Furnace and Fuel Bed simulation program “CombAte”

– Plant optimization by knowledge –

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2. The CombAte-Program
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4. Coupling of CombAte and real Plant
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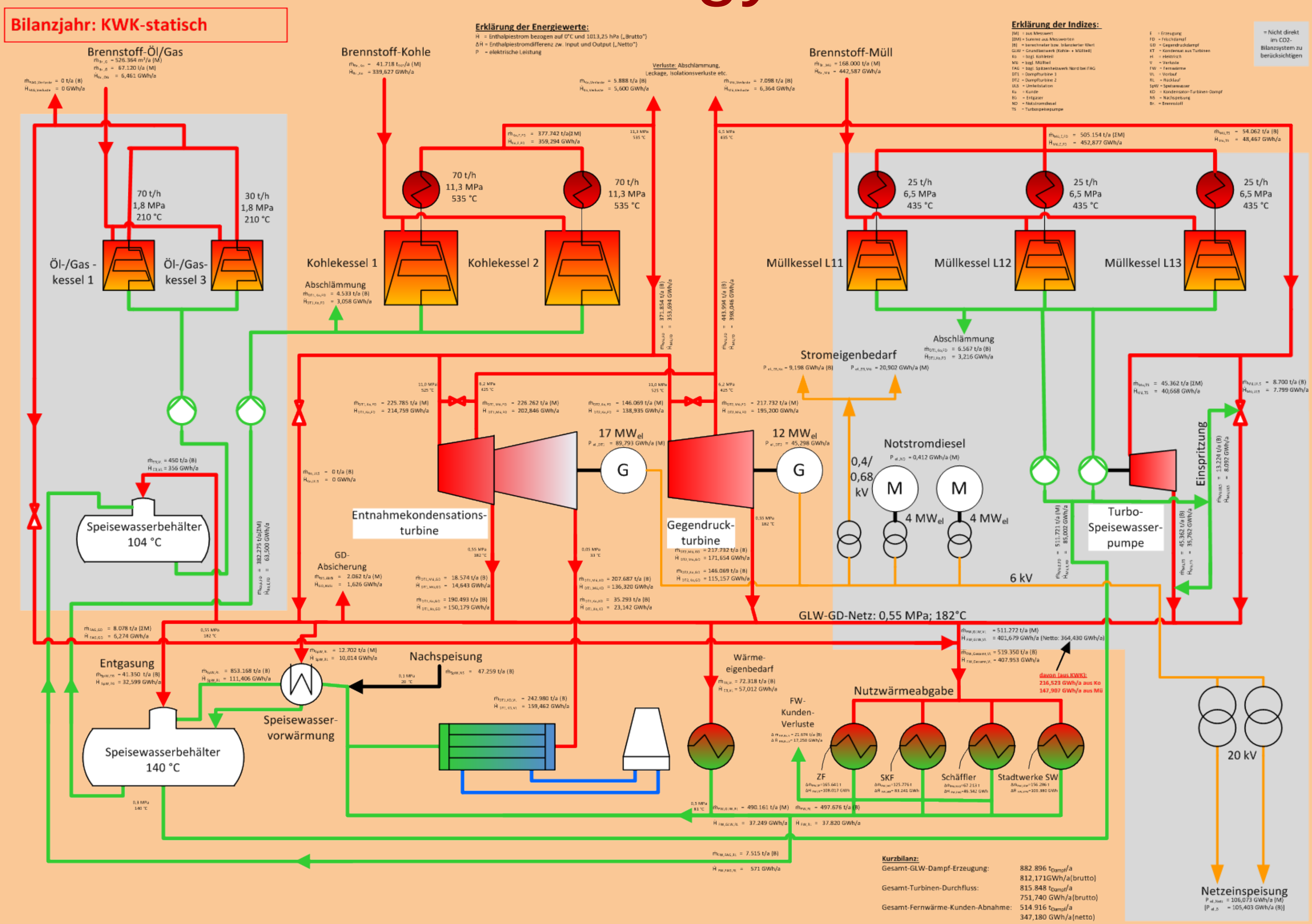
1. Introduction of GKS

GKS Mass and Energy Balance



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GKS – Waste to Energy with CHP

All over the whole year
Efficiency > 65 %!

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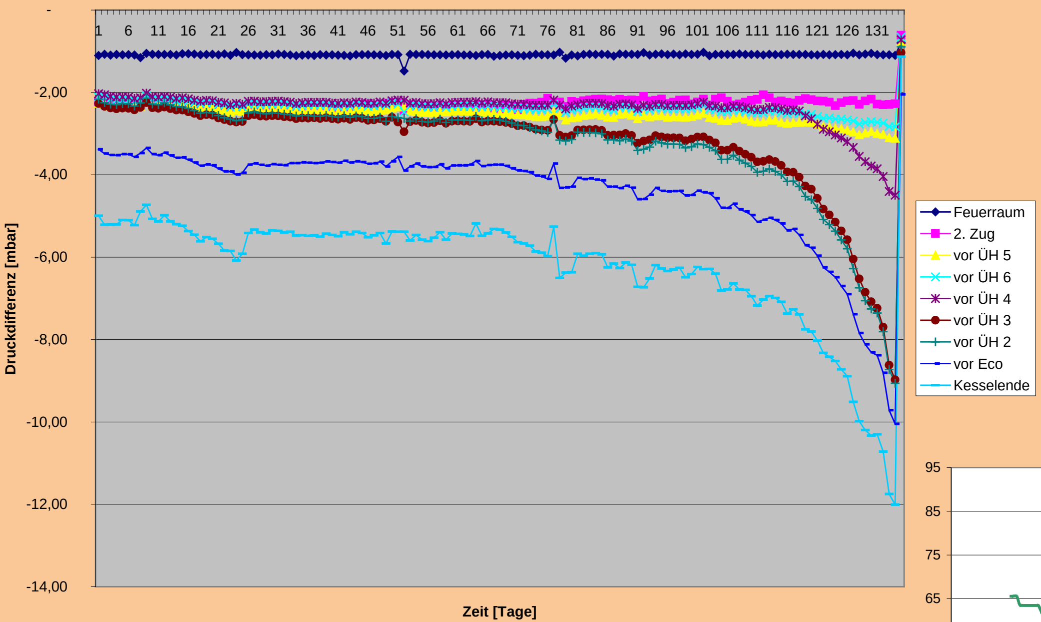
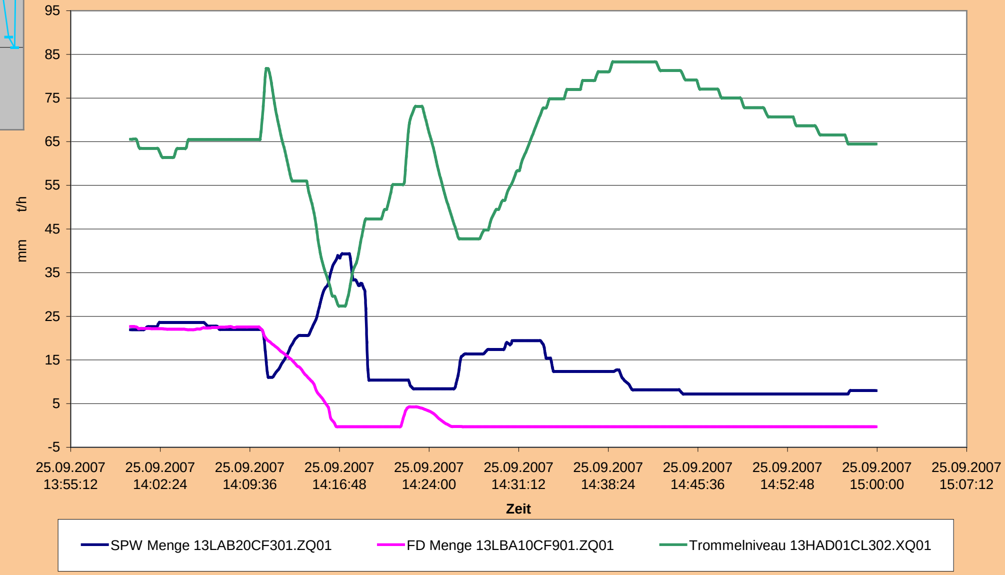
Motivation for Modelling

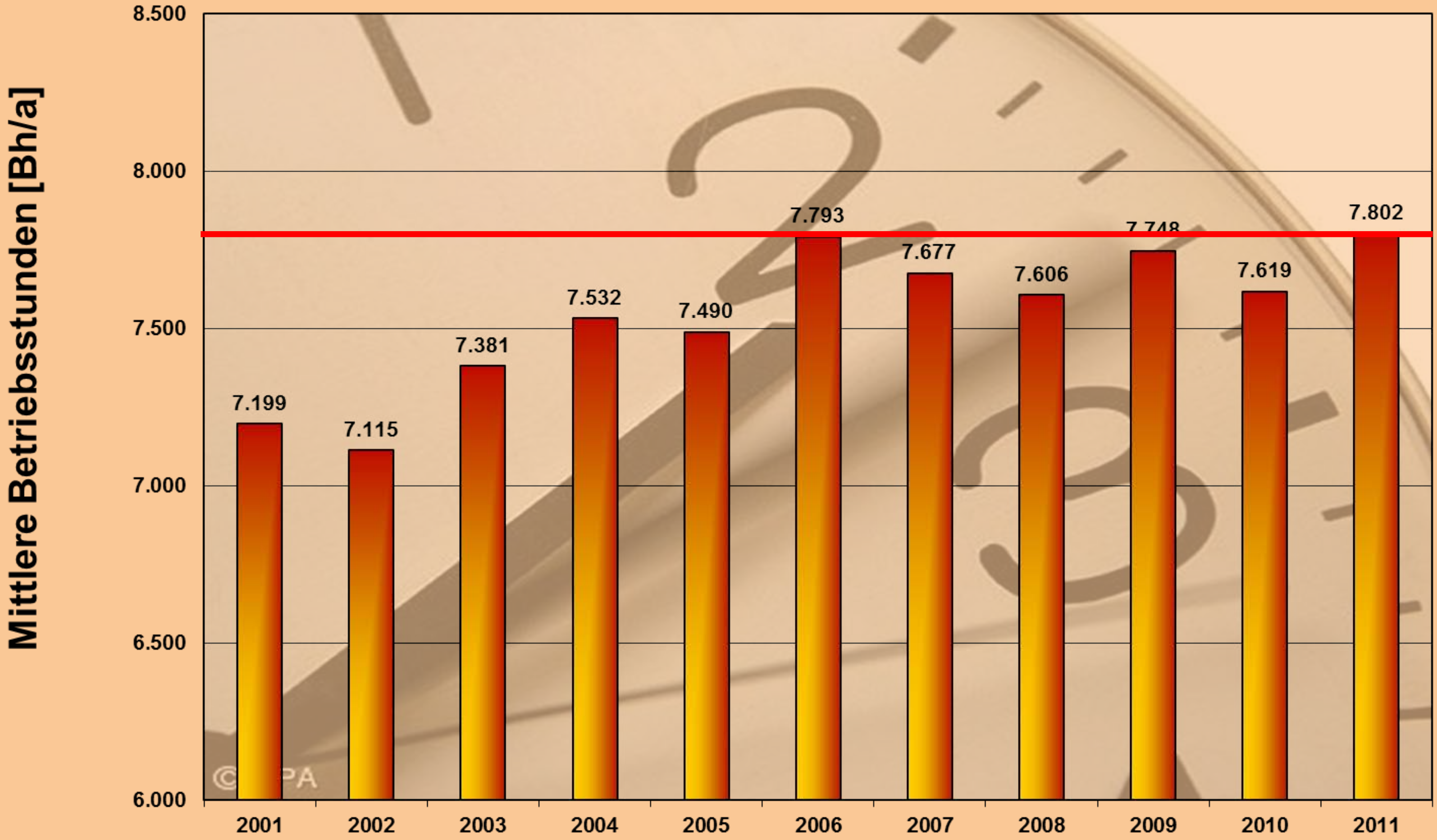


Deposits ↑

Corrosion →



Availability



Aim: > 7.800 h
<u>every</u> year

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2. The CombAte-Program

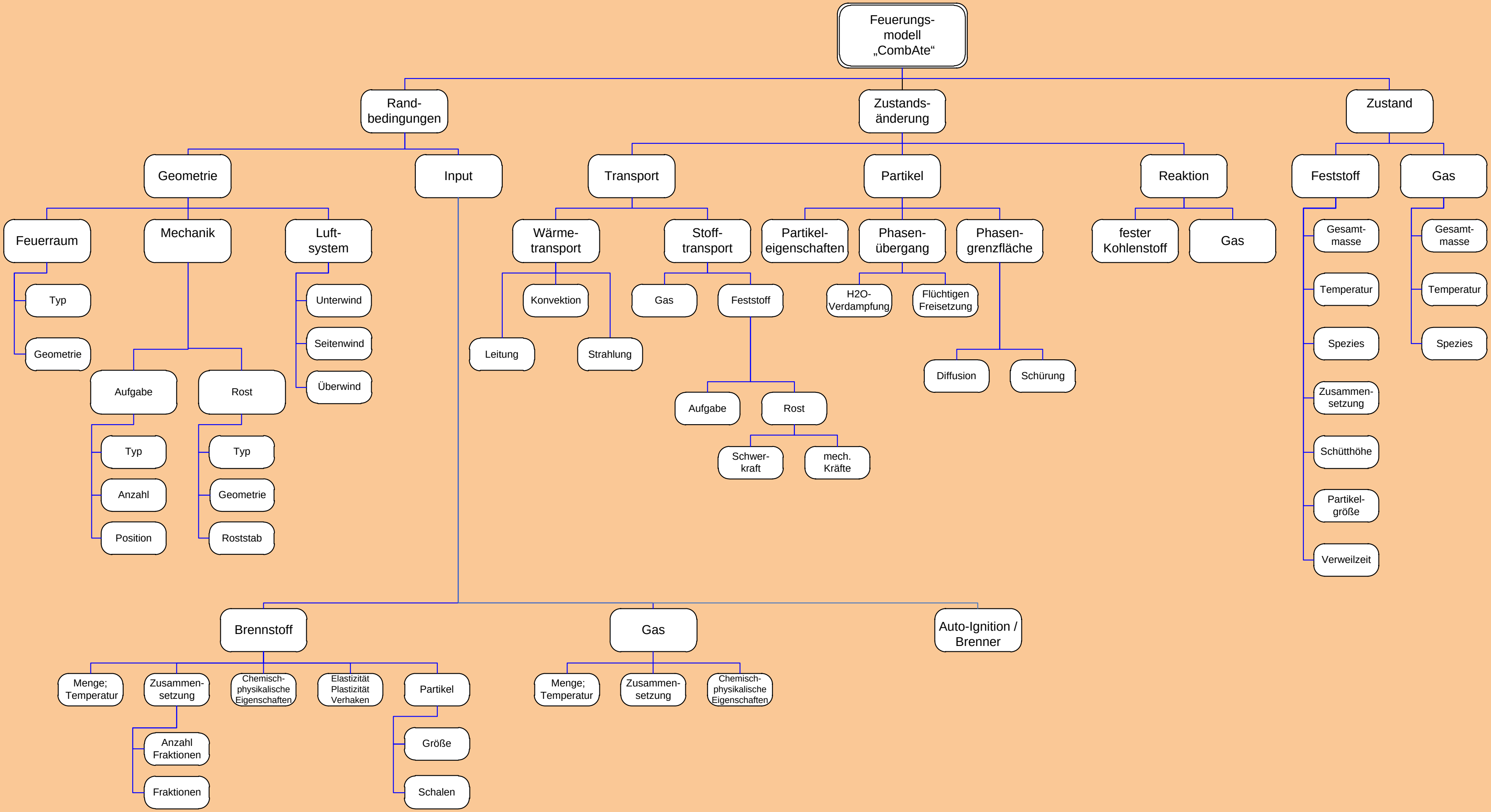
Primary Aim:

- Increasing availability
- Reducing costs

Secondary Aims:

- Understanding of processes on the grate
- Calculation of starting conditions for CFD
- Coupling of with combustion control system

Structure of Combustion-Model "CombAte"



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CombAte - Programming

Physical Base Model:

- "Multi stirring reactor"
- "Multi submodelling"

Computational Base Model:

- Java language
- Difference equations (not: differential equations)
- Single cell complete calculation
- Small program time steps in relation to real time processes
- Faster than real time (10 to 100 times faster)

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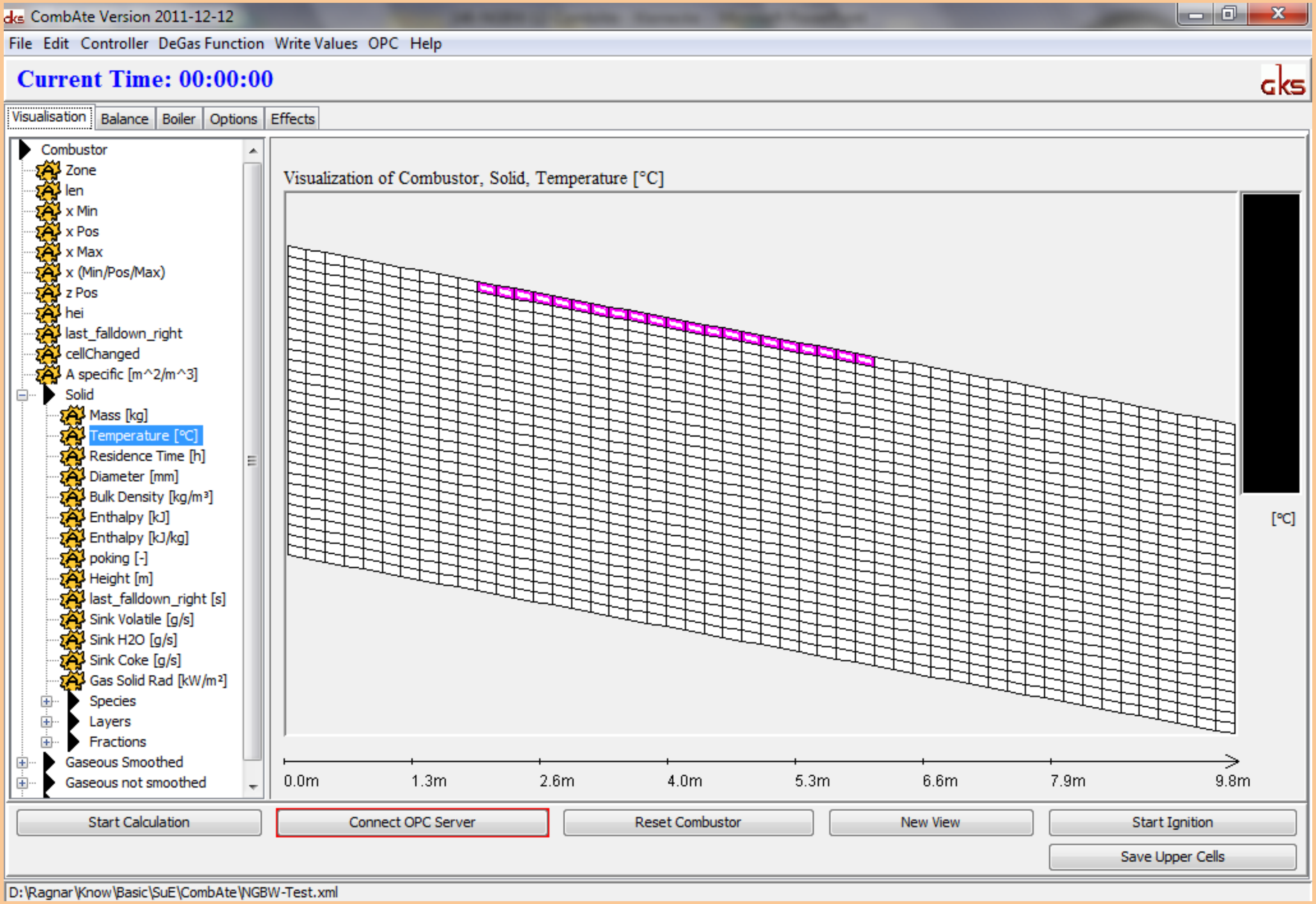
CombAte - Geometry
(www.gks-sw.de/online-application)



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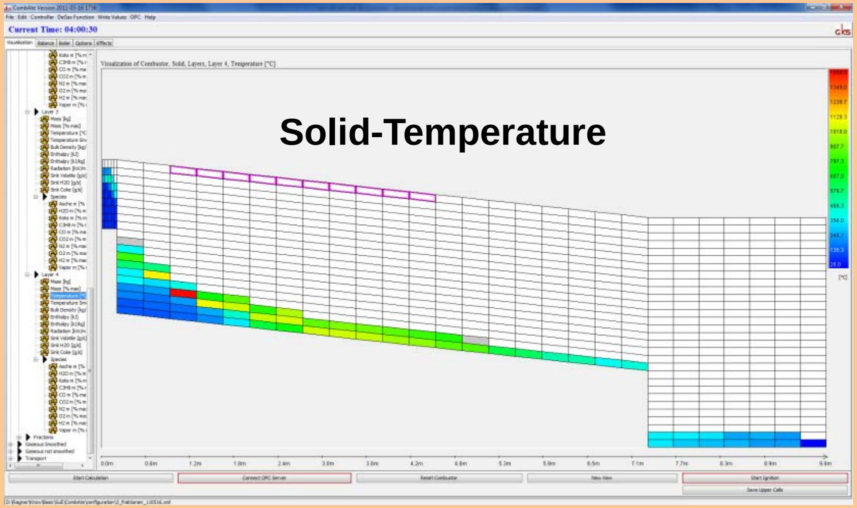
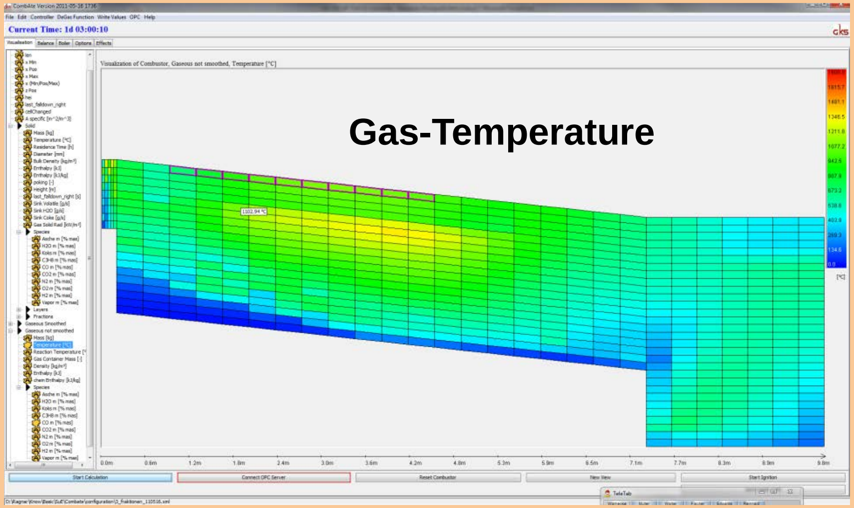
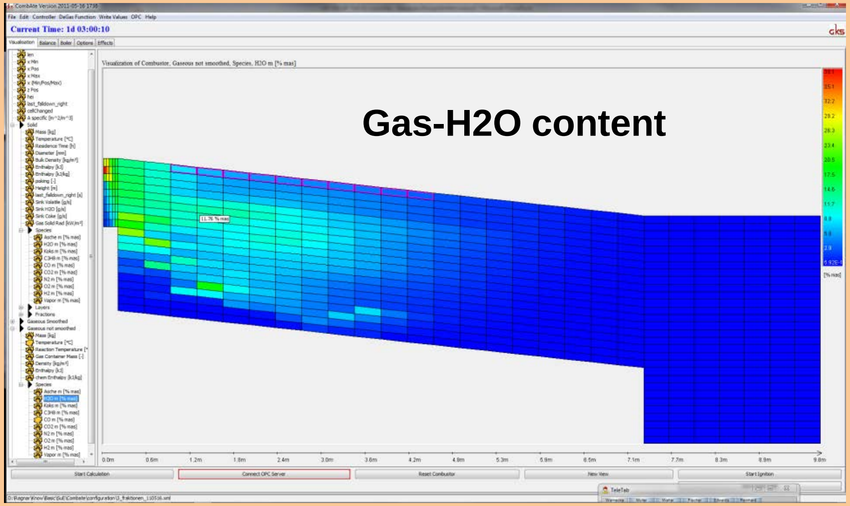
CombAte = **Comb**ustion on Gr**ate**







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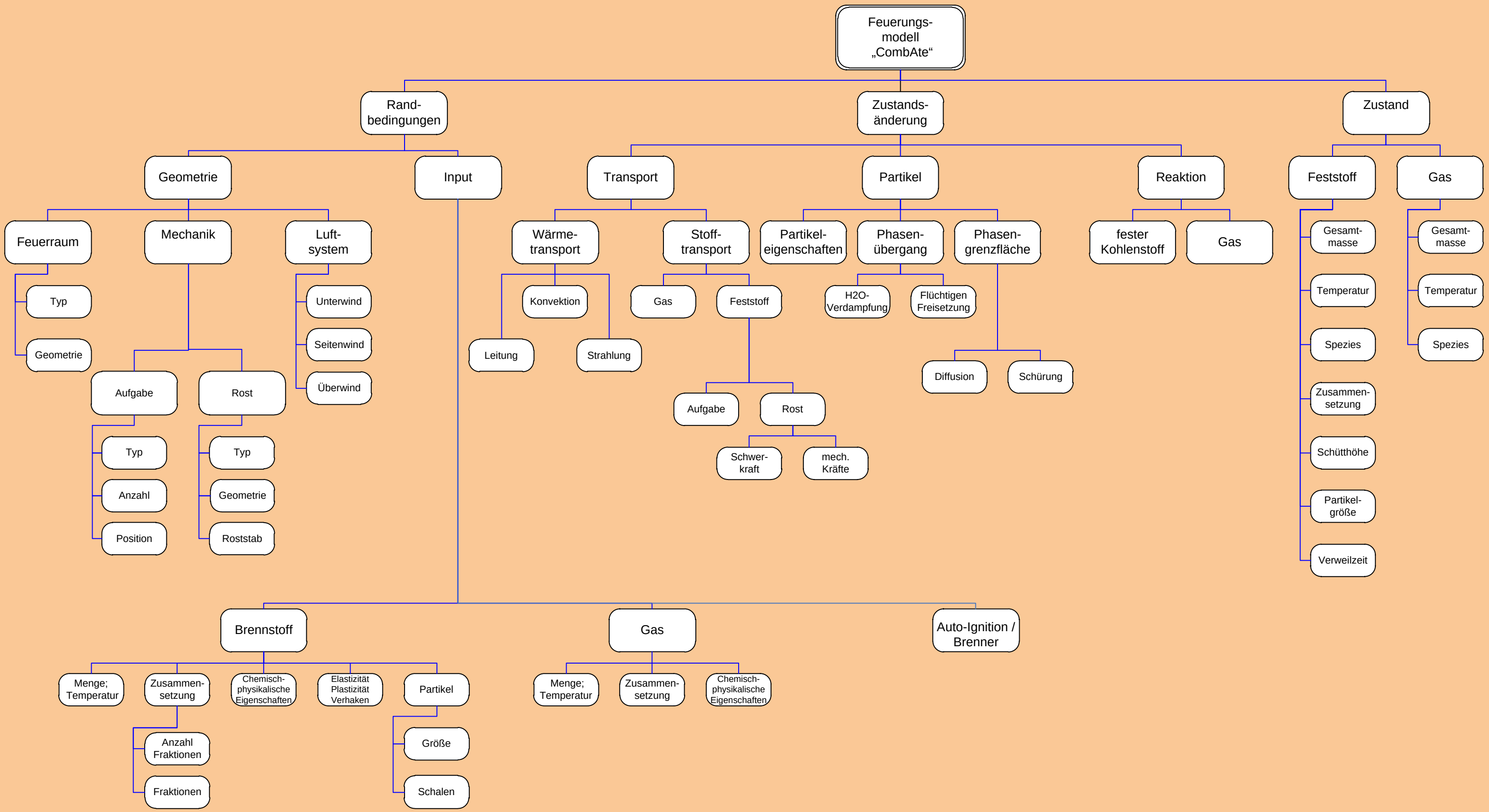
3. Key to truth – Confidence

Validation of every submodel has to be made



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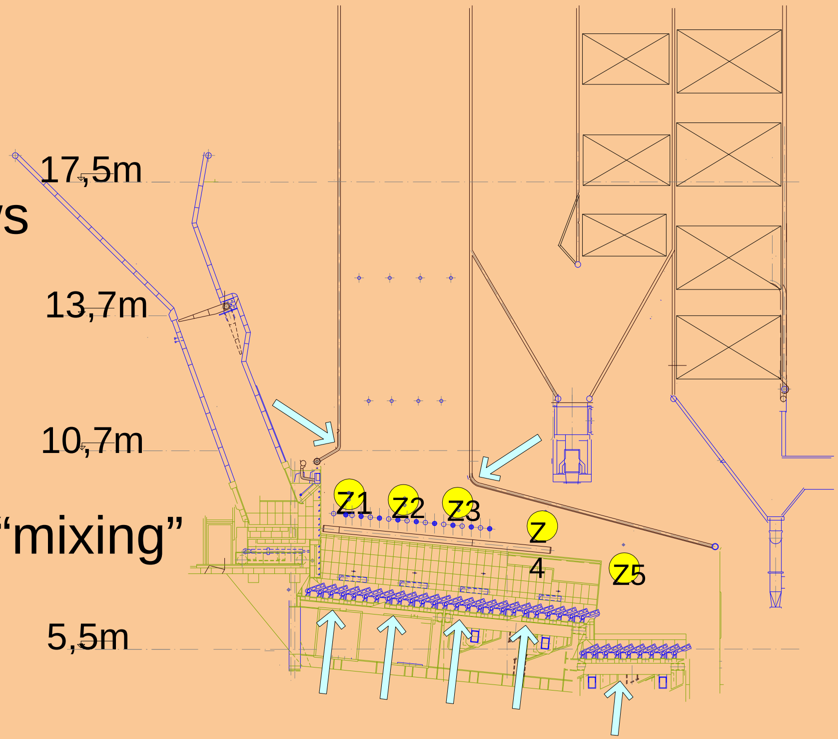
Parameter Validation

3.1 Basics:
- Using reliable physical/chemical laws
- with reliable material data

3.2 Fuel bed:
- Fuel bed height
- Total and local residence time
- Movement characteristics of “fuel” / “mixing”
- Ash content in slag
- Composition of bed material
- Pressure drop through “fuel” bed
- Temperature of grate bars
- Temperature in “fuel” bed

3.3 Combustion Chamber:
- Temperature in combustion chamber
- Gas phase an particles in combustion chamber



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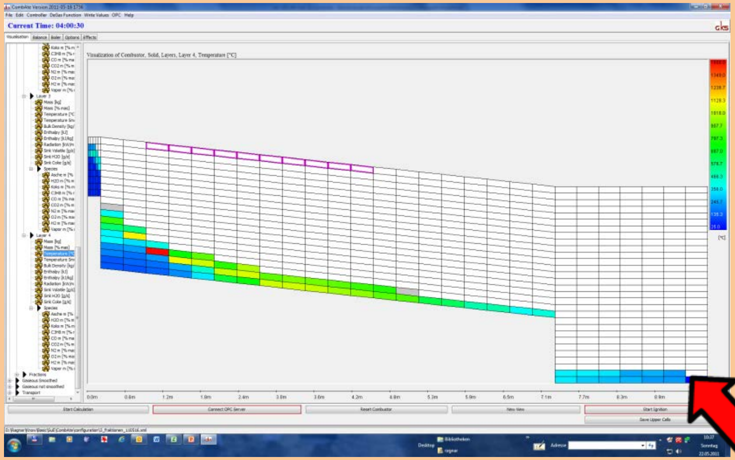
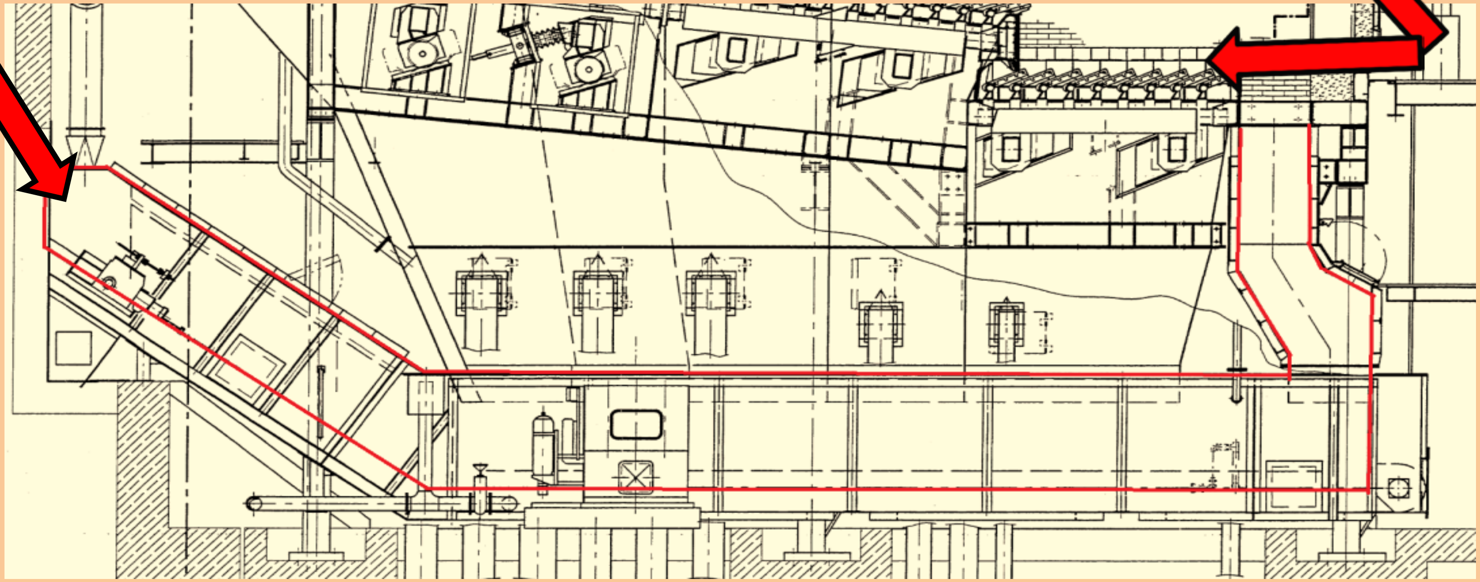
3.1 Reliable Material Data – Example: Slag



Deslagger



Last Grate

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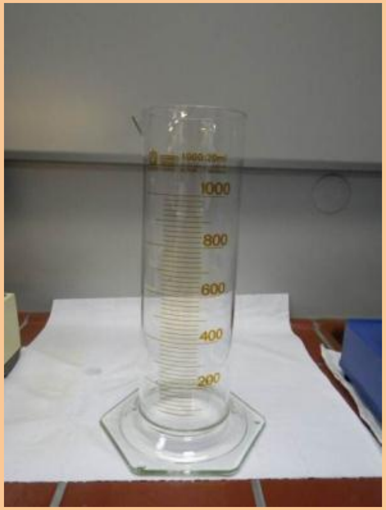
Slag: Bulk Density



					Werte für Mittelwertbildung:		
Größen:	**Bestimmung:**	**Einheit:**	**Messgefäß:**	**Mittelwerte:**	**Eimer 1**	**Eimer 2**	**Eimer 3**
Masse, feucht	gemessen	[g]	227	**3586**	3600	3449	3709
Masse, trocken	gemessen	[g]		**2735**	2747	2668	2789
Volumen	gemessen	[ml]	2750	**2750**	2750	2750	2750
Masse ohne Messgefäß, feucht	berechnet	[g]		**3359**	3373	3222	3482
Masse ohne Messgefäß, trocken	berechnet	[g]		**2508**	2520	2441	2562
Feuchte	berechnet	[%]		**25,32%**	25,29%	24,24%	26,42%
Feuchtdichte [kg/m³]	berechnet	[kg/m³]		**1221**	1226,5	1171,6	1266,2
Trockendichte [kg/m³]	berechnet	[kg/m³]		**912**	916,4	887,6	931,6
Epsilon, feucht	berechnet	[-]		**0,49**	0,49	0,51	0,47
Epsilon, trocken	berechnet	[-]		**0,62**	0,62	0,63	0,61

Slag:
Bulk Density, Moisture, Voidage

Größe:	Bemerkungen zu Größen:	Einheit:	Festgelegter Wert:	Festgelegter Bereich:	Mittelwert:	Standard-abweichung:
Quelle:	GKS				Berechnet	Berechnet
Messbedingung:	siehe Einzelmessungen					
Bemerkungen zu Messungen:						
Reindichte (trocken), qualitativ berechnet		[kg/m3]	**2.750**	**2.400-2.800**		
Reindichte (trocken), gemessen	verlässlich	[kg/m3]	**2.750**	**2.400-2.800**	**2770**	
Schüttdichte, feucht, aus Schlackebunker	verlässlich	[kg/m3]	**1.350**	**1.200-1.400**	**1342,83**	
Schüttdichte, trocken, aus Schlackebunker	verlässlich	[kg/m3]	**1.150**	**1.100-1.300**	**1168,26**	
Feuchte b. Verlad. aus Schlackebunker	verlässlich	[%]	**15%**	**10 - 15%**	**13,00%**	
Lückengrad, trocken, aus Schlackebunker	verlässlich	[-]	**0,58**	**0,5 - 0,6**	**0,58**	
Schüttdichte, feucht, n. Naßentschlacker	verlässlich	[kg/m3]	**1.100**	**1.000-1.200**	**1120,82**	77,58
Schüttdichte, trocken, n. Naßentschlacker	verlässlich	[kg/m3]	**850**	**800-900**	**838,45**	52,01
Feuchte n. Naßentschlacker	verlässlich	[%]	**23%**	**22-28%**	**25,11%**	0,02
Lückengrad, trocken, n. Naßentschlacker	verlässlich	[-]	**0,69**	**0,6 - 0,7**	**0,59**	0,03
Schüttdichte, trocken, auf Ausbrandrost	verlässlich	[kg/m3]	**600**	**500-800**	**593,35**	22,34
Lückengrad, trocken, auf Ausbrandrost	verlässlich	[-]	**0,78**	**0,7 - 0,8**		0,01

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Reliable Material Data: Fuel

Nr.:	Fractions:	[Mas.-%]
1	Fine Fraction < 10 mm	**12,6**
2	Medium Size Fraction 10-40 mm	**11,6**
3	Organic	**14,1**
4	Paper, Cardboard	**10,0**
5	Hygienic Products	**9,0**
6	Plastic Package incl. Foil, Other Plastics	**9,5**
7	Textiles, Shoes	**5,2**
8	Assembled Package, Elektronics, Renovation, Vacuum Cleaner Bags	**10,5**
9	Wood	**1,6**
10	Leather, Rubber, Cork	**4,4**
11	Rest	**11,5**
	Sum	**100,0**

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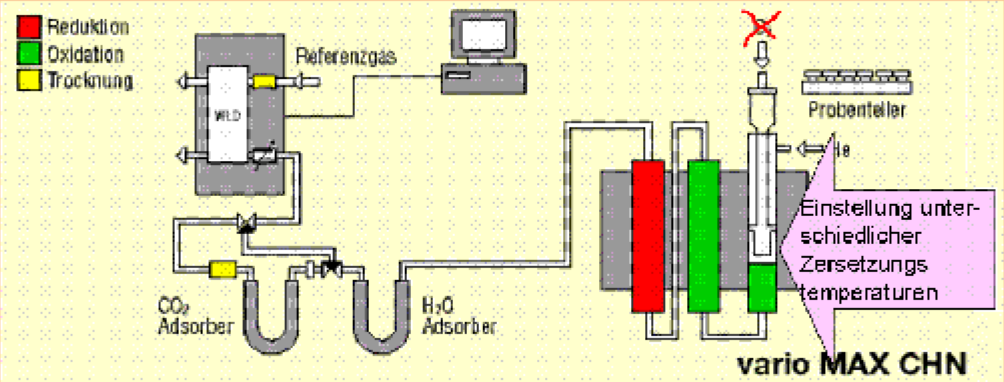
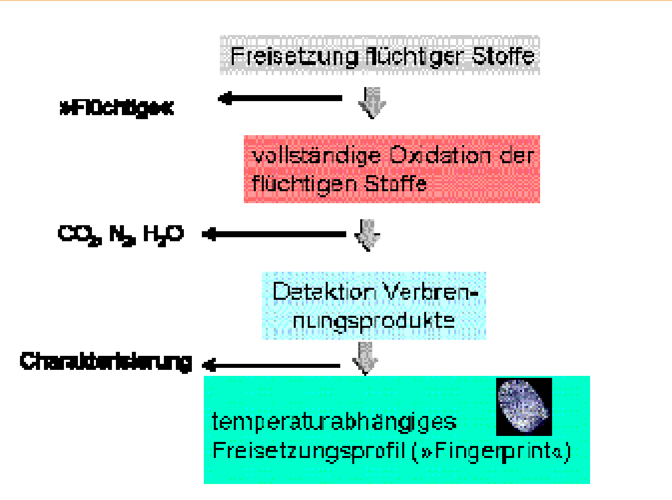
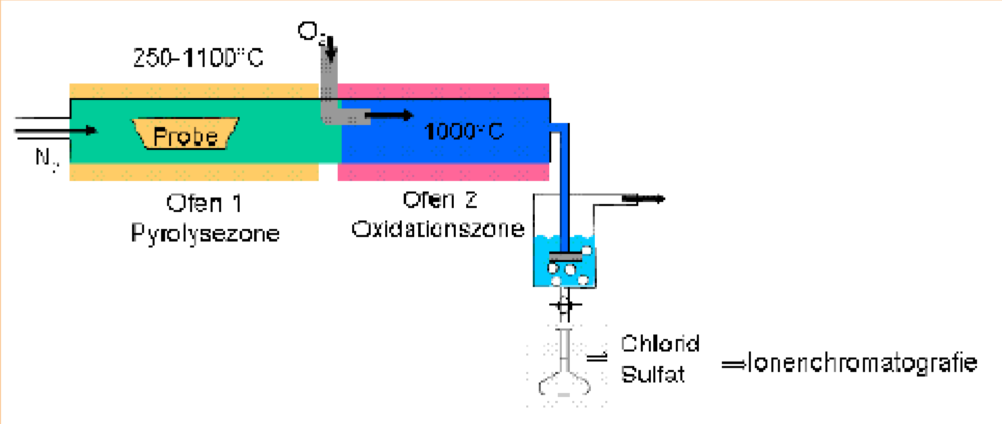
Fuel: Fingerprint-Analysis (UMSICHT-GKS)

Detection of released elements: C, H, O, N, S, Cl, (F) as function of temperature and time!





Detection of released elements: Na, K, Ca, Pb, Zn as chloride and as function of temperature and time!



Analysis of every single waste fraction!

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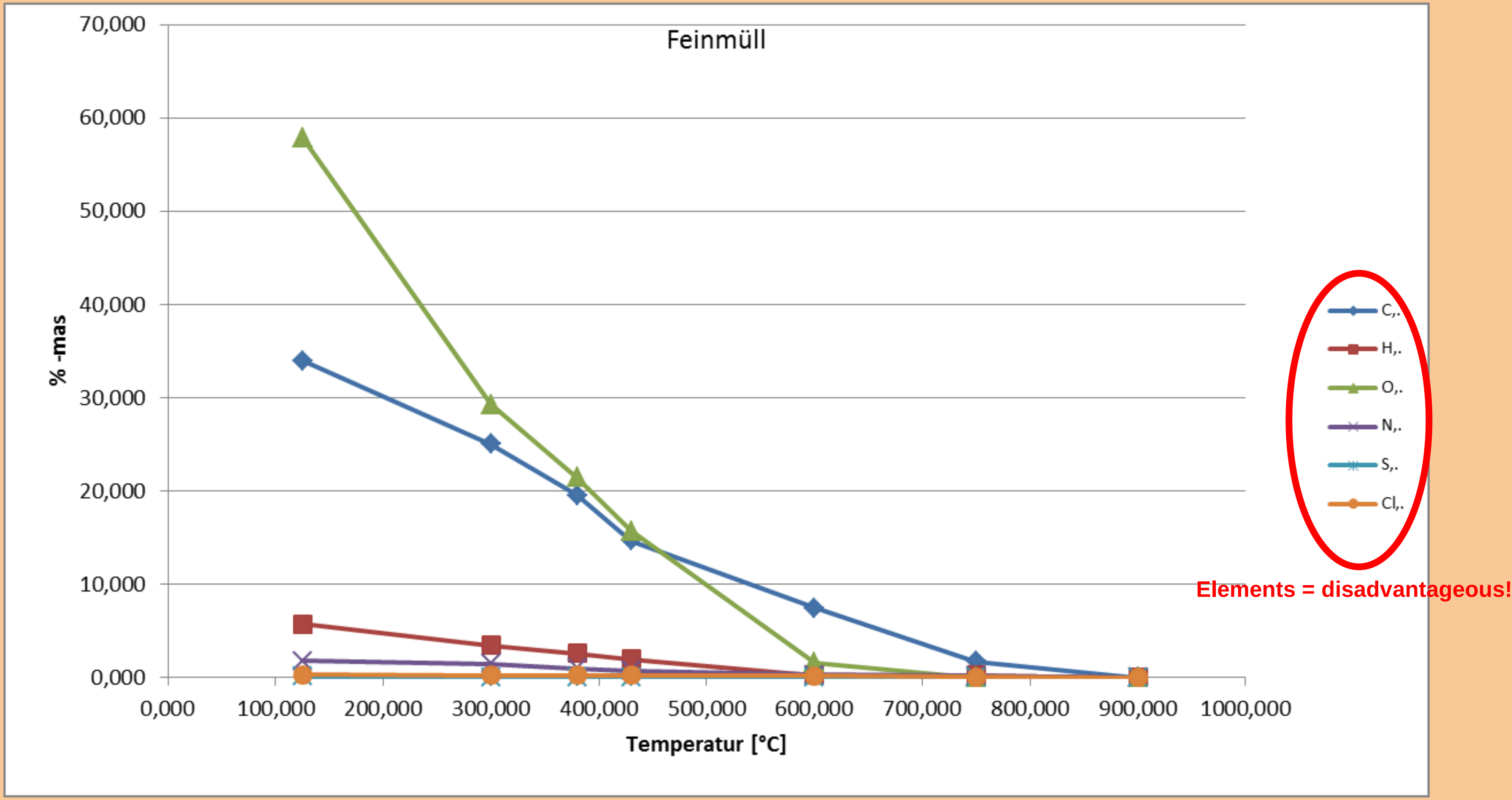
Fuel: Release of Elements of Volatiles



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Fuel: Calculation to Species

4.1.1 Daten aus der Sortieranalyse des BLU

Tabelle 4-1: Anteil am Restmüll und Wassergehalt für die Sortierfraktion „Feinmüll"

Stoffgruppe	Anteil am Restmüll (bez. auf Trockenmasse) [%]	Wassergehalt [%]
Feinmüll	12,6%	28,7

4.1.2 Konventionelle Brennstoffcharakterisierung

Tabelle 4-2: Feinmüll konventionelle Brennstoffcharakterisierung

Parameter	Wert
Wassergehalt [%]	5
Brennwert (Ho) [MJ/kg TS]	5,4
Heizwert (Hu) [MJ/kg TS]	5,0
Asche [% TS]	65
Flüchtige Bestandteile [% TS]	31
Cfix [% TS]	3,1
Chlor (ges) [% TS]*	0,11/0,25
Schwefel (ges.) [% TS]*	0,18/0,38
Kohlenstoff (ges.) [% TS]	15,8
Wasserstoff (ges.) [% TS]	2
Stickstoff (ges.) [% TS]	0,7

*Ergebnisse Doppelbestimmung

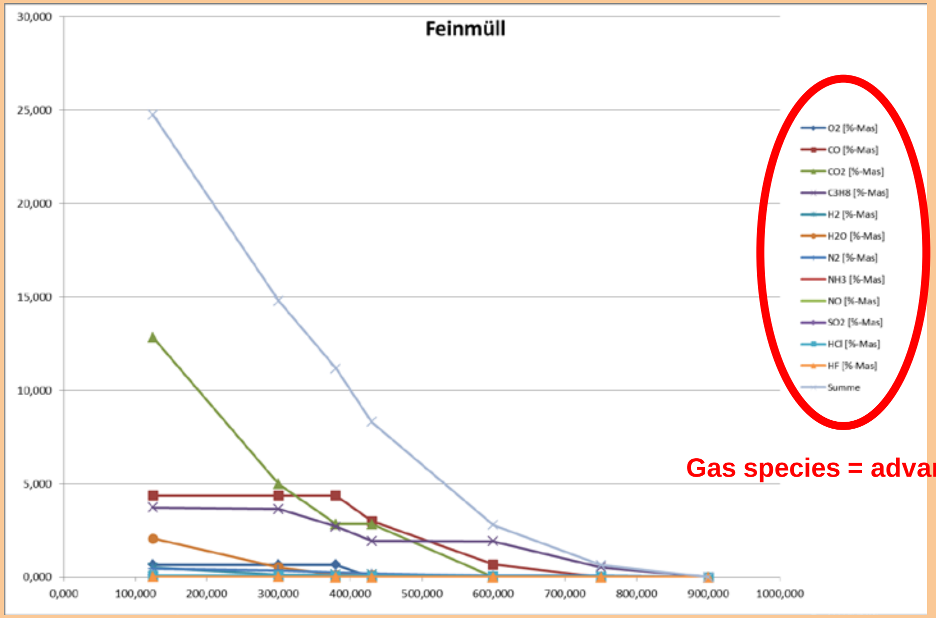
4.1.3 Temperaturabhängiges Freisetzungsverhalten von Flüchtigen und deren Heizwert

Tabelle 4-3: Temperaturabhängiges Freisetzungsverhalten von Flüchtigen und deren Heizwert-Feinmüll

Freisetzungs-temperatur [°]	Komponente	N [%]*	C * [%]	H * [%]	O** [%]	Hu** [MJ/kg]
300	Flüchtige	0,11	3,1	0,8	10,5	0,7
380	Flüchtige	0,28	5,0	1,1	13,2	1,3
430	Flüchtige	0,37	6,7	1,3	15,2	2,0
600	Flüchtige	0,52	9,2	1,9	22,9	2,5
750	Flüchtige	0,56	11,2	1,9	20,7	3,5
900	Flüchtige	0,63	11,8	2,0	20,1	3,9
900	Koksrückstand n. Entgasung	0,08	3,9	0,1		1,5
Gesamt***		0,7	15,7	2,1	19,3	5,4

*Messwerte, **berechnete Werte, ***Summe Koksrückstand und Flüchtige bei 900°C

Under attention of all balances!



Gas species = advantageous!

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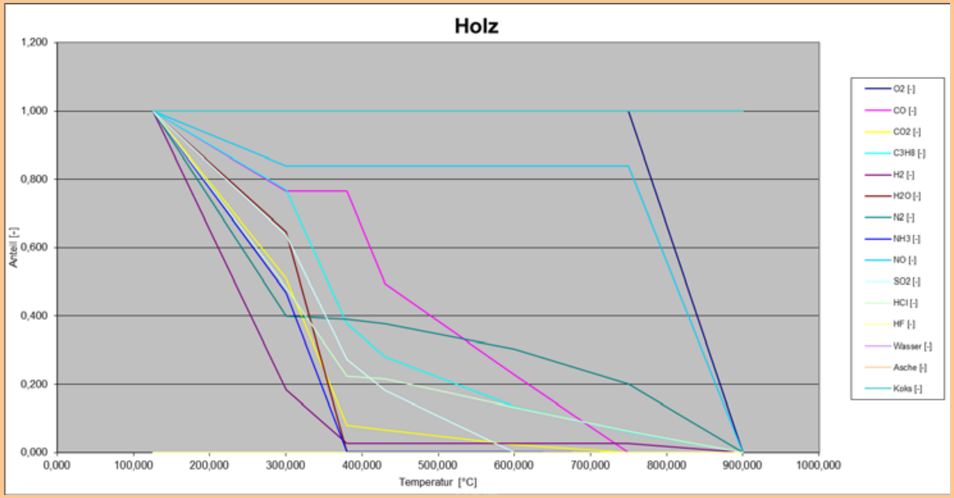
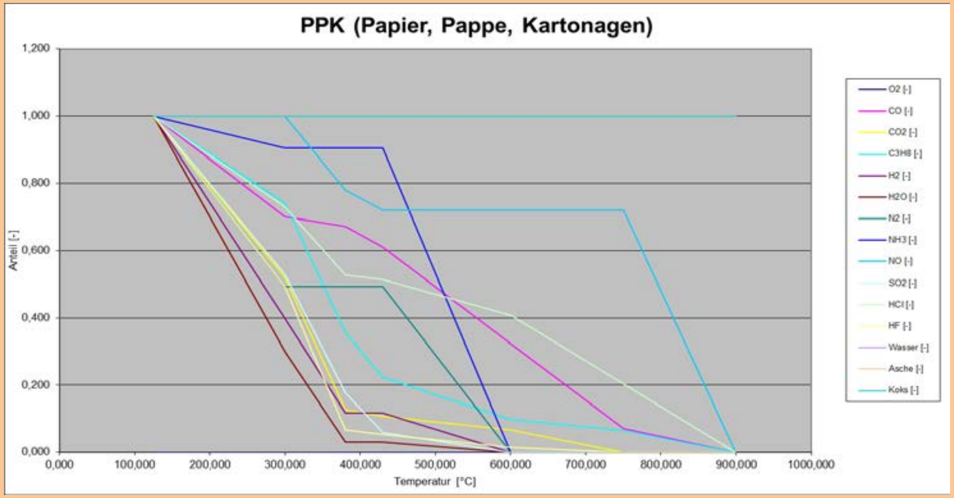
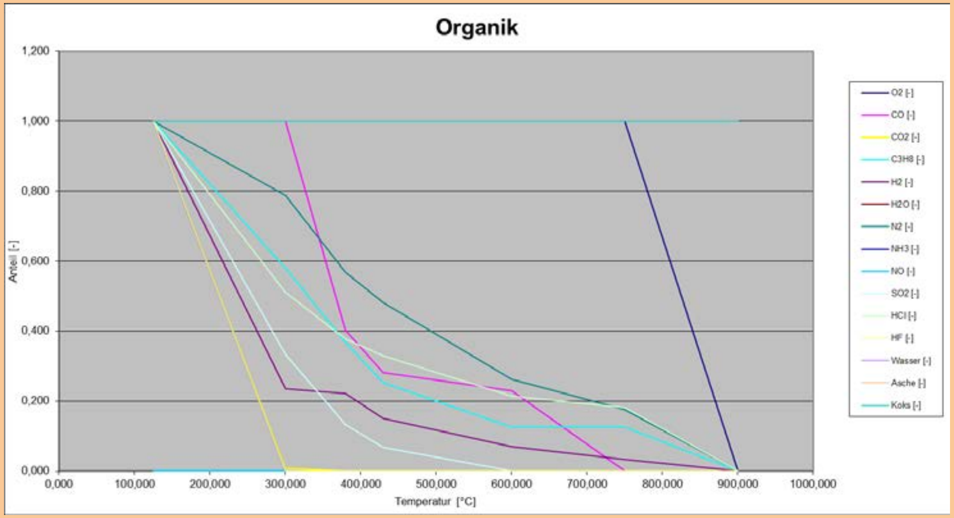
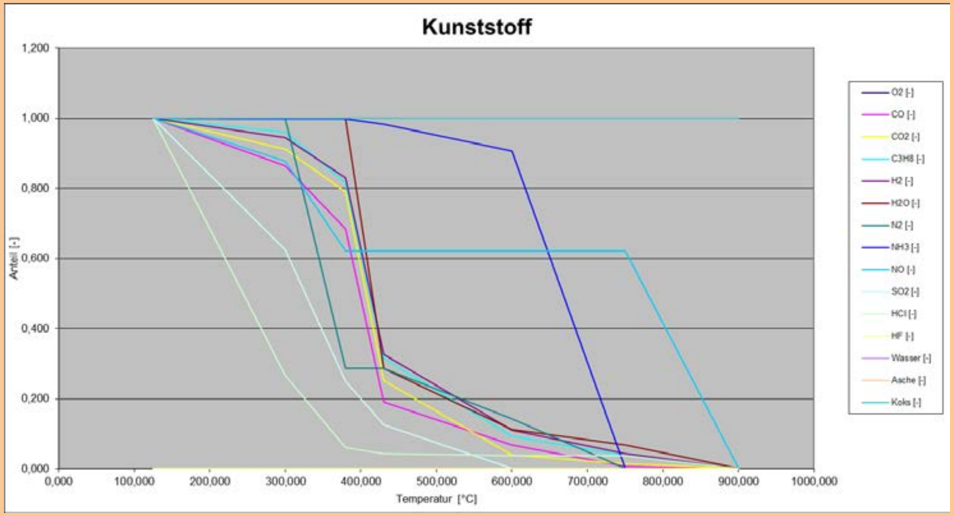
Fuel: Release of Fractions (Examples)









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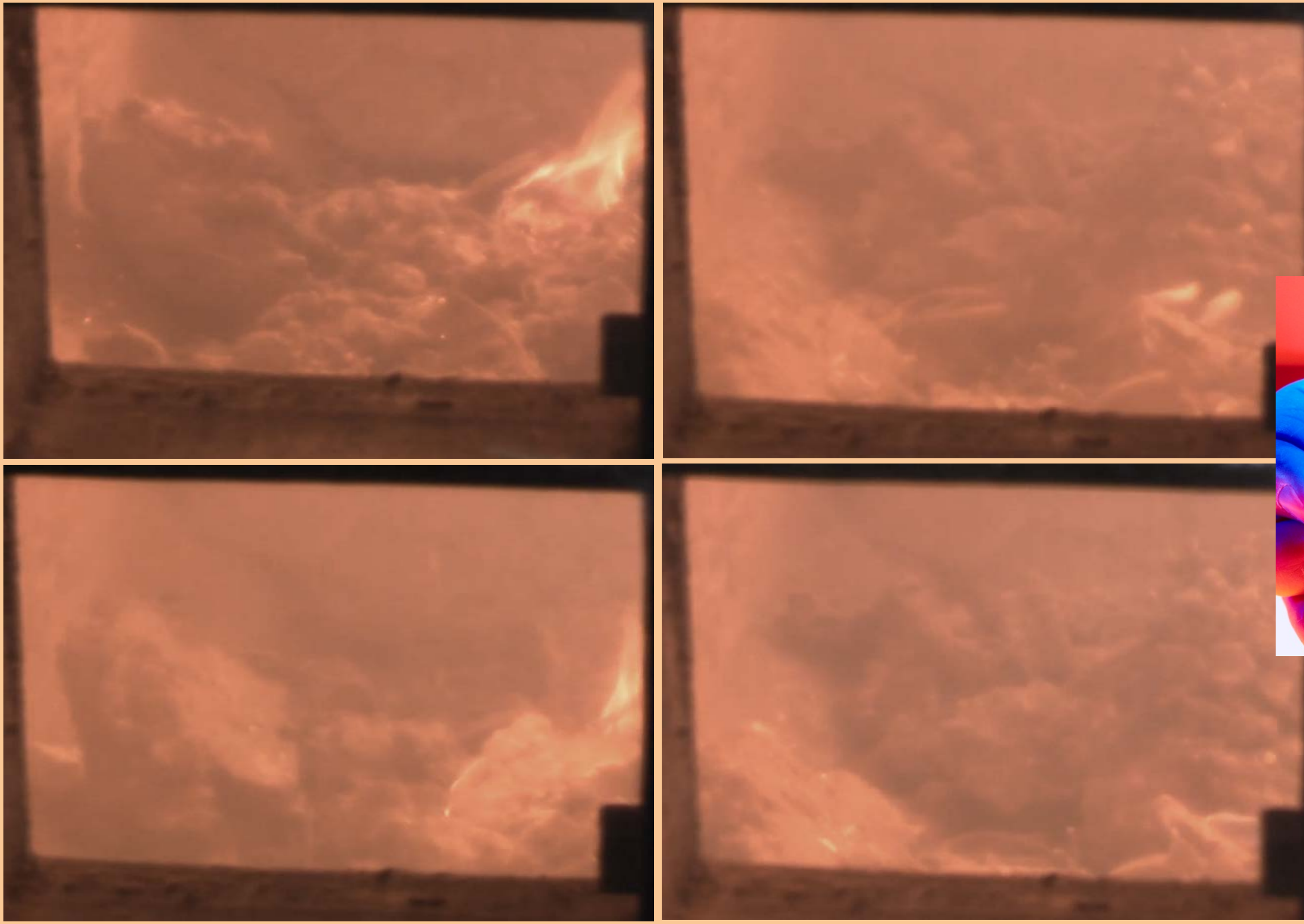
3.2 Height / Residence Time / Movement



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Movement of Waste / Height

Waste is moving as a „bulk“ over the grate with little mixing

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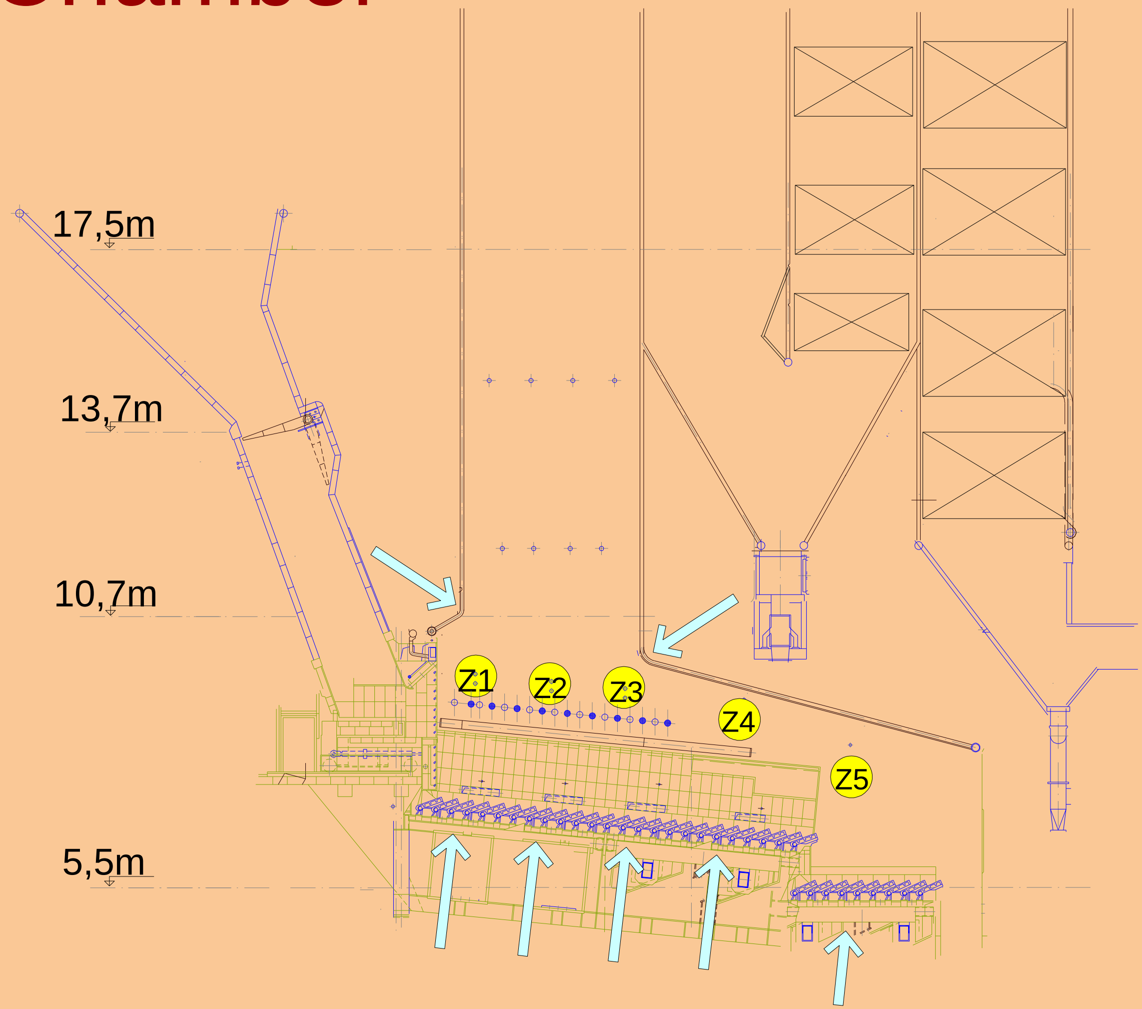
3.3 Temperature and Species in Combustion Chamber



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Process Data from Measurement in Combustion Chamber

Größe:	**Einheit:**	**Z 1**	**Z 2**	**Z 3**	**Z 4**	**Z 5**
Unterwind	m^3/h(N,tr)	1.250	3.300	4.750	3.600	900
Plattenluft	m^3/h(N,tr)	3.700	1.300	1.200	700	-
Primärluft	m^3/h(N,tr)	4.950	4.600	5.950	4.300	900
Vol.-Str.	m^3/h(N,tr)	4.577	4.862	10.636		873
CO	Vol.-%	2,49	1,64	0,07		0,00
CO2	Vol.-%	17,5	11,9	9,5		3,9
SO2	mg/m^3	947	953	325		108
HCl	mg/m^3	1.396	453	456		216
Temp.	°C	1.050	1.150(1.100)	1.100(1.150)	850	700
Schütthöhe	mm	?	?	?	150-200	200-250

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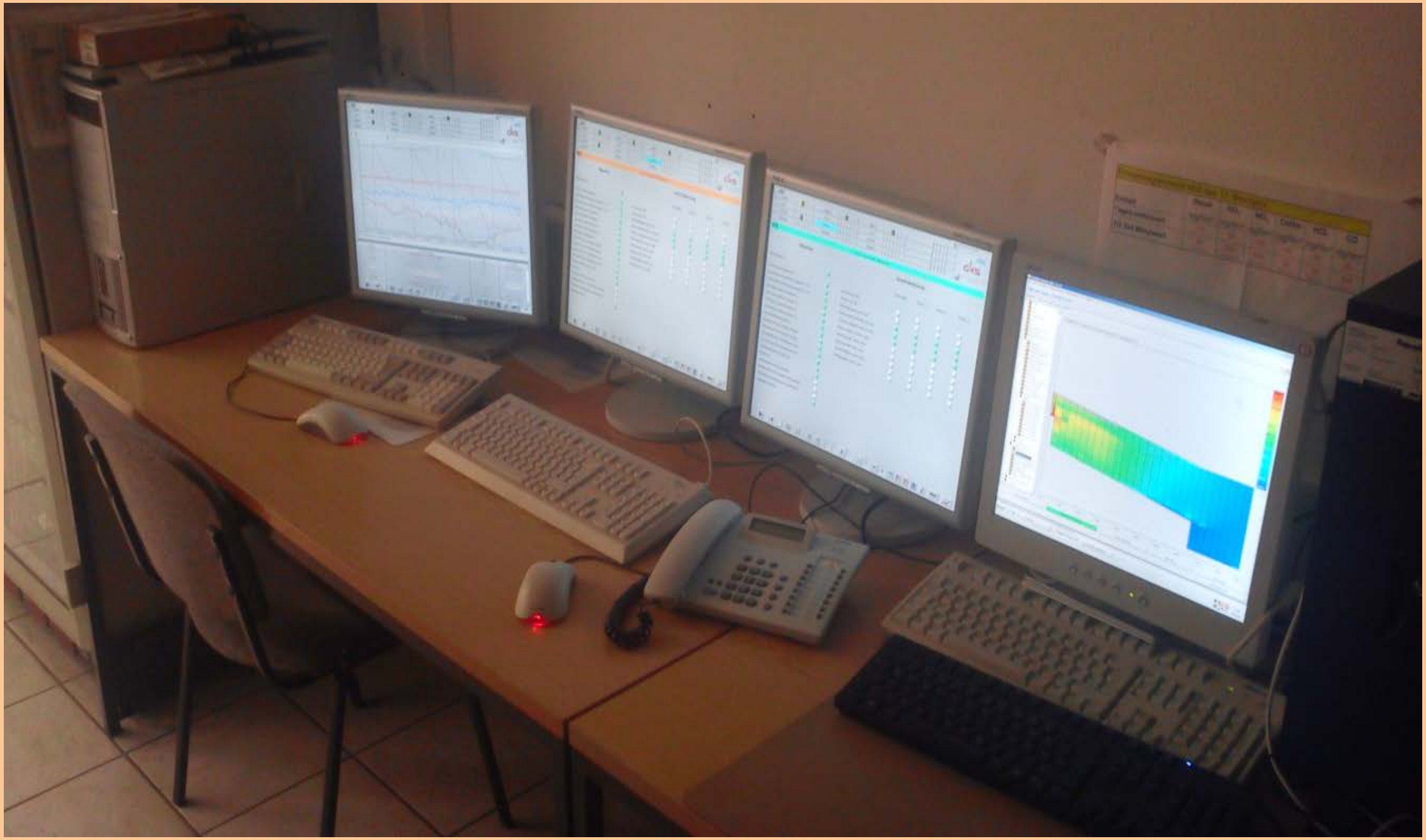
4. CombAte and Combustion Control coupled via OPC



