„High temperature combustion of biomass in an entrained flow reactor“

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Agenda

- Project / Motivation
- Main research
- Experimental plant
- Investigations
- Forecast

Project (FNR)

Investigation and development of process concepts for the thermal use of biomass

Topics:

- Reduction of emissions (CO, C_xH_y, fine dust, NO_x, C)
- Formation of tar
- Effect of biomass pretreatment
- Sustainability

WP 1
High-temperature combustion:
Entrained-flow combustor

WP 3
High-temperature gasification:
Entrained-flow gasifier

FNR

WP 2
Generation and corrosion:
High-temperature heat exchanger

WP 4
Biomass treatment:
HTC-reactor

Work package 1: High - temperature combustion

➡ Combustion temperature (range of 1000 -1300° C)

Depending on fuel and combustion technology combustion temperature should be:

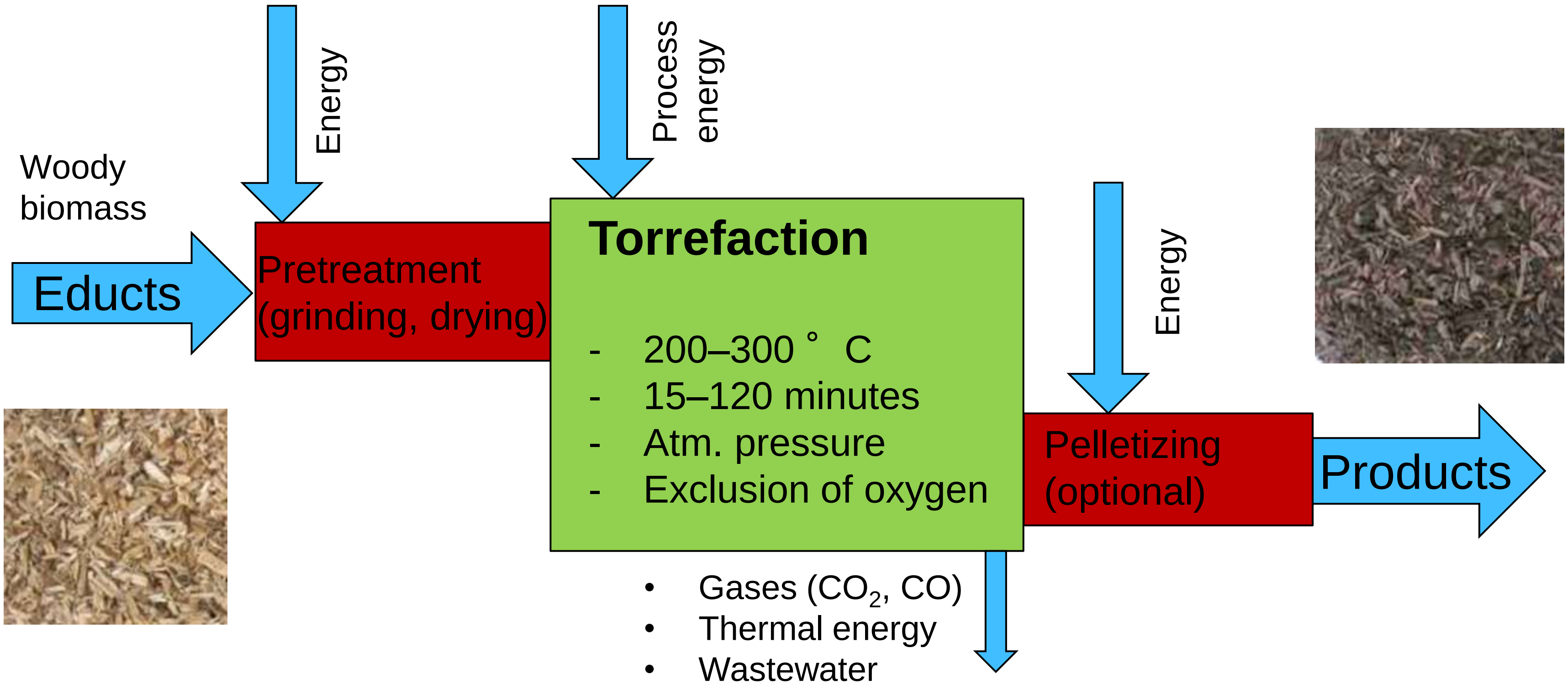
- below the ash melting point
- or in the range of forming a completely liquid phase (above T_{cr})
  Fuels: pulverised torrefied and hydrothermal carbonised biomass

➡ Investigation of:

- NOx - formation at different temperatures and reduction by primary measures (TA Luft/BImSchV)
- Gas quality of different biomasses
- Ash melting behavior
- Viscosity of ash meltings

Torrefaction

a form of pyrolysis under mild conditions in the range of 200 - 300 ° C under athmospheric pressure. During the process the biomass is dried and volatiles removed



[1]

Hydrothermal carbonisation (HTC)

the conversion of biomass under hydrothermal conditions (170 - 250 C /10-20 bar) in an aqueous environment to produce a lignite similar product.

Energy

Process energy
Process water
Catalysts

Educts

Pretreatment (grinding)

HTC
- 170 – 250 ° C
- 4 – 16 h
- 10 – 20 bar

Energy

Pelletizing (optional)

Products

Biomass:

- Straw / Hay
- Maize / grass – sillage
- Fermentation residues
- Sewage sludge
- Wood chips
- Draff

Gases (CO_2, CO, CH_4)
Thermal energy

Wastewater

[1]

