Thermodynamic investigations of coal ashes

GTT – Workshop Herzogenrath, 11 – 13/07/2012

Prof. Dr. K. Hack; T. Schreck

VORWEG GEHEN

Mining, power generation, upgrading

Lignite in the Rhineland

Lignite

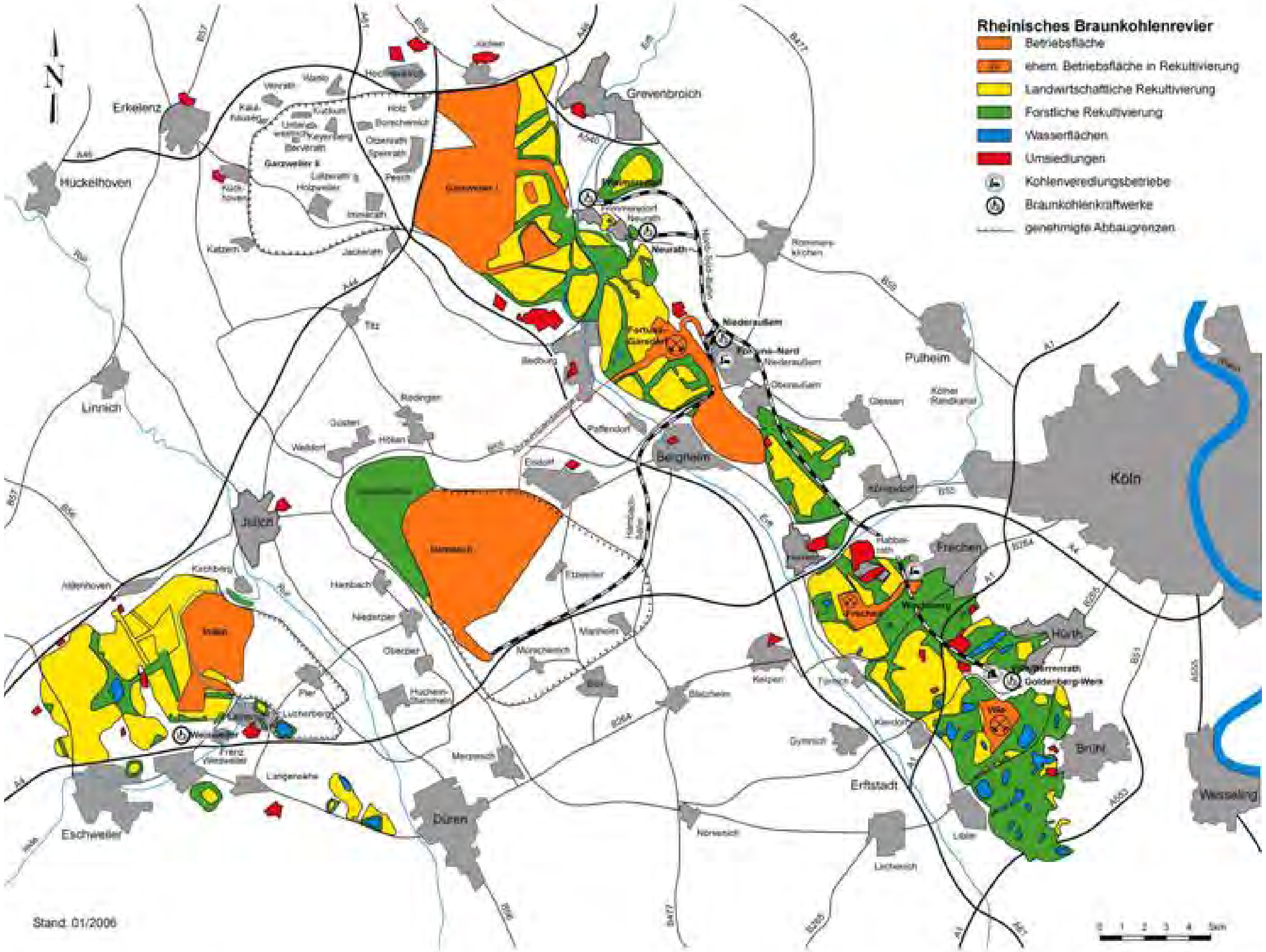
	Deposit
Origin	in the Tertiary period (12 – 20 mill. years ago) from subtropical vegetation
Volume	55 bn t in the Rhineland
Stripping ratio	4.7 : 1

	Quality
NCV	Ø 8,700 kJoules (= 1/3 tce)
Moisture	50 - 60 %
Ash	1.5 – 8.0 %
Sulphur	0.15 – 0.5 %
Calcium and magnesium	bind gaseous sulphur dioxide in the ash

Chronology

58	Tacitus describes "burning earth"
1632	Reference to "Cologne earth" or "Cologne umbra" (colorant, snuff additive and firewood substitute)
1700	Peat digging
1750	Production of "Klütten" (lignite nuggets)
1784	First electoral recultivation decree
1858	Invention of the briquette press
1877	First briquetting factory in the Rhineland
1900	Generating plant at Berggeist mine, Brühl
1907	"Iron miner" (first excavator) in the Brühl mine
1912	Fortuna power plant
1914	Goldenberg power plant
1955	Fortuna-Garsdorf mine, 100,000 t excavator
1978	Hambach mine, 240,000 t excavator
1998	Final approval for Garzweiler II mine
2003	Commissioning of BoA at Niederaußem

Rhenish Lignite Mining Area.



