AMBITION

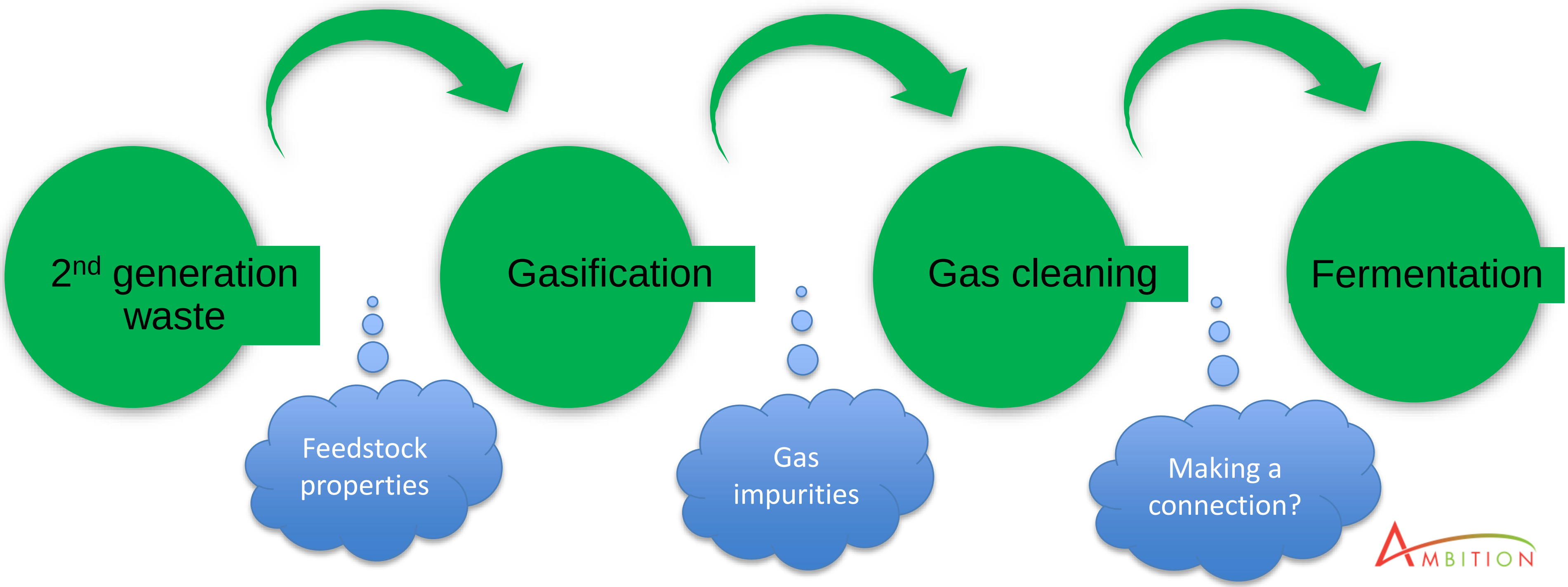
ADVANCED BIOFUEL PRODUCTION WITH ENERGY SYSTEM INTEGRATION

Connecting the world of gasification with syngas fermentation

Content

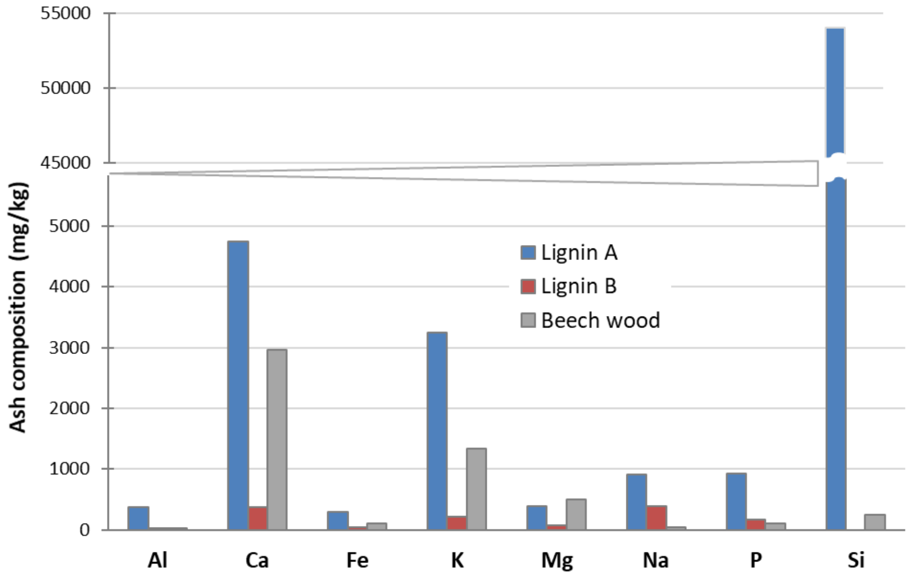
- Background information
- The challenge
- The technology
- Current results
- Conclusions

Background information



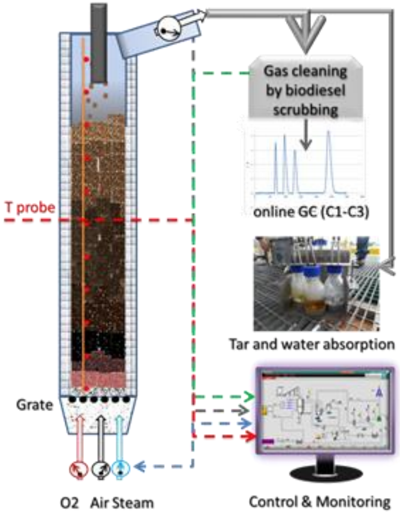
Challenges

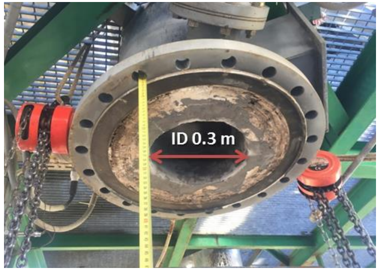
On dry basis	C (wt%)	O (wt%)	H (wt%)	N (wt%)	S (wt%)	Cl (wt%)	Ash (wt%)	Volatiles (wt%)	LHV (MJ/kg)
Lignin A	47.2	33.0	5.6	**1.3**	**0.18**	**0.020**	**14.0**	65	18.4
Lignin B	**57.7**	33.8	6.2	**0.8**	**0.13**	**0.002**	0.1	72	22.9
Beech wood	47.5	48.8	6.4	0.2	0.02	0.010	1.3	81	17.8



- Lower volatiles than wood
- Higher heating value than wood (lower O, higher C)
- **Lignin A:** high ash content
- **Lignin B:** low ash content

Fixed Bed gasification at ENEA

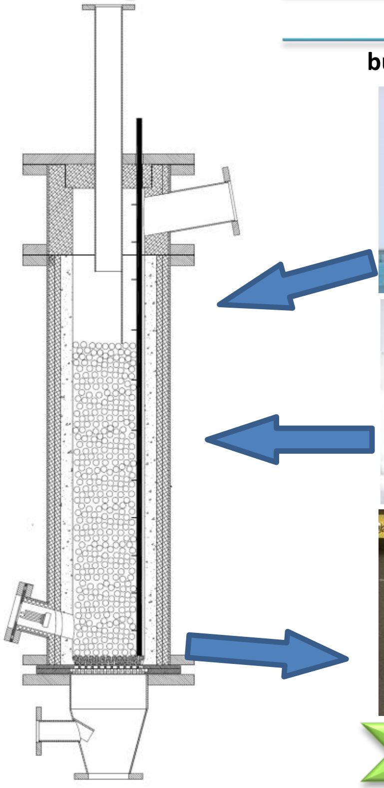




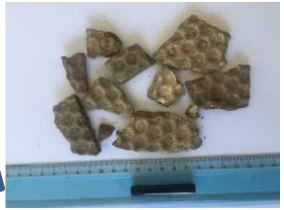
View of the gasifier from the bottom

Fixed Bed gasification at ENEA

Updraft gasifier



Lignin A	Lignin B
14% ash	0.1% ash
bulk density 427 kg_{DM}/m^3	bulk density 335 kg_{DM}/m^3






Ash from the bottom white color → **full conversion**

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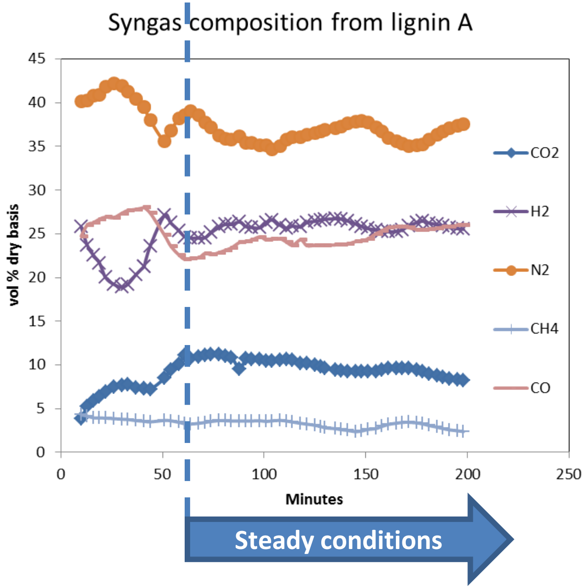
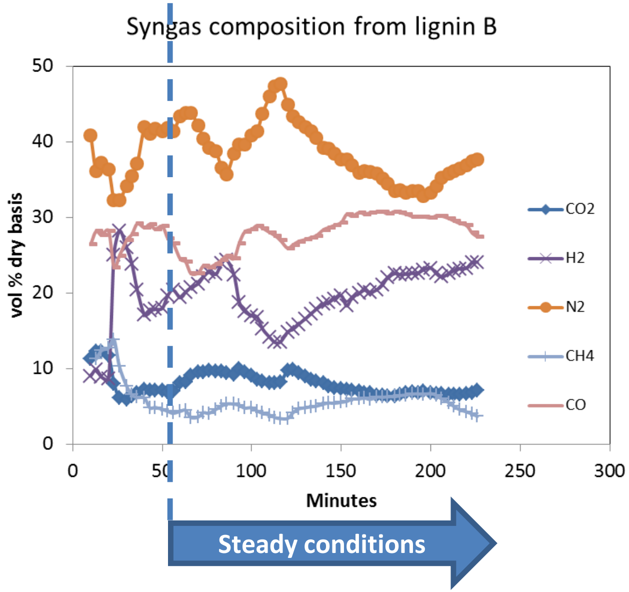
Results from Fixed Bed Gasification of lignin A and B

	Feed	Air flow	Steam flow	ER (O2)	ER(H2O)
Lignin A	31 kg/h	31.4 kg/h	3.0 kg/h	0.17	0.10
Lignin B	30 kg/h	36.2 kg/h	2.6 kg/h	0.18	0.07





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Summary of Fixed Bed gasification for lignin A and B

	Lignin A	Lignin B	
	%	%	
N_2	36.4	38.7	%
H_2	26.0	20.1	%
CO	24.8	28.0	%
CO_2	9.54	7.7	%
CH_4	3.0	5.1	%
C_3H_8	0.09	-	%
C_2H_6	0.0524	0.11	%
C_2H_4	-	0.08	%
H_2/CO	1.05	0.71	-
tar	75	82-93	g/Nm^3
LHV	6.35	6.78	MJ/Nm^3

Average syngas composition at steady conditions, clean and dry basis

Fluid bed gasification at LNEG

Gasifier Total Height (m): 1.5
Bed Dimensions (cm): 8

Temperature (ºC)	Experimental Conditions
750	Lignin Flow Rate = 7g daf/min Steam/Lignin – 0.35 g/g daf Equivalent Ratio (ER) = 0.13 Oxygen
800	
850	
900	

ER	Experimental Conditions
0	Lignin Flow Rate = 7g daf/min Temperature = 800 ºC Steam/Lignin – 0.35 g/g daf Oxygen
0.1	
0.2	
0.3	

Steam/Lignin Ratio (g/g daf)	Experimental Conditions
0	Lignin Flow Rate = 7g daf/min Temperature = 800 ºC Equivalent Ratio = 0.13 Oxygen
0.37	
0.45	
0.70	
1	

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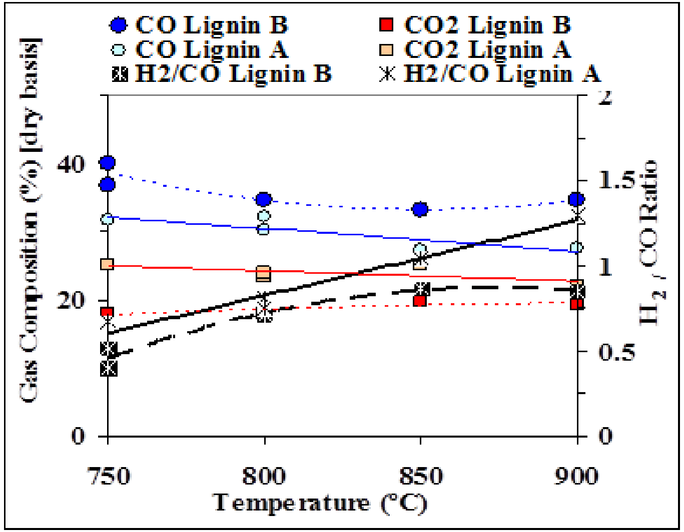
Fluid bed gasification at LNEG

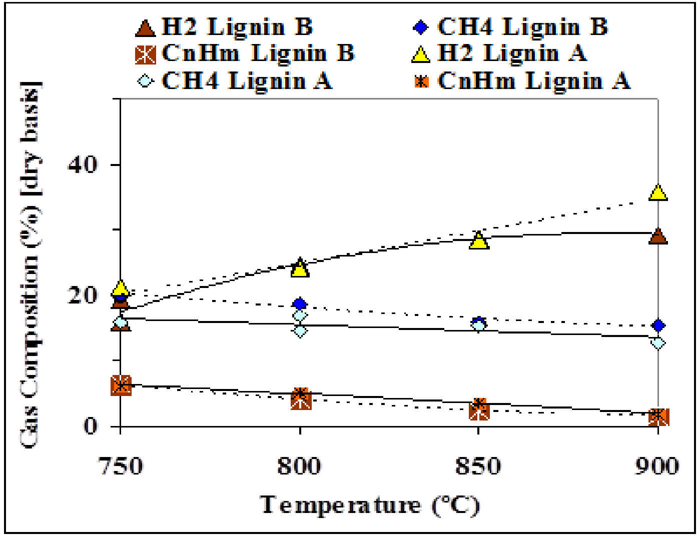
Coupled to hot syngas cleaning

Two step process

1. Fixed bed dolomite (or olivine/limestone
2. Fixed bed Ni-catalyst (11% Ni)

Results from Fluidized Bed Gasification of lignin A and B





- The **same trends were obtained** for both Lignins. The rise of **temperature favoured the formation of H_2**, probably, **at the expenses of hydrocarbons** (C_nH_m) and **tar** conversation.
- **Lignin A led to lower CO and higher CO_2 contents, though the total $CO+CO_2$ are similar. Thus, Lignin A led to higher H_2/CO ratio than Lignin B.**
- The increase of temperature led to a **increase in H_2/CO ratio**. Only for **temperatures below 850°C**, it was possible to obtain **H_2/CO ratios lower than 1 for Lignin A**.

Summary of Fluid Bed gasification for lignin A and B

Selected Conditions:	**800ºC**, ER=0.13 Steam/Lignin=0.35 g/g daf	
	Lignin A	Lignin B
CO	28	28
CO_2	21	15
H_2	22	20
CH_4	14	15
C_nH_m	5	3
H_2/CO	0.78	0.71
$CO:CO_2:H_2$	1 : 0.8 : 0.8	1 : 0.5 : 0.7
Tar (g/m³)	15	108
CGE (%)	75	76
Before the Quenching System		
NH_3 (mg/Nm³)	1 566	632
H_2S (mg/Nm³)	1 185	993

Lowest H_2/CO	ER = 0.13, Steam/Lignin = 0.35 g/g daf
0.52	**750ºC Lignin B**
0.67	**750ºC Lignin A**

- Similar **values were obtained** for both Lignins.
- **Tar** content was quite **different**.
- **NH_3 and H_2S** contents were also **different,** which agrees with the differences in N and S contents in lignins.

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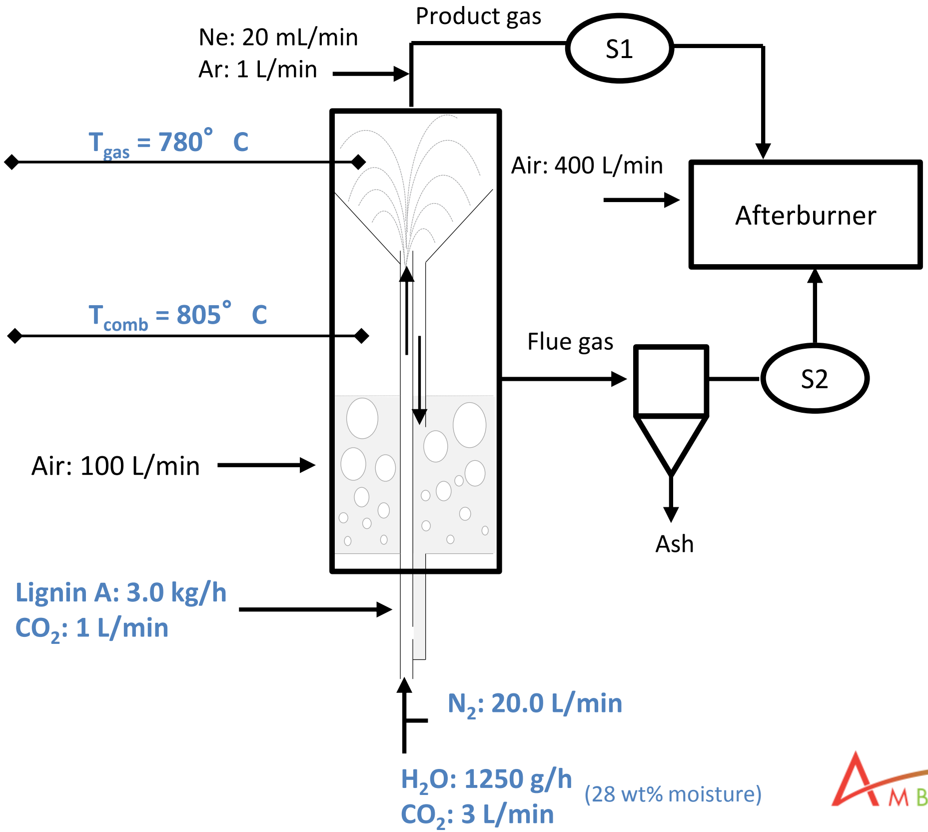
Indirect gasification at ECN part of TNO

Lignin A

- Bed material: fresh Austrian Olivine.
- Additional N_2 in riser for good fluidization.
- Lignin A: Low gasification temperature results in stable operation and a trade-off between fuel conversion and release of contaminants.

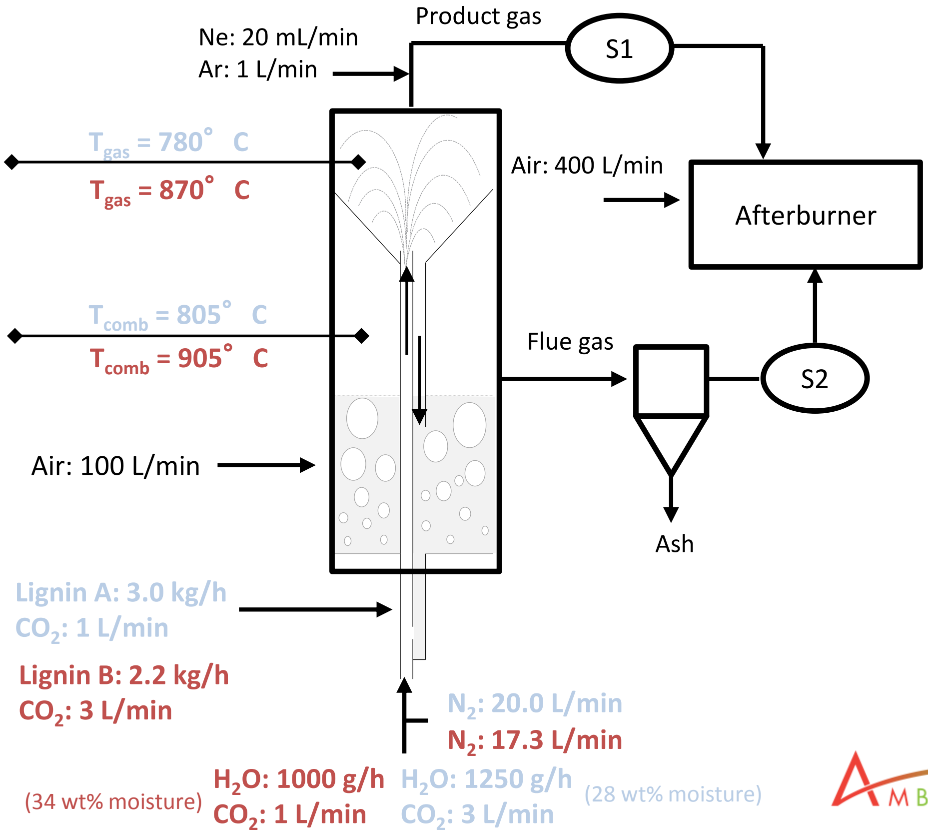


Indirect gasification at ECN part of TNO

Lignin A **Lignin B**

- Bed material: fresh Austrian Olivine.
- Additional N_2 in riser for good fluidization.
- Lignin A: Low gasification temperature results in stable operation and a trade-off between fuel conversion and release of contaminants.

- Lignin B: higher gasification temperature to increase conversion and reduce tar content.



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Product gas composition - impurities

Main gas components, dry basis (vol%)	Lignin A	Lignin B
CO	13.9	15.6
H_2	**8.6**	**14.1**
CO_2	17.9	18.0
CH_4	5.9	6.9
N_2	45.1	39.2
C_2H_2	0.1	0.3
C_2H_4	2.8	2.0
C_2H_6	0.3	0.1
Benzene	**0.5**	**0.7**
Toluene	**0.1**	**0.1**
Ar*	2.1	2.2
Trace components	2.3	1.1
H_2O (wt%)	42.6	42.1
H_2/CO	0.62	0.90
Product gas flow (L/h)	2960	2970
Product gas energy LHV (kW)	8.0	7.7

Trace components, dry basis (ppmv)	Lignin A	Lignin B
Sum C_3	3100	350
Sum C_4	330	350
Sum C_5	520	230
Sum C_6	80	0
H_2S	1100	640
COS	30	20
Thiophene	34	18
Methylmercaptane	32	2
Other S-organics	9	3
NH_3	8770	4160
HCN	1290	115
HCl	8	12
Tar	5990 (34 g/m^3)	4660 (30 g/m^3)
Ne*	410	405

