Management of ashes from co-firing biomass with coal

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Content

- Introduction
- Fly ash 0-50% wood co-combustion
  - Utilization & technical requirements
  - Properties
- Fly ash 100% wood combustion
  - properties
- Fly ash 50-99% wood combustion
  - properties
  - Utilization
- Evaluation and conclusions

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Introduction

- 1982: Vliegasunie founded by Dutch coal-fired power plants
- core business: by-product management
- 1.5 Mton/year ashes and gypsum
- Sources: Dutch power plants)RWE, Vattenfall and Engie)
- Market: North-West Europe
- Since 1995 co-combustion

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Fly ash 0-50% wood co-combustion: Utilization

- Raw material for cement and concrete
  - Kiln feed cement industry
  - Major constituent of blended cement
  - Reactive filler in concrete
- REACh registered
- Covered by EN 450 standard Fly ash for concrete

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Fly ash 0-50% wood co-combustion: technical requirements EN 450 (1/5)

- co-combustion allowed, but:
  - ≤50% m/m wood only (fuel based) or
  - ≤40% m/m Solid Bio Fuels acc EN14588:2010
  - <30% m/m ash based
  - Waste wood excluded !
- Chemical requirements
- Physical requirements
- Performance requirements

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Fly ash 0-50% wood co-combustion: technical requirements EN 450 (2/5)

- Influence on initial hydration of cement
- Maximum retardation of inital setting of cement paste with fly ash 2x setting of cement only

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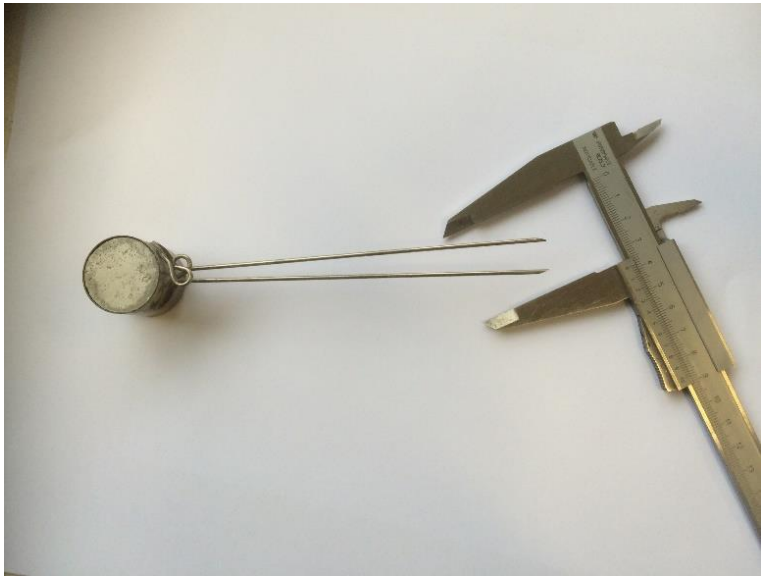
Fly ash 0-50% wood co-combustion: technical requirements EN 450 (3/5)

- Expansion due to hydration of CaO to Ca(OH)2
- Measured with LeChatelier test
- max expansion 10 mm



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Fly ash 0-50% wood co-combustion: technical requirements EN 450 (4/5)

- Contribution to strength development of mortar and concrete
- Activity index = $\sigma'_{cfm} / \sigma'_{cm} * 100$ [%]
- Whereby:
  - σ'cfm = compressive strength of a standard mortar whereby 25% of cement has been replaced by fly ash to be tested
  - σ'cm = compressive strength of a standard mortar with Portland cement as binder

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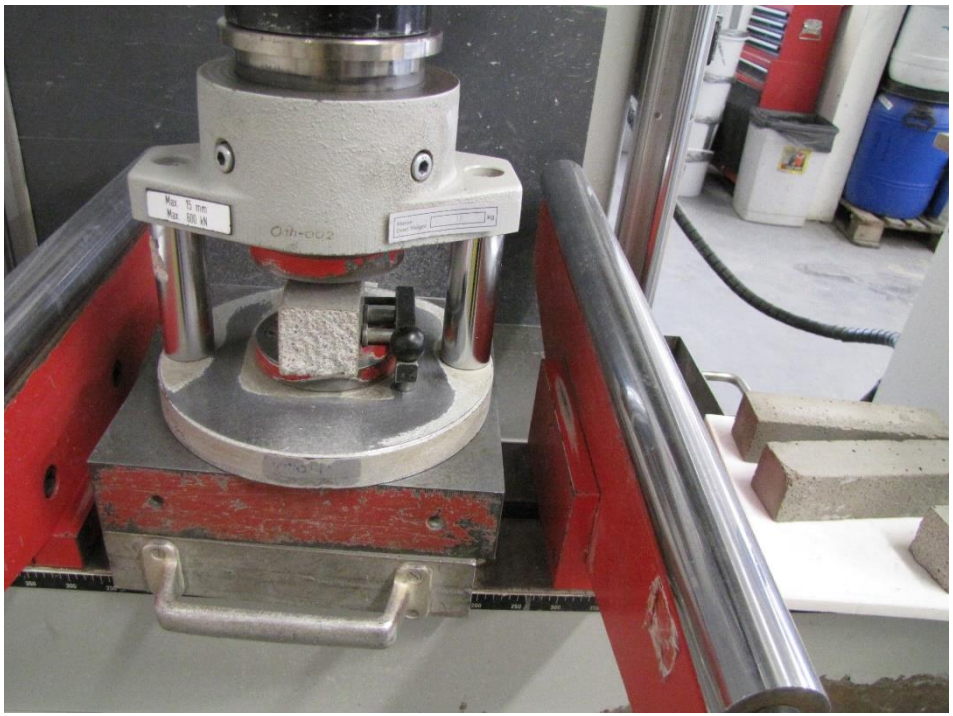
Fly ash 0-50% wood co-combustion: technical requirements EN 450 (5/5)

- After 28 days: >75%
- After 91 days: >85%



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Fly ash 0-50% wood co-combustion: properties (1/3)

power plant		A-E	D	D	D	E	EN 450
co-combustion fuel based	% m/m	0	33	37	50	50	
co-combustion ash based	% m/m	0	1,0	1,9	5,3	?	
sum SiO_2+Al_2O_3+Fe_2O_3	% m/m	89±2,3	89,7	87,7	87,85	83,2	≥70
Reactive SiO2	% m/m	42±6	38	35	40	40	≥25
Loss on Ignition	% m/m	5,4±±2,3	3,6	1,6	3,01	3,04	≤5,0
CaO free	% m/m	0,31±0,23	1,19	0,87	0,28	1,42	≤2,5*
MgO	% m/m	1,5±0,45	1,13	2,00	1,88	2,7	≤4,0
SO_3	% m/m	0,68±0,18	0,89	0,72	0,91	0,86	≤3,0
Na2O eq	% m/m	1,6±0,54	1,38	0,76	2,48	3,5	≤5,0
chloride	% m/m	<0,01	<0,01	<0,01		<0,01	≤0,10
CaO	% m/m	4,5±1,7	6,9	6,3	4,7	5,6	≤10,0
P_2O_5	% m/m	0,77±0,40	1,18	0,8	0,76	0,45	≤5,0
morphology	-	mainly spherical particles					
fraction > 45um	% m/m	22±2,3	21	14	22,2	12,5	<40

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Fly ash 0-50% wood co-combustion: properties (2/3)

power plant		REF	AC9	AC9	AC9	CG13	EN 450
initial setting ref	min.		152	185	167	199	2C
initial setting fly ash	min.		173	220	211	253	
activity index 28 days	%	80±5,6	85	82	83	86	>75
activity index 91 days	%	93±6,5	91	97	105	97	>85
soundness	mm		2		nd	2	≤10

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Fly ash 0-50% wood co-combustion: properties (3/3)

power plant	D	D	D	E
co-combustion fuel based	33	37	50	50
co-combustion ash based	1,0	1,9	5,3	?
always present				
Amorphous phases***	yes	yes	yes	yes
Unburnt matter*	yes	yes	yes	yes
nearly always present				
Anhydrite				
Free CaO**		yes	yes	yes
Quartz		yes	yes	yes
Hematite	yes			possible
Mullite	yes	yes	yes	yes
sometimes present				
Calcite				
Magnetite				
Corund				
incidentally present				
Perclase				
Silimanite				
Rutile				
feldspar		possible	possible	

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Fly ash 100% wood combustion: properties (1/4)

power plant		F	F	F	EN 450
sum SiO_2+Al_2O_3+Fe_2O_3	% m/m	36,9	27,5	32,1	≥70
Reactive SiO2	% m/m				≥25
Loss on Ignition	% m/m	10,26	11,21	10,90	≤5,0
CaO free	% m/m	6,10	10,30	8,90	≤2,5*
MgO	% m/m	5,65	5,67	4,79	≤4,0
SO_3	% m/m	5,78	4,20	3,55	≤3,0
Na2O eq	% m/m	9,3	8,6	7,6	≤5,0
chloride	% m/m	0,42	0,21	0,16	≤0,10
CaO	% m/m	29,68	32,63	29,92	≤10,0
P_2O_5	% m/m	2,86	2,93	2,54	≤5,0
morphology		agglomerates			mainly spherical
fraction > 45um	% m/m			28	<40

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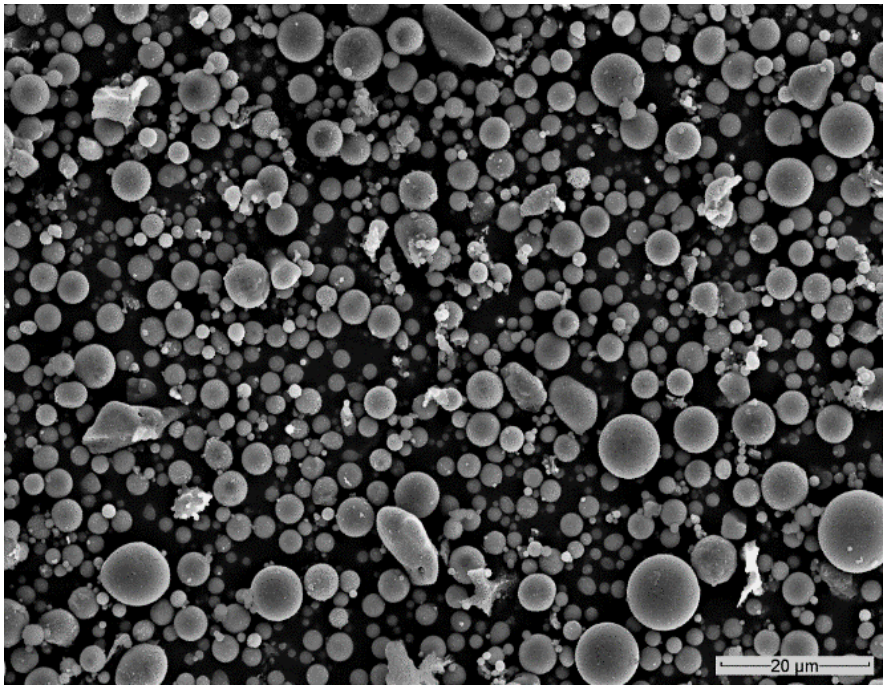
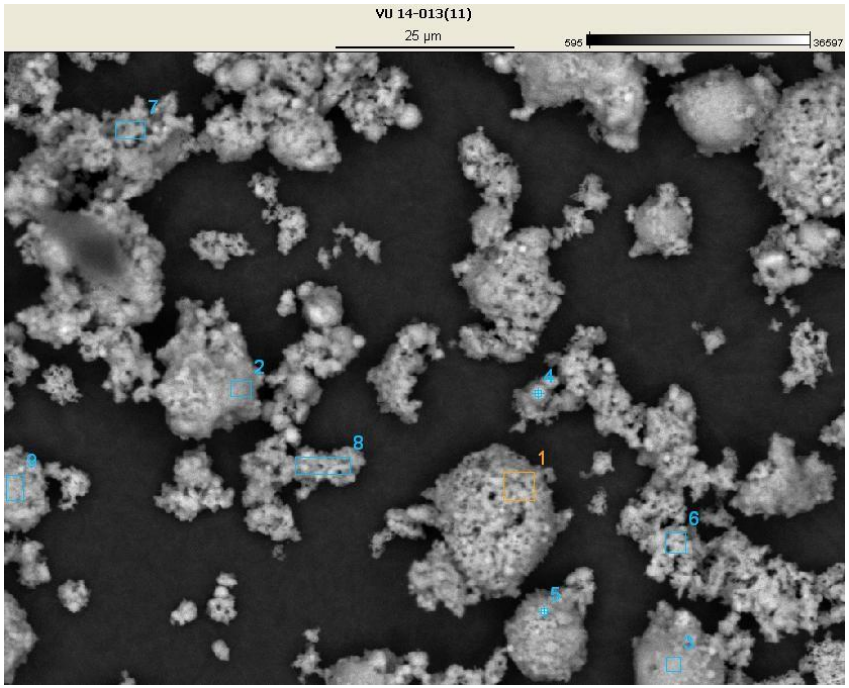
Fly ash 100% wood combustion: properties (2/4)





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Fly ash 100% wood combustion: properties (3/4)

Mineral	Formulae	WD100-1		WD100-2		WD100-3	
		QXRD	XRD	QXRD	XRD	QXRD	XRD
Quartz	SiO_2	4.3	yes	3.8	yes	6.1	Yes
Tridymite	SiO_2	0.3	-	0.2	-	-	-
Dicalcium silicate α-C2S	Ca_2SiO_4	6.0	-	4.0	-	4.7	-
Calcite	$CaCO_3$	6.4	yes	7.0	Yes	6.6	Yes
Lime	CaO	6.1	yes	11.0	Yes	8.9	Yes
Periclase	MgO	3.5	yes?	4.1	-	3.1	-
Srebrodolskite	$Ca_2Fe_2O_5$	3.4	-	3.0	-	2.3	-
Tricalcium aluminate	$Ca_3Al_2O_6$	3.2	-	0.8	-	0.7	-
Portlandite	$Ca(OH)_2$	1.3	yes	2.1	-	0.9	-
Anhydrite	$CaSO_4$	0.4	-	0.4	-	0.5	-
Alunite	$KAl_3(OH)_6(SO4)_2$	0.6	-	0.5	-	0.3	-
Arcanite	K_2SO_4	7.1	yes	7.2	Yes	6.3	Yes
Langbeinite	$K_2Mg_2(SO_4)_3$	1.0	-	0.6	-	0.7	-
Sylvine	KCl	1.7	yes	0.8	-	1.4	-
Merwinite	$Ca_3Mg(SiO_4)_2$	-	-	6.4	-	5.5	-
Anatase	TiO_2	-	-	0.2	-	0.3	-
Amorphous		54.7	-	47.9	-	51.2	-

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Fly ash 100% wood combustion: properties (4/4)

	Unit	F	Fg	F	F	Eis
Initial set ref	min.	140	140	150	150	-
Initial set	min.	10	10	10	5	-
28 days activity inde	%	61	61	54	56	75
91 days activity inde	%	68		62	63	85
Soundness	mm	31	9	74	77	≤ 10

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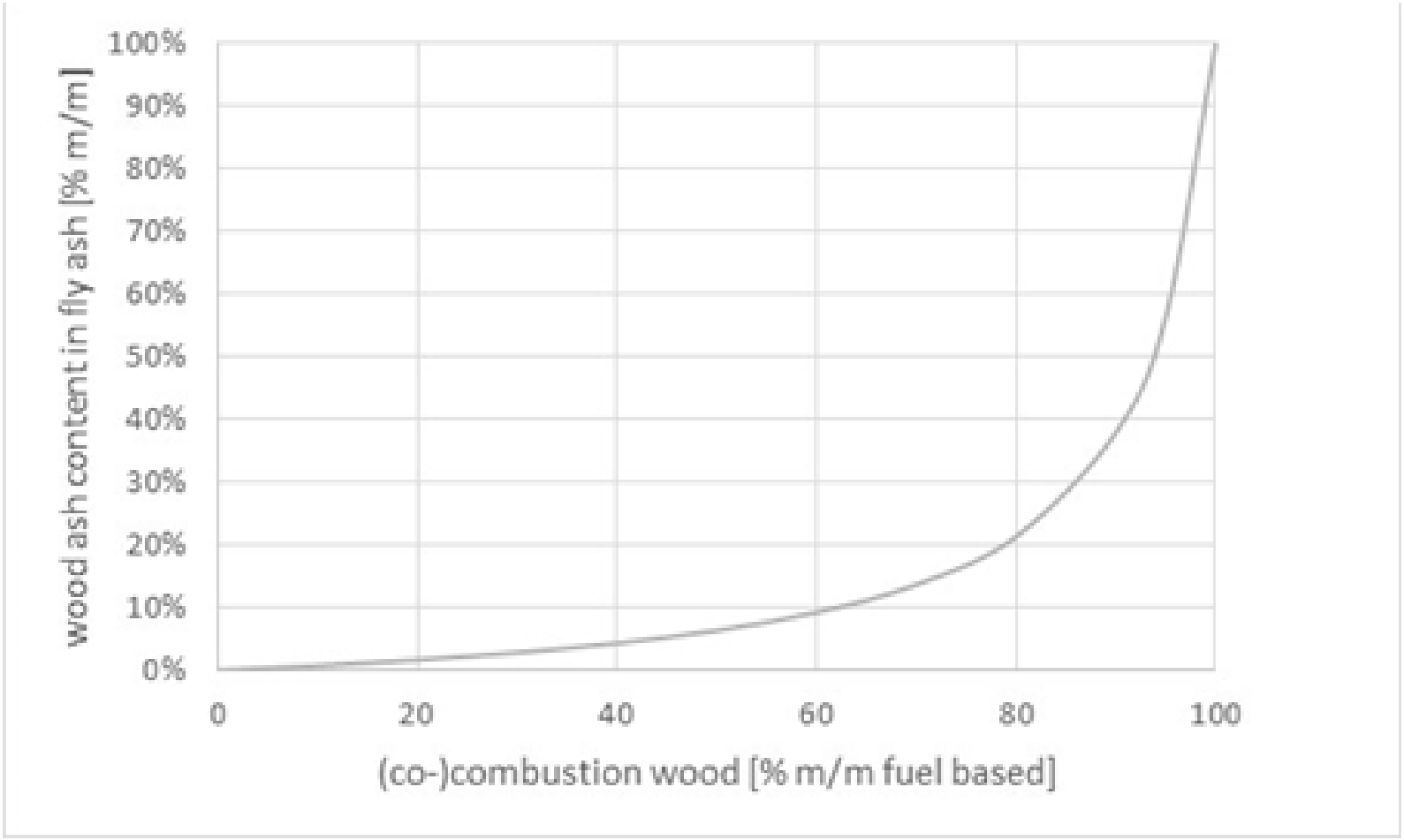
Fly ash 50-99% wood combustion: properties



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Fly ash 50-99% wood combustion: properties (1/4)

- Wood firing 50-99%: no experience in NL
- Experience in DK with co-firing fly ash to wood
- Theoretical appraoch by calculating
- Using concept of relative enrichment factors
  - Based on KEMA TRACE model®
  - Modified RE-factors for wood firing
  - Derived relation between potassium and sulphur binding

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Fly ash 50-99% wood combustion: properties (2/4)

- $C_{ash}=RE*[C_{fuel}/AFM]*100$
- Where:
  - RE = relative enrichment factor of a specific element
  - C_{ash} = concentration of a specific element in fly ash
  - C_{fuel} = concentration of a specific element in fuel
  - AFM = amount of ash forming matter of the fuel [% m/m]

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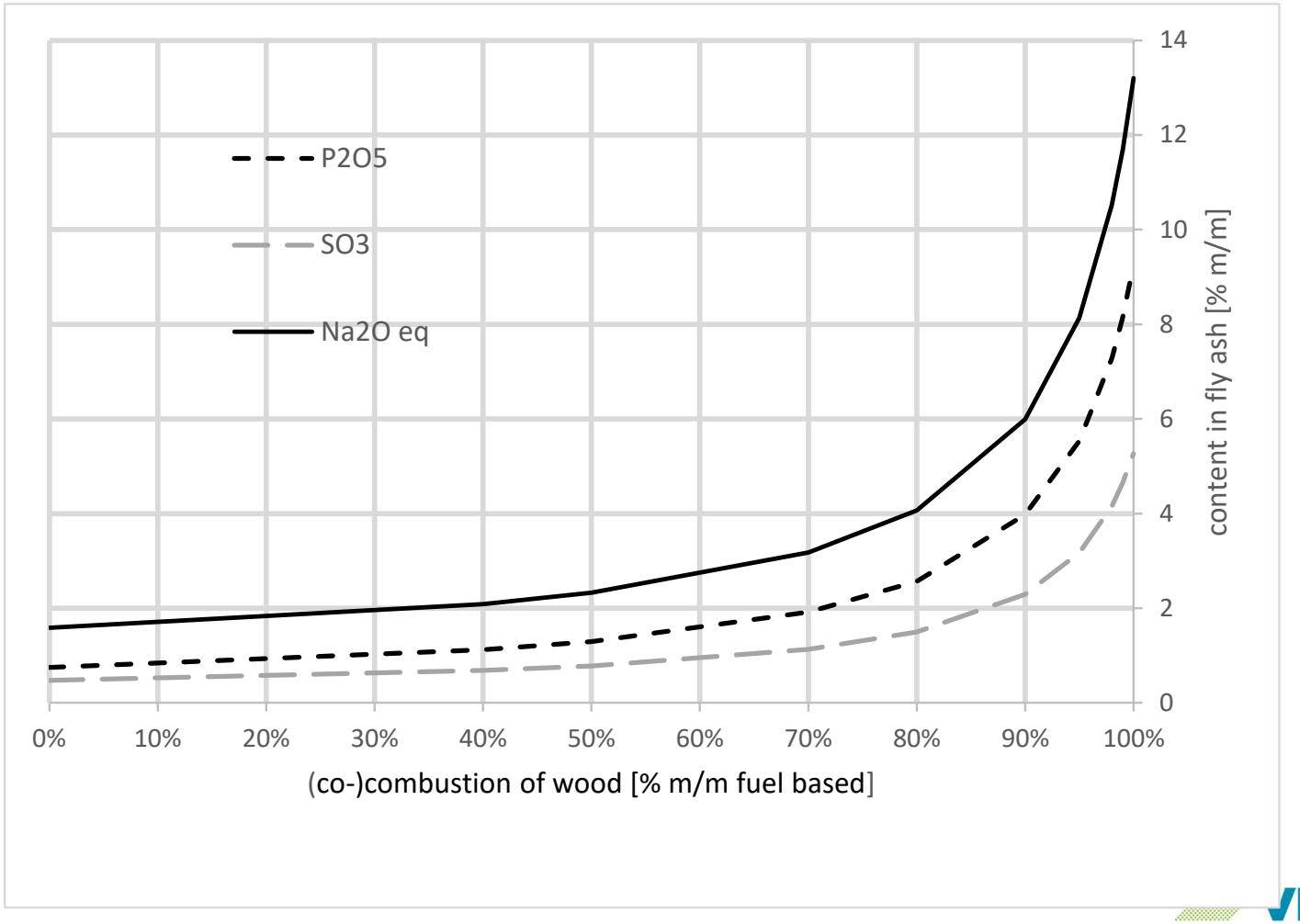
Fly ash 50-99% wood combustion: properties (3/4)



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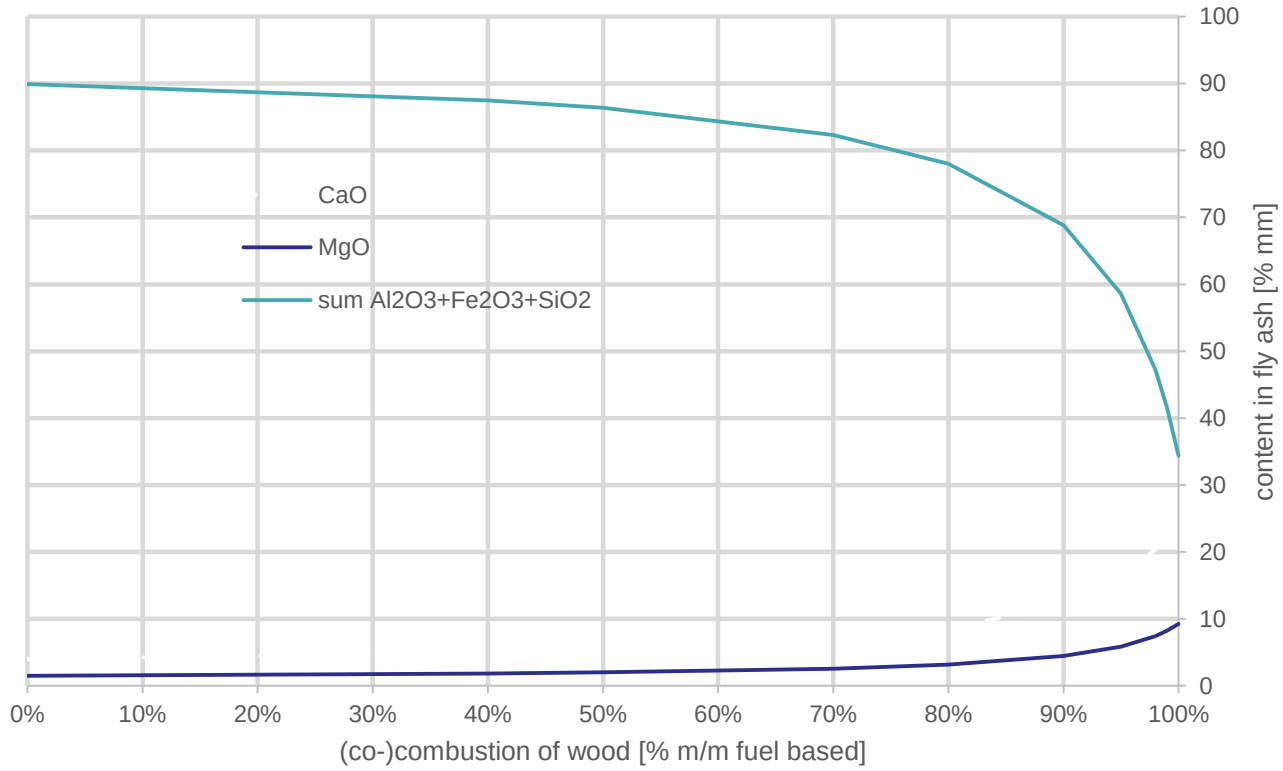
Fly ash 50-99% wood combustion: properties (4/4)



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Fly ash 50-99% wood combustion: utilization (1/4)

- Up to ca 80% wood firing fly ash suitable for concrete as pozzolanic filler (averages!)
- Trade name: BioCoal fly ash (50-ca 80%)
- European Assesment Document in preparation
  - practically same requirements
  - Maximum 45% biomass co-firing ash based

Fly ash 50-99% wood combustion: utilization (2/4)

- Non-structural concrete (not mentioned asfiller in concrete standards)
- Long-term goal: structural concrete (if experiences are good)

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Fly ash 50-99% wood combustion: utilization (3/4)

- Above ca 80% m/m wood
- Only suitable for low quality concrete
- Other applictions:
  - Asphaltic filler
  - Road construction
  - Sand-lime bricks
- Addition of coal fly ash beneficial not only for combustion process but also for fly ash quality!

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Conclusions (1/2)

- 0-50% co-combusion of wood and other biomass:
  - well investigated and understood
  - Covered by technical standards
- 50-ca 80% wood combustion:
  - Opportunity: fly ash filler for (non-structural) concrete
  - Knowledge and applications to be developed

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Conclusions

- 80-99% wood combustion
  - Low grade concrete and other applications
  - Knowledge and applications to be developed

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Thank you for your attention!