report

AshMelT project

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Tables and Figures to the Final Publishable Report

AshMelT Project

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Date	31. December 2014
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Lead beneficiary	BIOENERGY2020+ GmbH
Project coordination	Bioenergy2020+ GmbH
Dissemination level	PU
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Publishable Report - Figures and Tables

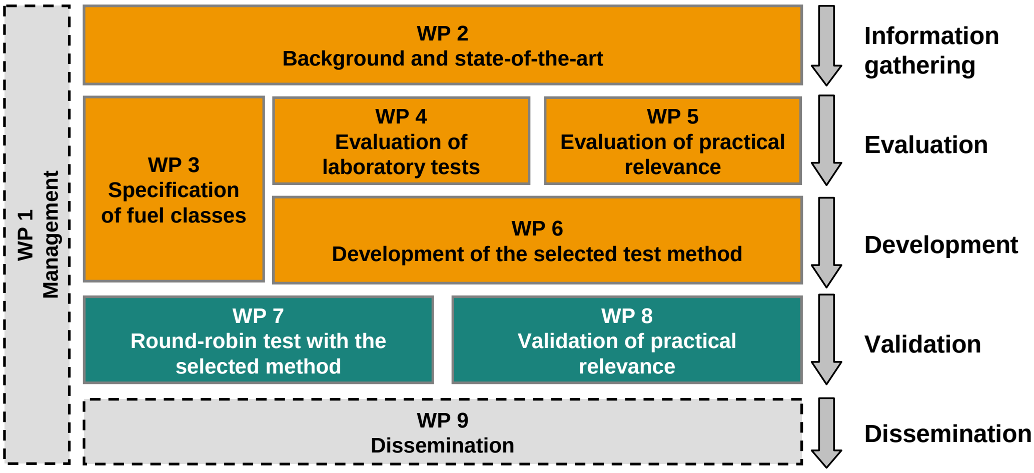


Figure 1: Objectives & Concept - AshMelT project concept and approach

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)

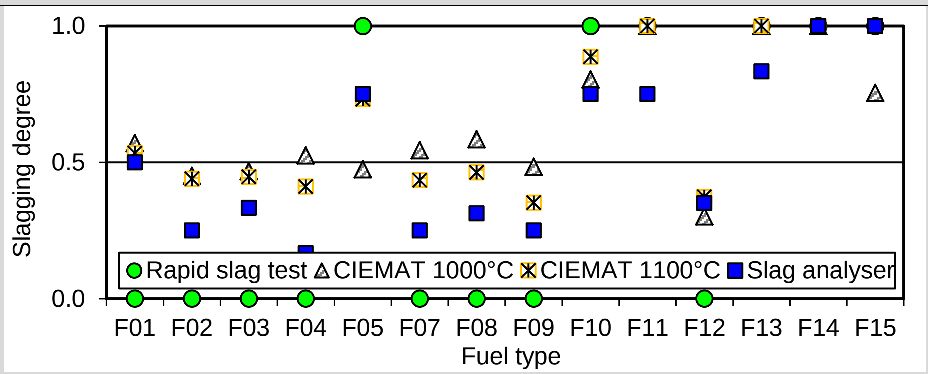
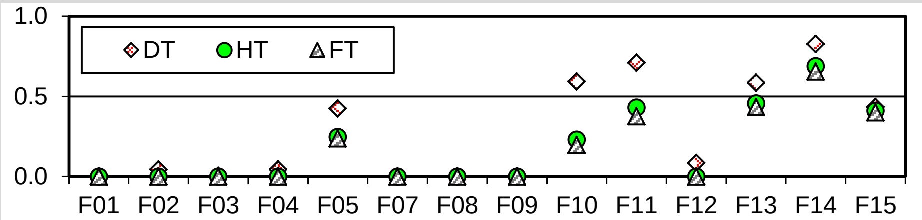
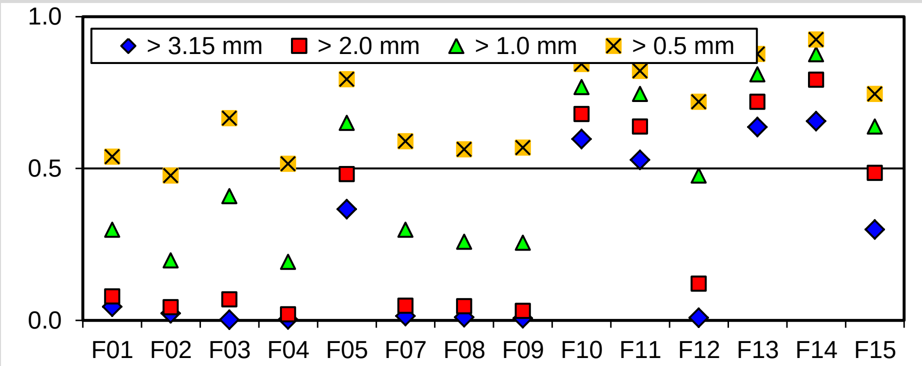
Method	Results
Laboratory tests (Rapid slag test, CIEMAT method, Slag analyser)	
Ash Fusion Test (AFT) (ashing temp. of 550°C)	
Boiler 1 (horizontally moving grate) Here: results of granulometric analysis of residues with several sieves	

