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Investigation and evaluation of a biomass gasifier

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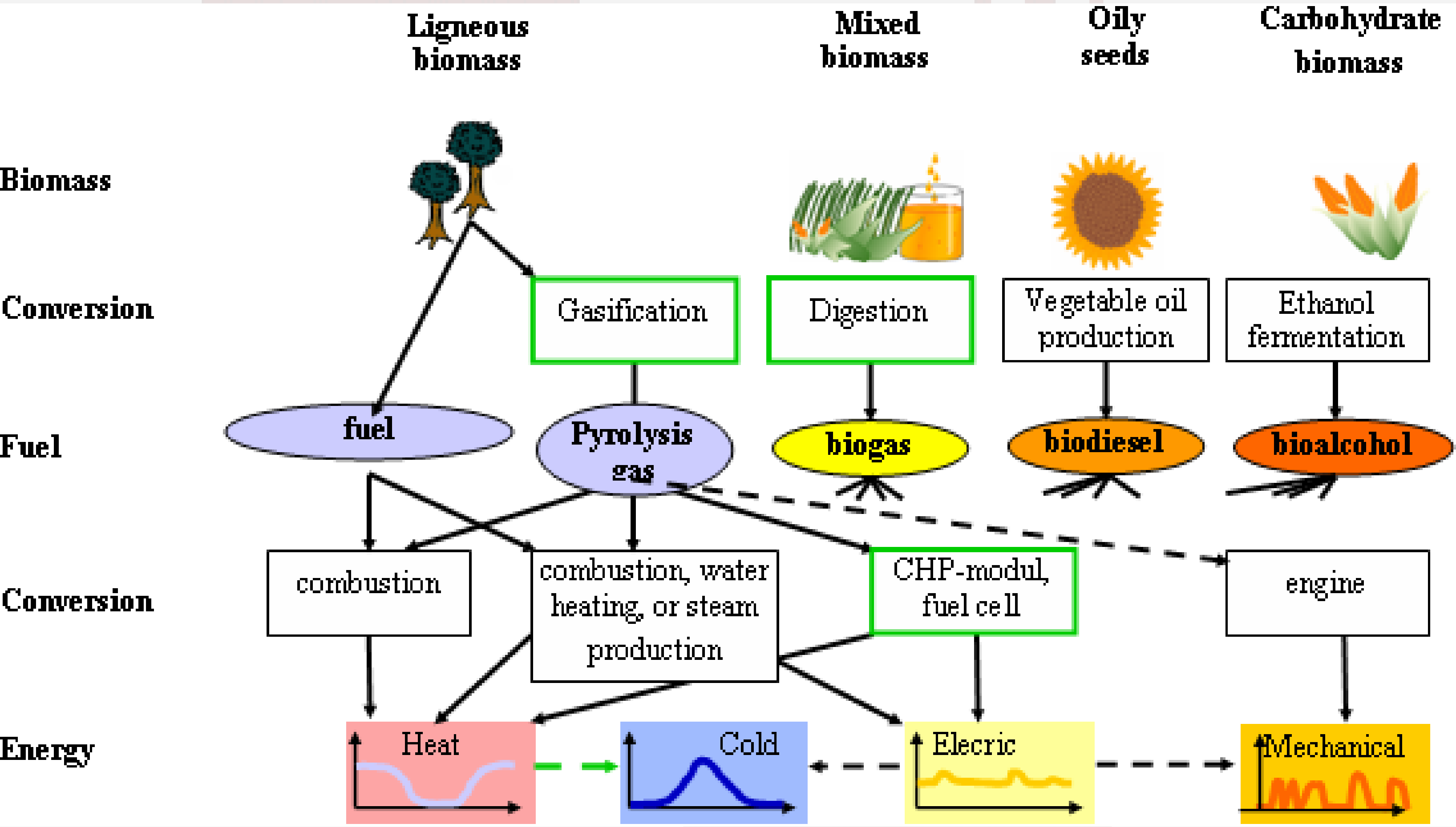
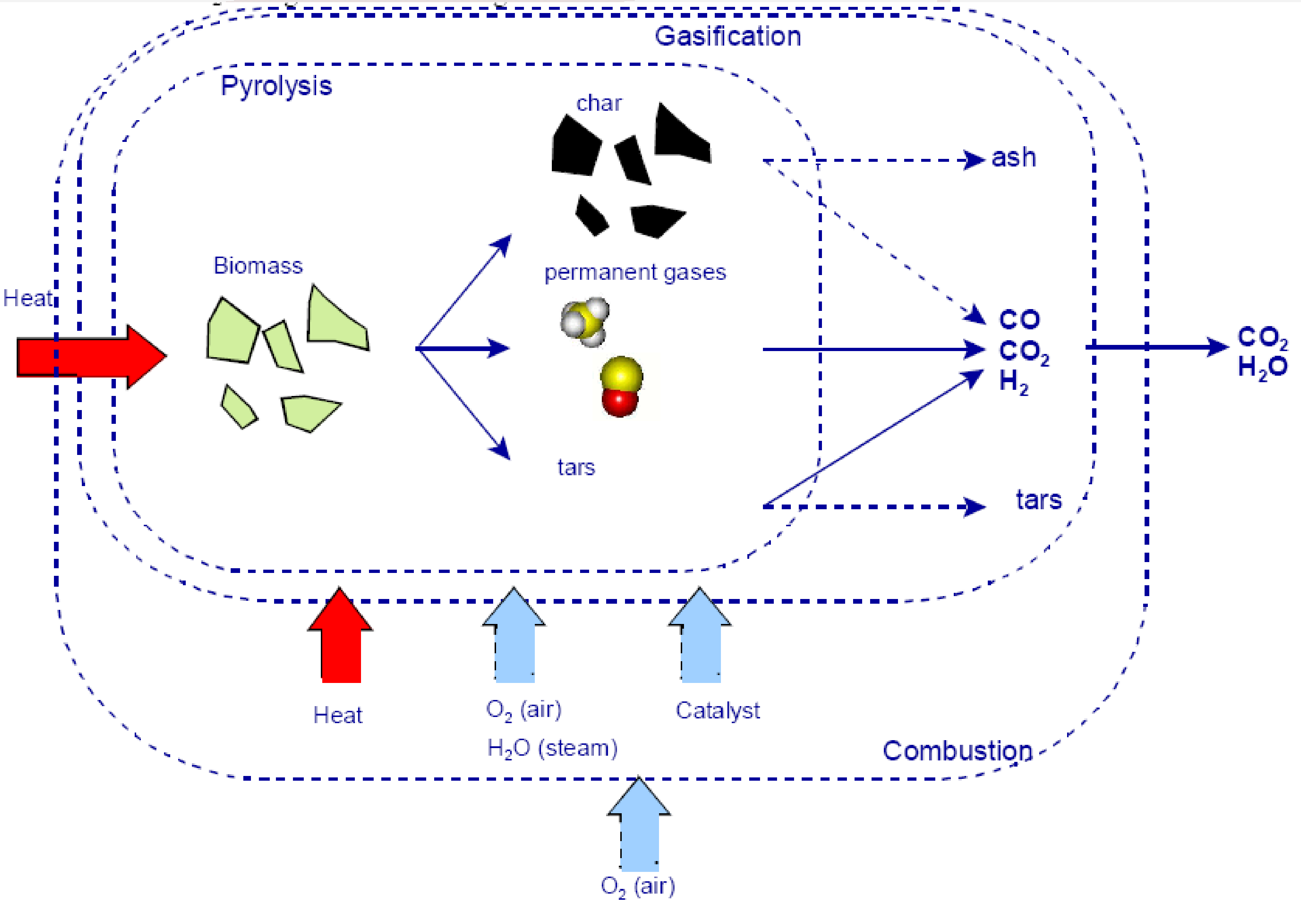
Summary of biomass conversion technologies



Gasification as one of the thermal conversion processes



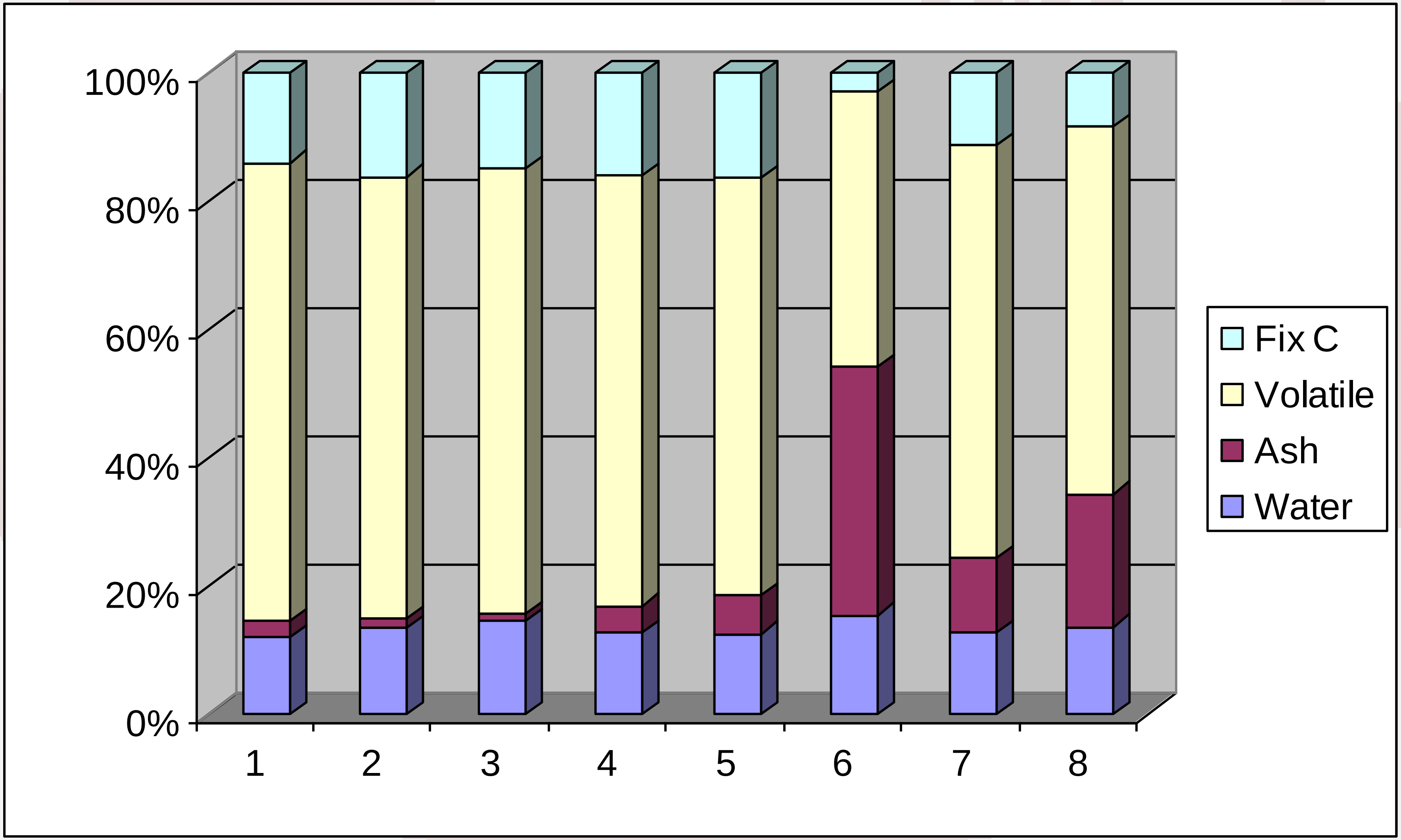
Introduction

- Gasification of biomass and other combustible waste materials is a promising and developing field of efficient energy generation based on renewables.
- It makes possible to feed pyrolysis gas e.g. to internal combustion engines, or to gas turbines and makes possible to generate electricity at comparatively high efficiency
- Gasification is a kind of thermal conversion of fuels, which is very complex and outcome can be very various
- Besides pyrolysis gas other liquid and solid components generated too.
- But it is important to know efficiency, mass and energy balance of the system. In this paper we would like to show a method on an example for determination of gasifier energy balance and efficiency.

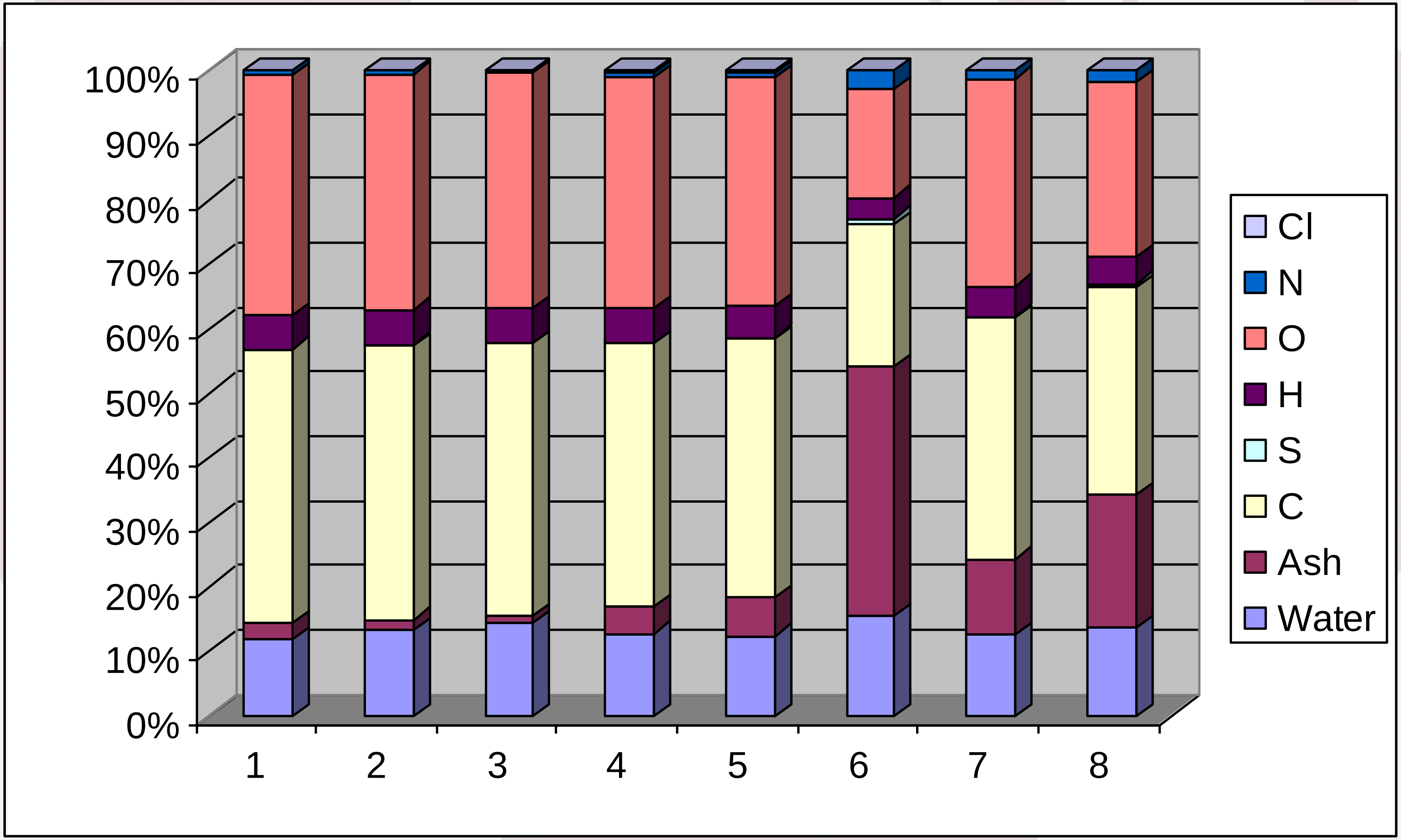
Fuels and test results

Denomination	Water	Ash	Volatile matter	C	S	H	O	N	Cl	HHV	LHV
Unit	m/m %	m/m %	m/m %	m/m %	m/m %	m/m %	m/m %	m/m %	m/m %	kJ/kg	kJ/kg
1. Acacia chips	11,8	2,7	71,6	42,3	0,04	5,22	37,23	0,66	0,049	17085	15657
2. Poplar chips	13,4	1,58	68,87	42,51	0,09	5,38	36,56	0,46	0,01	17181	15653
3. Willow chips	14,4	1,20	69,64	42,06	0,09	5,44	36,43	0,37	0,01	16816	15253
4. Wheat-straw pellet	12,75	4,10	67,32	40,91	0,10	5,34	35,81	0,67	0,33	16449	14942
5. Energygrass pellet	12,5	5,9	65,4	40,12	0,1	4,95	35,424	0,77	0,236	16319	14933
6. Sewage sludge	15,4	38,8	43,1	22	0,89	3,23	16,722	2,87	0,088	9841	8760
7. 75% Acacia 25% sewage sludge	12,7	11,73	64,48	37,23	0,25	4,72	32,1	1,21	0,059	15274	13933
8. 50% Acacia 50% sewage sludge	13,6	20,75	57,35	32,15	0,47	4,23	26,98	1,77	0,069	13463	12209

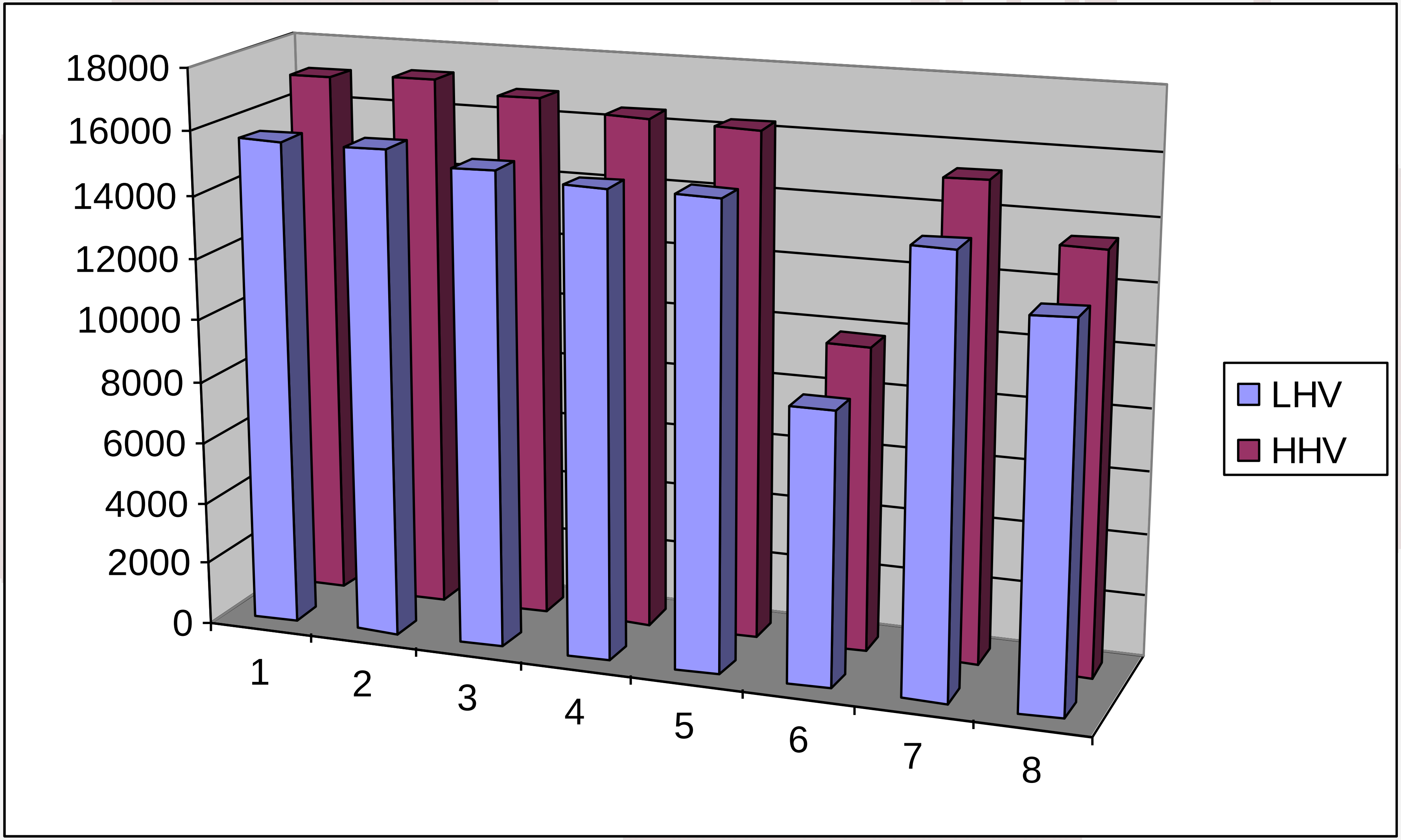
Proximate analysis results of fuels



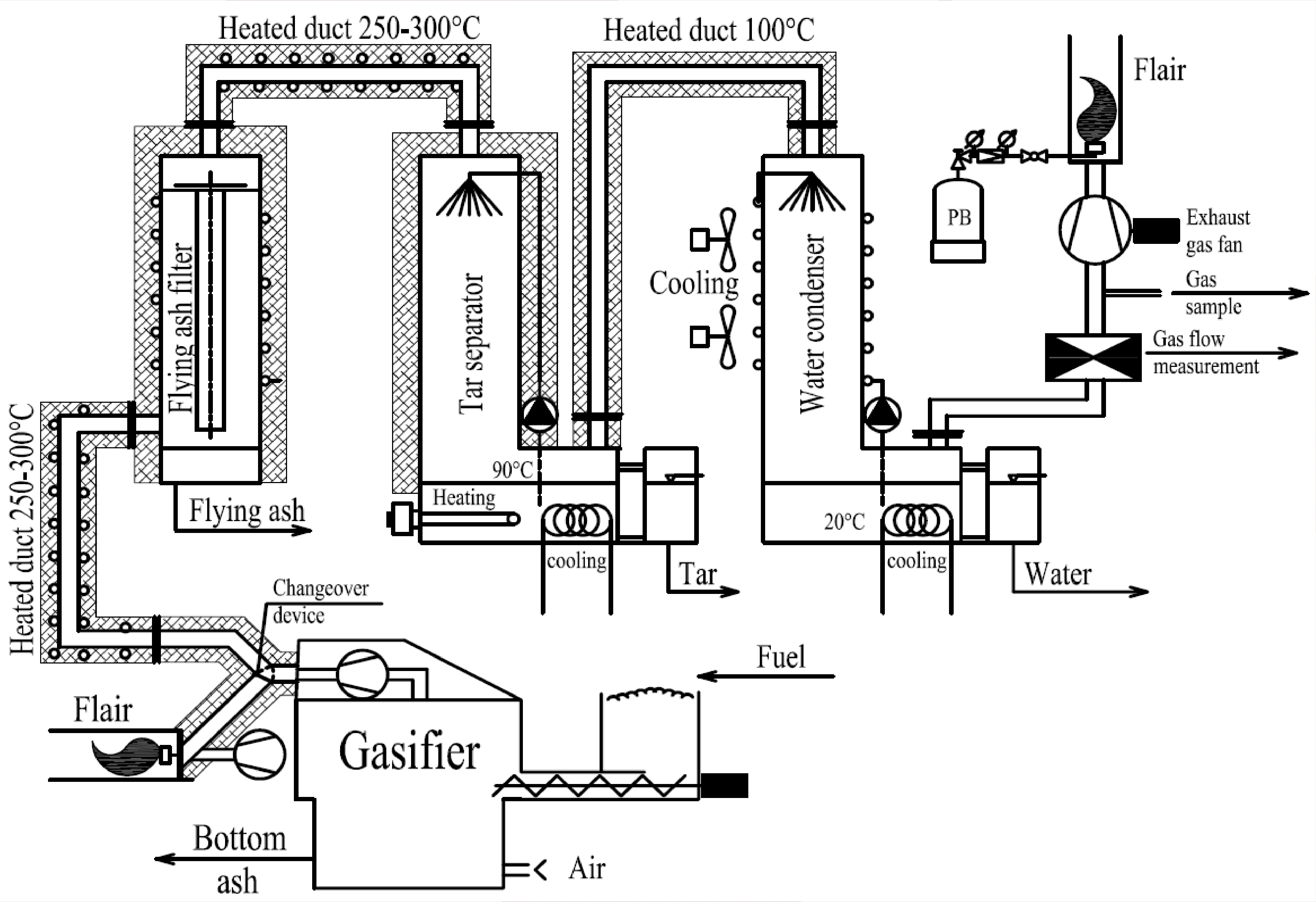
Ultimate analysis results of fuels



Heating value variation of fuels



Sample system arrangement

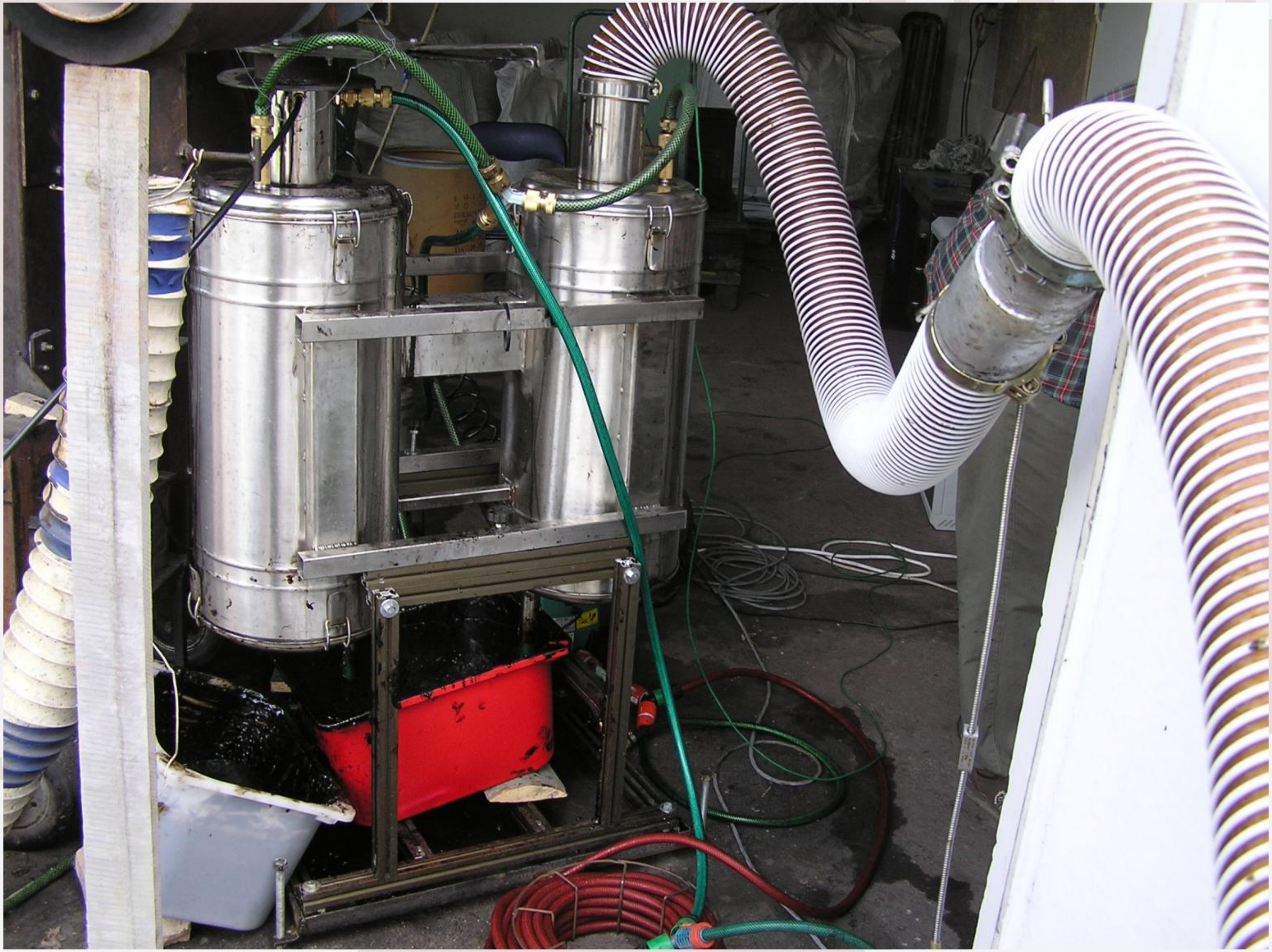


Measured and tested parameters

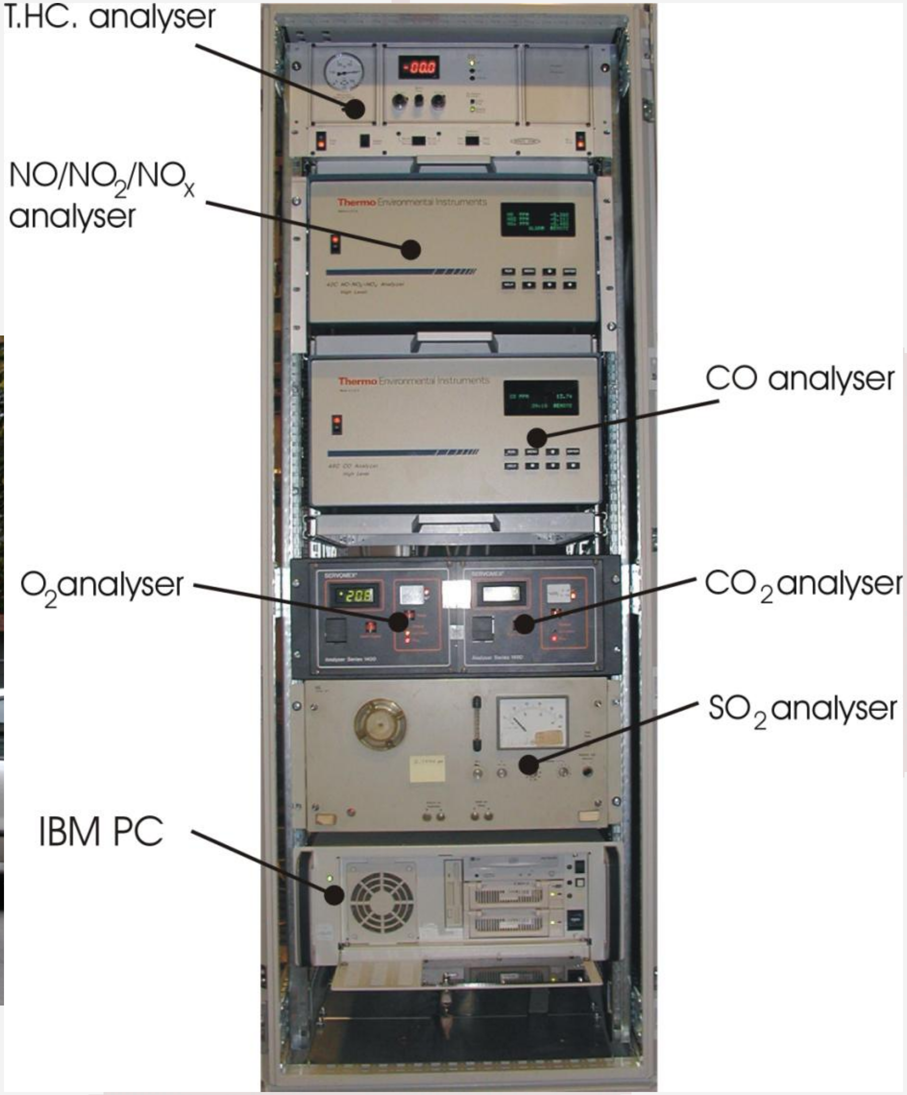
- Feeding: Mass of consumed fuel
  Duration time of consumption
- Products: Gas quantity
  Tar quantity
- Samples: Original fuel
  Product gas
  Tar
  Ash

The gasifier and the test system

Sample system



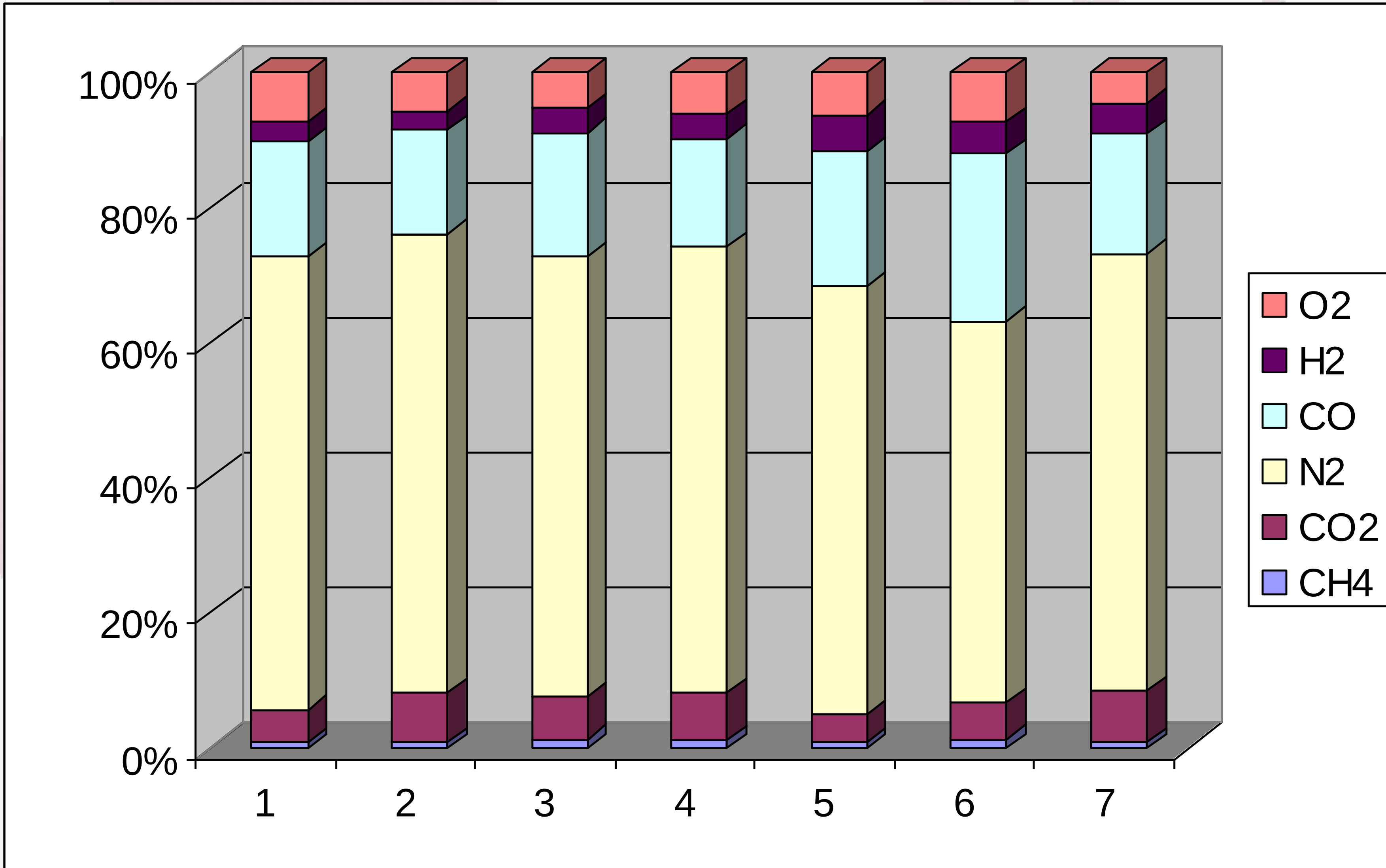
Gas Analyser System



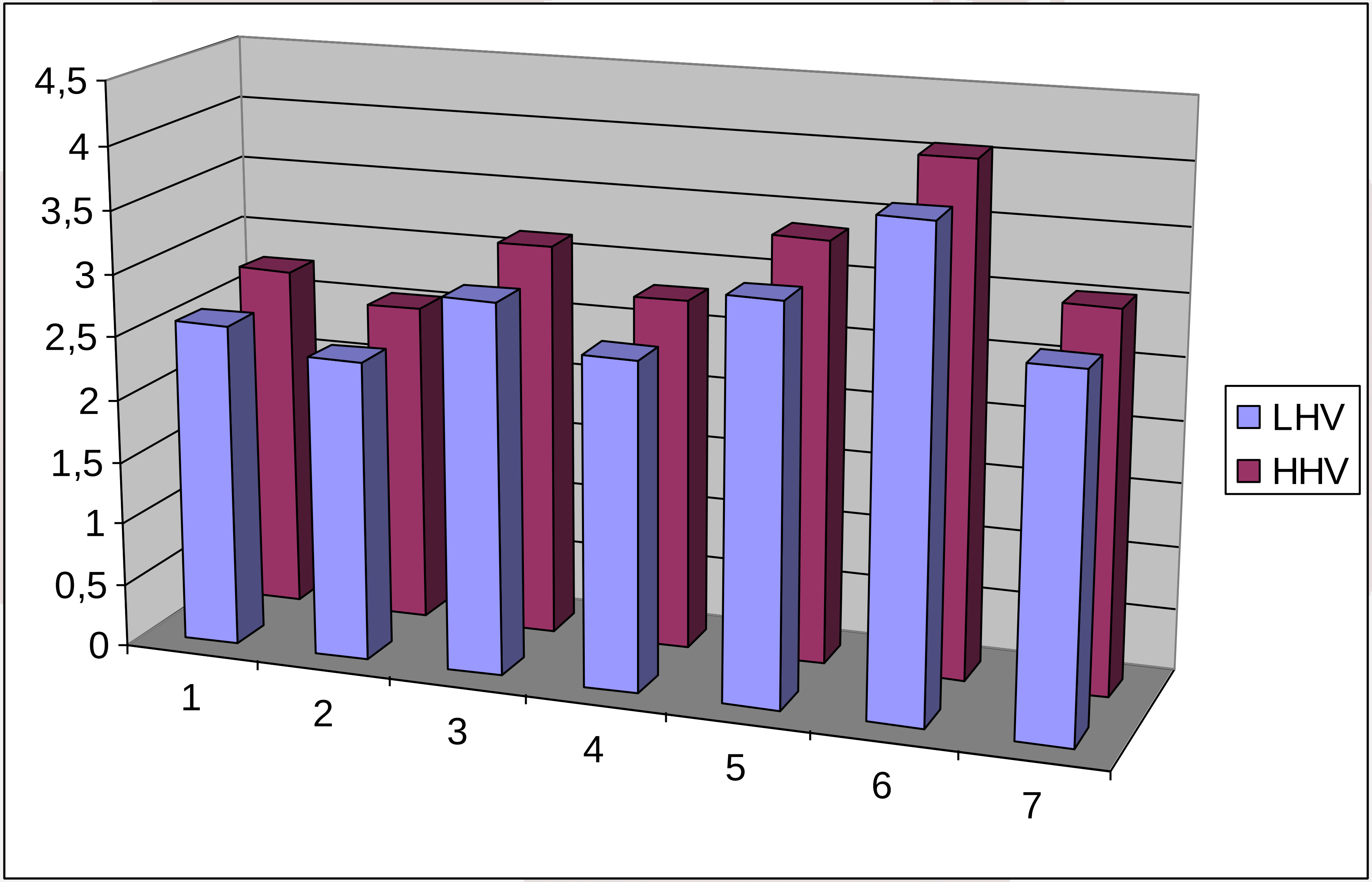
Product gas composition

Denomination	CH_4	CO_2	N_2	CO	H_2	O_2	Density	HHV	LHV
Unit	V/V%	V/V%	V/V%	V/V%	V/V%	V/V%	kg/m^3	MJ/m^3	MJ/m^3
1. Acacia chips	0,79	4,86	67,00	17,06	3,07	7,22	1,259	2,76	2,58
2. Poplar chips	0,89	7,30	67,94	15,47	2,70	5,69	1,278	2,55	2,39
3. Willow chips	1,27	6,24	65,16	18,46	3,62	5,26	1,257	3,14	2,96
4. Wheat-straw pellet	1,08	7,03	66,13	15,93	3,74	6,09	1,263	2,80	2,61
5. Energy-grass pellet	0,81	4,20	63,39	19,98	5,33	6,30	1,226	3,37	3,16
6. 75% Acacia 25% sewage sludge	1,3	5,4	56,5	24,9	4,7	7,2	1,241	4,07	3,84
7. 50% Acacia 50% sewage sludge	0,9	7,6	64,7	17,7	4,6	4,5	1,256	3,03	2,85

Product gas composition



Heating value variation of product gas



Tar quantity

Denomination	Source material	Tar quantity	Tar ratio by mass
Unit	Kg	kg	%
1. Acacia chips	**10,0**	**2,6**	**26,0**
2. Poplar chips	**16,71**	**4,5**	**26,9**
3. Willow chips	**10,08**	**2,95**	**29,3**
4. Wheat-straw pellet	**14,0**	**3,6**	**25,7**
5. Energy-grass pellet	**17,0**	**4,2**	**24,7**
6. 75% Acacia 25% sewage sludge	**10,0**	**2,95**	**29,5**
7. 50% Acacia 50% sewage sludge	**14,2**	**3,1**	**21,8**

Tar compositions and heating values

Denomination	C	S	H	O	N	HHV	LHV
Unit	m/m %	m/m %	m/m %	m/m %	m/m %	kJ/kg	kJ/kg
1. Acacia chips	**67,73**	**0,46**	**4,43**	**26,77**	**0,61**	**27099**	**25896**
2. Poplar chips	**66,10**	**0,51**	**3,96**	**28,85**	**0,58**	**25762**	**24699**
3. Willow chips	**64,47**	**0,55**	**3,50**	**30,93**	**0,54**	**24424**	**23501**
4. Wheat-straw pellet	**51,60**	**0,35**	**8,98**	**38,38**	**0,69**	**25477**	**23473**
5. Energy-grass pellet	**53,86**	**0,34**	**8,71**	**36,38**	**0,70**	**26174**	**24195**
6. 75% Acacia 25% sewage sludge	**57,30**	**0,03**	**6,29**	**36,20**	**0,18**	**23397**	**22024**
7. 50% Acacia 50% sewage sludge	**56,5**	**0,04**	**6,54**	**36,61**	**0,31**	**23305**	**21878**

Ash quantity and combustible residue

Denomination	Source material	Ash	Combustible part of ash
Unit	kg	kg	m/m %
1. Acacia chips	10,0	0,52	47,7
2. Poplar chips	16,71	0,35	23,6
3. Willow chips	10,08	0,21	42,4
4. Wheat-straw pellet	14,0	1,08	46,6
5. Energy-grass pellet	17,0	1,45	30,9
6. 75% Acacia 25% sewage sludge	10,0	1,313	10,7
7. 50% Acacia 50% sewage sludge	14,2	3,75	21,5