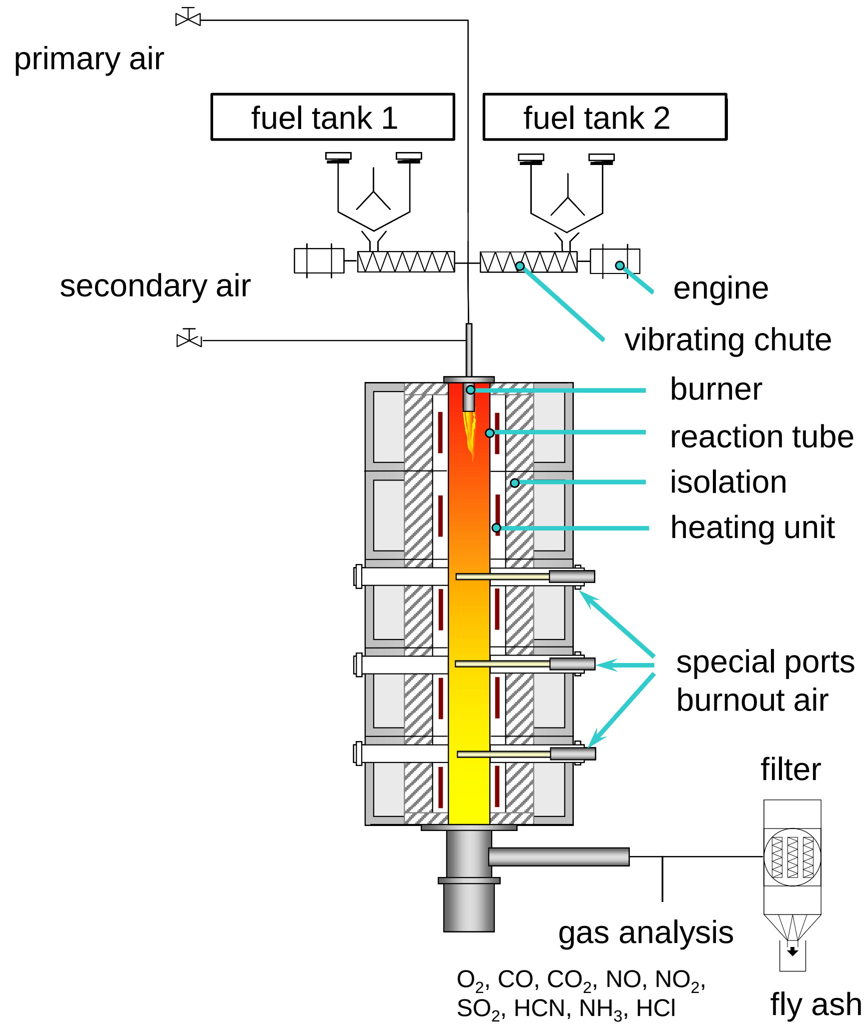
Entrained flow reactor (EFR)

Possible solid fuels

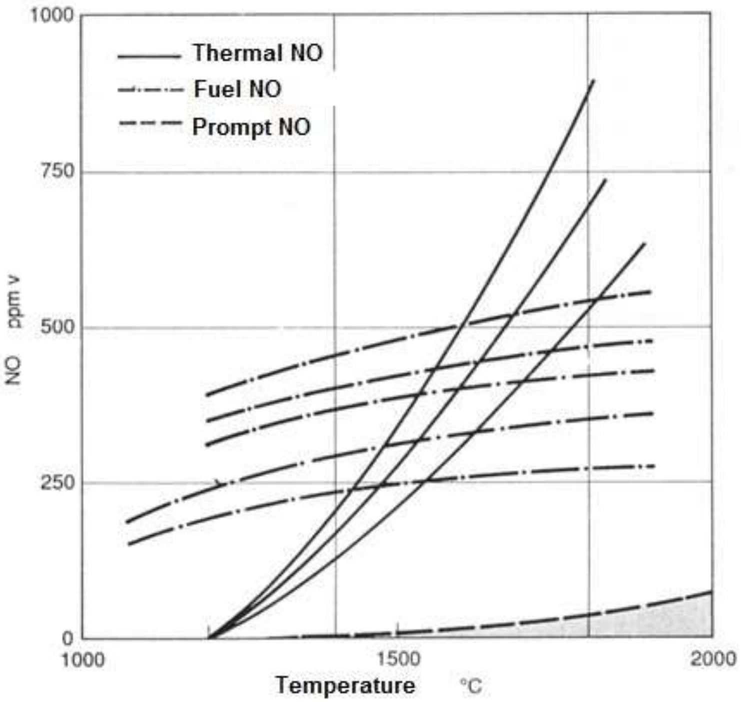
- Butiminious / brown coal
- Torrefied biomass / HTC coal in ground form
- Sludge

Technical data

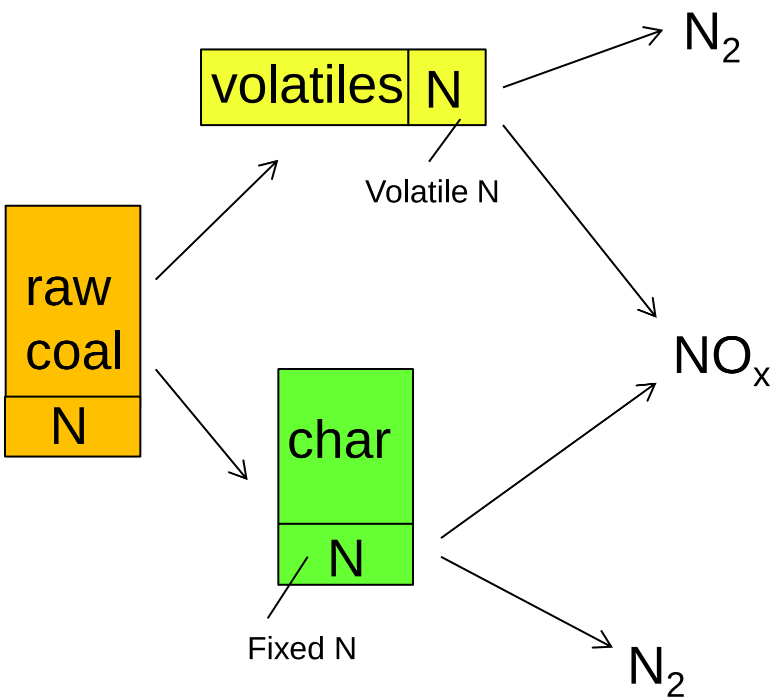
- Reactor height: 2 m
- Inner diameter: 150 mm
- heat output: 50 kWth
- max. operating temperature: 1500° C
- operating pressure: atmospheric
- fuel mass flows: 1 kg/h
- residence time : 0,2 – 1,5 s



NO_x Formation



[2]



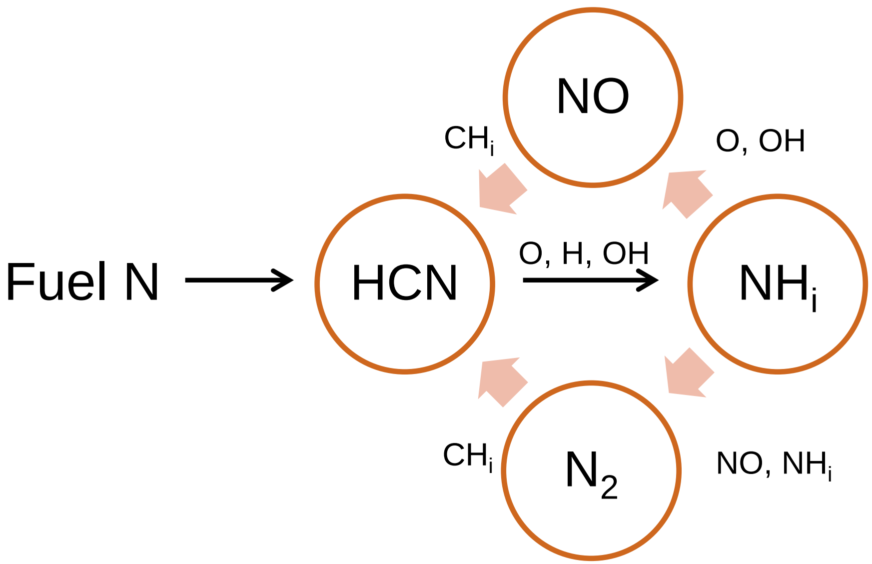
NO_x formation from fuel nitrogen in pulverised coal combustion depends on:

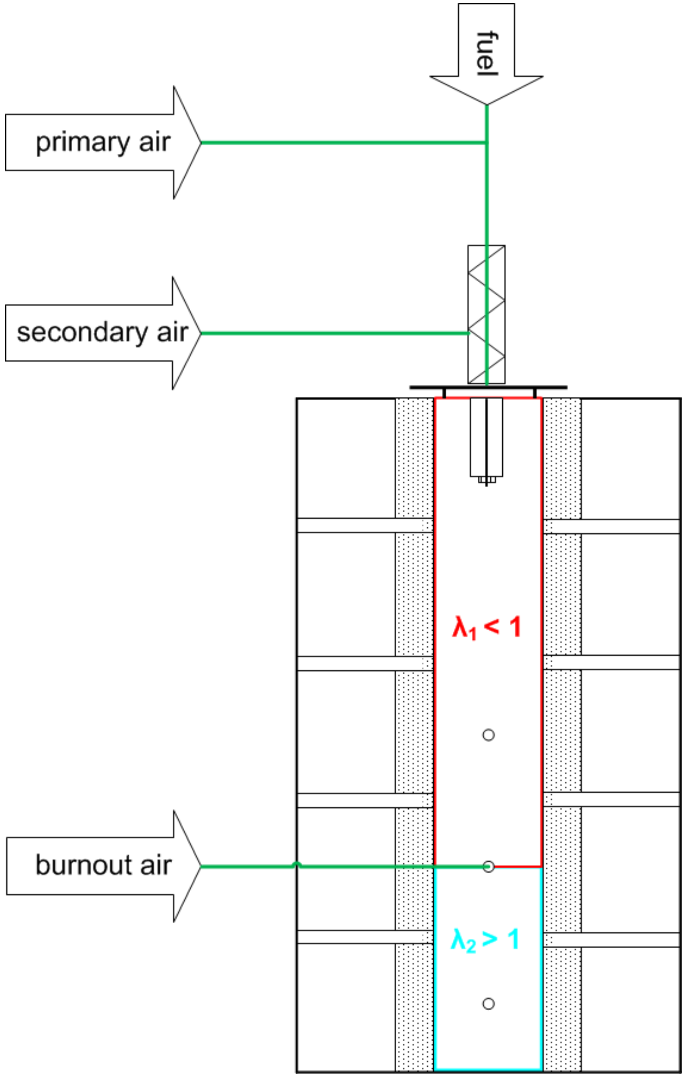
- the devolatilisation of the fuel nitrogen
- the formation of NO from residual char nitrogen and
- the formation of NO from the nitrogen of volatile matter

[3]

Reduction of NO_x with air staging

- Substoichiometric in the primary zone
  ➡ $\lambda_1 = 0{,}6 – 1{,}1$

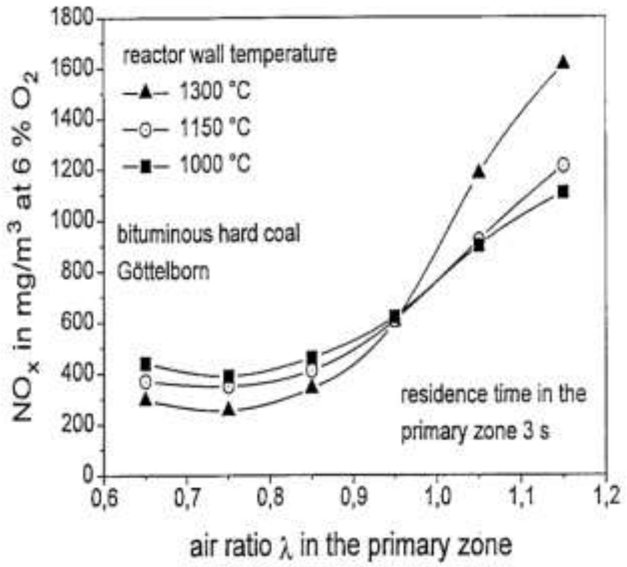


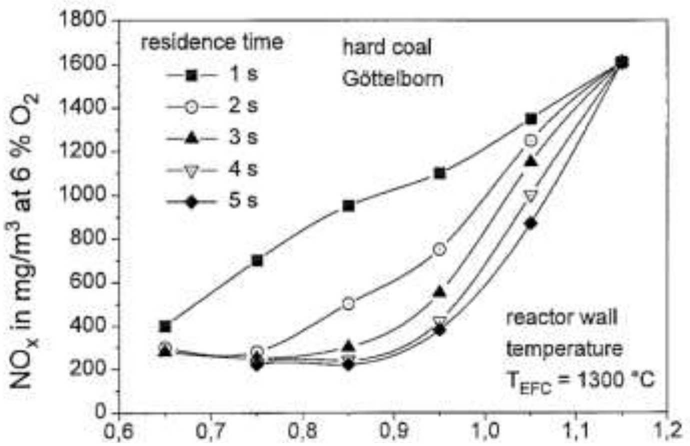


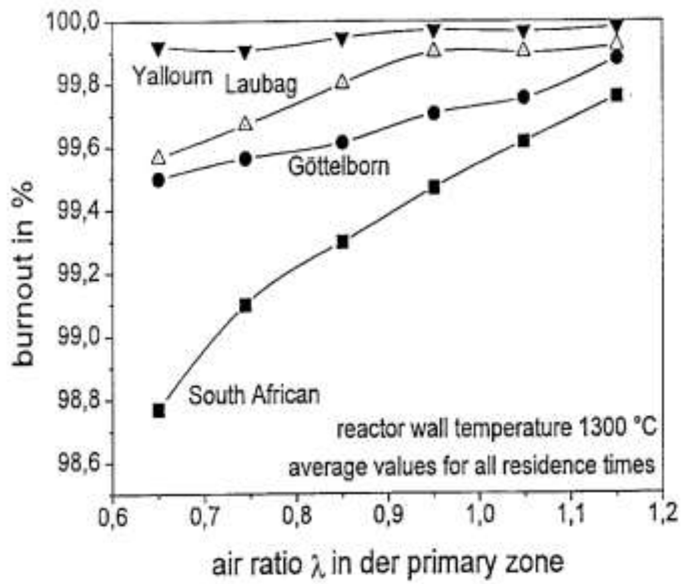
- Less excess air in the burnout zone
  ➡ $\lambda_2 = 1{,}2$

Significant factors for the NO_x reduction:

- Temperature
- Residence time
- Air ratio

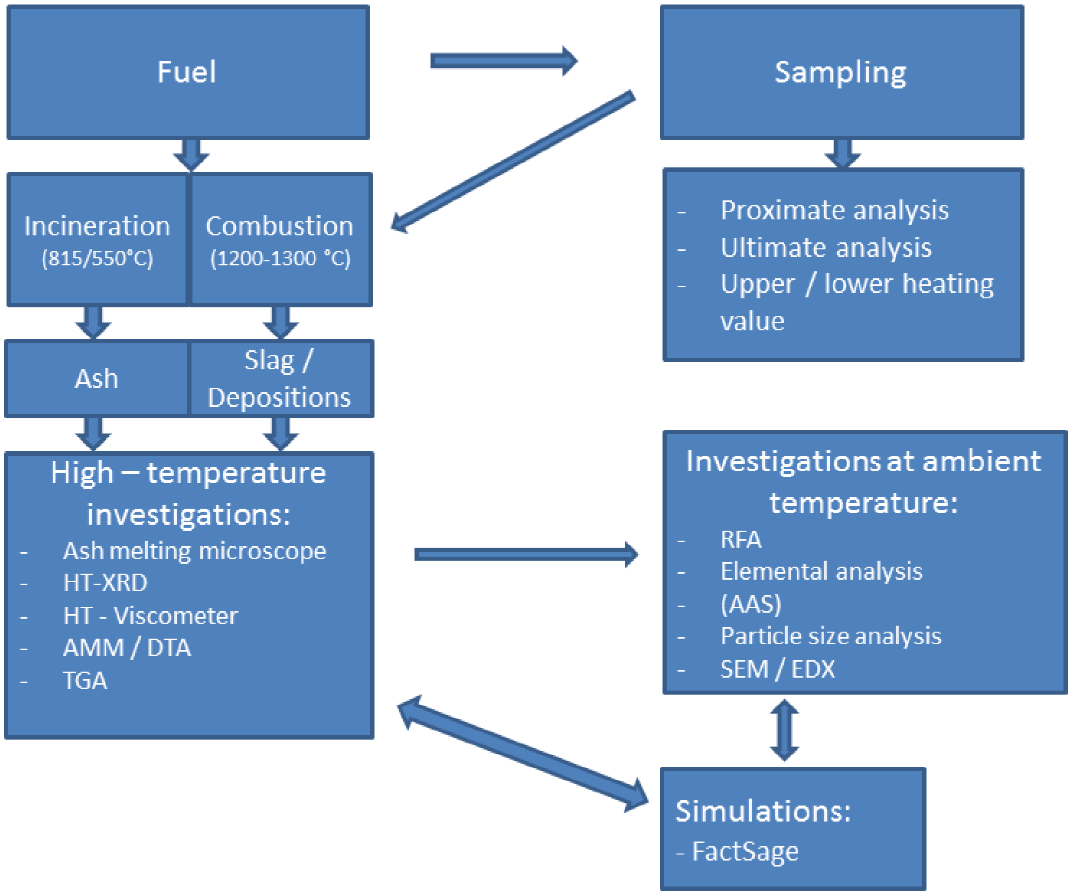






[4]

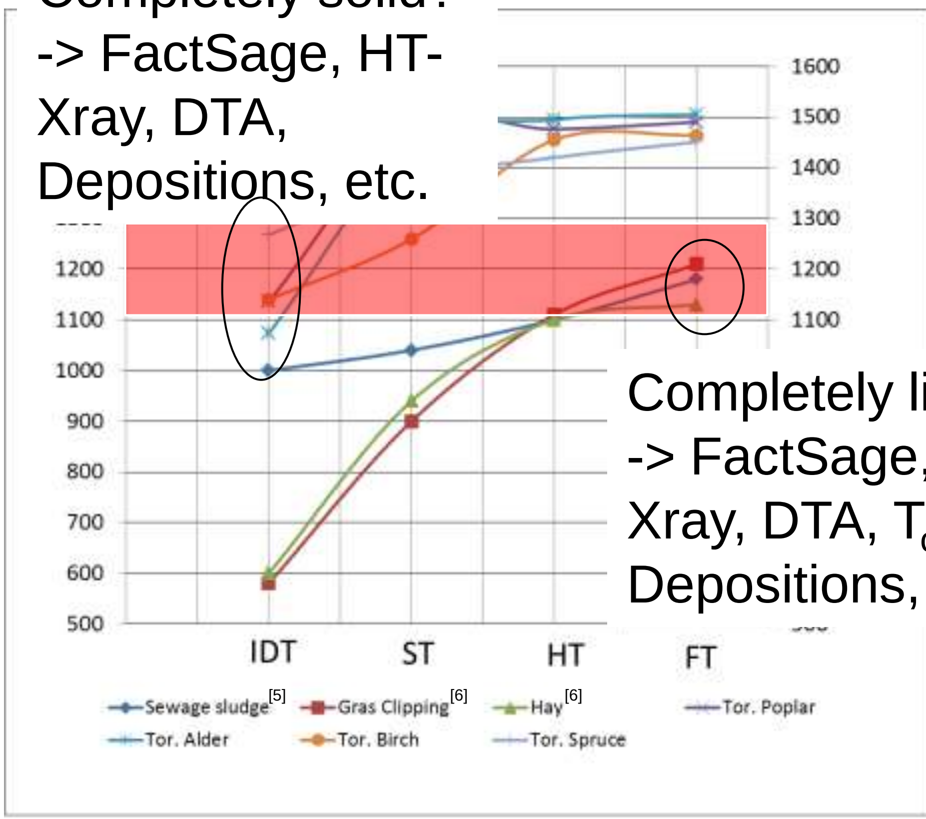
Ex – situ measurements to analyse the Ash behavior



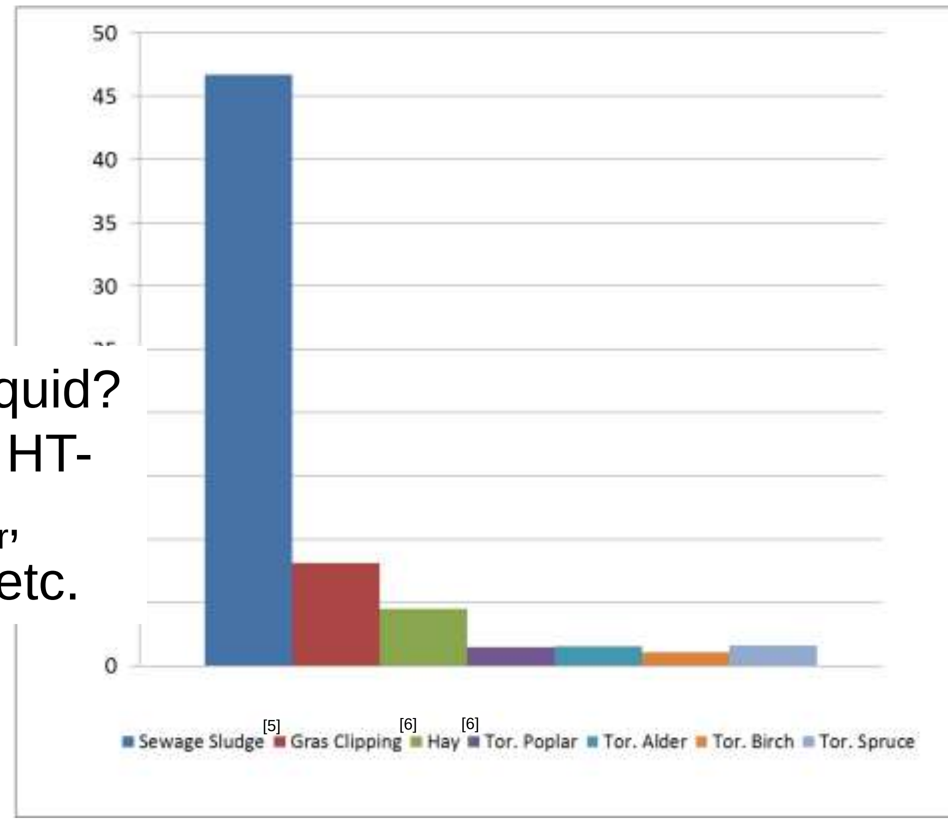
Characteristic temperatures [° C]

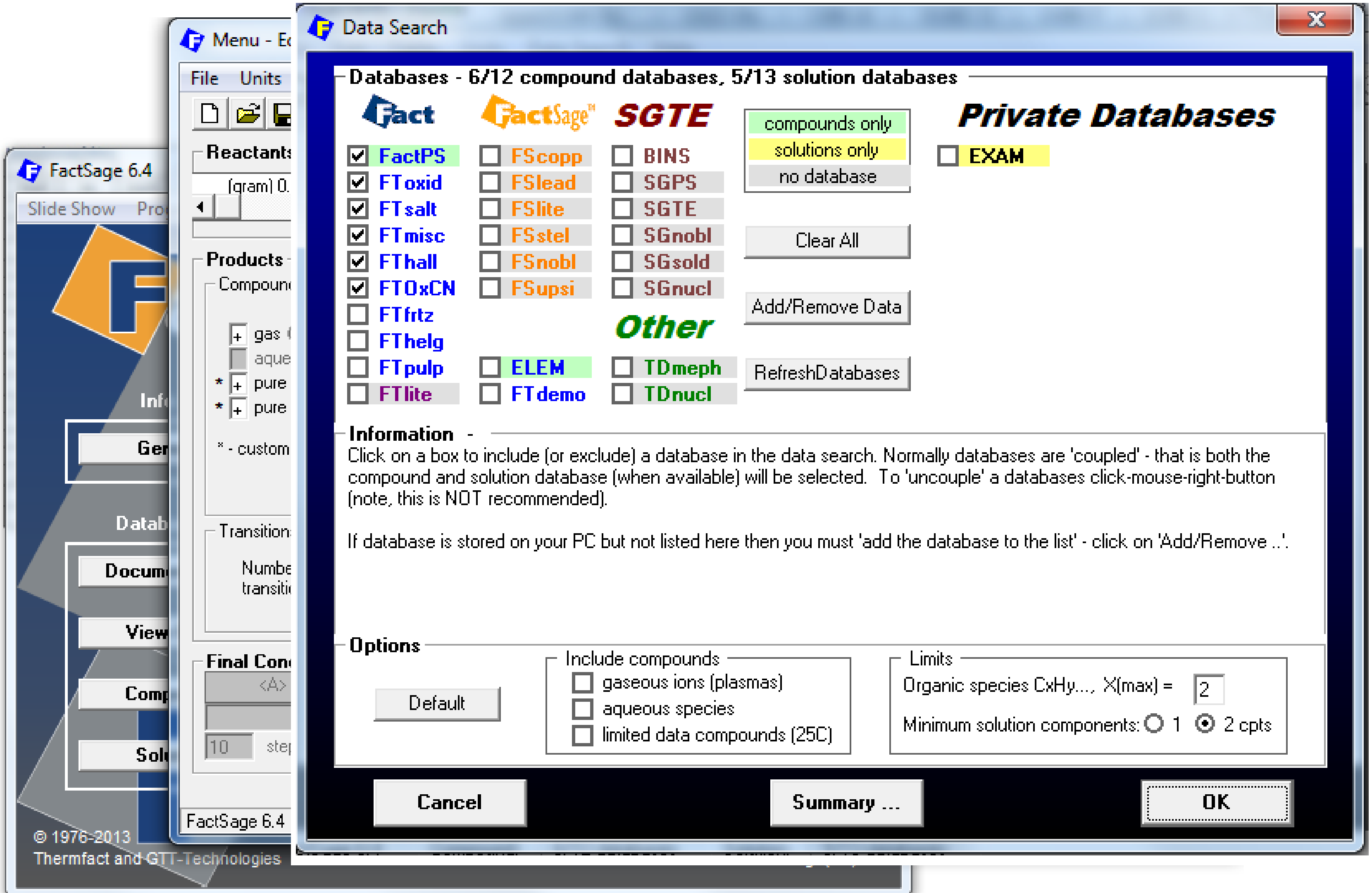
Ash content [wt.-%]

Completely solid?
-> FactSage, HT-Xray, DTA, Depositions, etc.



Completely liquid?
-> FactSage, HT-Xray, DTA, T_{cr}, Depositions, etc.




Data Search
Databases - 6/12 compound databases, 5/13 solution databases
Fact
FactSage
SGTE
Private Databases
FactPS
FToxid
FTsalt
FTmisc
FThall
FTOxCN
FTfrtz
FThelg
FTpulp
FTlite
FScopp
FSlead
FSlite
FSstel
FSnobl
FSupsi
ELEM
FTdemo
BINS
SGPS
SGTE
SGnobl
SGsold
SGnucl
Other
TDmeph
TDnucl
compounds only
solutions only
no database
Clear All
Add/Remove Data
RefreshDatabases
EXAM
Information -
Click on a box to include (or exclude) a database in the data search. Normally databases are 'coupled' - that is both the compound and solution database (when available) will be selected. To 'uncouple' a databases click-mouse-right-button (note, this is NOT recommended).
If database is stored on your PC but not listed here then you must 'add the database to the list' - click on 'Add/Remove ..'.
Options
Default
Include compounds
gaseous ions (plasmas)
aqueous species
limited data compounds (25C)
Limits
Organic species CxHy..., X(max) = 2
Minimum solution components: 1 2 cpts
Cancel
Summary ...
OK
FactSage 6.4
Slide Show
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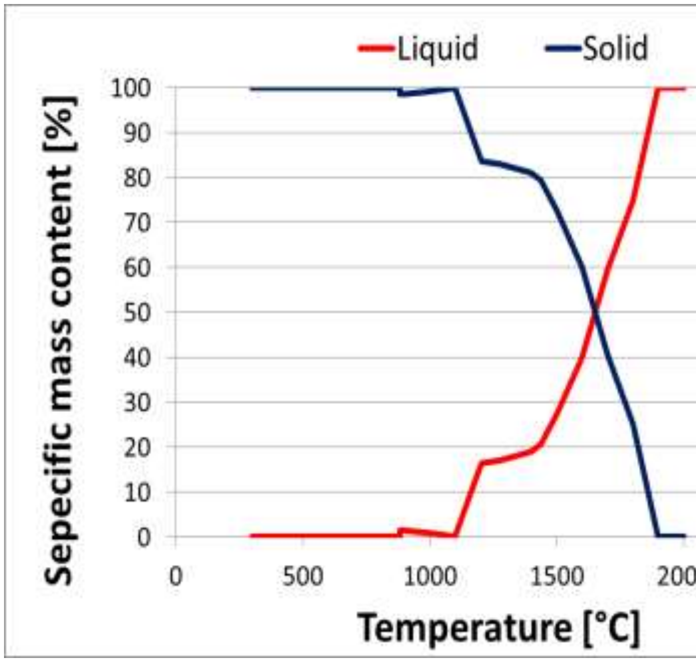
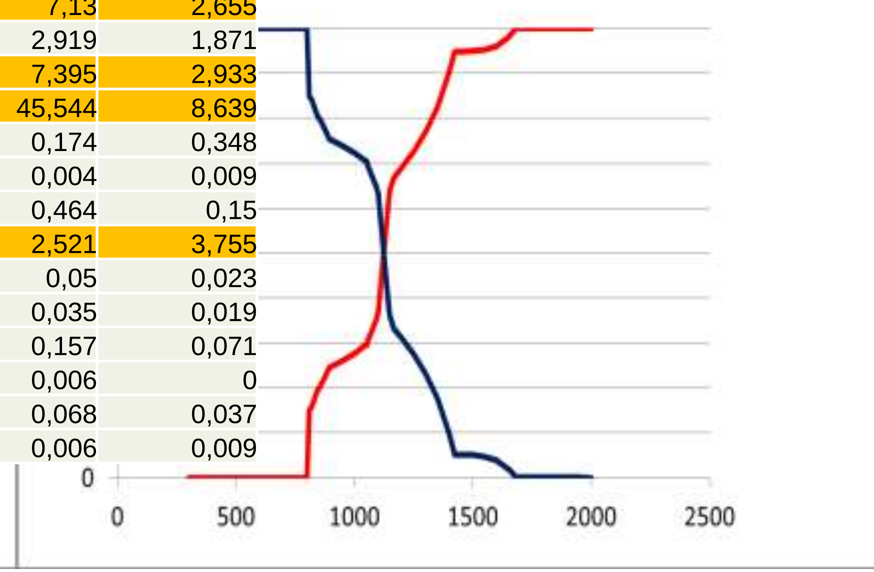
Thermfact and GTT-Technologies
Menu - E
File Units
Reactants
Products
FactSage 6.4

	Torr. Poplar	HTC beech
	ma-%	ma-%
Na2O	0,804	0,97
MgO	6,297	2,158
Al2O3	3,398	6,701
SiO2	13,074	75,276
P2O5	7,13	2,655
SO3	2,919	1,871
K2O	7,395	2,933
CaO	45,544	8,639
TiO2	0,174	0,348
V2O5	0,004	0,009
MnO	0,464	0,15
Fe2O3	2,521	3,755
NiO	0,05	0,023
CuO	0,035	0,019
ZnO	0,157	0,071
As2O3	0,006	0
SrO	0,068	0,037
PbO	0,006	0,009



Torrefied poplar



Hydrothermal carbonised beech

Forecast

- Start up of the experimental plants
- Investigation of NO_x reduction with air staging
- Characterisation of the phase formation of different biomasses (TGA, DTA, AMM, Xray)
- Slag investigation with a deposit probe (EDX, SEM)
- Calculations with FactSage regarding the viscosity, the qulitative and quantitative phase content
- Correlation of the results

References

[1] Bewertung des Potenzials sowie der Einsatzmöglichkeiten verschiedener Biomasse Veredelungsverfahren; P. Kloibhofer (diploma thesis)

[2] Anthropogenic air pollution sources; F. Popescu and I. Ionel

[3] Verbrennung fester Brennstoffe zur Strom- und Wärmeerzeugung; Prof. Dr.-Ing. Spliethoff

[4] Investigations into NOx emissions and burnout for coals with high ash content in a bench scale test facility; U. Greul, F. Kugler, H. Spliethoff, K. R. G. Klein

[5] Sintering characteristics of sewage sludge ashes at elevated temperatures; Liang Wang , Geir Skjevrak, Johan E. Hustad, Morten G. Grønli

[6] 3. Wissenschaftskongress Abfall -und Ressourcenwirtschaft in Stuttgart 22.03.2013; Dipl.-Ing Kathrin Weber

Thank you!

Questions / Suggestions?

Attachment

Results of the RFA

Calculation factors:

A	B		B zu A	Anteil B in Asche	Masse B
Na_2O	Na	[ma%]	0,7419	0,007	0,070
MgO	Mg	[ma%]	0,603	0,042	0,447
Al_2O_3	Al	[ma%]	0,5293	0,020	0,212
SiO_2	Si	[ma%]	0,4674	0,068	0,719
P_2O5	P	[ma%]	0,4364	0,035	0,366
SO_3	S	[ma%]	0,4005	0,013	0,138
K_2O	K	[ma%]	0,8302	0,068	0,723
CaO	Ca	[ma%]	0,7147	0,361	3,832
TiO_2	Ti	[ma%]	0,5993	0,001	0,012
V_2O5	V	[ma%]	0,5602	0,000	0,000
MnO	Mn	[ma%]	0,774	0,004	0,042
Fe_2O_3	Fe	[ma%]	0,6994	0,020	0,208
NiO	Ni	[ma%]	0,7858	0,000	0,005
CuO	Cu	[ma%]	0,7989	0,000	0,003
ZnO	Zn	[ma%]	0,8034	0,001	0,015
As_2O_3	As	[ma%]	0,7574	0,000	0,001
SrO	Sr	[ma%]	0,8762	0,001	0,007
PbO	Pb	[ma%]	0,9283	0,000	0,001
		SUMME			6,799965851

Mass ash: (an)

10,6	[g]	mit Sauers
6,799966	[g]	ohne saue
3,800034	[g]	Sauerstoff

Mass fuel:

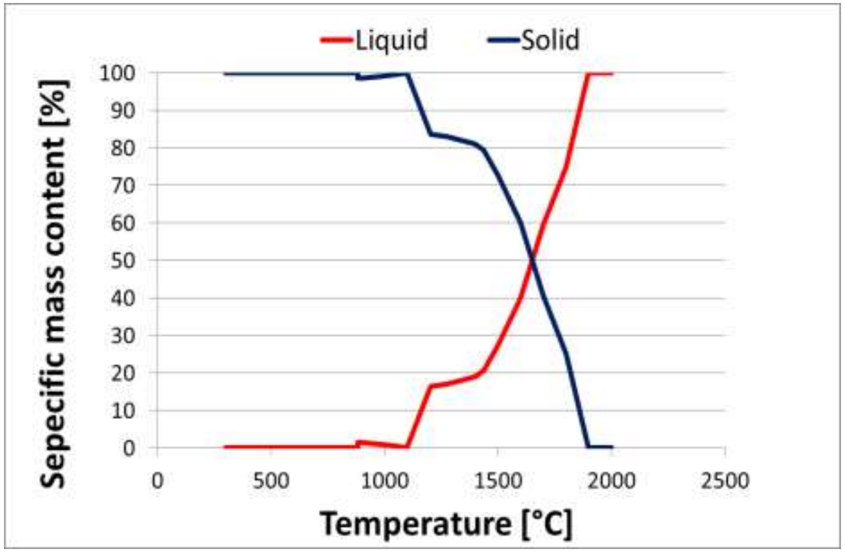
1000	[g]	konstant

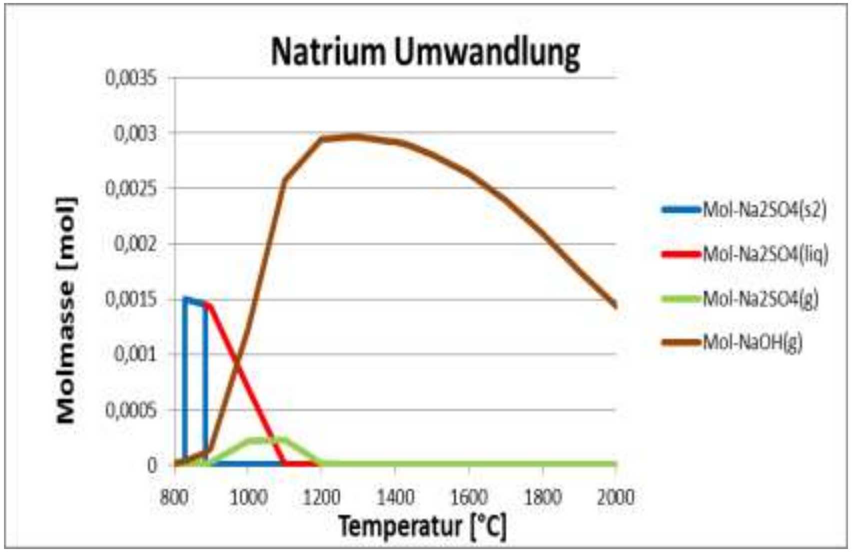
Mass fluegas (an)

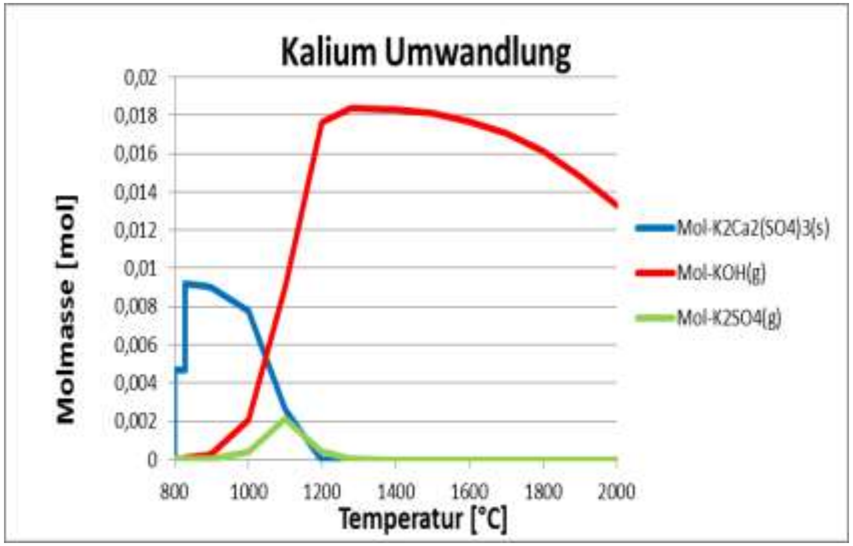
Komponente	M.Strom	Brennstoff	Luft	Sum. Komp.
C	[g]	541,97	5,0293488	547,00
H	[g]	71,86		71,86
N	[g]	1,73	6437,395978	6439,12
S	[g]	1,10		1,10
O	[g]	387,19	1972,101432	2359,29
Cl	[g]	0,00		0,00

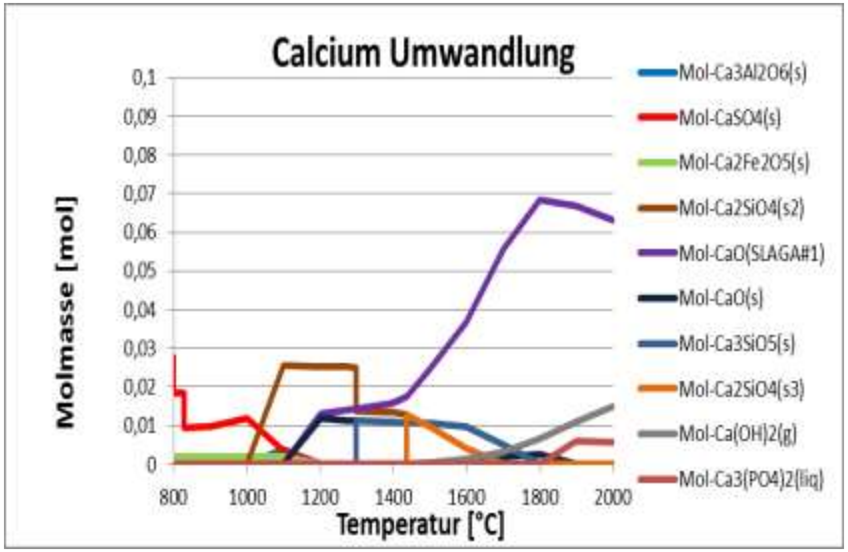
Results of the Ultimate Analysis

Input FactSage

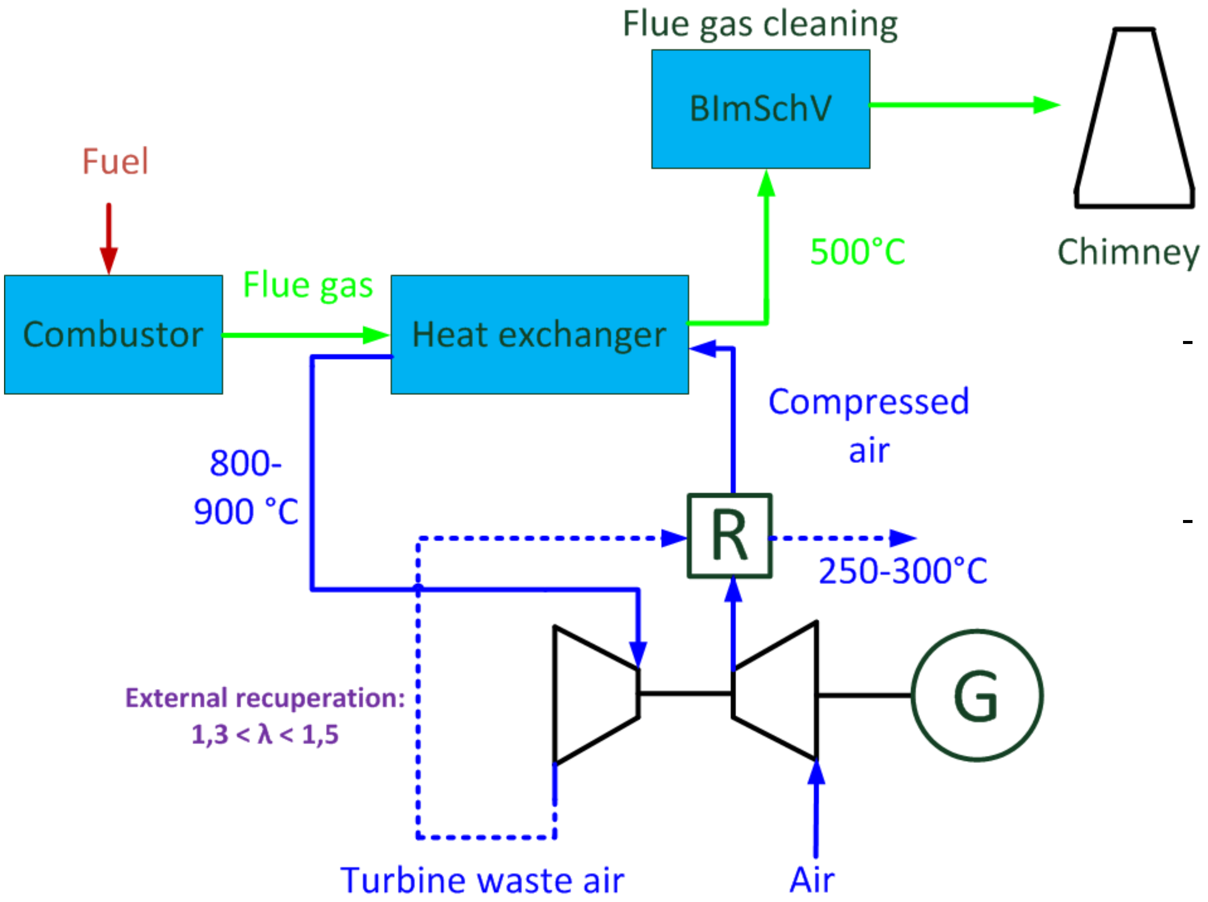

Liquid
Solid
Sepecific mass content [%]
Temperature [°C]


Natrium Umwandlung
Molmasse [mol]
Temperatur [°C]
Mol-Na2SO4(s2)
Mol-Na2SO4(liq)
Mol-Na2SO4(g)
Mol-NaOH(g)


Kalium Umwandlung
Molmasse [mol]
Temperatur [°C]
Mol-K2Ca2(SO4)3(s)
Mol-KOH(g)
Mol-K2SO4(g)

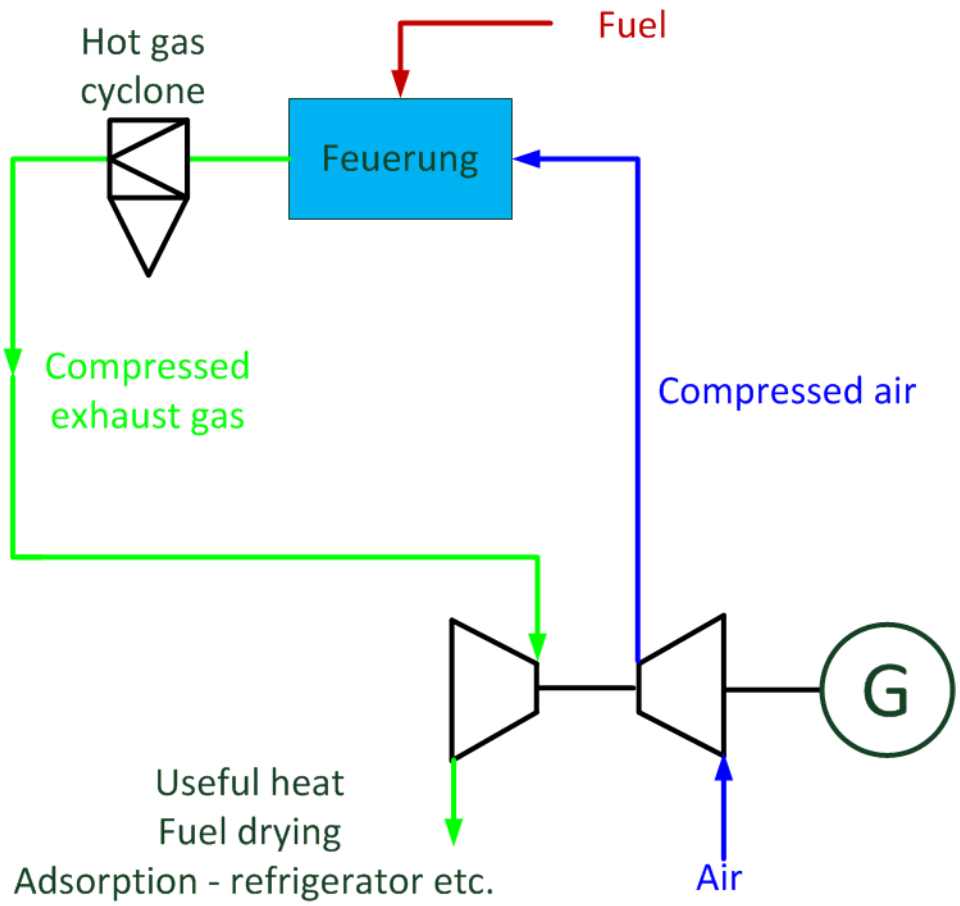

Calcium Umwandlung
Molmasse [mol]
Temperatur [°C]
Mol-Ca3Al2O6(s)
Mol-CaSO4(s)
Mol-Ca2Fe2O5(s)
Mol-Ca2SiO4(s2)
Mol-CaO(SLAGA#1)
Mol-CaO(s)
Mol-Ca3SiO5(s)
Mol-Ca2SiO4(s3)
Mol-Ca(OH)2(g)
Mol-Ca3(PO4)2(liq)

Generation with an indirectly fired gas turbine



- Decentralised biomass electricity conversion plant (<500 kW)
- Micro gas turbine (60–200 kW)
  - Turbec, Capstone, Ingersoll

Generation with an directly fired gas turbine



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