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 perfomance	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

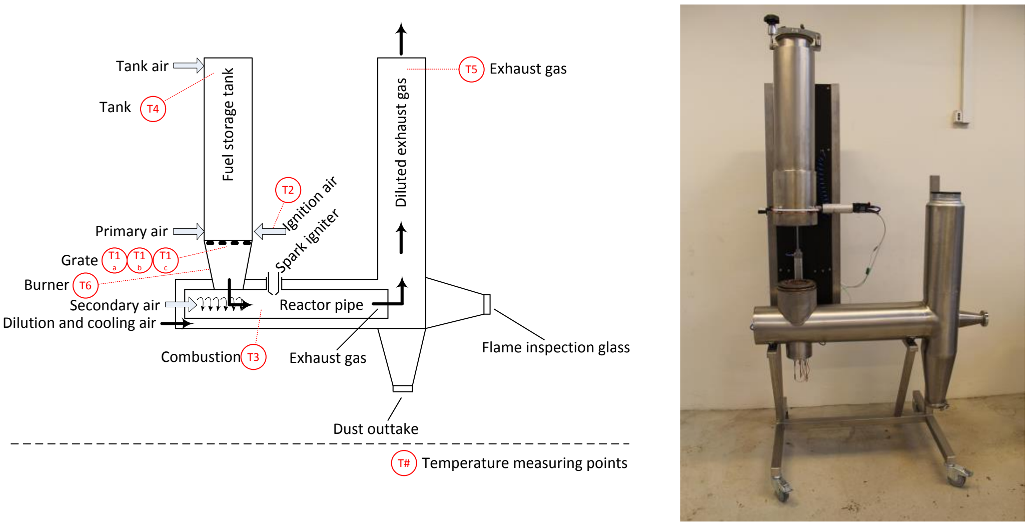


Figure 4: S&T results, method development – Experimental validation- Particle size distribution of all boilers tested in WP5 compared with the average particle size distribution of the slag analyser using the granulometric sieving