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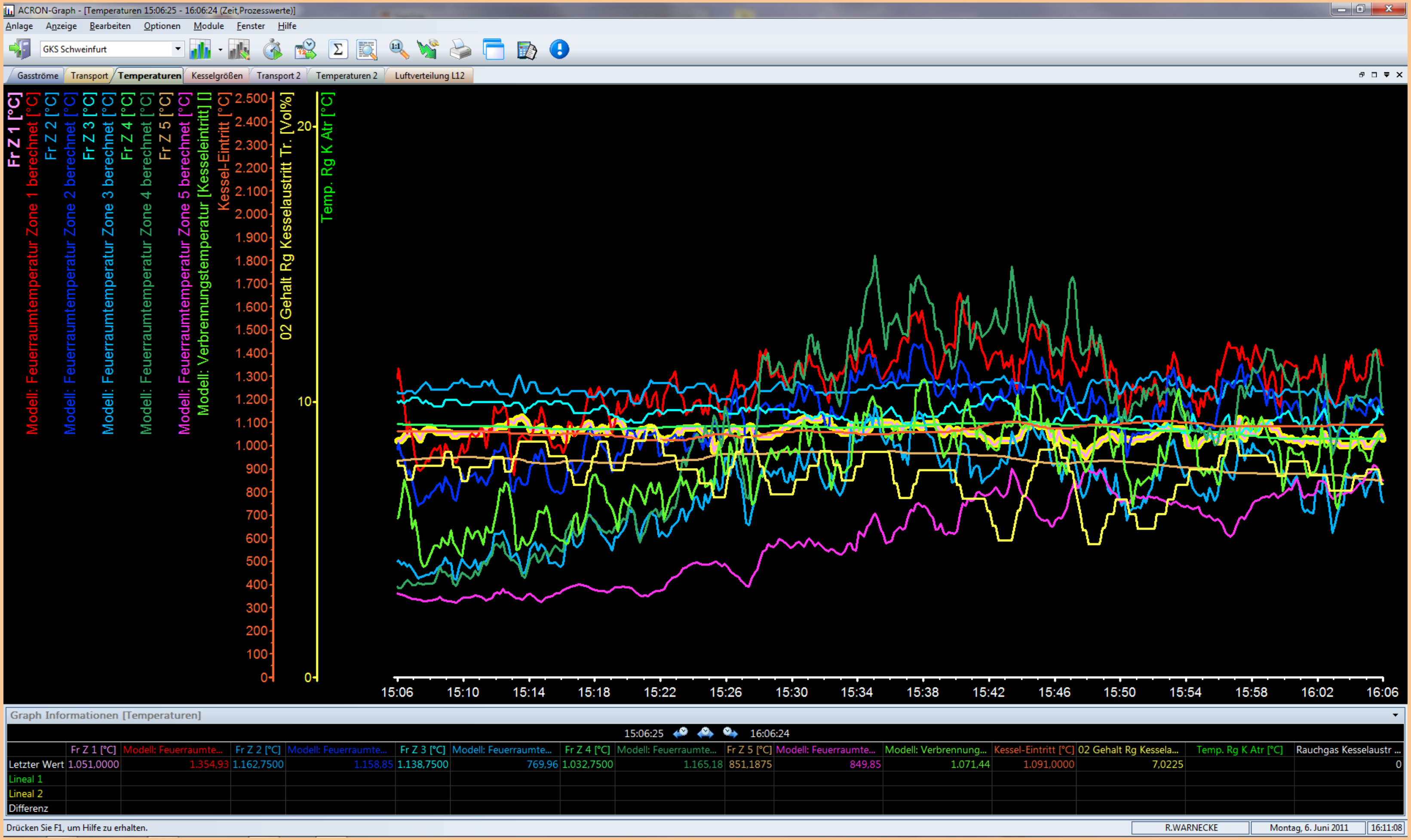
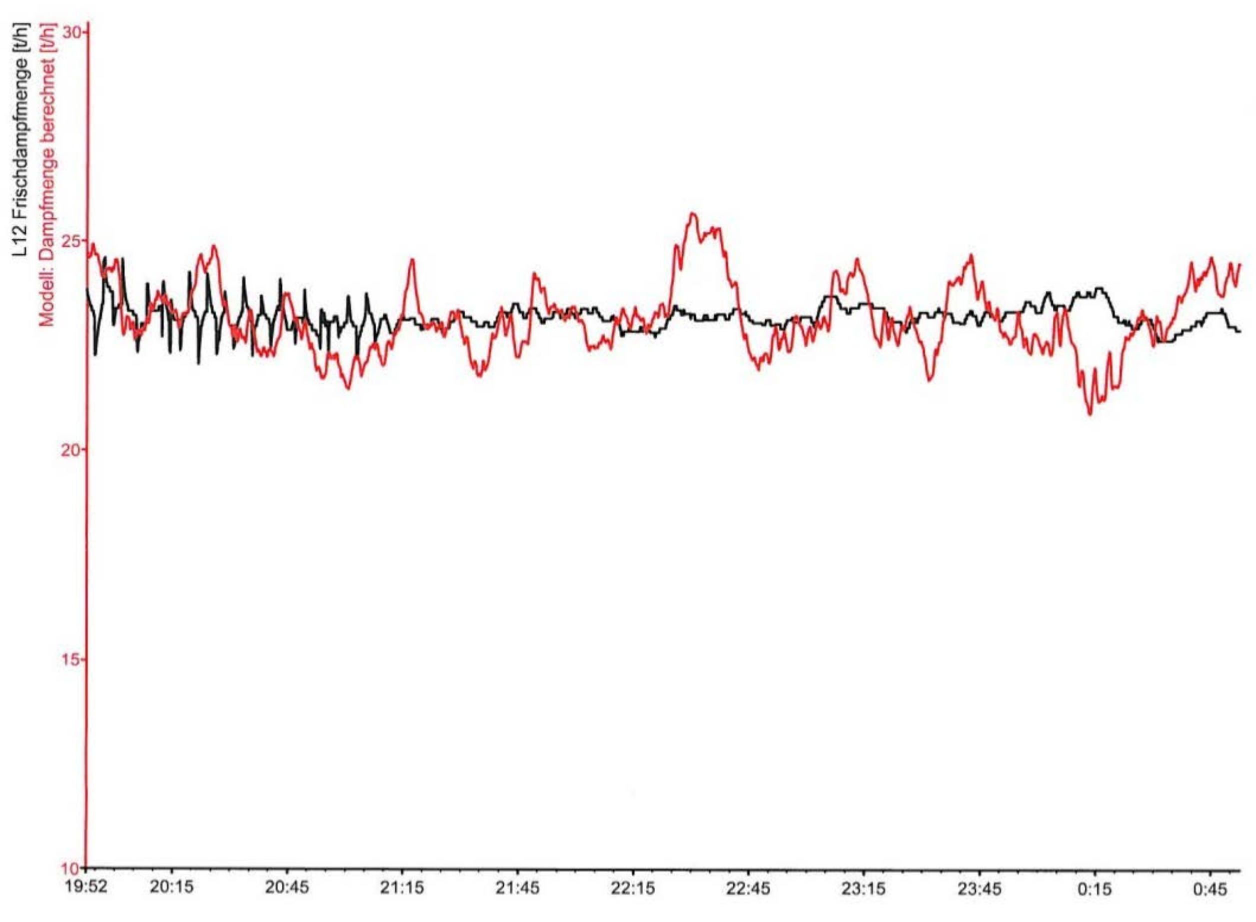
Comparison of Data



Comparison Steam Production of CombAte and Plant



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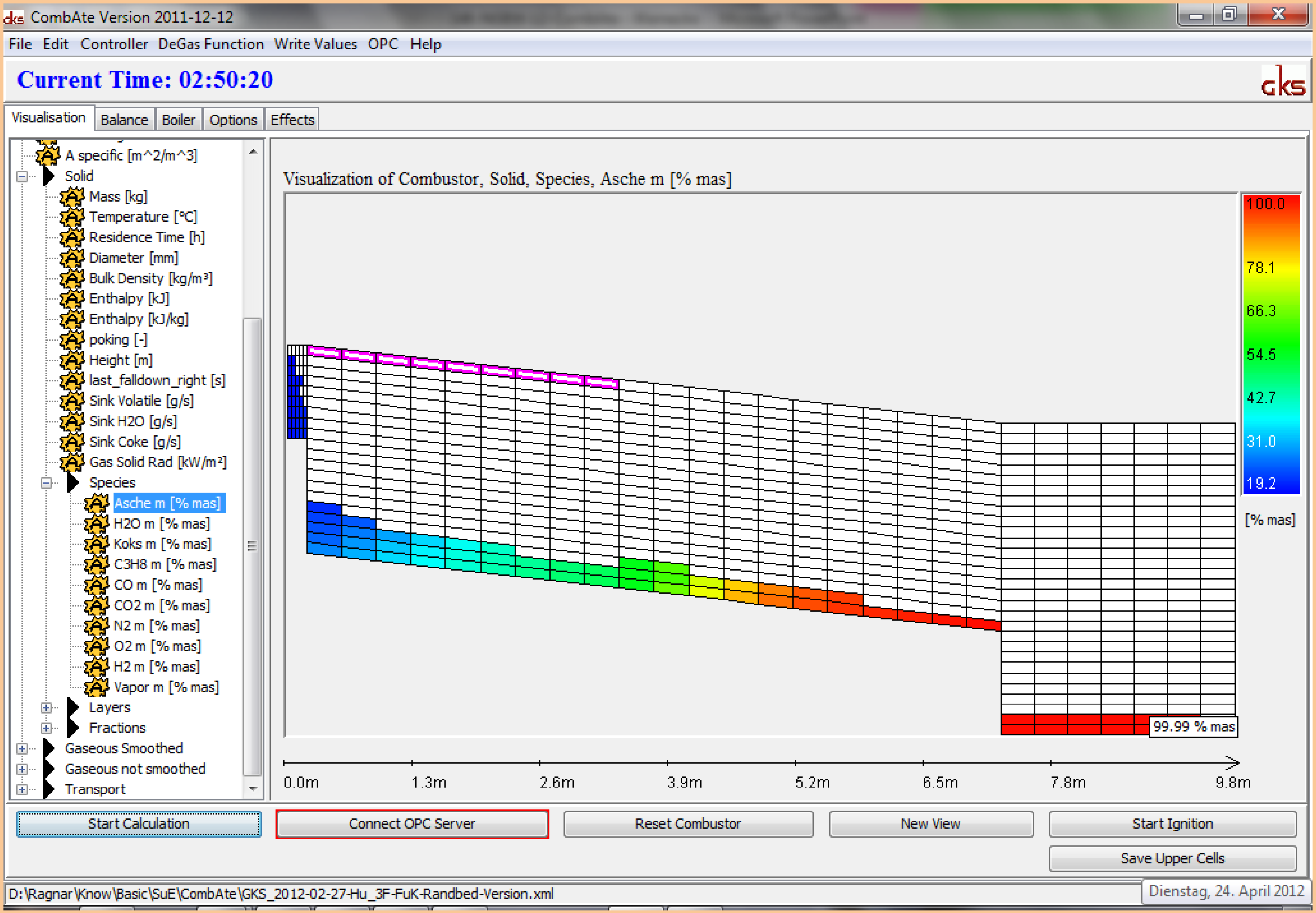
5. Operating CombAte



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6. Conclusion and Outlook

1. Very pleasant results in comparison to the real plant

2. Further investigations are under operation now (measurement of fuel bed temperature and species)

3. Use for starting conditions for CFD calculation allows realistic CFD

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