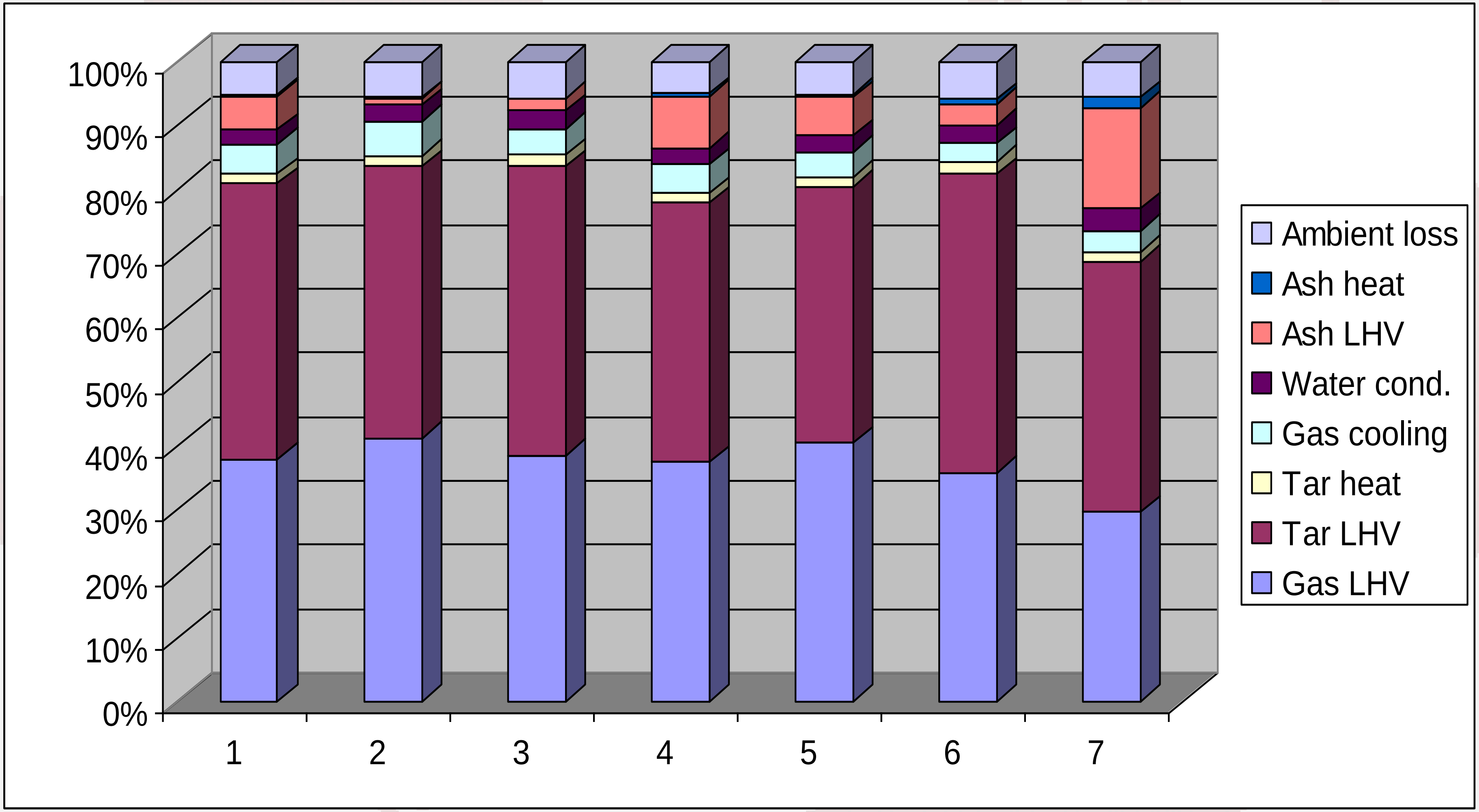
Heat balance of the gasifier

- $Q_{input} = m_{fuel} * LHV_{fuel} = Q_{gas\ combustible} + \Sigma Q_{loss}$
- $\eta_{gasifier} = Q_{gas\ combustible} / Q_{input}$
- *Losses:* - *gas cooling*
  - *water condensation*
  - *tar as combustible*
  - *tar physical heat*
  - *ash combustible part*
  - *ash physical heat*
  - *ambient heat loss*

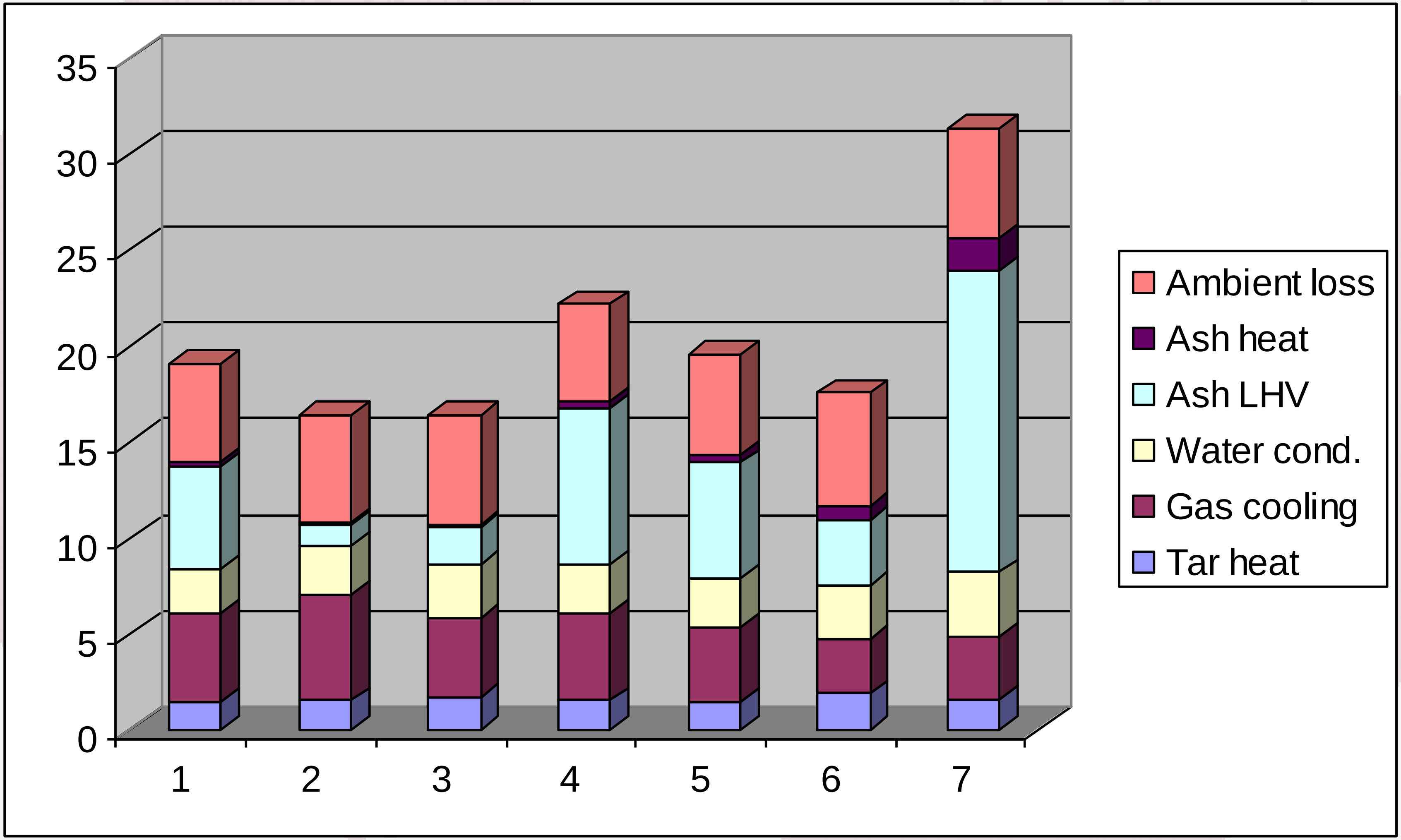
Results of efficiency and heat balance calculations

	Feeding	Useful	Losses						
Denomination	Firing power	Efficiency of gas production	Gas cooling	Water cond.	Tar com-bustible	Tar heat	Ash com-bustible	Ash heat	Ambient loss
Unit	%	%	%	%	%	%	%	%	%
1. Acacia chips	100	37,9	4,62	2,27	43,0	1,5	5,32	0,25	5,14
2. Poplar chips	100	41,19	5,5	2,58	42,49	1,55	1,055	0,1	5,61
3. Willow chips	100	38,5	4,09	2,84	45,09	1,73	1,96	0,1	5,69
4. Wheat-straw pellet	100	37,43	4,53	2,57	40,4	1,55	8,1	0,39	5,04
5. Energy-grass pellet	100	40,46	3,92	2,52	40,03	1,49	5,98	0,44	5,17
6. 75% Acacia 25% sewage sludge	100	35,83	2,9	2,74	46,63	1,91	3,41	0,72	5,87
7. 50% Acacia 50% sewage sludge	100	29,59	3,26	3,35	39,12	1,61	15,74	1,65	5,68

Efficiency and heat balance of the gasifier



Variation of minor losses



Summary

- Tested gasifier actually was small power rate low temperature gasifier with air atmosphere gasification.
- According to results this gasifier is better to call distiller, because tar production has larger share than product gas.
- But investigation or further development of the gasification process did not belong to our task, only to evaluate existing operation of the gasifier with fuels.
- Our aim was to develop a method for evaluation of gasifiers.
- Measurement and test results covering each component together made possible to calculate the energy balance and efficiency of the gasifier.
- Developed method basically appropriate for measurement and evaluation of each gasifier.
- According to experience sample system can be developed further. Since all the loss is calculated separately this method may give ideas for further development of the investigated gasifier.

Thank You for Your Attention !

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