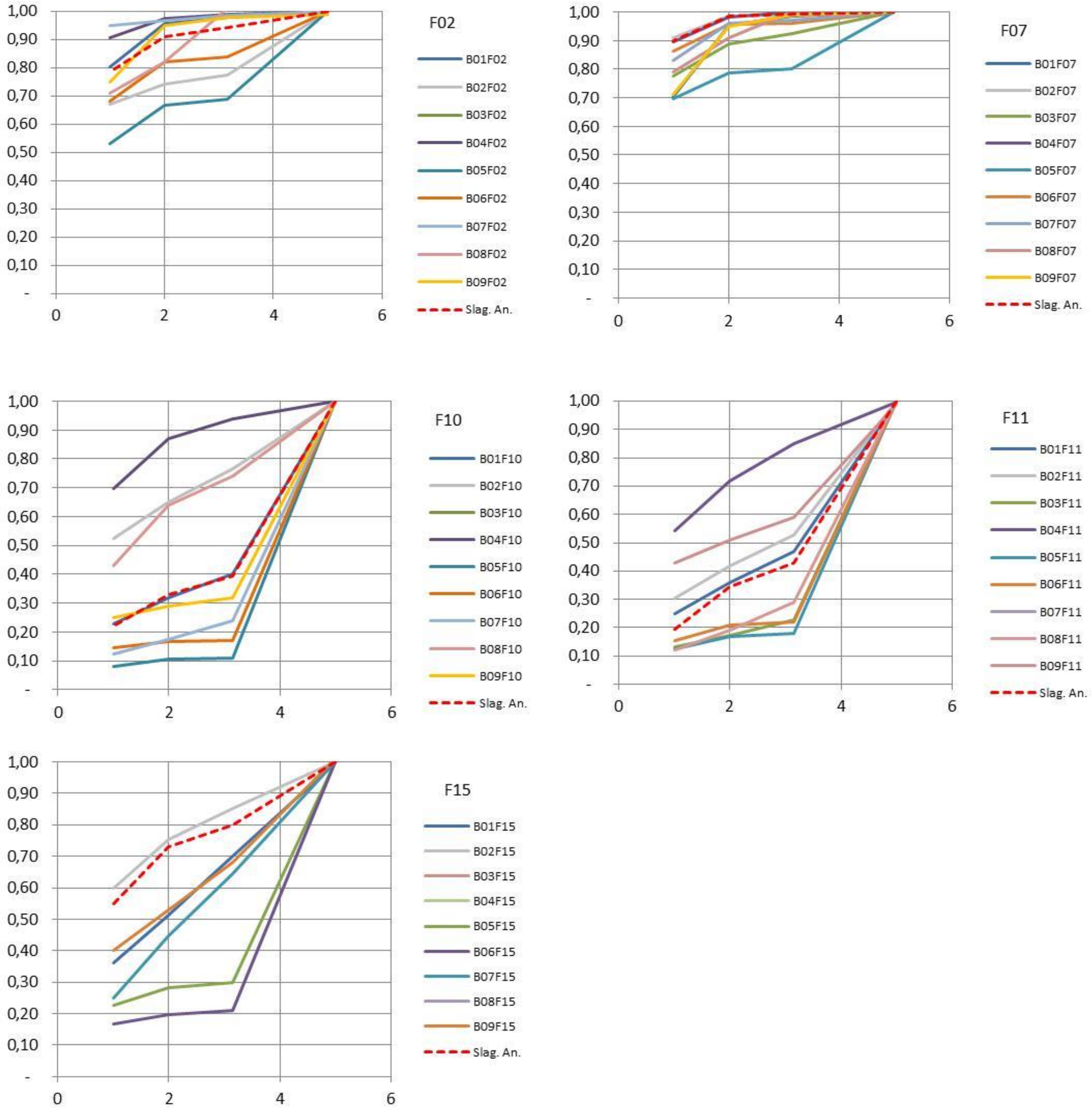
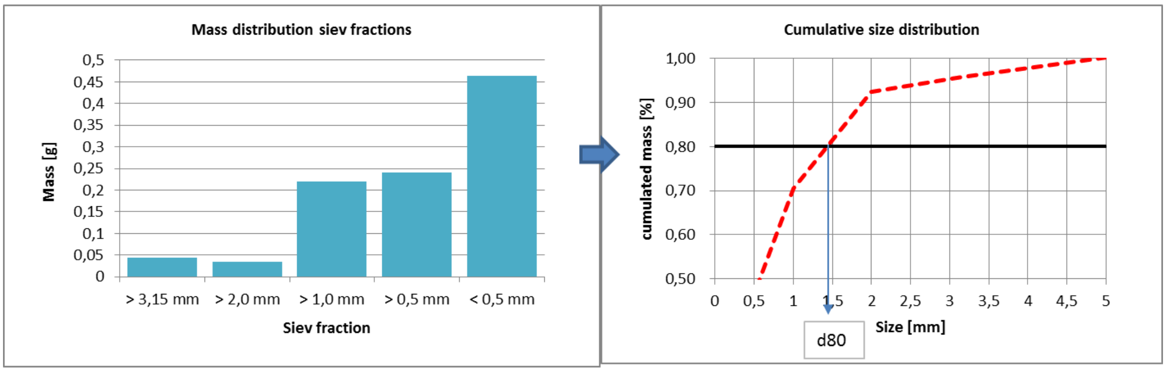