Performance Figures of RWE Power AG

Opencast mines: 97,3 mill. t lignite

Garzweiler	Hambach	Inden
35,7 mill. t	39,1 mill. t	22,6 mill. t

Frimmersdorf: 14 TWh/a
2,265 MW_n, 14 units

Neurath: 15 TWh/a
2,200 MW_n, 5 units

Weisweiler: 19 TWh/a
2,280 MW_n, 6 units

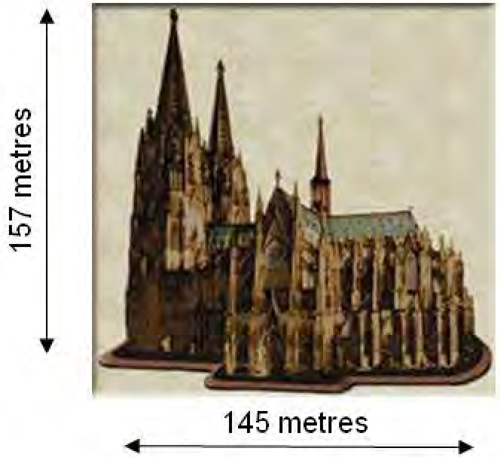
Total:
2,905 employees
11,000 MW_n capacity
75 TWh/a_n power generation

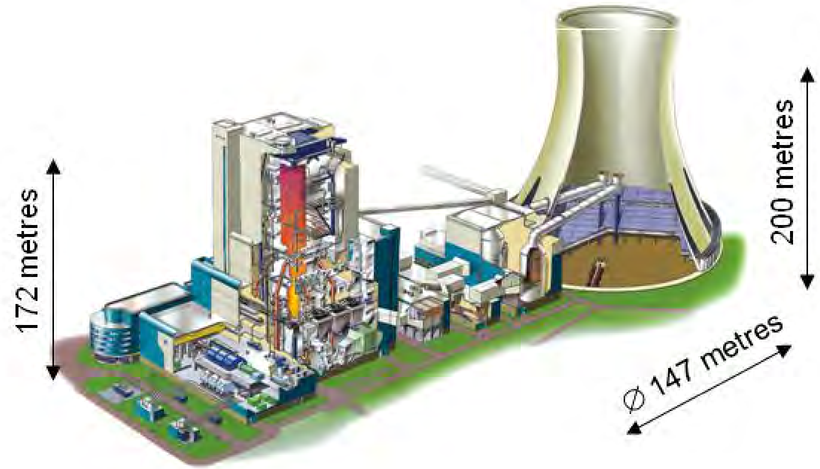
Niederaussem: 27 TWh/a
3,800 MW_n, 9 units

Factories: 4.1 mill. t upgraded products

Fortuna-Nord	Frechen	Ville/Berrenrath

Lignite-fired Power Station with Optimized Plant Technology (BoA)





History:

Start of planning for Niederaussem site	January 1996
Request for approval	March 1997
Building permit	November 1997
Start of construction	August 1998
First power generation	August 2002
Commissioning	January 2003
Power generation (in arithmetic terms) for	4.7 mill. inhab.

Technical data:

Gross capacity	1,012 MW
Net power generation	965 MW
Net el. efficiency	> 43%
Lignite demand	847 t/h
Steam parameters	275 bar/580°C
Power generation of more than	7.5 TWh/a
Height of cooling tower	200 m
Height of boiler house	172 m

CHIO Aachen has it:

The RWE fence to jump

Temperature-dependent concentration of melt phase.

Thermochemical calculations using FactSage

Thermochemical qualification of coal ash

» The agglomeration of two contacting ash particles, or the adhesion of ash particles on a surface has little to do with the overall chemical composition. Rather, the chemical composition, the presence, amount and the viscosity of the liquid phases for the initial adhesion and the subsequent sintering is responsible.«

Lockwood, Costen „ Mineral Ash Transformation“

Thermochemical qualification of coal ash
Evaluation criteria

> Characteristics of the ash melting behavior (DT, ST, HST, FT)

> Amount of liquid phase (partial melt) and solid phase

> Composition of the liquid phase

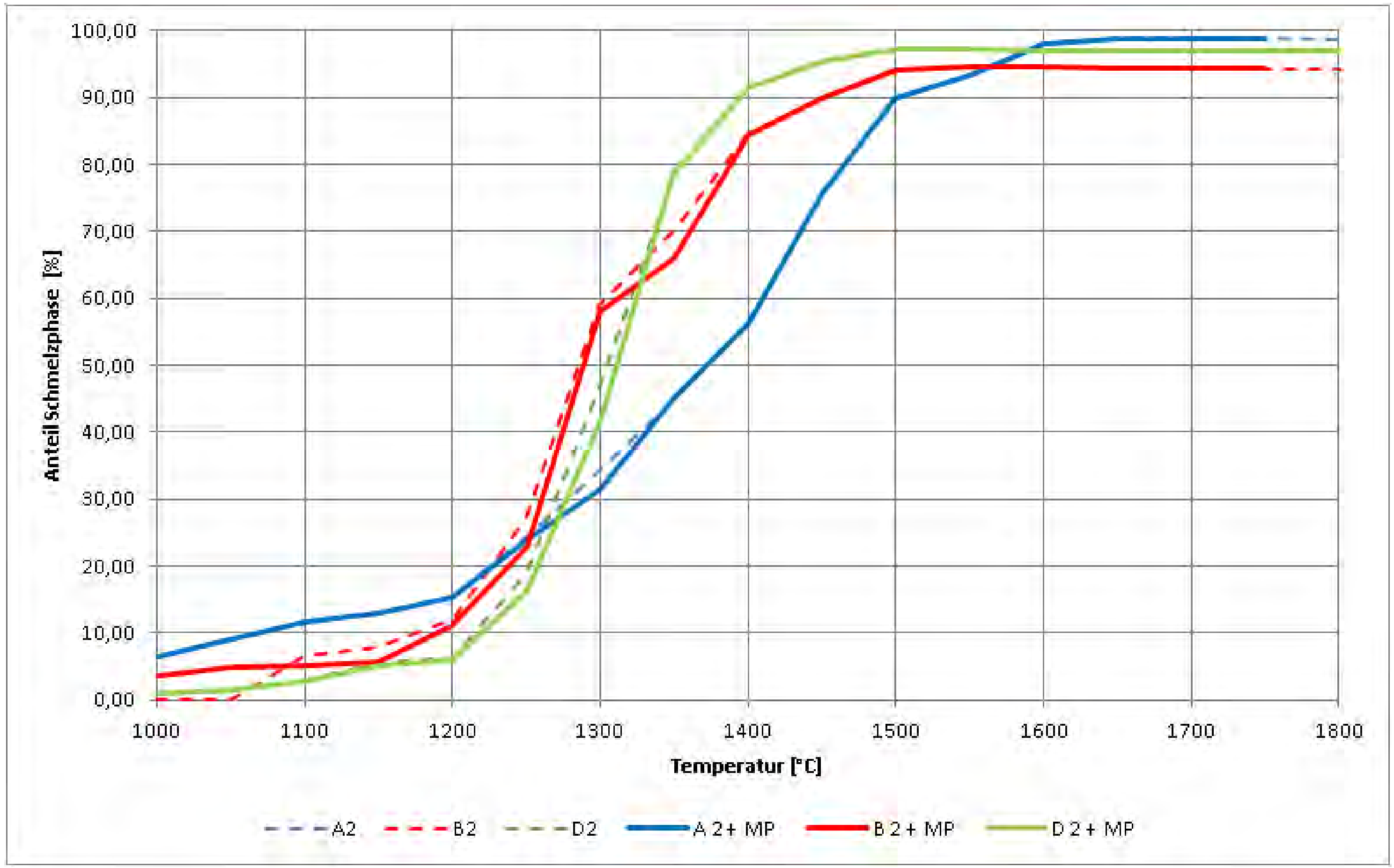
> Viscosity of the melt or partial melt (liquid phase)

> Surface tension

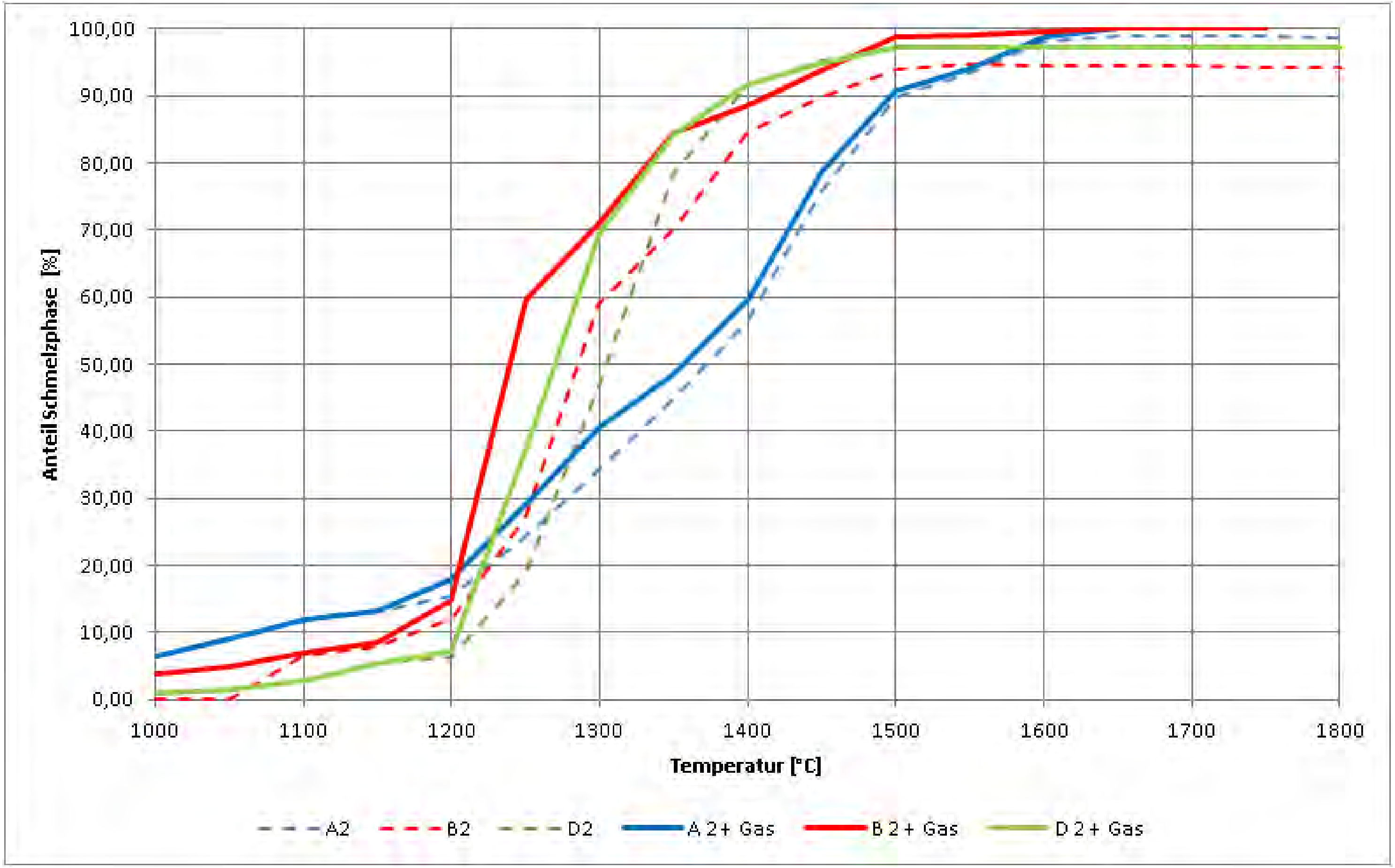
> Particle viscosity

> Kinetic Particle Energy

Thermochemical calculations. Upgrade Brown Coal. Influence of solid-phase mixing



Thermochemical calculations. Upgrade Brown Coal. Influence of the gas phase



Thermochemical calculations.
Correction of the XRF results of coal samples

Heizwert	Wasser	Asche	Na	K	Ca	Mg	Al	Si	Fe	Ti	S	C	H	N	Na2O	K2O	CaO	MgO	Al2O3	SiO2	Fe2O3	TiO2	SO3	Summe
[kJ/kg]	[%]	[%]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
7.116	59,5	6,17	133	120	11.800	906	823	13.965	3.293	72	0,40	23,2	1,67	0,23	0,29	0,23	26,77	2,44	2,52	48,44	7,63	0,19	16,1	104,63
7.025	59,1	6,89	117	146	11.534	862	858	16.431	4.824	80	0,39	22,9	1,66	0,23	0,23	0,26	23,44	2,08	2,35	51,04	10,02	0,19	14,2	103,86

- **Correction of mineral elements required (total >> 100 %)**

> 100-(Na2O+K2O+CaO+MgO+Al2O3+SiO2+Fe2O3+TiO2) = % SO3 in the ash

> % SO3 (total) - % SO3 (ash) = % SO3 (organic) --> % S (raw Coal)

> Air, i.e. O_2 quantity calculated for the current carbon content ($\lambda = 1$)

Thermochemical calculations.
Mean values 2011.

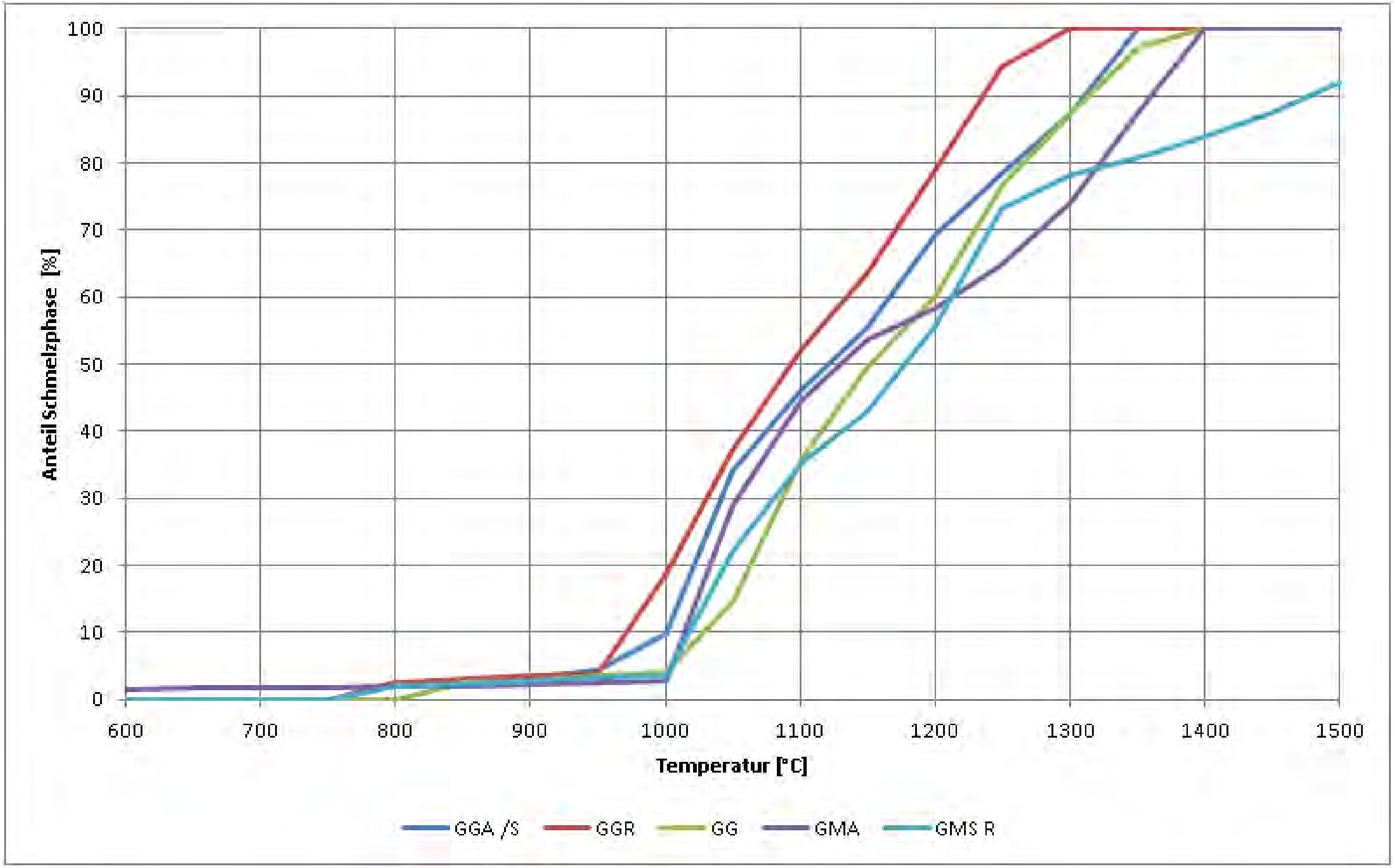
Kohlesorte	Heizwert	Wasser	Asche	S	C	H	N	O	Na_2O	K_2O	CaO	MgO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	SO_3	O_2 - Bedarf	N_2 - Bedarf
	[kJ/kg]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[g]	[g]
GGA/S	7116	59,5	6,17	0,114	23,20	1,67	0,23	9,11	0,29	0,23	26,77	2,44	2,52	48,44	7,63	0,19	11,48	52,75	211,00
GGR	7025	59,1	6,89	0,107	22,94	1,66	0,23	9,04	0,23	0,26	23,44	2,08	2,35	51,04	10,02	0,19	10,40	52,14	208,55
GG	7068	59,3	6,55	0,110	23,06	1,67	0,23	9,07	0,26	0,25	24,91	2,24	2,43	49,89	8,96	0,19	10,88	52,43	209,70
GMA	8644	57,1	3,24	0,071	27,06	1,90	0,32	10,29	0,45	0,25	33,47	5,93	2,79	29,17	13,71	0,24	13,99	61,86	247,43
GMS/R	8272	55,6	6,54	0,182	25,84	1,84	0,29	9,70	0,20	0,20	17,14	2,49	1,57	59,68	6,62	0,16	11,93	59,22	236,87
Tgb. Garzweiler	8062	56,4	6,30	0,160	25,38	1,81	0,28	9,62	0,22	0,21	19,35	2,57	1,79	56,52	7,37	0,17	11,79	58,07	232,29
HKA	10127	53,5	2,09	0,049	30,53	2,20	0,35	11,25	5,07	0,62	35,38	15,22	4,64	5,49	15,81	0,40	17,37	70,15	280,59
HKN	10479	51,8	2,27	0,070	31,40	2,27	0,35	11,80	6,64	0,65	33,59	14,60	4,02	8,64	11,90	0,34	19,62	71,94	287,78
HKF	9925	52,9	2,76	0,026	30,09	2,18	0,32	11,76	3,64	0,54	32,13	13,13	2,10	15,54	17,19	0,31	15,42	68,47	273,88
HKE	9918	53,3	2,46	0,039	30,09	2,17	0,33	11,61	3,99	0,52	31,94	13,49	2,13	7,39	26,43	0,24	13,87	68,63	274,53
HKR	10167	51,9	2,86	0,105	30,63	2,24	0,33	11,96	4,32	0,51	33,12	13,09	2,04	19,19	19,01	0,40	8,32	69,72	278,90
HKS	10150	50,9	3,92	0,105	30,54	2,23	0,32	11,95	3,12	0,68	22,76	9,42	4,02	36,25	12,24	0,50	11,02	69,48	277,93
HKT	10241	50,8	4,65	0,149	30,64	2,21	0,35	11,15	2,95	1,29	17,03	7,65	16,35	33,39	8,60	1,25	11,50	70,56	282,24
NV																			
HKpur	10389	52,2	2,27	0,064	31,19	2,25	0,35	11,72	6,20	0,63	33,64	14,55	3,91	8,46	13,38	0,34	18,88	71,44	285,76
HKRest	10224	50,9	4,51	0,141	30,62	2,22	0,35	11,30	2,98	1,19	17,97	7,94	14,33	33,86	9,20	1,12	11,42	70,36	281,42
K-Kohle	10345	51,8	2,86	0,085	31,04	2,24	0,35	11,61	4,86	0,86	27,13	11,81	8,24	19,01	11,64	0,66	15,78	71,16	284,62
HBA	10464	52,3	1,98	0,039	31,37	2,26	0,36	11,65	7,47	0,69	37,05	16,08	3,56	4,57	12,88	0,32	17,39	72,01	288,05
HBG	10581	52,1	2,15	0,032	31,61	2,27	0,37	11,48	6,80	0,64	34,95	15,14	6,04	6,42	10,44	0,36	19,21	72,81	291,23
B-Kohle	10465	52,3	1,98	0,039	31,38	2,26	0,36	11,65	7,46	0,69	37,03	16,07	3,59	4,59	12,85	0,32	17,41	72,02	288,08
Tgb. Hambach	10383	52,0	2,58	0,070	31,14	2,25	0,35	11,62	5,49	0,82	29,51	12,83	7,12	15,54	11,93	0,58	16,17	71,43	285,71

Stream 1
Coal

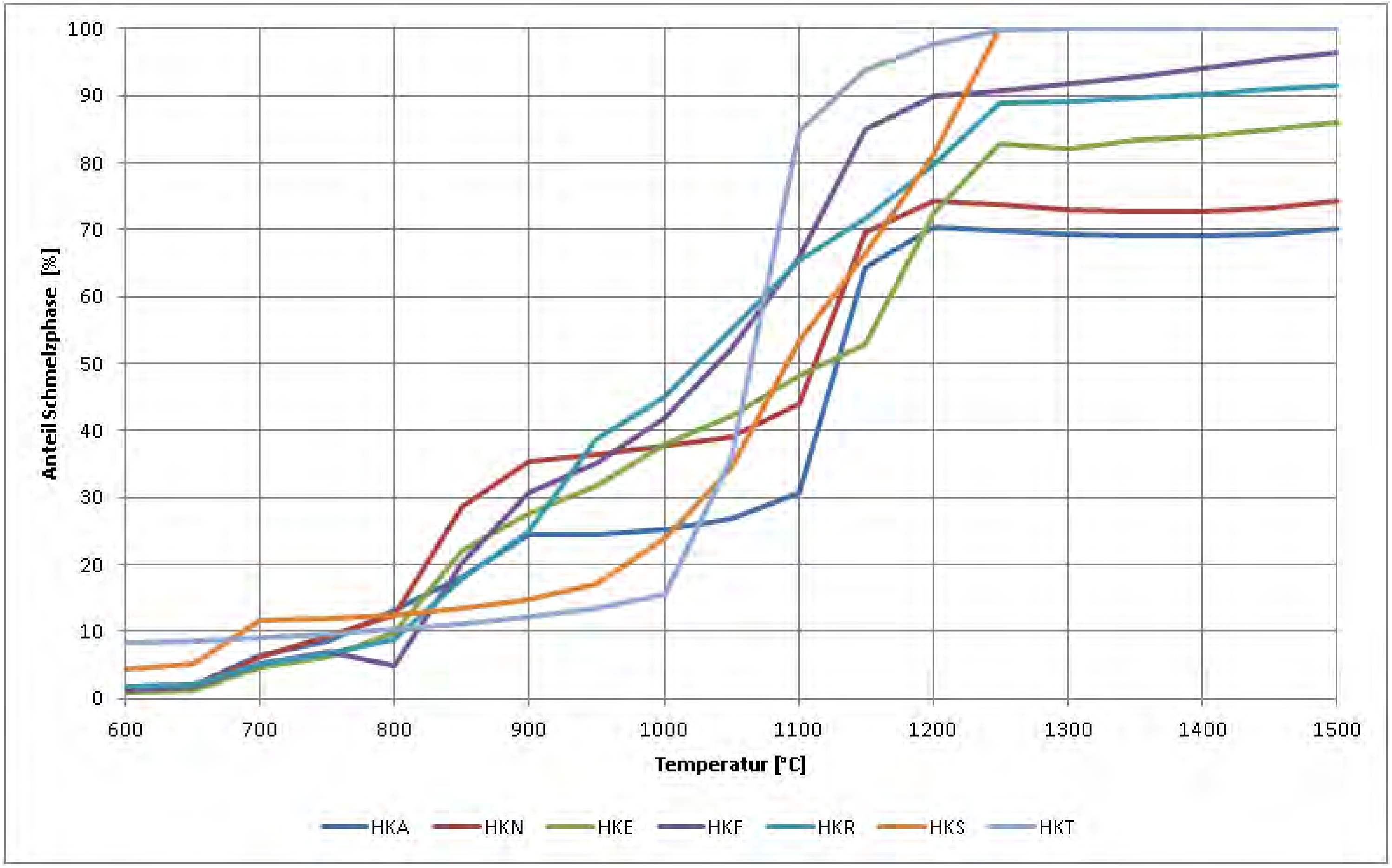
Stream 2
Ash

Stream 3
Air

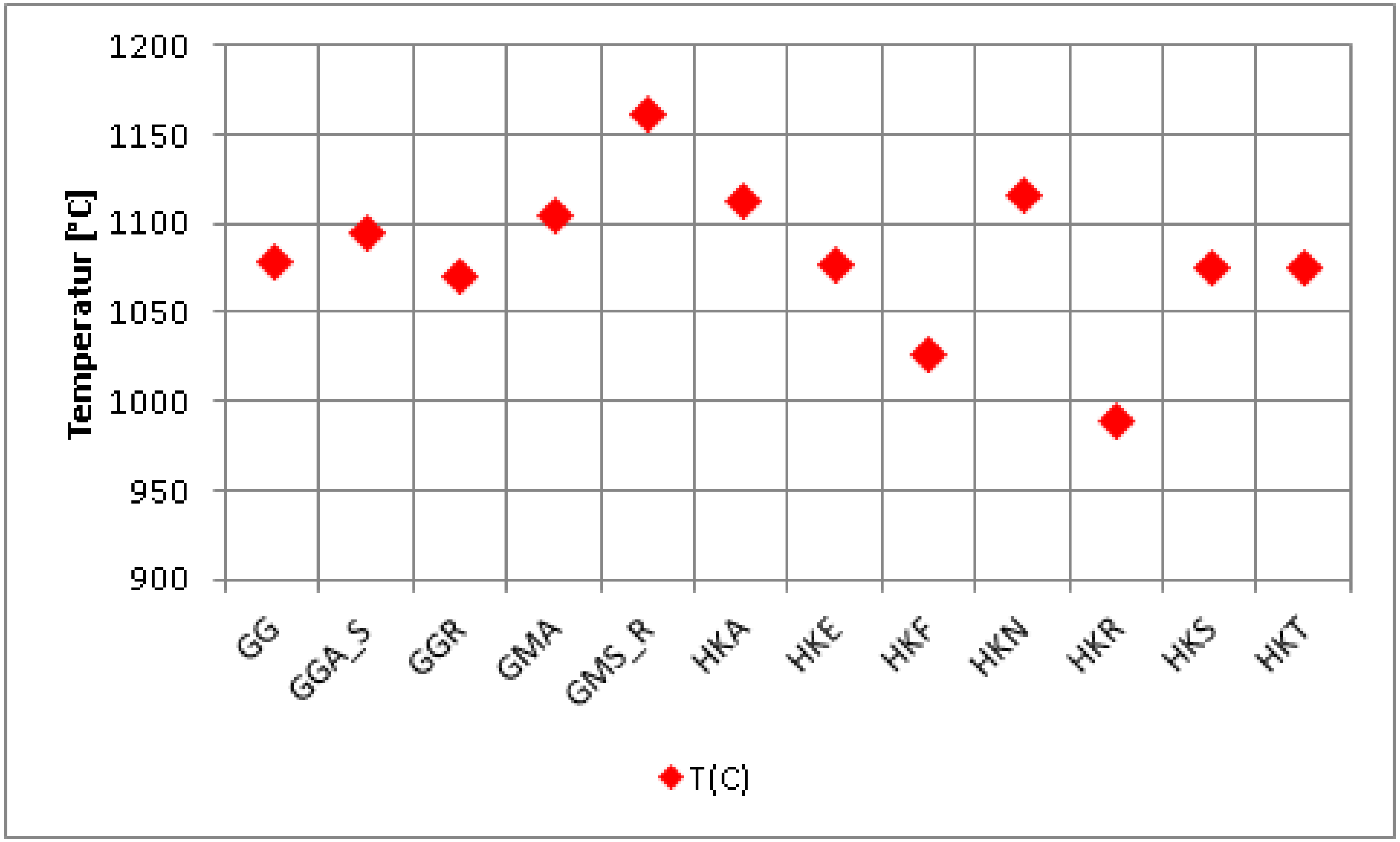
Thermochemical calculations.
GRZ – Lignite: Liquid phase vs. Temperature



Thermochemical calculations.
HAM – Lignite: Liquid phases vs. Temperature

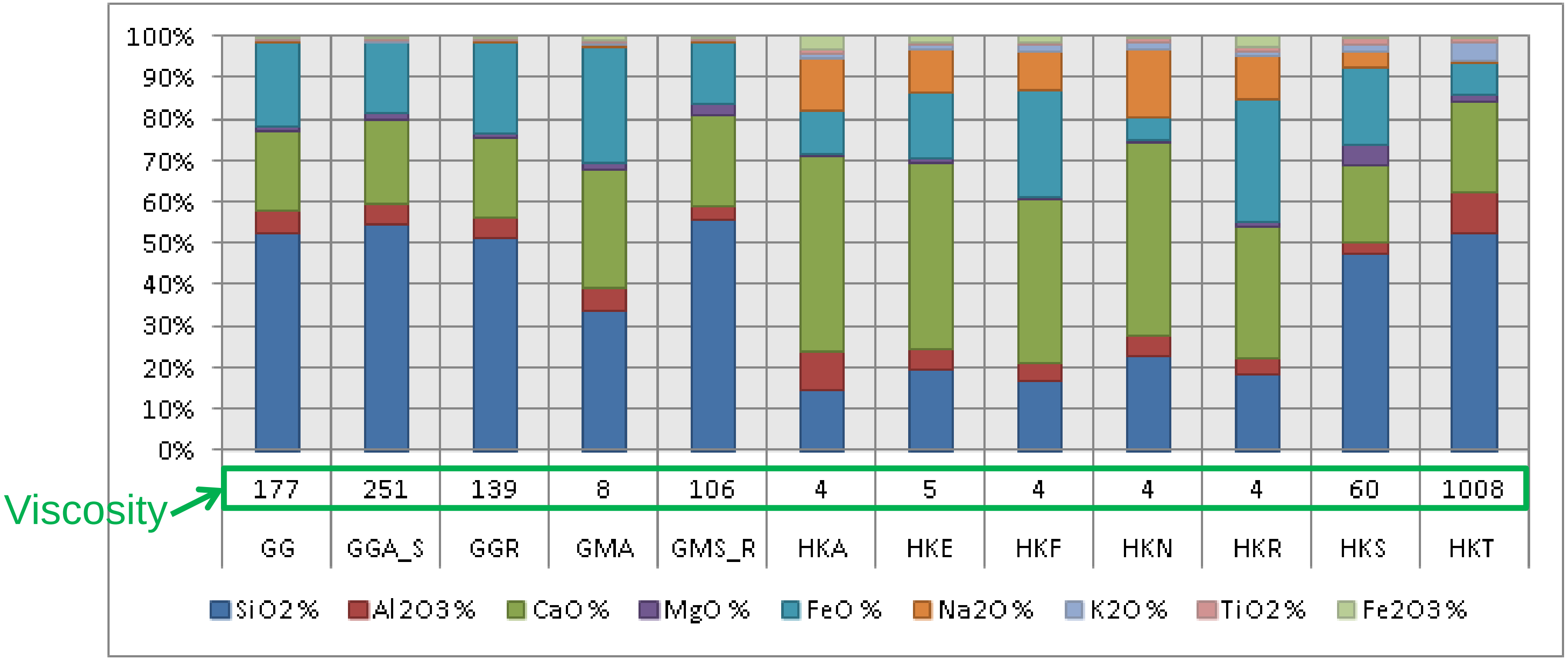


Thermochemical calculations.
Formation Target Phase – SlagA – 40 %.



Temperature where 40% liquid phase occur

Thermochemical calculations.
Composition of the slag at SlagA=40%.



Composition of the slag at the temperature where 40% of liquid phase are reached

Thermochemical calculations with FactSage
Options from the calculations

> Calculations on the basis of elemental analysis possible (deposits file)

> Considering the temperature dependence
  e.g. liquid phase vs. temperature

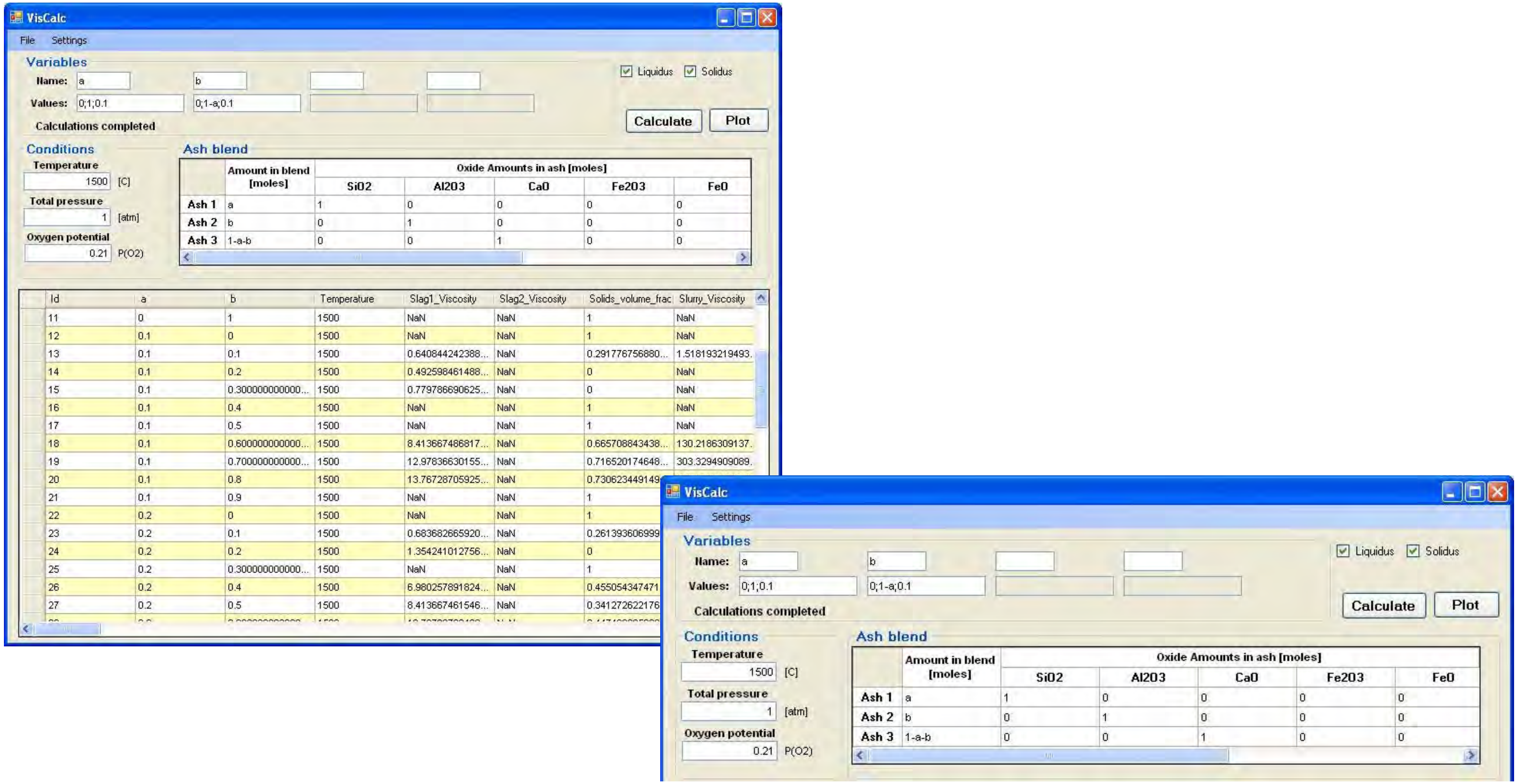
> Consideration of the flue gas composition (Oxidizing – Reducing)

> Automated calculations (Excel / ChemSheet)

> Implementation into fuel dispatch possible (day-to-day routine)

> Coupling with process data possible (Boiler data)

Thermochemical calculations
Outlook – Options for user interfaces



Thank you very much for your attention

VORWEG GEHEN