- **Lignin B:** Lower C2+ hydrocarbons content

S-compounds

- **Lignin B:** lower than **Lignin A**
- Lower S-content in lignin
- High ratio $H_2S/COS > 30$, for wood is ~10

NH_3, HCN

- **Lignin B:** lower than **Lignin A**
- Lower N-content in lignin

HCl

- **Lignin B:** slightly higher
- Lower Cl-content in lignin but gasification at higher T

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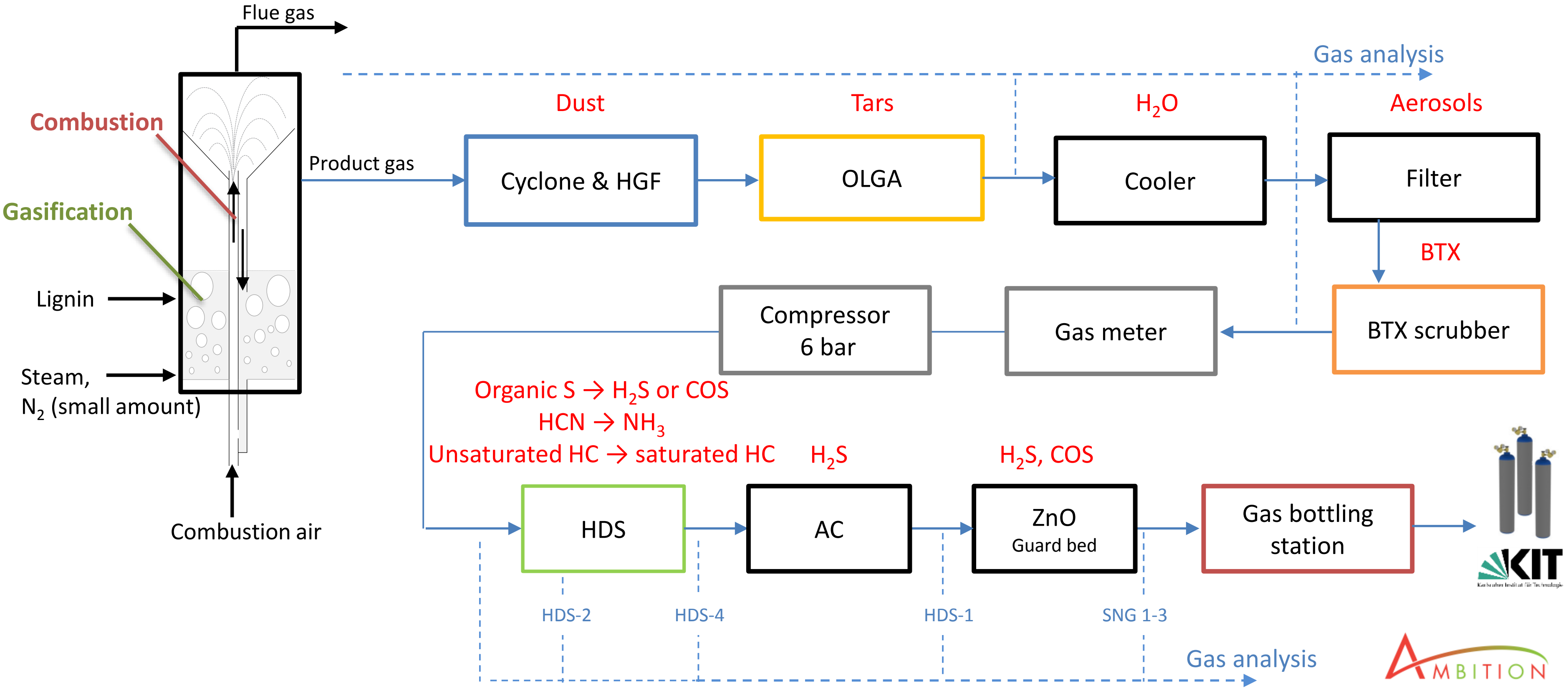
Indirect gasification at ECN part of TNO



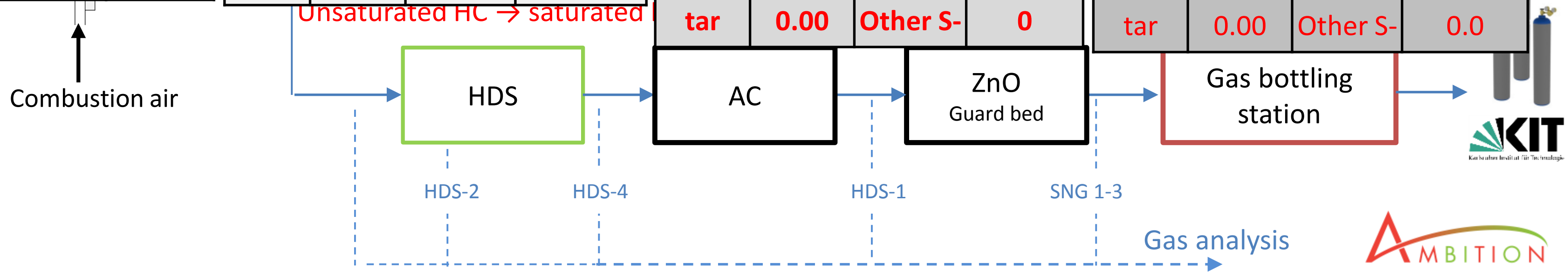
Indirect gasification at ECN part of TNO

	Vol%		ppmV
CO	28.0	Benzene	6022
H_2	33.4	Toluene	211
CO_2	23.8	C3	85
CH_4	8.8	C4	87
N_2	1.0	C5	51
C_2H_2	0.03	C6	7
C_2H_4	1.6	H_2S	115
C_2H_6	0.05	COS	4
tar	0.3	Other S-	3

	Vol%		ppmV
CO	30.4	Benzene	4684
H_2	31.9	Toluene	319
CO_2	21.9	C3	113
CH_4	9.1	C4	16
N_2	1.4	C5	1
C_2H_2	0.14	C6	19
C_2H_4	1.7	H_2S	89
C_2H_6	0.06	COS	7
tar	**0**	Other S-	4

	Vol%		ppmV
CO	32.3	**Benzene**	**86**
H_2	28.3	**Toluene**	**<10**
CO_2	23.2	C3	290
CH_4	11.3	C4	106
N_2	1.4	C5	17
C_2H_2	**<0.0**	C6	0
C_2H_4	**<0.0**	H_2S	7
C_2H_6	2.4	COS	1
tar	**0.00**	**Other S-**	**0**

	Vol%		ppmV
CO	32.3	Benzene	13
H_2	28.5	Toluene	<10
CO_2	23.3	C3	323
CH_4	11.7	C4	37
N_2	1.6	C5	63
C_2H_2	<0.0	C6	8
C_2H_4	0.0	H_2S	0.1
C_2H_6	2.5	COS	0.0
tar	0.00	Other S-	0.0



Conclusions

- Both lignin A and B gasified successfully. Feedstock pre-treatment requirements are very different. Improvements can be made at the biorefinery to feedstock quality.
- Biorefinery processing not only affects the form of the lignin, but also the type of impurities in it.
- Impurities in feedstock end up in gas and need to be removed. So far tar, unsaturated HC, cyanide and benzene have been identified as problematic. Question for fermentation is to what extent the NH_3 and H_2S are acceptable and to what levels the rest needs to be removed.
- H_2/CO ratio is between 0.5 and 1 in most cases. Further shifting is necessary if more hydrogen is needed. Particular strain used for fermentation is determining the final ratio of $H_2/CO/CO_2$

The Ambition TEAM

THANK YOU FOR LISTENING

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