Figure 5: S&T results, method development – illustration of the d80 calculation



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

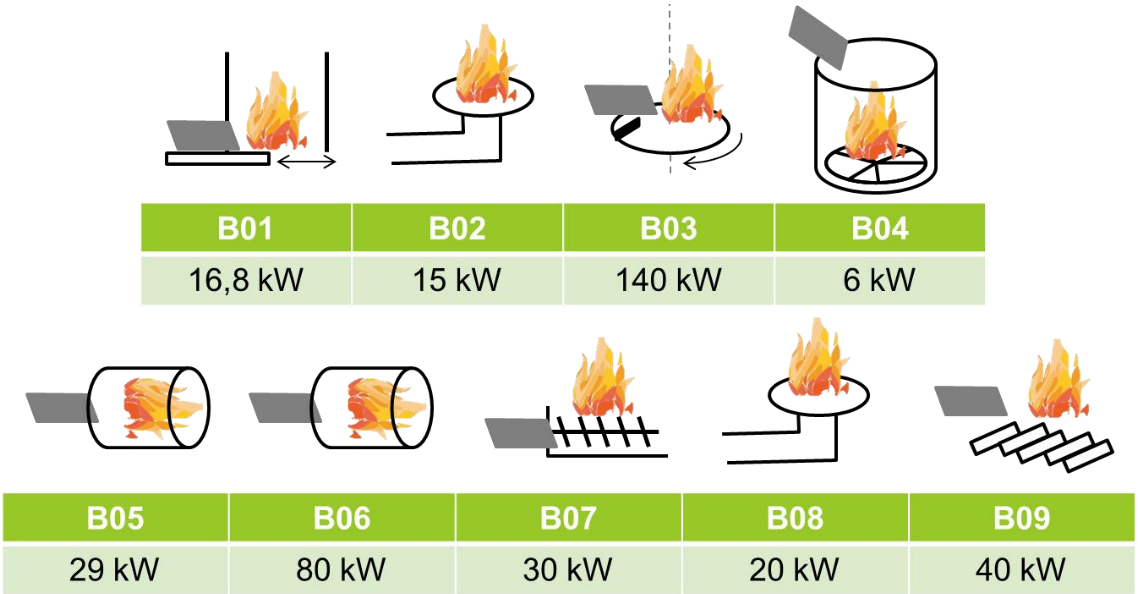


Table 5: S&T results, practical relevance of AshMelT methods - Test fuels for the combustion tests

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 AshMelT methods - Severity versus Applicability

