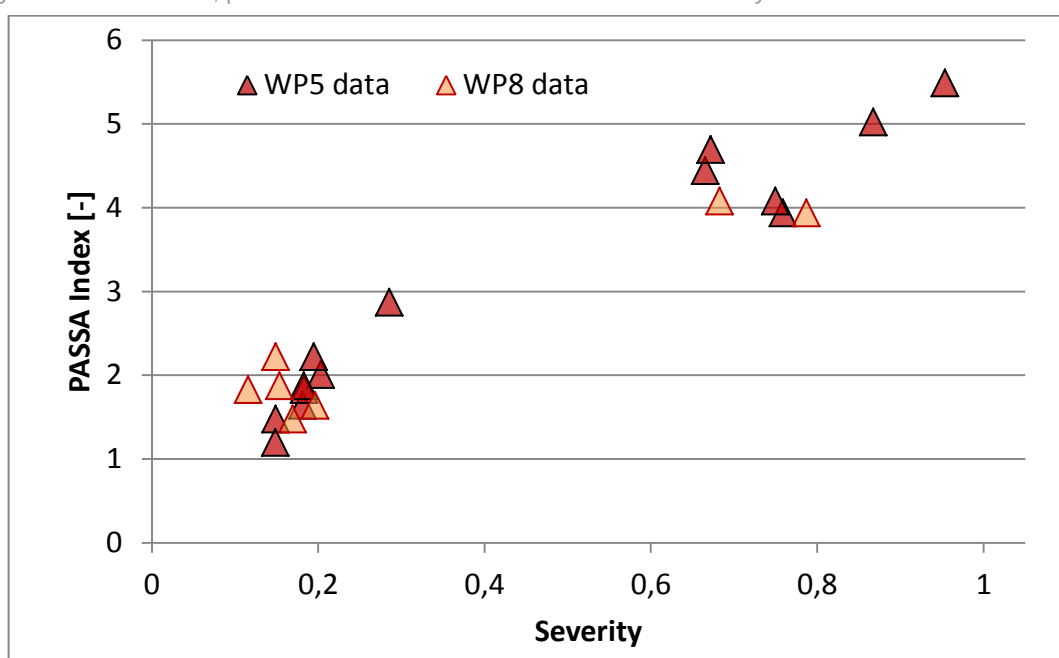


Figure 10: S&T results, practical relevance of AshMeIT methods – Severity versus PASSA test results



Limits	-	0	+
K ₂ O (wt-% in the K ₂ O+CaO+SiO ₂ system)	< 10	10-30	>30
CaO (wt-% in the K ₂ O+CaO+SiO ₂ system)	< 30	30-60	>60
SiO ₂ (wt-% in the K ₂ O+CaO+SiO ₂ system)	<40, > 90	40-60	60-90
Ash content (wt-% of d.s.)	<0.8	0.8-3	>3

Table 6: S&T results, fuel classification system - Limits for the fuel parameters that is used in the conceptual/qualitative classification system presented in this report. Data is approximated from *Näzelius et al, Energy Fuels 2015* [http://dx.doi.org/ 10.1021/ef502531m](http://dx.doi.org/10.1021/ef502531m)

Fuel	Fuel name	Burner	Case	AC	SiO ₂	CaO	K ₂ O	B01	B02	B03	B04	B05	B06	B07	B08	B09	>3.15 mm
F01	pine and spruce mixture	B01	1	-	-	+	0	0	0	0	0	0	0	0	0	0	0.04
F02	stem wood without bark	B01	2	-	-	0	0	0	0	0	0	0	0	0	0	0	0.02
		B02	3	-	-	0	0	0	0	0	0	0	0	0	0	0	0.22
		B04	4	-	-	0	0	0	0	0	-	0	0	0	0	0	0.01
		B05	5	-	-	0	0	0	0	0	0	+	0	0	0	0	0.3
		B06	6	-	-	0	0	0	0	0	0	0	+	0	0	0	0.16
		B07	7	-	-	0	0	0	0	0	0	0	0	0	0	0	0.02
		B08	8	-	-	0	0	0	0	0	0	0	0	0	0	0	0.00
		B09	9	-	-	0	0	0	0	0	0	0	0	0	0	0	0.01
F03	80% hardwood + 20% softwood	B01	10	-	-	+	0	0	0	0	0	0	0	0	0	0	0.00
F04	bark rich	B01	11	-	-	+	0	0	0	0	0	0	0	0	0	0	0.00
F05	wood from untreated wastewood	B01	12	+	+	-	-	0	0	0	0	+	0	0	0	0	0.37
F07	willow spruce 30/70	B01	13	-	-	0	+	0	0	0	0	0	0	0	0	0	0.01
		B02	14	-	-	0	+	0	0	0	0	0	0	0	0	0	0.01
		B03	15	-	-	0	+	0	0	0	0	0	0	0	0	0	0.07
		B04	16	-	-	0	+	0	0	0	-	0	0	0	0	0	0.00
		B05	17	-	-	0	+	0	0	0	0	+	0	0	0	0	0.2
		B06	18	-	-	0	+	0	0	0	0	0	+	0	0	0	0.04
		B07	19	-	-	0	+	0	0	0	0	0	0	0	0	0	0.03
		B08	20	-	-	0	+	0	0	0	0	0	0	0	0	0	0.00
		B09	21	-	-	0	+	0	0	0	0	0	0	0	0	0	0.01
F08	willow spruce 60/40	B01	22	-	-	0	+	0	0	0	0	0	0	0	0	0	0.01
F09	willow 100	B01	23	0	-	0	+	0	0	0	0	0	0	0	0	0	0.01
		B07	24	0	-	0	+	0	0	0	0	0	0	0	0	0	0.01
F10	miscanthus	B01	25	+	+	-	0	0	0	0	0	0	0	0	0	0	0.6
		B02	26	+	+	-	0	0	0	0	0	0	0	0	0	0	0.24
		B04	27	+	+	-	0	0	0	0	-	0	0	0	0	0	0.06
		B05	28	+	+	-	0	0	0	0	0	+	0	0	0	0	0.89
		B06	29	+	+	-	0	0	0	0	0	0	+	0	0	0	0.83
		B07	30	+	+	-	0	0	0	0	0	0	0	0	0	0	0.76
		B08	31	+	+	-	0	0	0	0	0	0	0	0	0	0	0.26
		B09	32	+	+	-	0	0	0	0	0	0	0	0	0	0	0.68
		B01	33	+	+	-	0	0	0	0	0	0	0	0	0	0	0.53
F11	wheat straw	B02	34	+	+	-	0	0	0	0	0	0	0	0	0	0	0.47
		B03	35	+	+	-	0	0	0	0	0	0	0	0	0	0	0.77
		B04	36	+	+	-	0	0	0	0	-	0	0	0	0	0	0.15
		B05	37	+	+	-	0	0	0	0	0	+	0	0	0	0	0.82
		B06	38	+	+	-	0	0	0	0	0	0	+	0	0	0	0.78
		B08	39	+	+	-	0	0	0	0	0	0	0	0	0	0	0.71
		B09	40	+	+	-	0	0	0	0	0	0	0	0	0	0	0.4
F12	vineyard pruning	B01	41	+	+	-	0	0	0	0	0	0	0	0	0	0	0.01
F13	corn cobs with 20% hay	B01	42	+	0	-	+	0	0	0	0	0	0	0	0	0	0.64

Table 7: S&T results, fuel classification system - Semi-validation set of the proposed qualitative classification system/function for predicting the amount of slag formed i.e. fraction of the bottom ash from the combustion experiments with a particle size >3.15 mm (by sieving).

Fuel	Fuel name	Burner	Case	AC	SiO ₂	CaO	K ₂ O	B01	B02	B03	B04	B05	B06	B07	B08	B09	Time
F01	pine and spruce mixture	B01	1	-	-	+	0	0	0	0	0	0	0	0	0	0	24
F02	stem wood without bark	B01	2	-	-	0	0	0	0	0	0	0	0	0	0	0	24
		B02		-	-	0	0	0	0	0	0	0	0	0	0	0	24
		B04		-	-	0	0	0	0	0	0	0	0	0	0	0	24
		B05		-	-	0	0	0	0	0	0	0	0	0	0	0	24
		B06		-	-	0	0	0	0	0	0	0	+	0	0	0	24
		B07		-	-	0	0	0	0	0	0	0	+	0	0	0	24
		B08		-	-	0	0	0	0	0	0	0	0	0	0	0	24
		B09		-	-	0	0	0	0	0	0	0	0	0	0	+	24
F03	80% hardwood + 20% softwood	B01	3	-	-	+	0	0	0	0	0	0	0	0	0	0	24
F04	bark rich	B01	4	-	-	+	0	0	0	0	0	0	0	0	0	0	24
F05	wood from untreated wastewood	B01	5	+	+	-	-	0	0	0	0	0	0	0	0	0	11
F07	willow spruce 30/70	B01	6	-	-	0	+	0	0	0	0	0	0	0	0	0	24
		B02		-	-	0	+	0	0	0	0	0	0	0	0	0	24
		B03		-	-	0	+	0	0	0	0	0	0	0	0	0	24
		B04		-	-	0	+	0	0	0	0	0	0	0	0	0	24
		B05		-	-	0	+	0	0	0	0	0	0	0	0	0	24
		B06		-	-	0	+	0	0	0	0	0	+	0	0	0	24
		B07		-	-	0	+	0	0	0	0	0	+	0	0	0	24
		B08		-	-	0	+	0	0	0	0	0	0	0	0	0	24
		B09		-	-	0	+	0	0	0	0	0	0	0	0	+	24
F08	willow spruce 60/40	B01	7	-	-	0	0	0	0	0	0	0	0	0	0	0	24
F09	willow 100	B01	8	0	-	0	+	0	0	0	0	0	0	0	0	0	24
		B07		0	-	0	+	0	0	0	0	0	0	0	0	0	24
F10	miscanthus	B01	9	+	+	-	0	0	0	0	0	0	0	0	0	0	5
		B02		+	+	-	0	0	0	0	0	0	0	0	0	0	11
		B04		+	+	-	0	0	0	0	0	0	0	0	0	0	4.3
		B05		+	+	-	0	0	0	0	0	0	0	0	0	0	24
		B06		+	+	-	0	0	0	0	0	0	+	0	0	0	24
		B07		+	+	-	0	0	0	0	0	0	+	0	0	0	24
		B08		+	+	-	0	0	0	0	0	0	0	0	0	0	5.5
		B09		+	+	-	0	0	0	0	0	0	0	0	0	+	24
F11	wheat straw	B01	10	+	+	-	0	0	0	0	0	0	0	0	0	0	2
		B02		+	+	-	0	0	0	0	0	0	0	0	0	0	2
		B03		+	+	-	0	0	0	0	0	0	0	0	0	0	9
		B04		+	+	-	0	0	0	0	0	0	0	0	0	0	4.5
		B05		+	+	-	0	0	0	0	0	0	0	0	0	0	14
		B06		+	+	-	0	0	0	0	0	0	+	0	0	0	12.5
		B08		+	+	-	0	0	0	0	0	0	0	0	0	0	1
		B09		+	+	-	0	0	0	0	0	0	0	0	0	+	24
F12	vineyard pruning	B01	11	0	-	0	0	0	0	0	0	0	0	0	0	0	24
F13	corn cobs with 20% hay	B01	12	+	0	-	+	0	0	0	0	0	0	0	0	0	8.5

Table 8: S&T results, fuel classification system - Semi-validation set of the proposed qualitative classification system/function for predicting the problem arised from slag formation i.e. a matrix of the elapsed time from the combustion experiments

Figure 11: Logos of project consortium



We also would like to higly acknowledge the contributions of:

