ÅBO AKADEMI 100 YEARS;
PRESENT RESEARCH

Markus Engblom, Åbo Akademi

Current Recovery Boiler Research at Åbo Akademi

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The research strategy of the Combustion and Materials Chemistry research group at Åbo Akademi is to provide expertise on the detailed knowledge of chemistry in high-temperature processes and properties of high-temperature-made materials. Our main research endeavors are foremost in bioenergy and biomedicine, with a wider outreach to clean-tech and circular economy. Management of material streams and emissions, treatment and recycling of different waste streams that contain inorganic materials in energy efficient and environmentally friendly manner are essential topics in our research.

Within the bioenergy field, our research includes characterizing the composition and behavior of different biomasses and waste-derived fuels, modeling of combustion processes, measurement of emissions to the atmosphere, and development of a generic understanding of the interactions between the materials in the combustion devices, the fuels and their ashes.

This presentation focuses on the recent research activities relevant for black liquor recovery boilers, with special focus on the on-going research done in close collaboration with the Finnish Recovery Boiler Committee. Recent work concerning the following topics are discussed:

i) Non-process elements in Finnish pulp mills,
ii) Alkali chloride enrichment at the steel surface of superheaters,
iii) Thermal-NOx

SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Åbo Akademi

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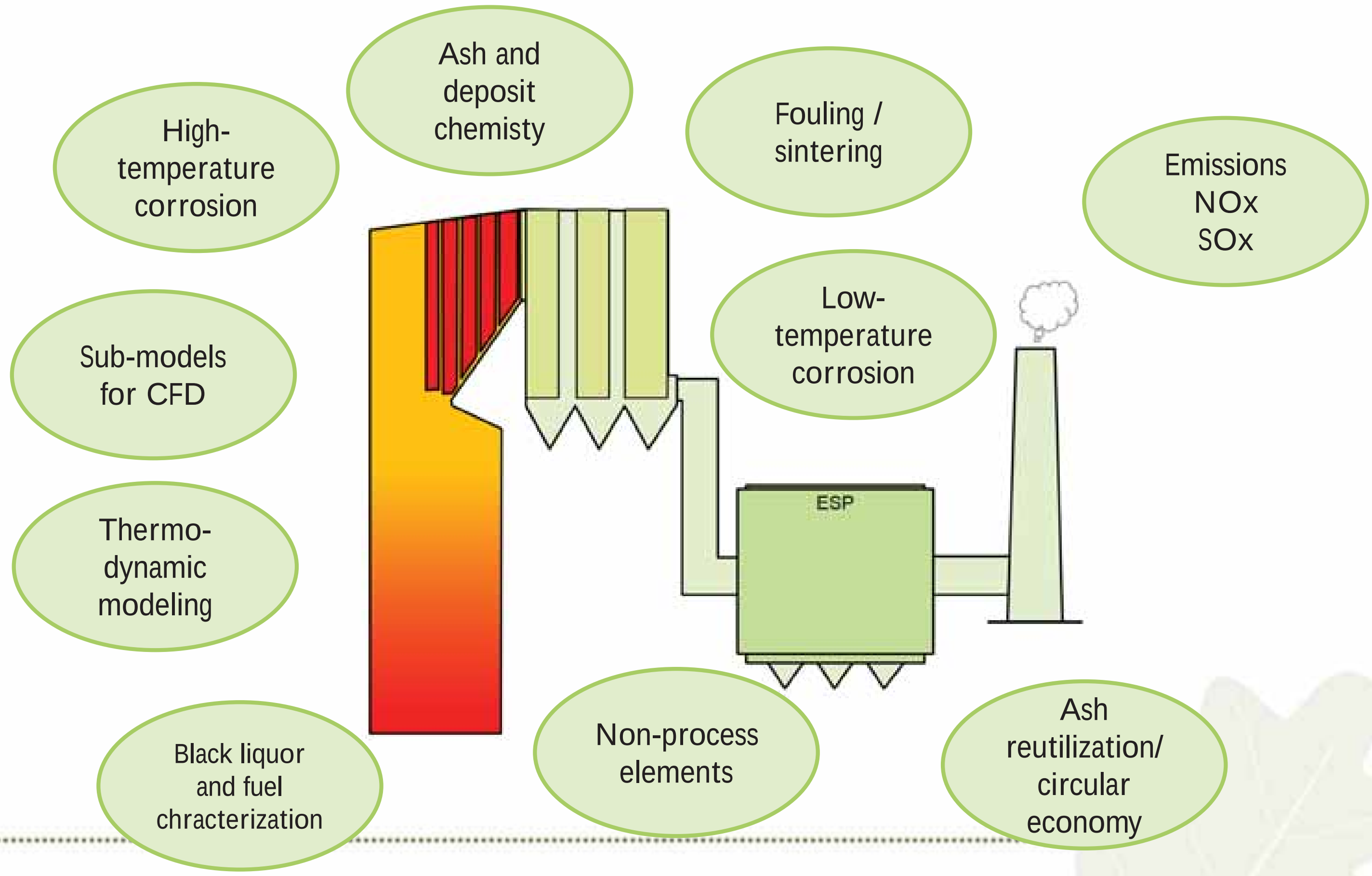
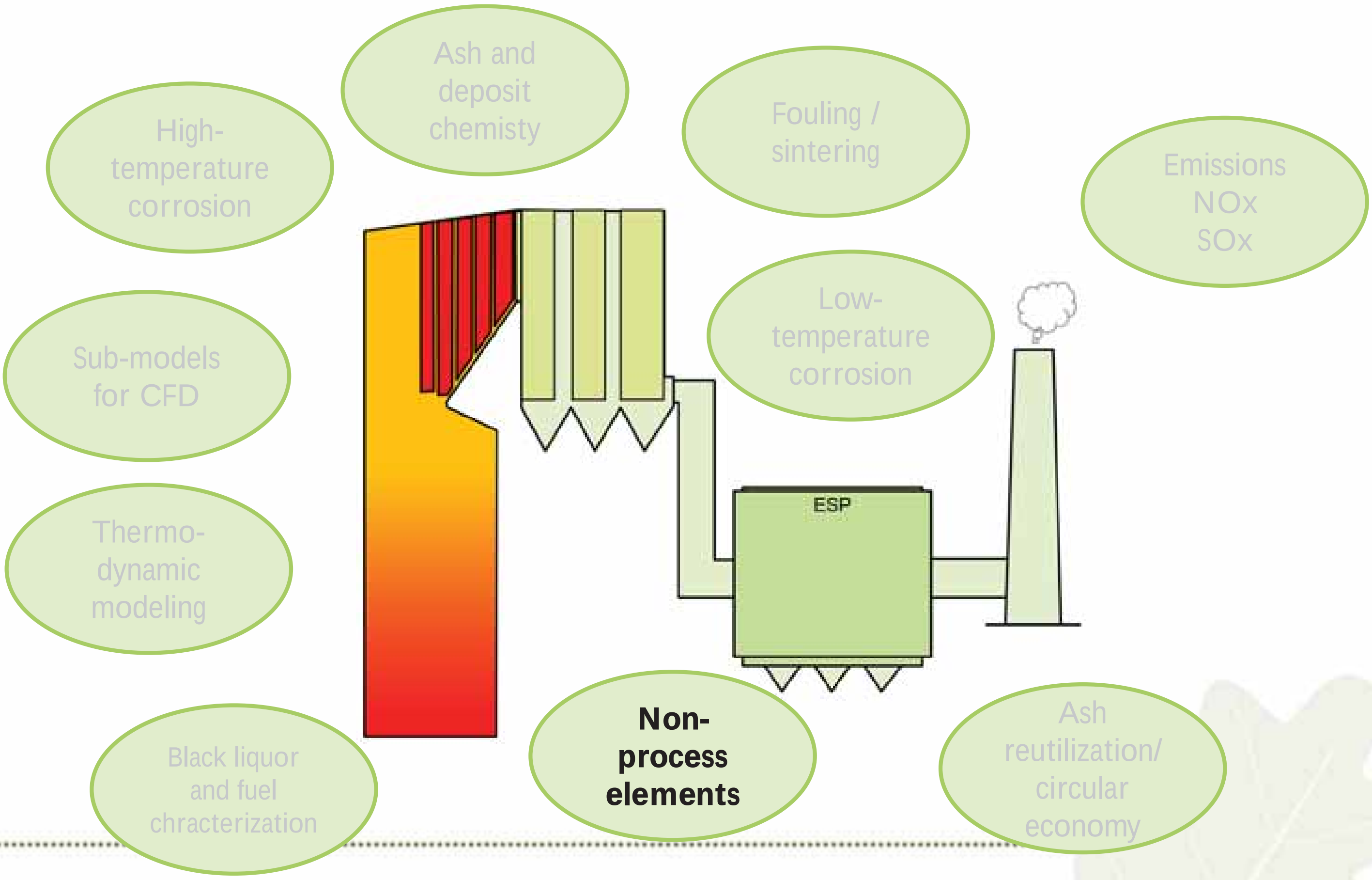
Mikko Hupa

Åbo Akademi recovery boiler research areas



Åbo Akademi recovery boiler research areas



Non-process elements in Finnish Kraft pulp mills

- Topic suggested at Soodakattilapäivä 2017
- Project initiative by Lipeätyöryhmä
- MSc thesis by Camilla Karlemo
  - *”Non-process elements in the recovery cycle of six Finnish Kraft pulp mills”*
  - 6 pulp mills
  - 7 sampling points in recovery cycle
  - Al, Si, Ca, P, Mg, Mn, Cl, K, (Na, S)

Non-process elements in the recovery cycle of six Finnish Kraft pulp mills

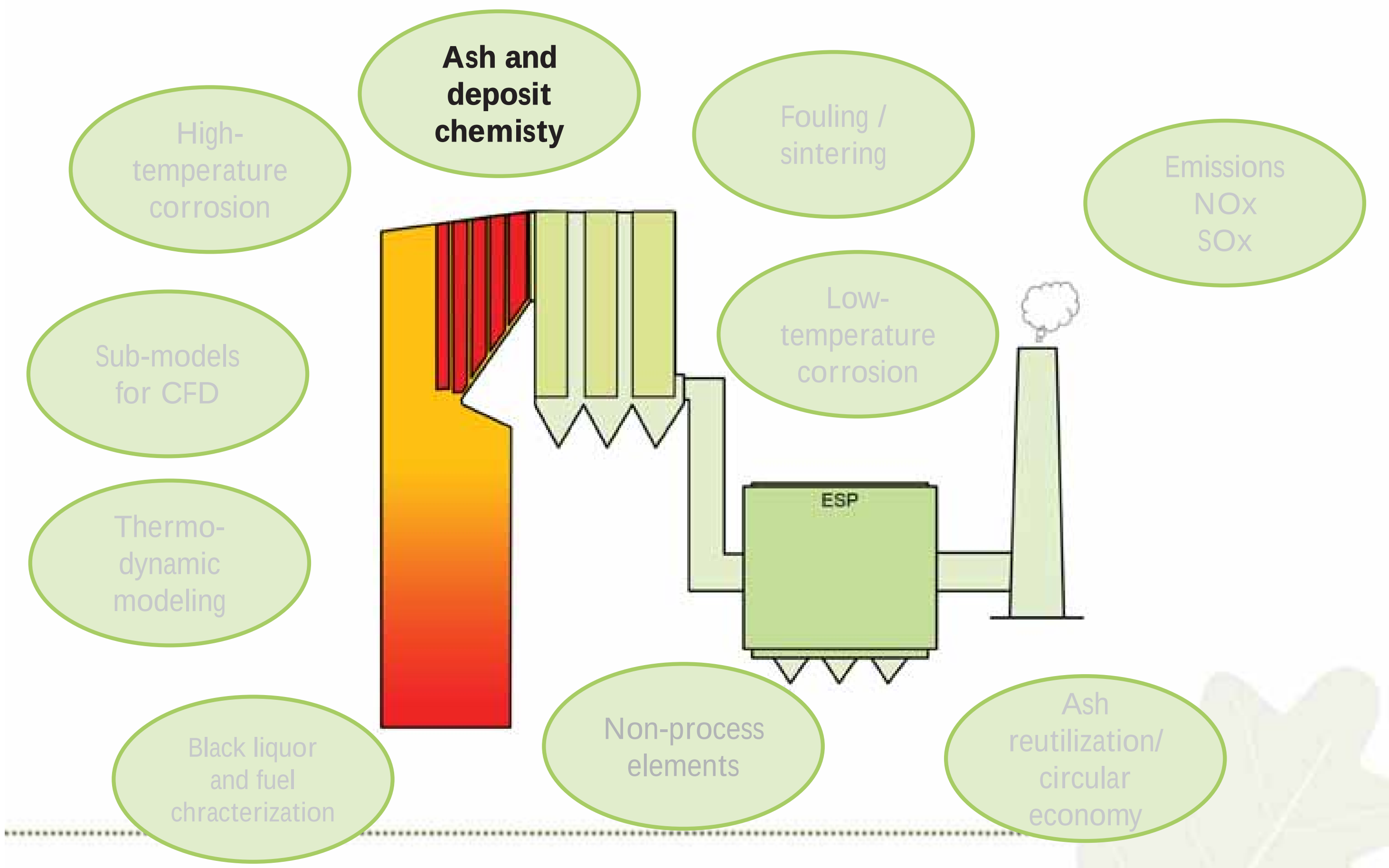
- A special Thank You! to
  - Lipeätyöryhmä
    - Antti Tikkanen, Aino Vettenranta, Esa Vakkilainen, Jorma Torniainen, Jouni Hiltunen, Klaus Niemilä, Markus Nieminen, Sami Metiäinen, Teppo Pakarinen, Timo Saarinen, Toni Orava, Tuuli Oljakka, Ville Korhonen
  - AN, AR, EH, IL, KP, MK, MV, TF
    at the mills A, B, C, D, E, F – sampling, visits, discussions,...
  - Esa Vakkilainen – mill balances
  - Jorma Torniainen – analyses
  - Antti Tikkanen – planning, mill contacts, reading/commenting thesis text ,...

How have the NPE levels changed in Finnish pulp mills in two decades ?

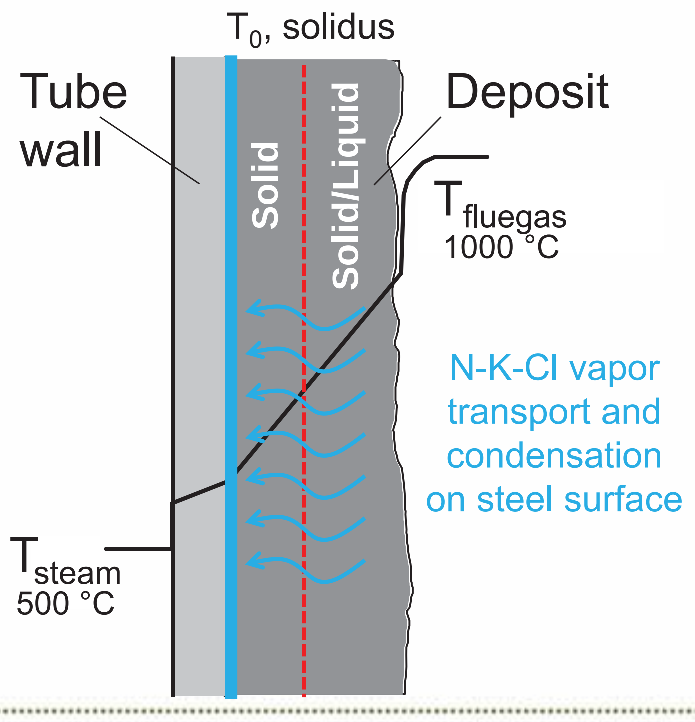
		Al *	Si	Ca	P	Mg	Mn	Cl	K
Weak BL	Older FIN	32	277	156	84	129	68	2351	18969
	FIN 2018	39	340	132	72	135	49	1606	19359
	p-value	0.277	0.269	0.086	**0.007**	0.696	**5.64E-08**	**0.003**	0.804
As-fired BL	Older FIN	33	284	219	71	154	1600	27800	
	FIN 2018	48	324	254	108	206	2376	24800	
	p-value	0.227	0.345	0.586	**0.002**	0.236	0.140	0.532	
ESP ash	Older FIN	6	105	77	25	46		8200	52863
	FIN 2018	15	164	129	44	93		8316	44731
	p-value	**0.014**	**0.037**	**0.020**	**0.022**	**1.30E-05**		0.924	0.240
Green liquor	Older FIN	10	164	11	31	2	5		9788
	FIN 2018	10	152	9	48	2	2		9793
	p-value	0.942	0.597	0.740	**6.17E-05**	0.954	**0.016**		0.997
White liquor	Older FIN	17	153	26	13	0.9	4	1250	8194
	FIN 2018	15	158	17	16	0.6	3	722	10052
	p-value	0.641	0.797	0.112	**0.028**	**0.036**	**0.008**	**8.73E-05**	**0.042**
Lime mud	Older FIN	287	1155	381889	6959	6987	379		378
	FIN 2018	471	827	382083	7366	4104	255		231
	p-value	0.054	**0.011**	0.989	0.784	0.365	0.096		0.477
GL dregs	Older FIN	3881	6914	174667	2315	33812	16150		7013
	FIN 2018	6618	8265	117118	1001	35937	11638		11616
	p-value	**0.044**	0.625	0.094	0.314	0.848	0.355		0.265

Camilla Karlemo, MSc thesis 2019 "Non-process elements in the recovery cycle of six Finnish Kraft pulp mills"

Åbo Akademi recovery boiler research areas



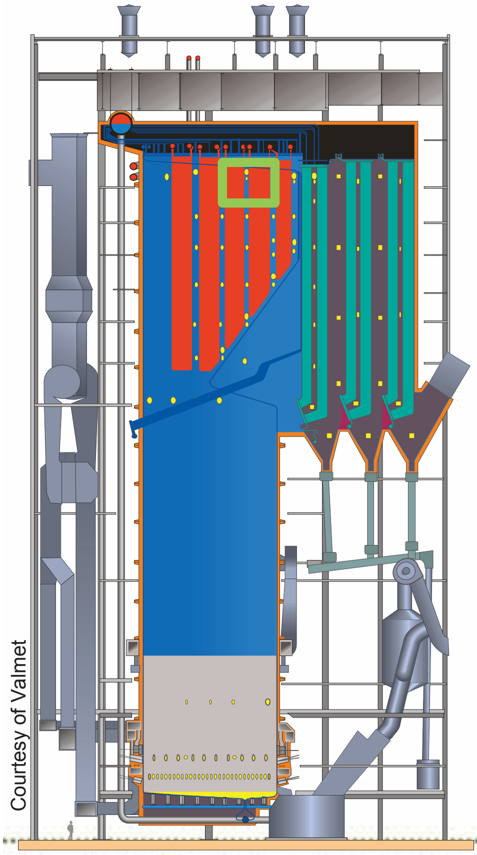
Alkali chloride enrichment at the steel surface of superheaters

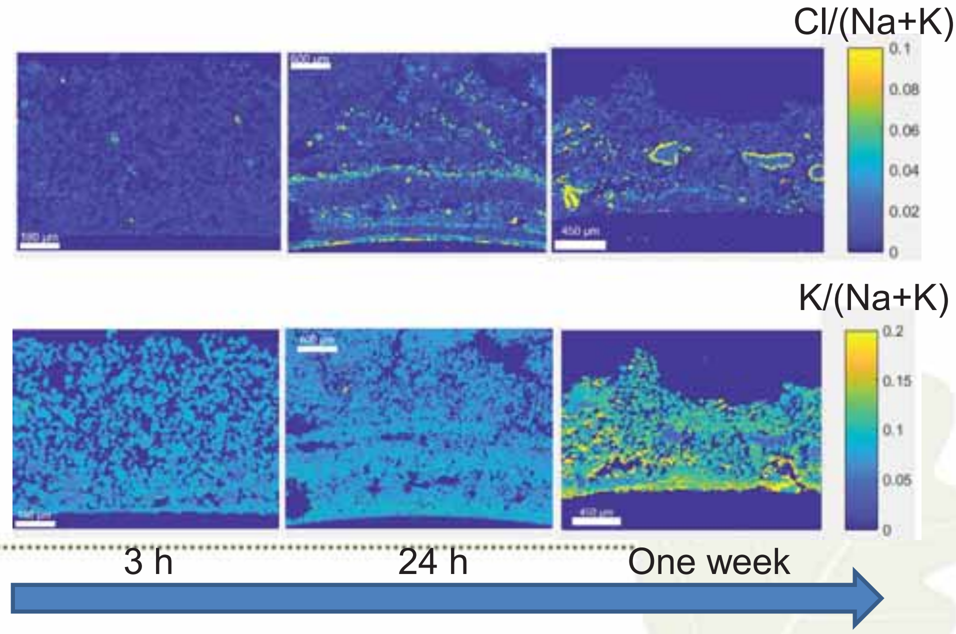


Superheater deposit

- Alkali chlorides (Na-K-Cl) evaporate inside the deposit, and are transported toward and to the steel surface, where they can condense

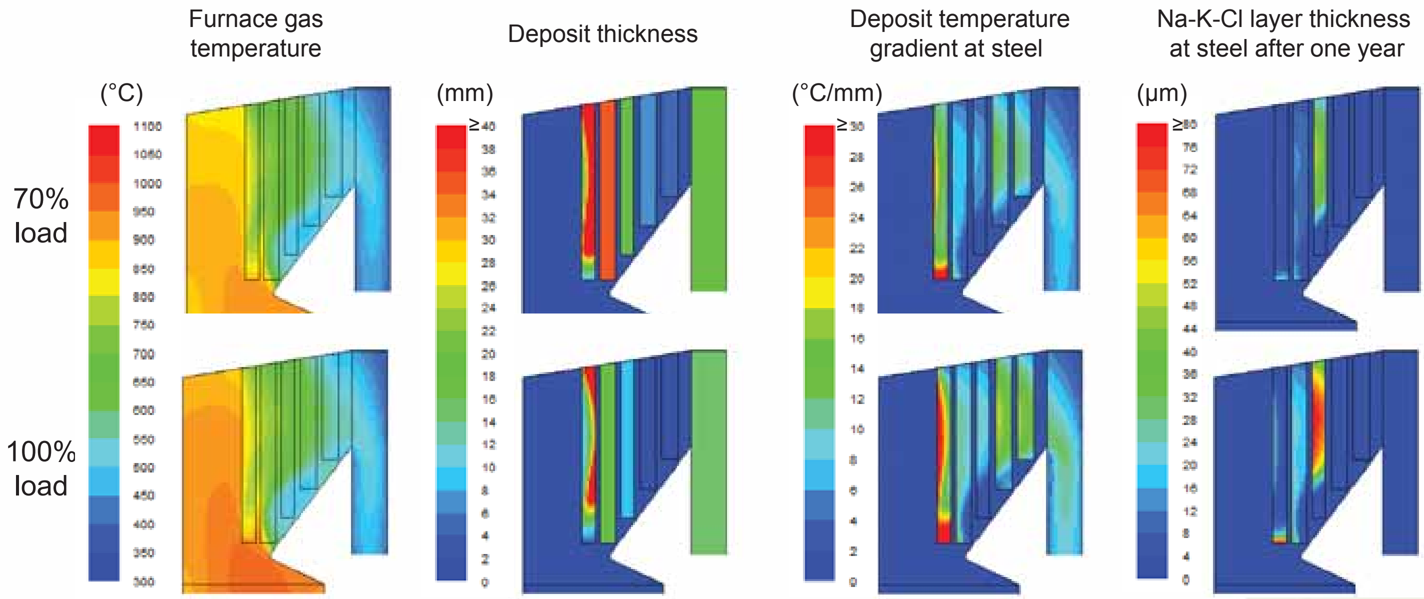
Probe measurements at Rauma





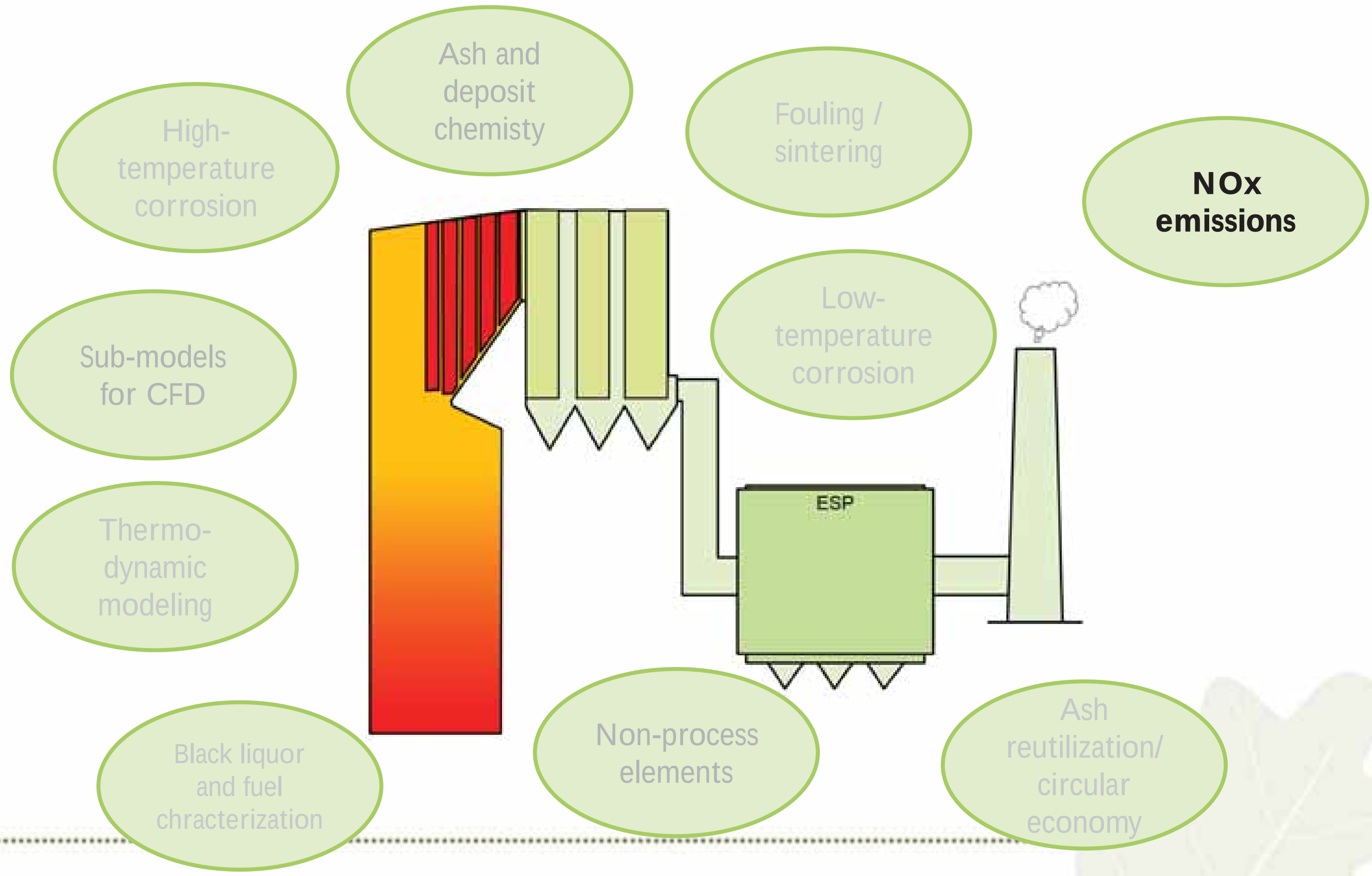
(Balint, 2018)

Alkali chloride enrichment at the steel surface of superheaters

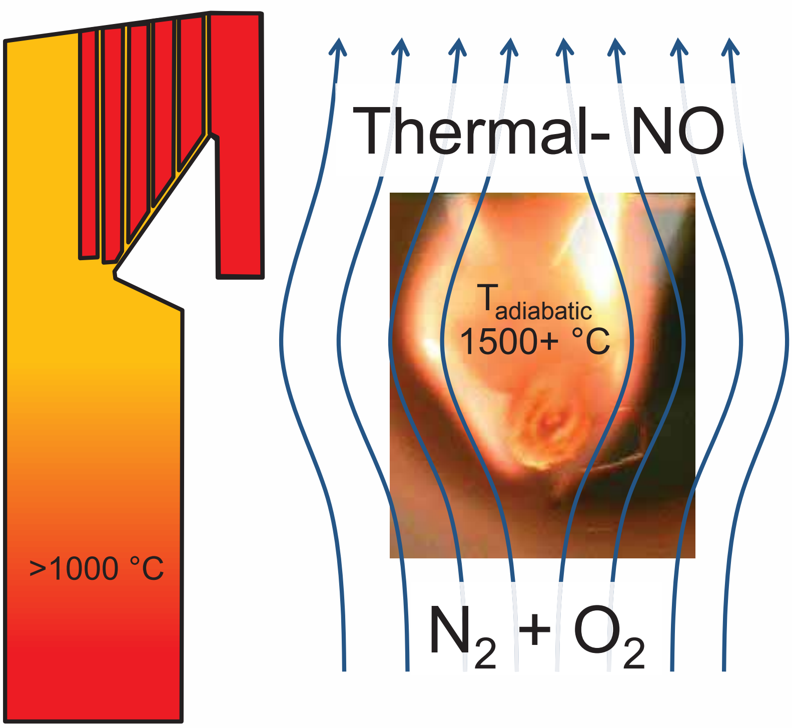


Alkali chloride enrichment is strongly dependant on steam/steel temperature
Most enrichment in superheater with hottest steam

Åbo Akademi recovery boiler research areas



Thermal-NOx in recovery boilers

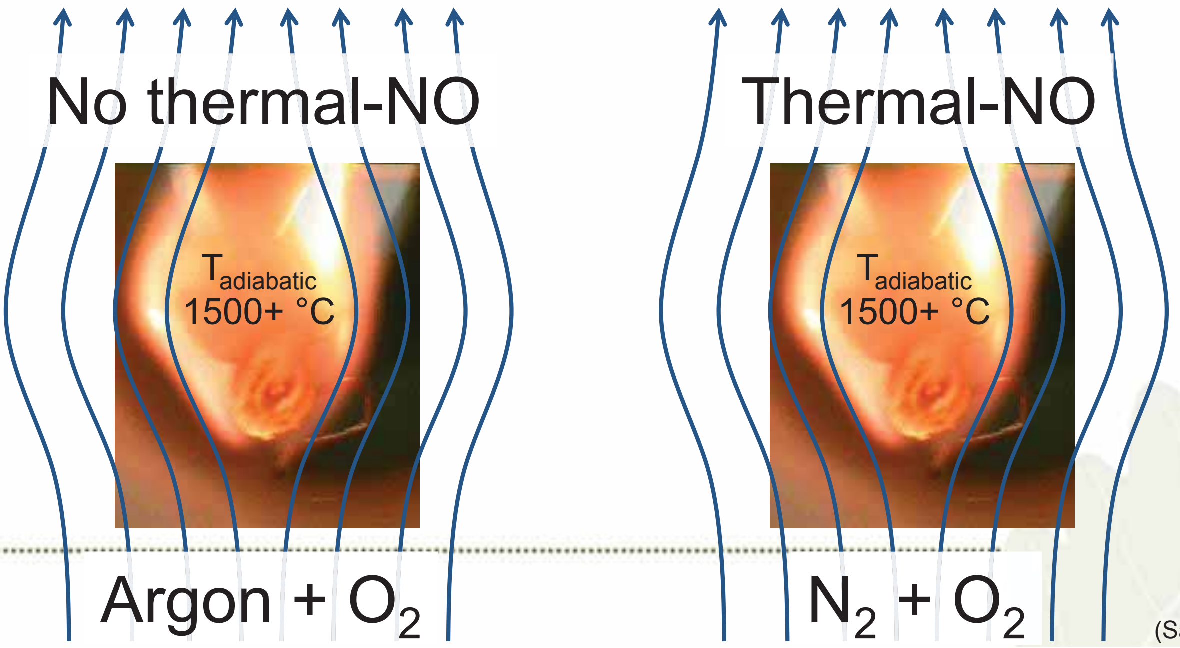


- RB NOx currently believed to originate exclusively from fuel-N
- Could there be thermal-NO formation ?
- Hot flame during droplet burning

(Santochi 2019)

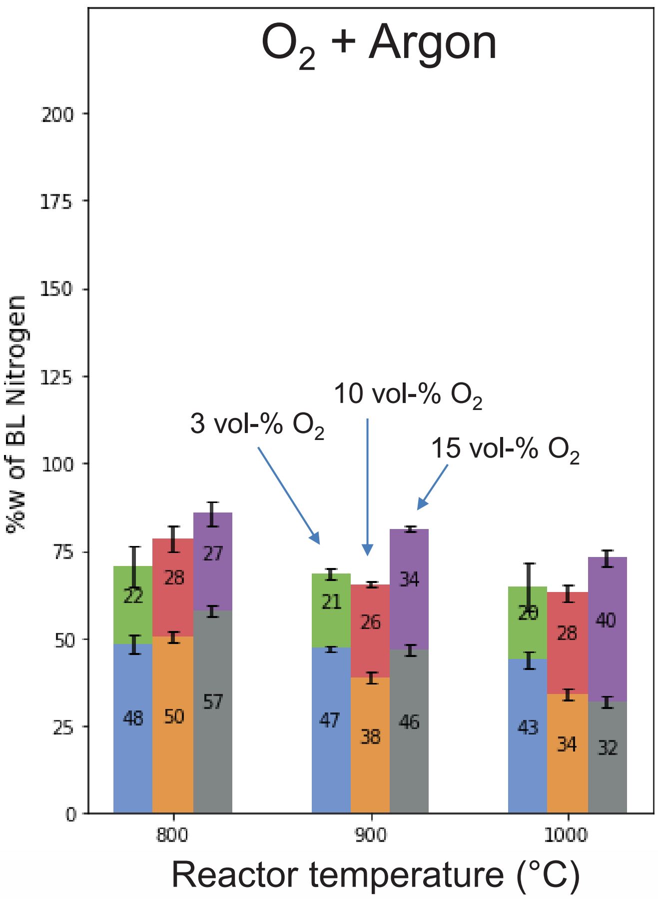
Thermal-NOx in flame

- Single Droplet Experiments
- Replacing N_2 with Argon removes possibility for thermal-NO formation



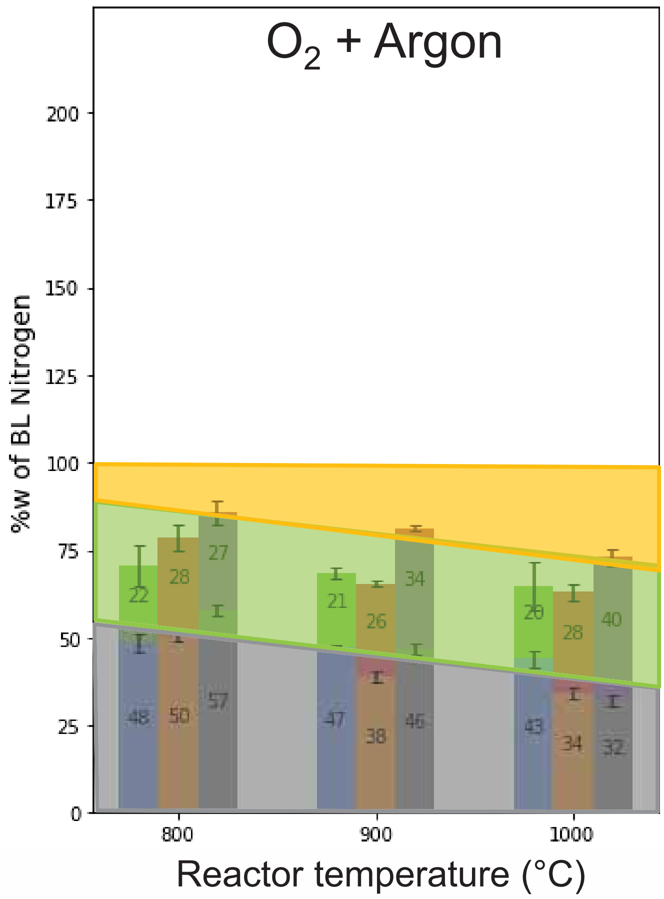
(Santochi 2019)

Single droplet experiments



(Santochi 2019)

Single droplet experiments



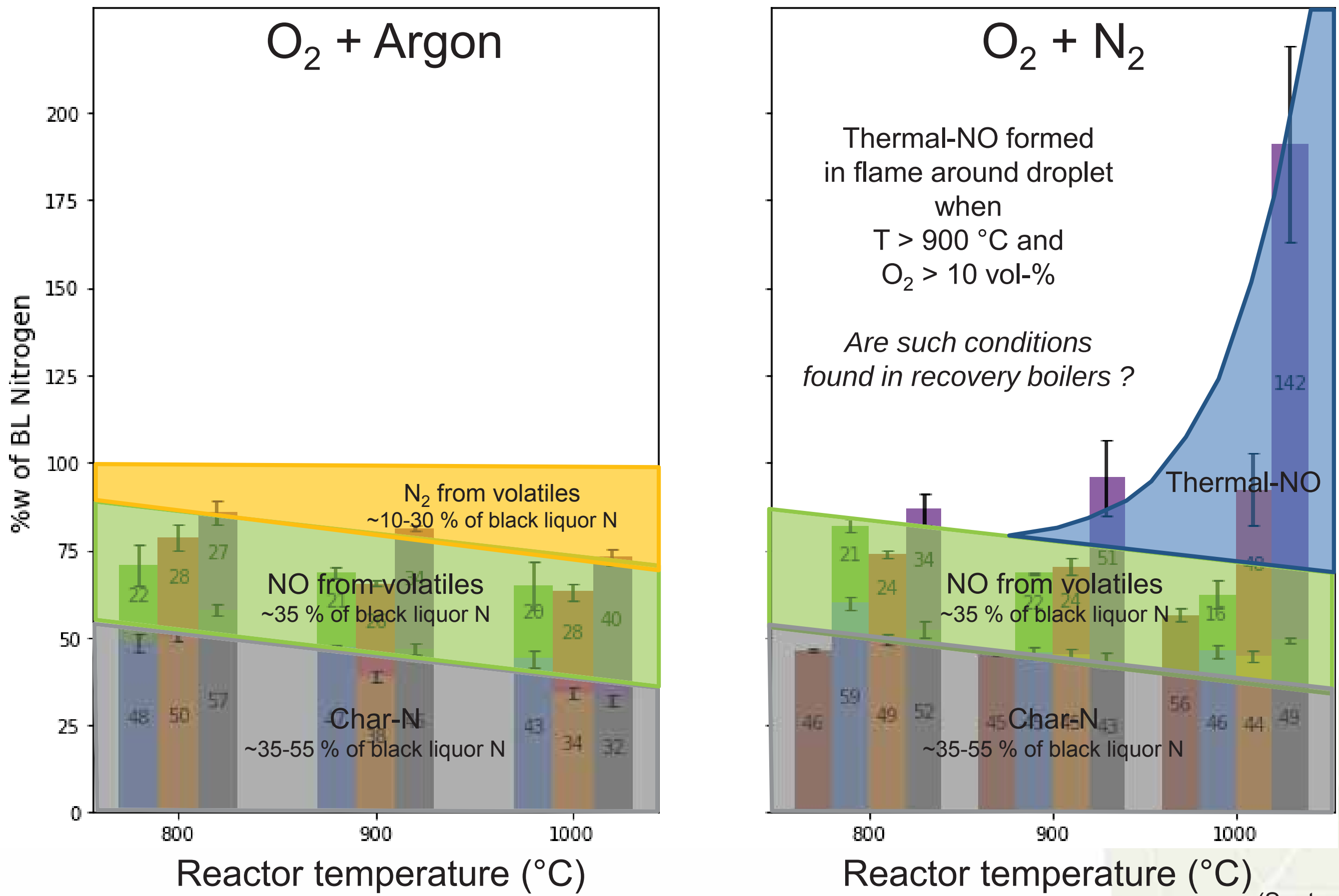
N_2 from volatiles
~10-30 % of black liquor N

NO from volatiles
~35 % of black liquor N

Char-N residue
~35-55 % of black liquor N

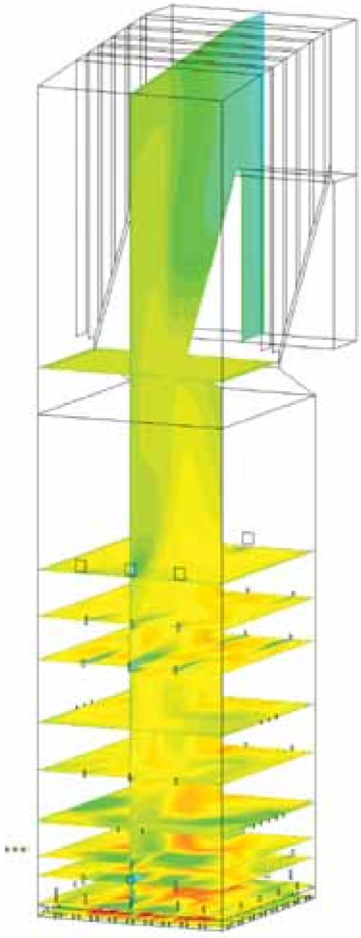
(Santochi 2019)

Single droplet experiments

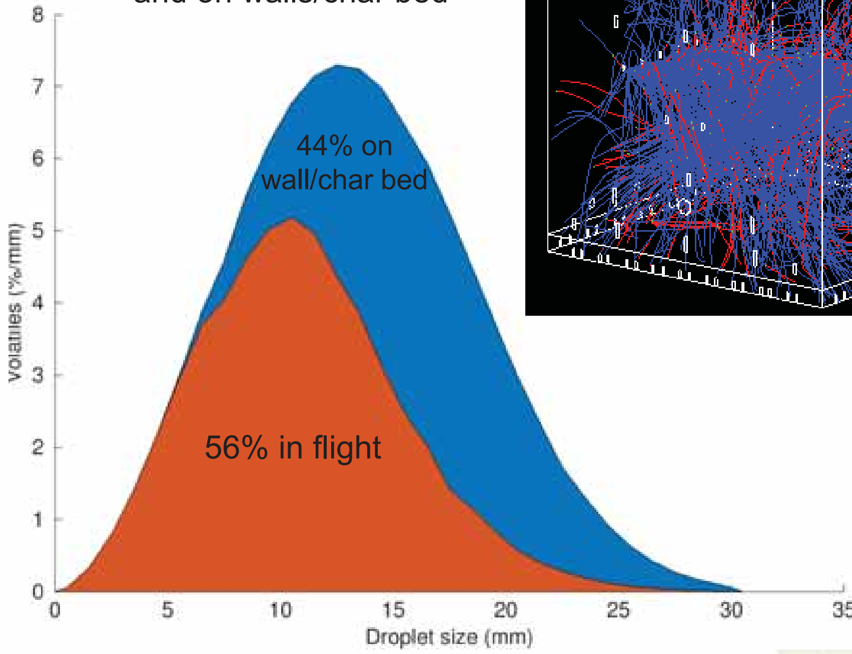


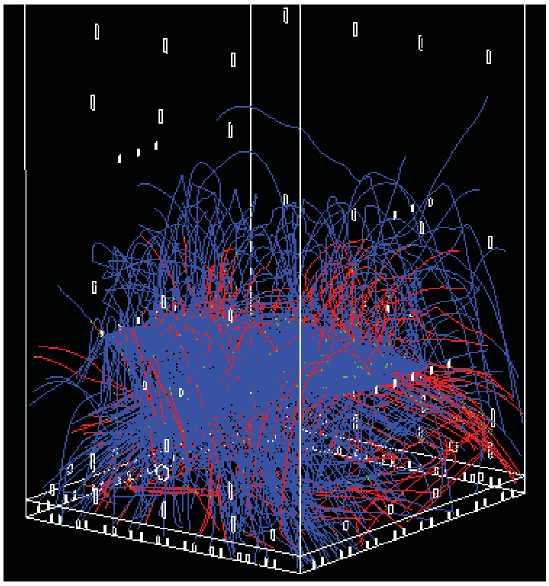
(Santochi 2019)

Thermal-NO in recovery boilers



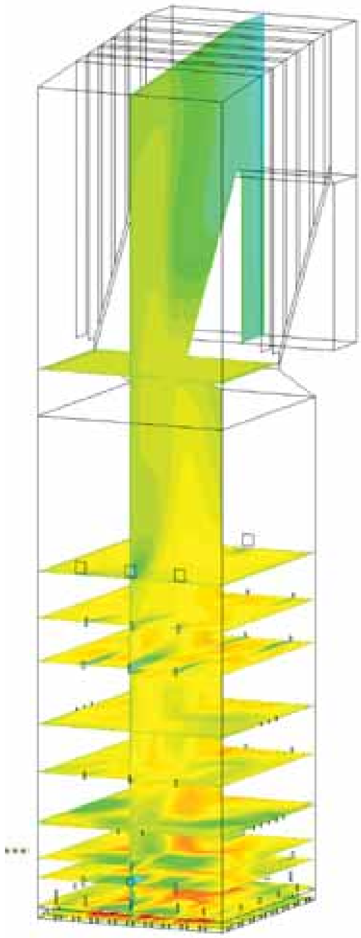
Volatiles release
in-flight
and on walls/char bed





(Santochi 2019)

Thermal-NO in recovery boilers



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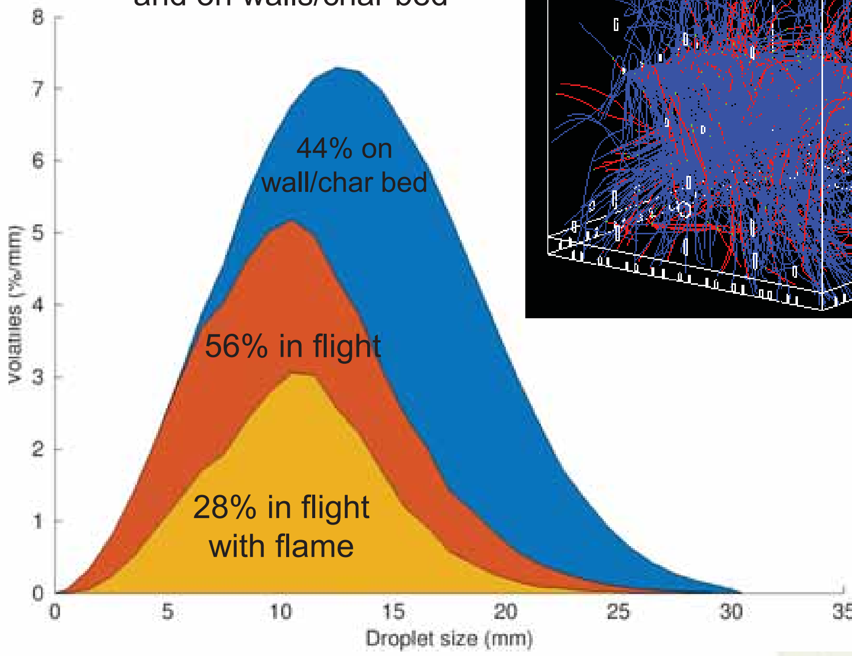
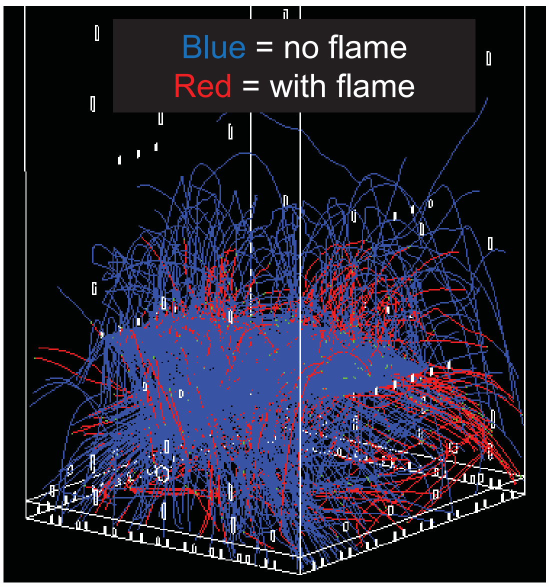
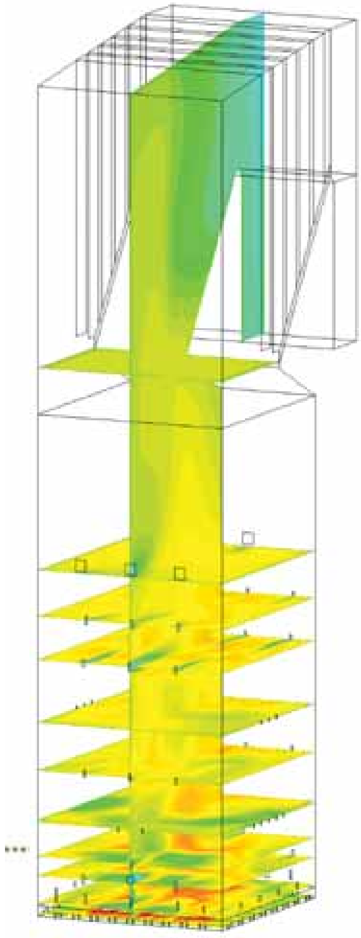
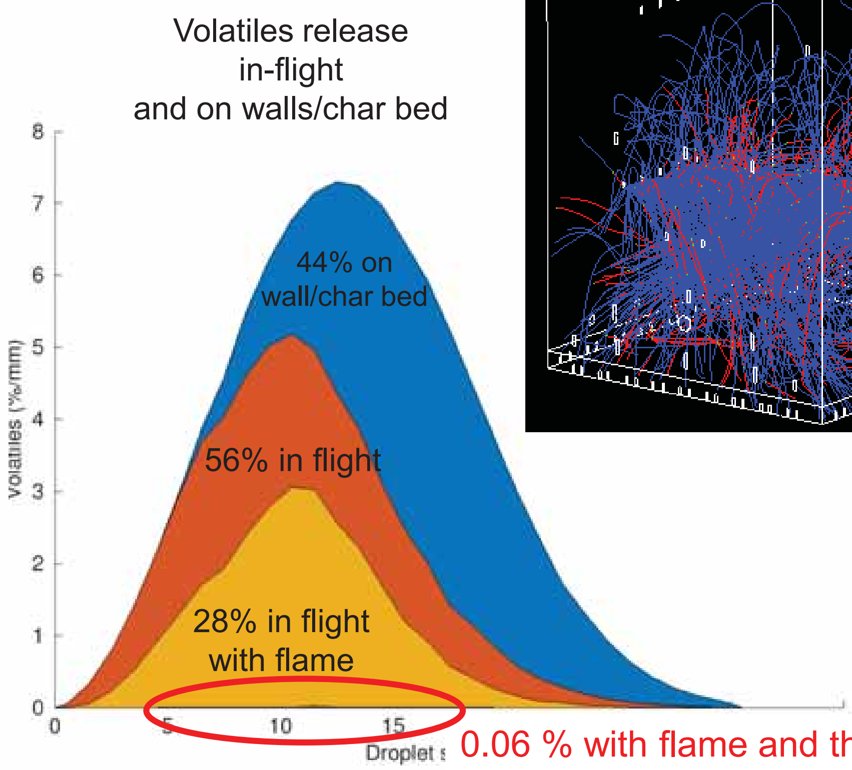


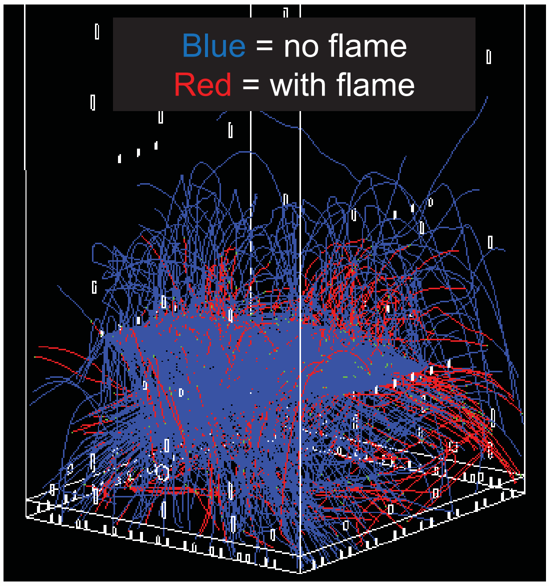


(Santochi 2019)

Thermal-NO in recovery boilers







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Conclusions

- Conditions identified for thermal-NO formation in black liquor droplet burning
  - T > 900 °C and O_2 > 10 vol-%
- Such conditions are not found in recovery boilers with current operation: Thermal-NO does not seem to be relevant

Summary

- Current research at Åbo Akademi connected to recovery boilers includes
  - Non-process elements
  - Alkali chloride enrichment at the steel surface of superheaters
  - Recovery boiler NO formation chemistry
- Our focus is on the chemical details
- These and other research are carried out in collaboration with SKY and industry, which ensures the industrial relevance of the research