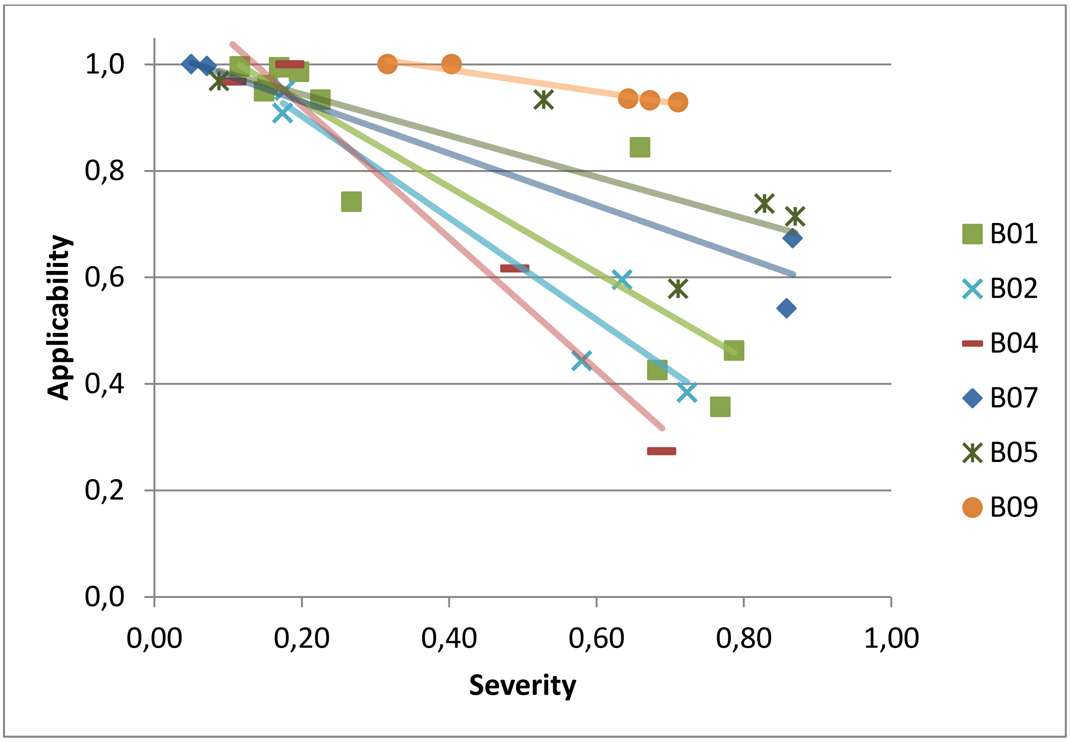


Figure 8: S&T results, practical relevance of AshMelT methods – Severity versus shrinkage starting temperature (SST)

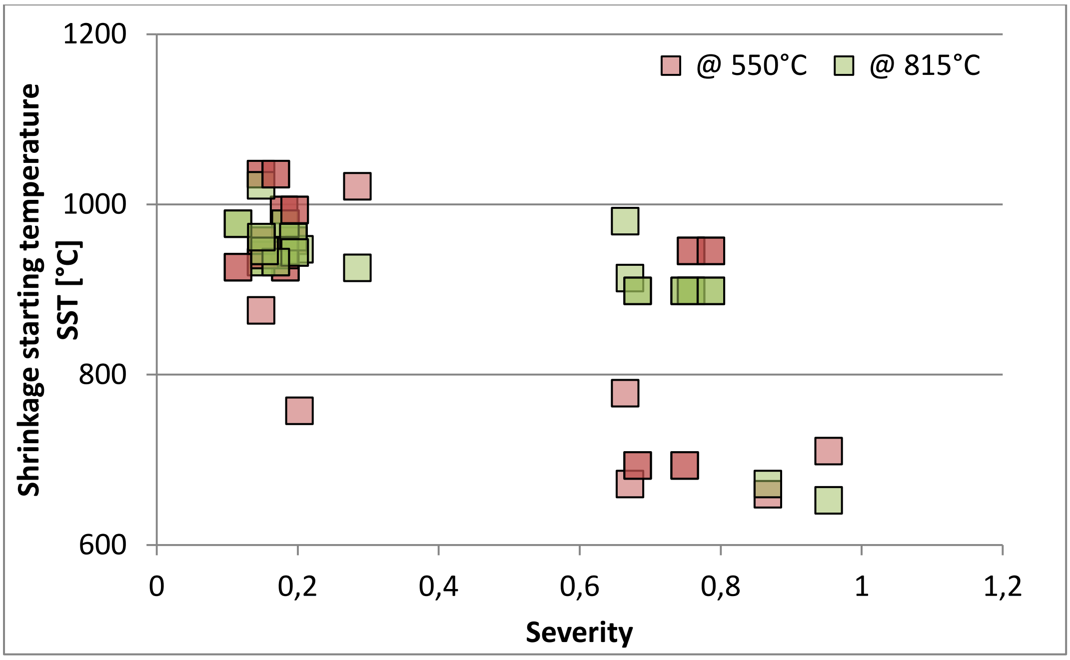


Figure 9: S&T results, practical relevance of AshMelT methods – Severity versus Slag analyser results

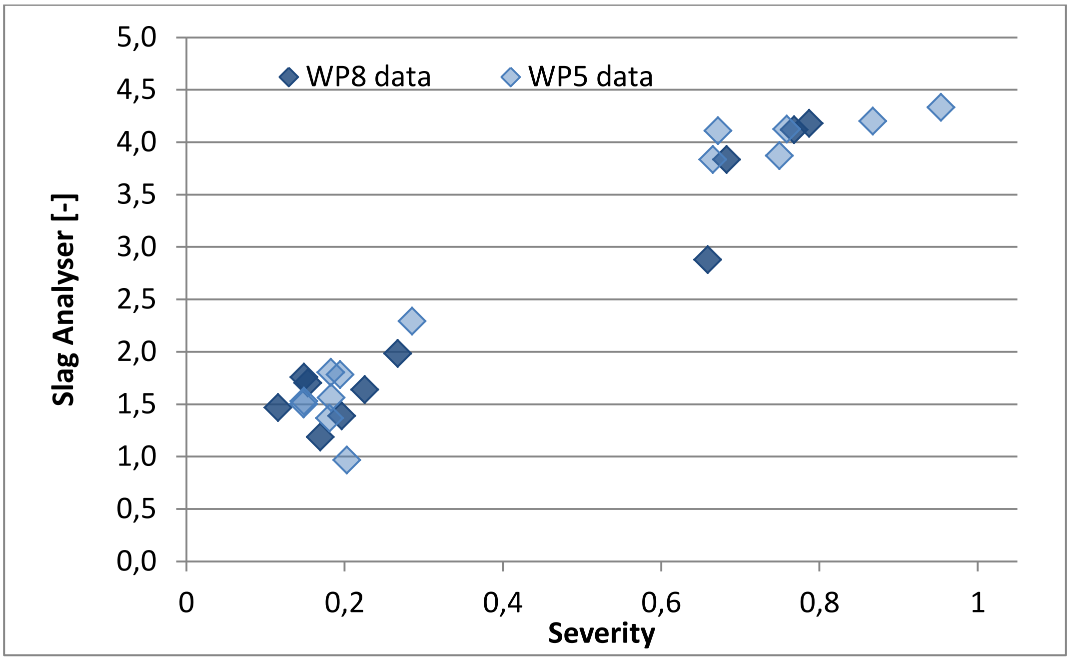
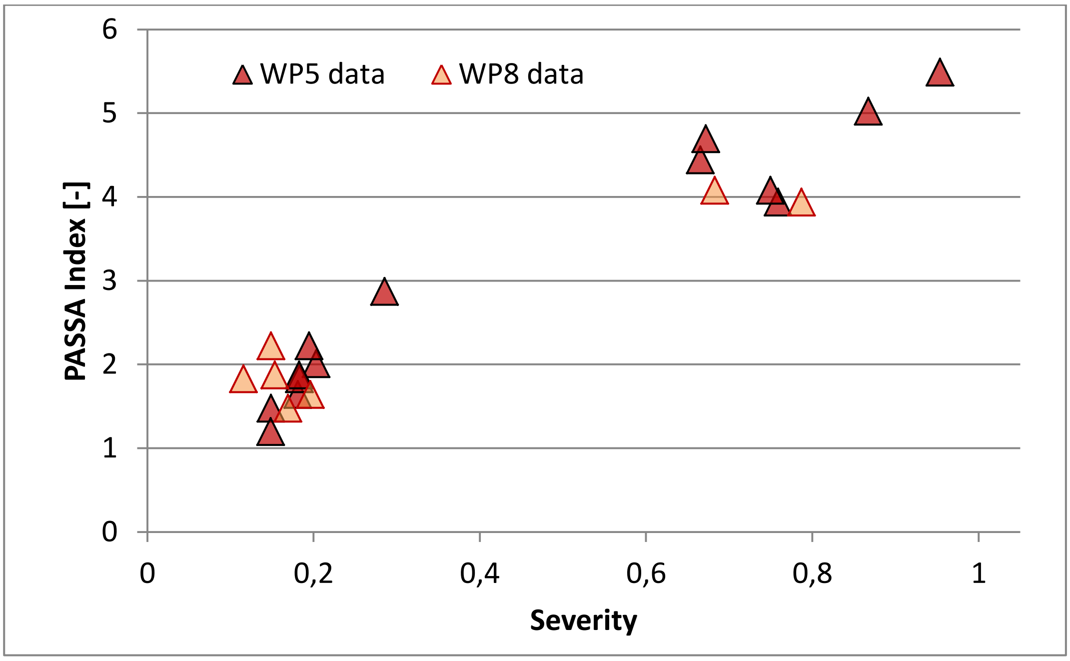


Figure 10: S&T results, practical relevance of AshMelT methods – Severity versus PASSA test results



Limits	**-**	**0**	**+**
K_2O (wt-% in the K_2O+CaO+SiO_2 system)	< 10	10-30	>30
CaO (wt-% in the K_2O+CaO+SiO_2 system)	< 30	30-60	>60
SiO_2 (wt-% in the K_2O+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

Fuel	Fuel name	Burner	Case	AC	SiO_2	CaO	K_2O	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 un-treated 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
F11	wheat straw	B01	33	+	+	-	0	0	0	0	0	0	0	0	0	0	0.53
		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_2O	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: