JOINT INSTITUTE FOR HIGH TEMPERATURES
OF THE RUSSIAN ACADEMY OF SCIENCES

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THE METHOD AND DEVICE FOR A TWO-STAGE PYROLYTIC PROCESSING OF BIOMASS INTO SYNTHESIS GAS

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Motivation

1st According to the Federal State Statistics Service in the Russian Federation over 2017 year wood processing, production of wood products, pulp and paper production gave **10.4 million tons** of waste.

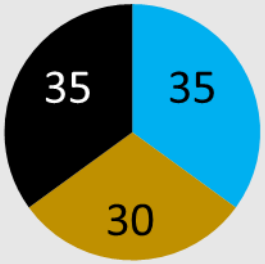
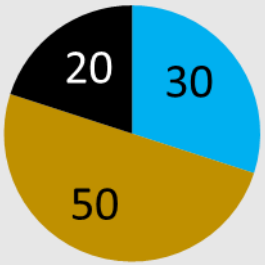
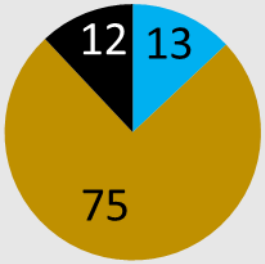
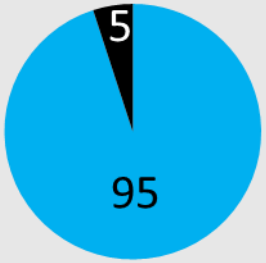
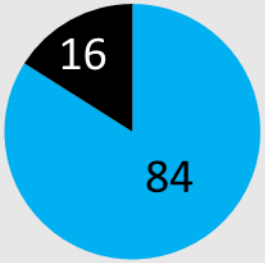
2nd **Air gasification**:

- low heating value (typically 2 to 6 MJ/m^3)
- high tar content (typically 0.5–10 g/m^3)

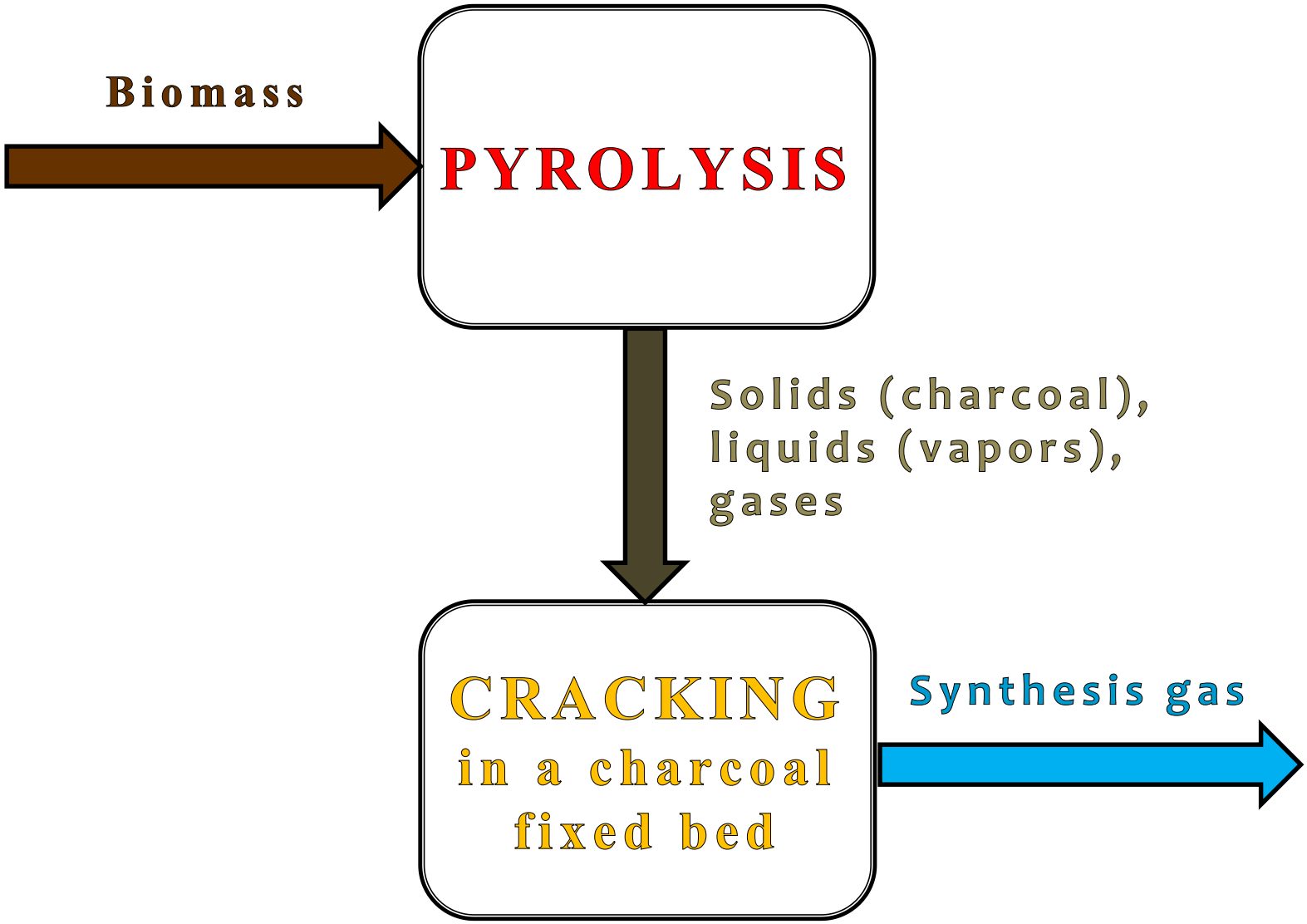
3rd Traditional **pyrolysis**:

- low energy conversion degree (usually does not exceed 0.3).

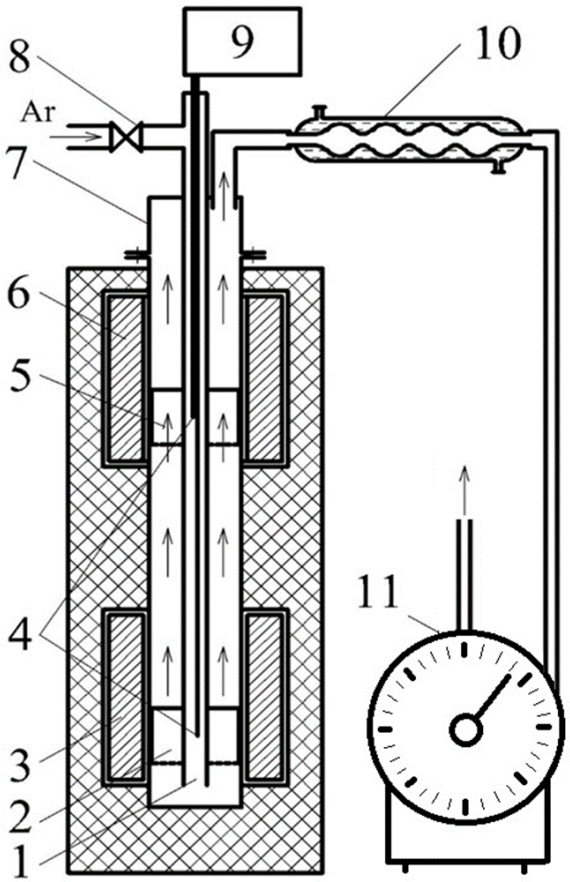
Technology comparison

Technology	Pyrolysis			Downdraft air gasification	Two-stage pyrolytic conversion
	Slow	Fast	Flash		
Yield: **GASES**, **LIQUIDS**, **SOLIDS**					
Gas heating value	**HIGH** **20–30 MJ/m³**			**LOW** **2–5 MJ/m³**	**MEDIUM** **10–13 MJ/m³**
Biomass to gas energy conversion efficiency	**LOW** **Up to 30 %**			**HIGH** **Up to 95 %**	**HIGH** **Up to 86 %**
Tar content	**HIGH** **> 100 g/m³**			**MEDIUM** **0.2–10 g/m³**	**LOW** **0.01–0.1 g/m³**

Two-stage pyrolytic conversion principle



Laboratory-scale experimental setup



1 – pipe for purging the retort;
2 – bowl for initial biomass sample;
3 – furnace; *4* – thermocouples;
5 – bowl for the charcoal; *6* – heater;
7 – retort; *8* – argon inlet tap;
9 – thermometer; *10* – condenser;
11 – gas volume meter

(a) (b) (c)

Wood chips (a) and its coke residue before (b) and after (c) the experiment.

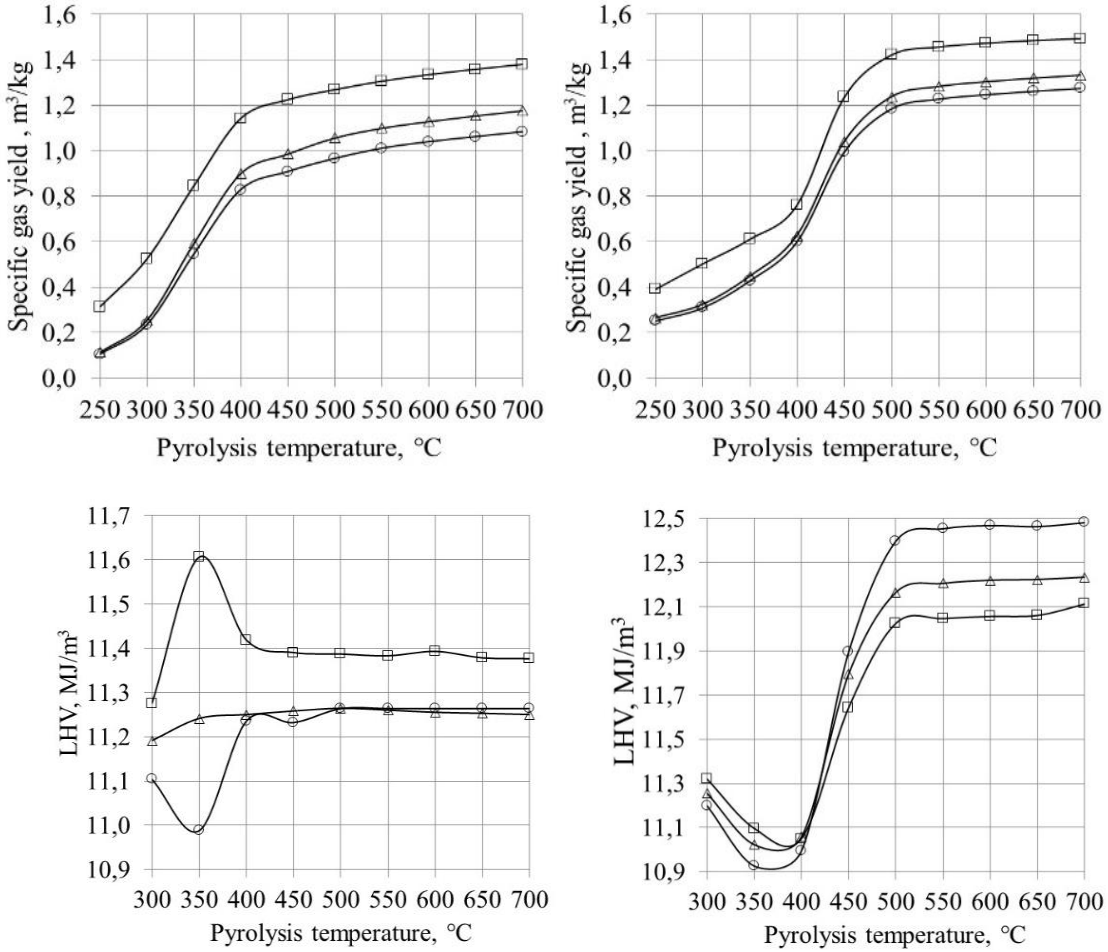
(a) (b) (c)

Bark (a) and its coke residue before (b) and after (c) the experiment.

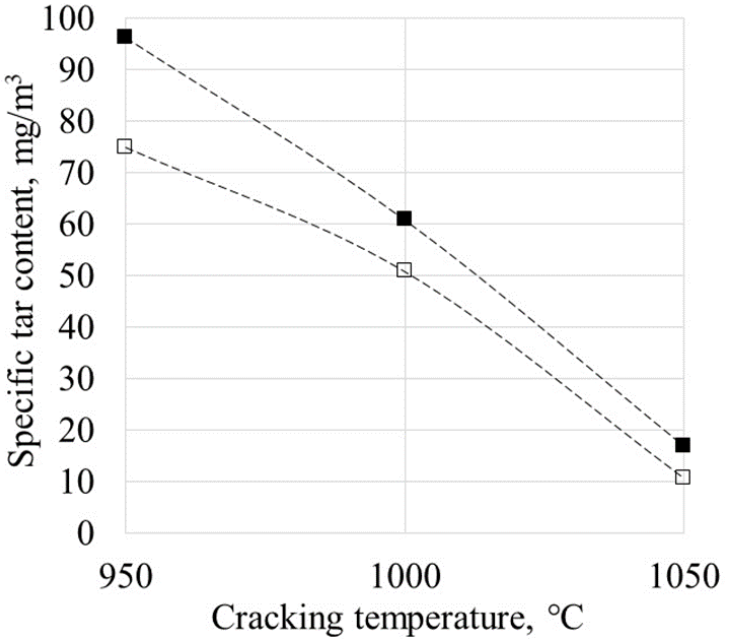
Raw material	Ash, wt. %	Volatiles, wt. %	Heating value, MJ/kg		Element composition, wt. %				
			Higher	Lower	C	H	N	S	O
Chips	0,99	80,83	20,6	19,3	50,16	6,24	0,09	0,85	41,67
Bark	0,38	93,48	34,7	32,5	71,46	9,95	0,05	0,00	18,20

Synthesis gas characteristics 1

Specific gas yield and lower heating value (LHV) for chips (left) and bark (right) at different cracking temperatures:
○ – 950 °C; Δ – 1000 °C; □ – 1050 °C.

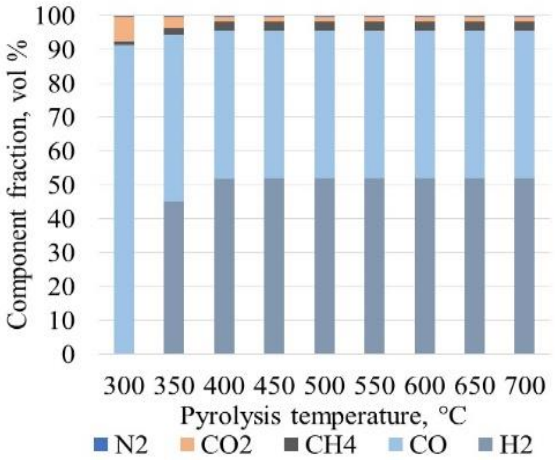


Specific tar content for chips (□) and bark (■) at different cracking temperatures

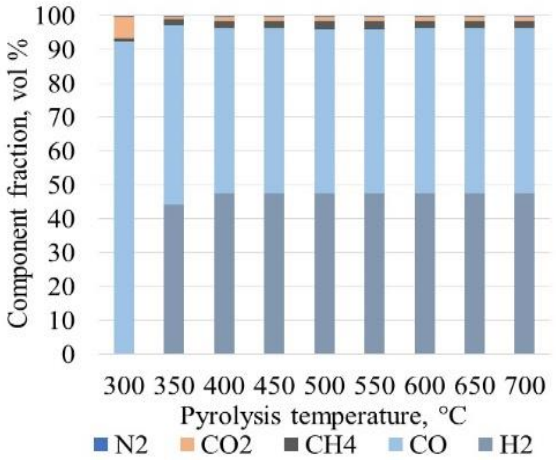


Synthesis gas characteristics 2

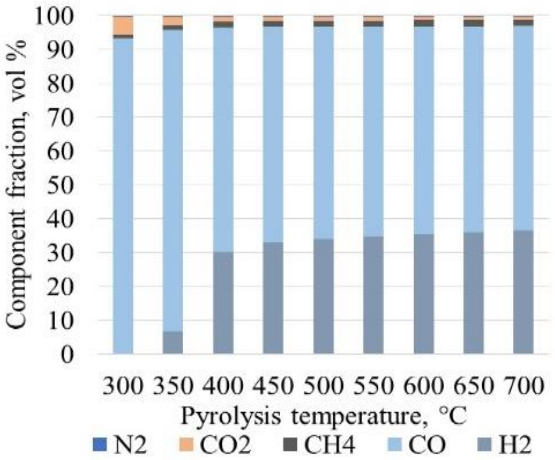
Gas chemical composition at different cracking temperatures:



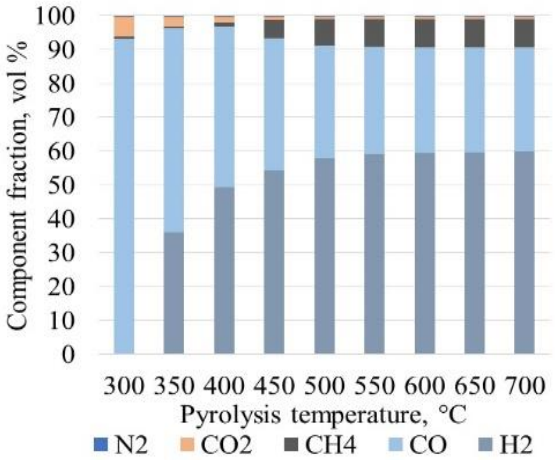
Chips 950 °C



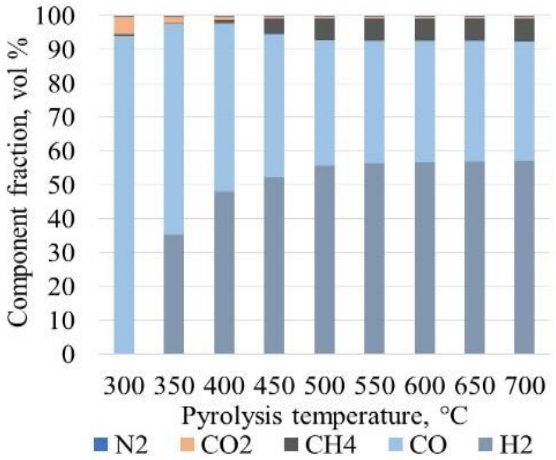
Chips 1000 °C



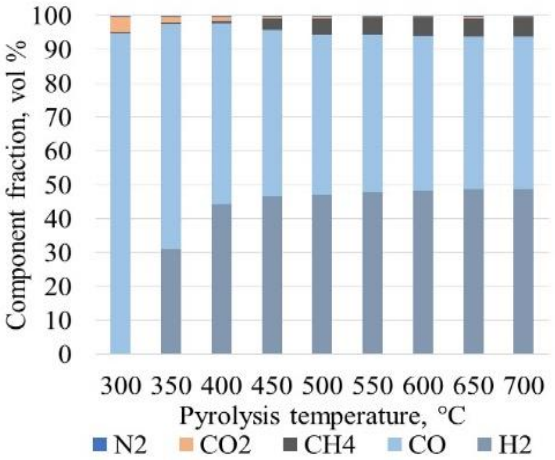
Chips 1050 °C



Bark 950 °C

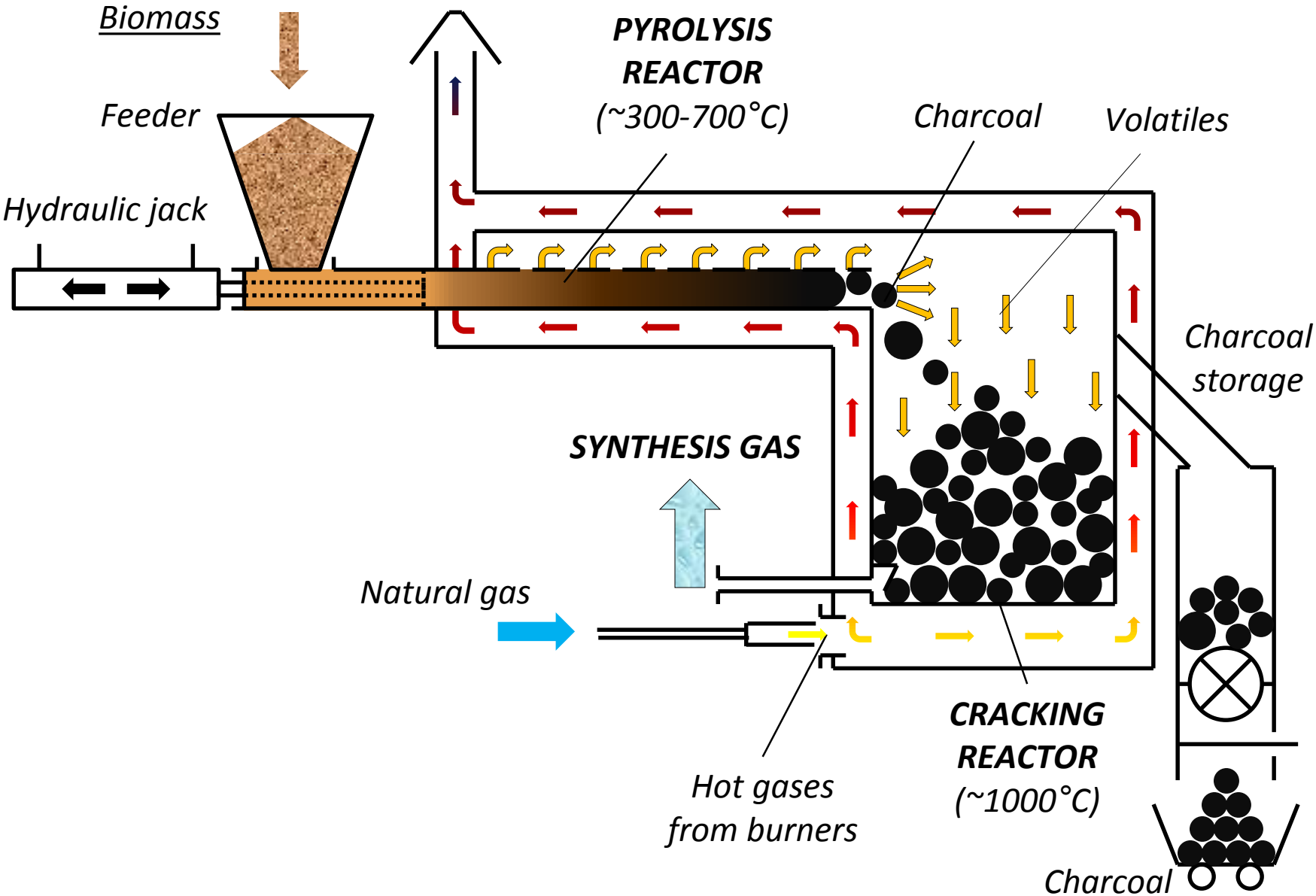


Bark 1000 °C

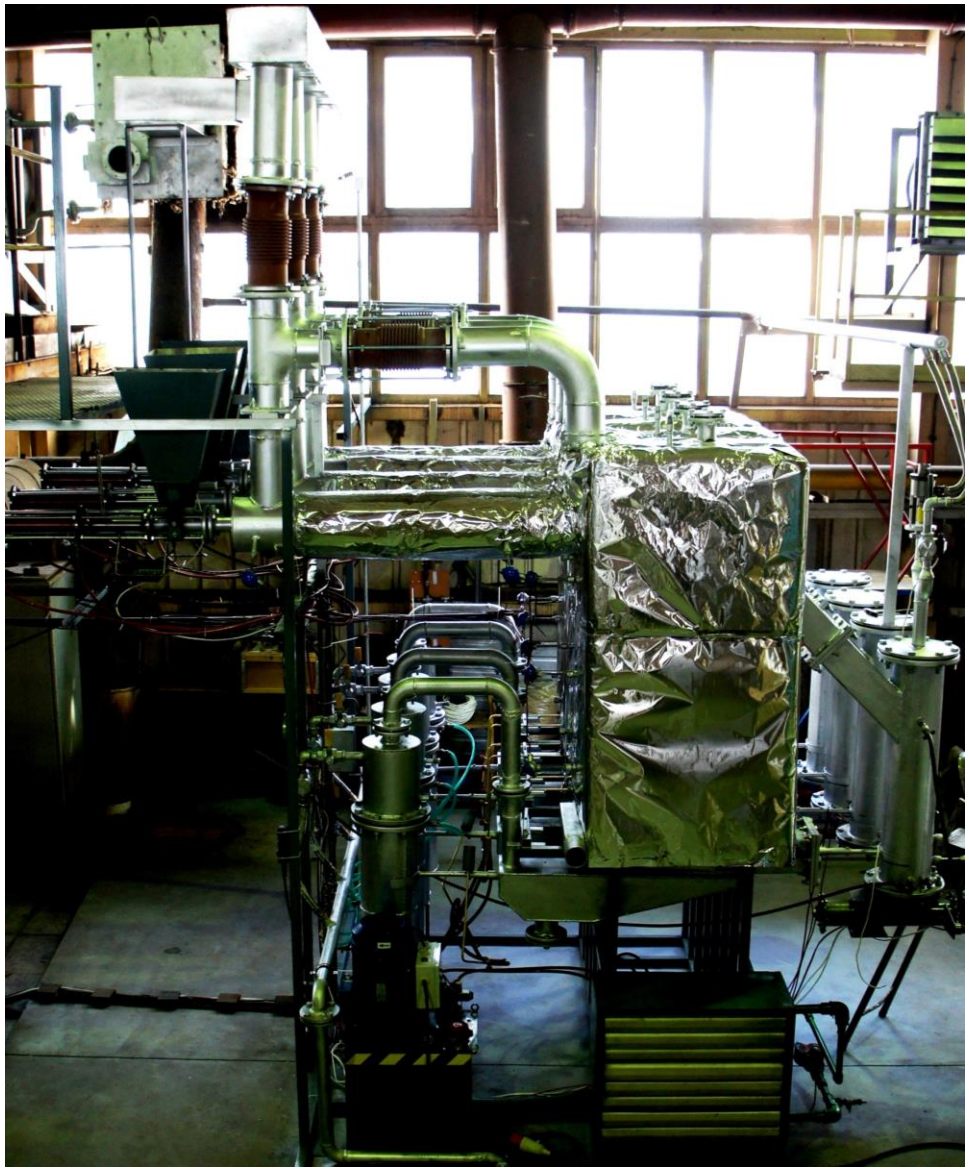


Bark 1050 °C

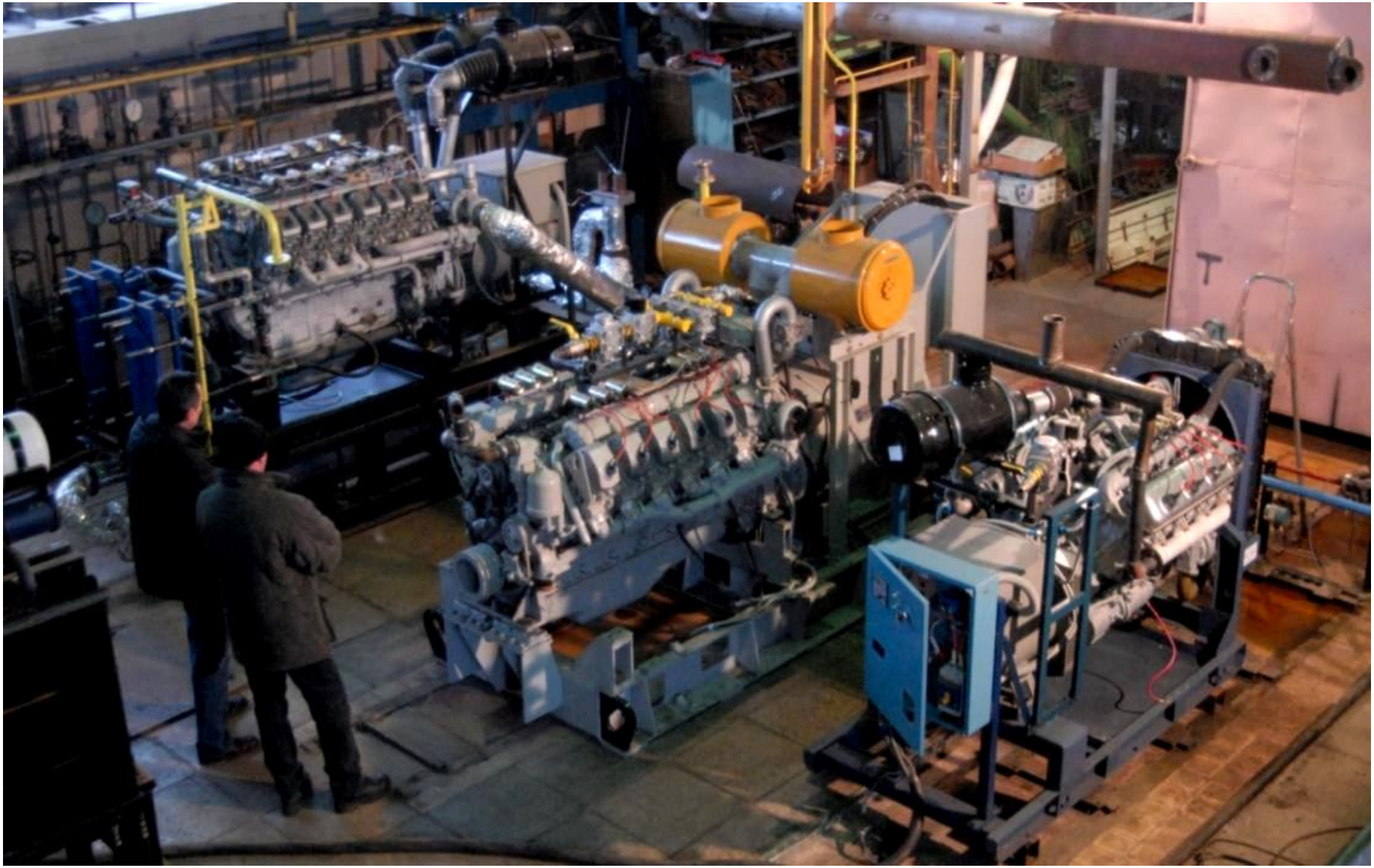
Pre-pilot-scale unit scheme



Pre-pilot-scale unit

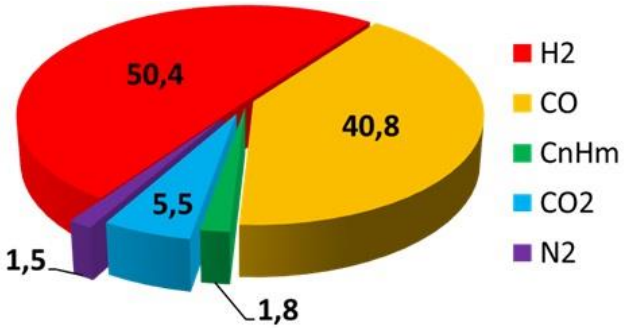


Mini-CHP gas-piston engines

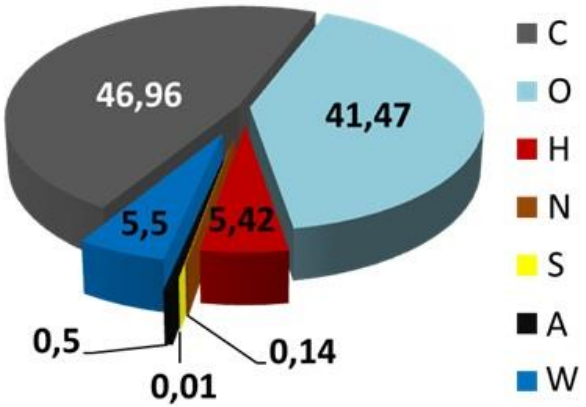


Pre-pilot-scale unit characteristics

Synthesis gas composition:



Biomass elemental composition:



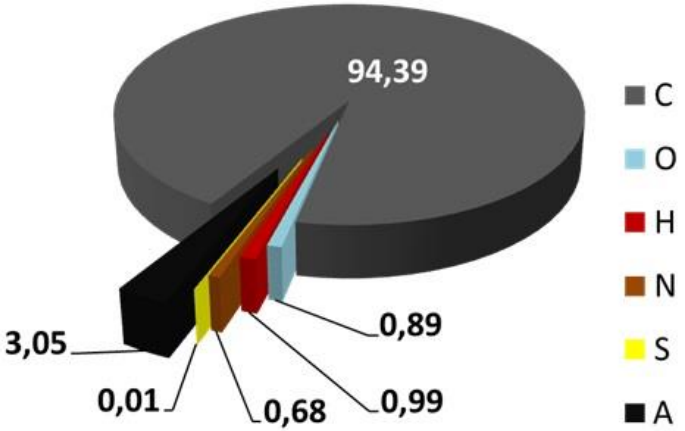
Capacity up to: 50 kg/h

Gas yield per 1 kg of biomass: 1,33 m^3

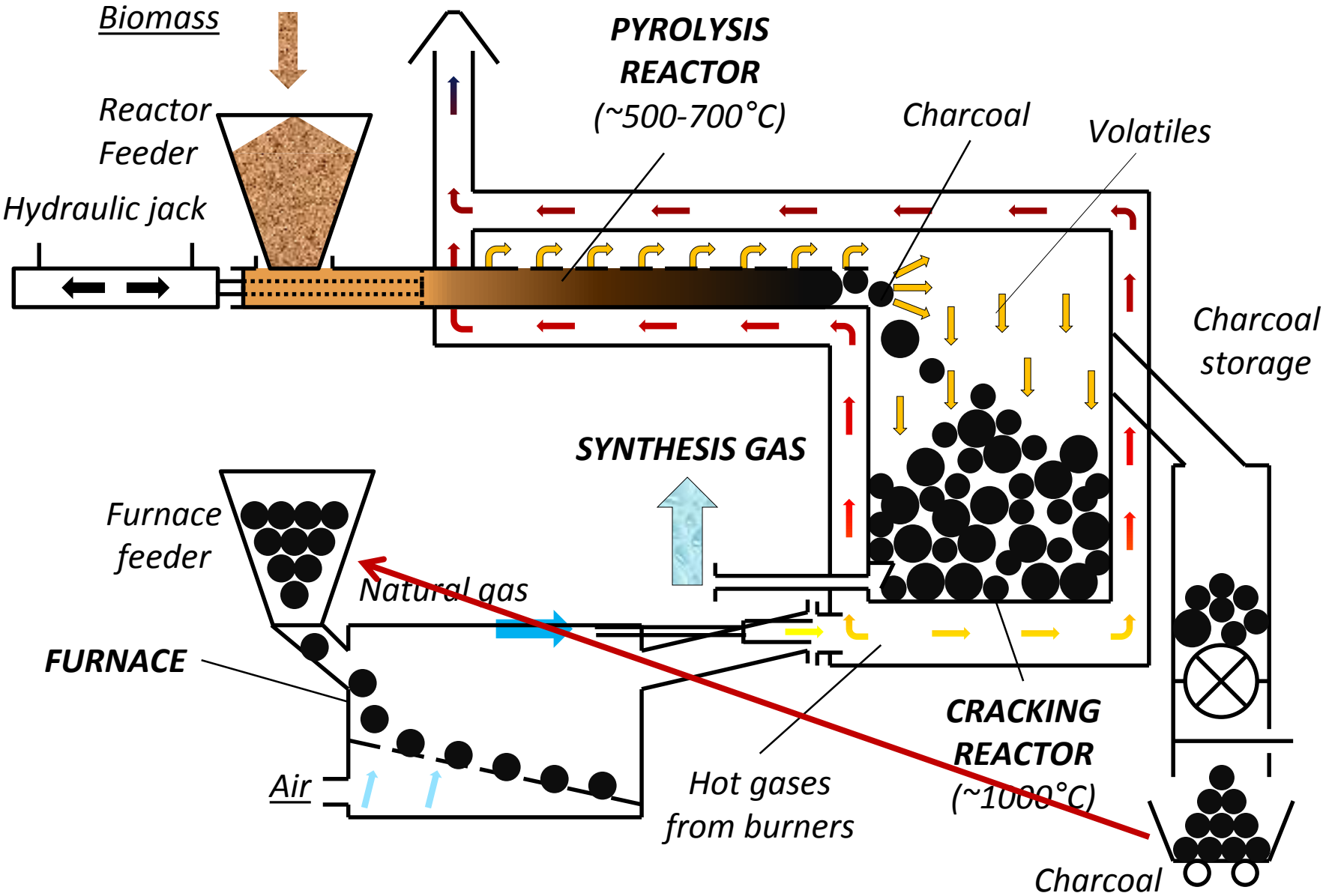
Lower heating value: 10,5 MJ/m^3

Energy conversion efficiency: ~ 79 %

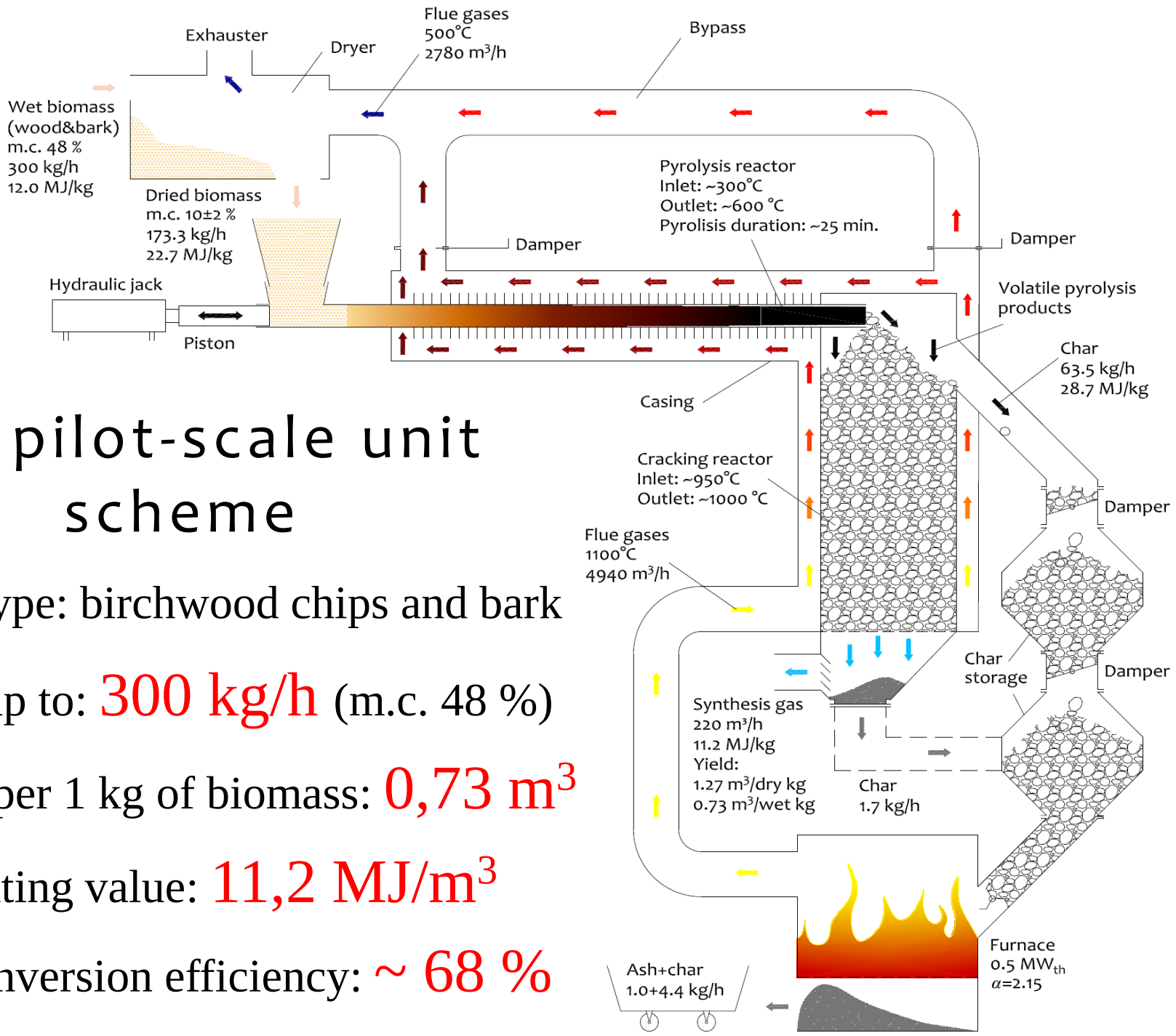
Charcoal elemental composition:



The pilot-scale unit scheme changes



The pilot-scale unit scheme



Biomass type: birchwood chips and bark

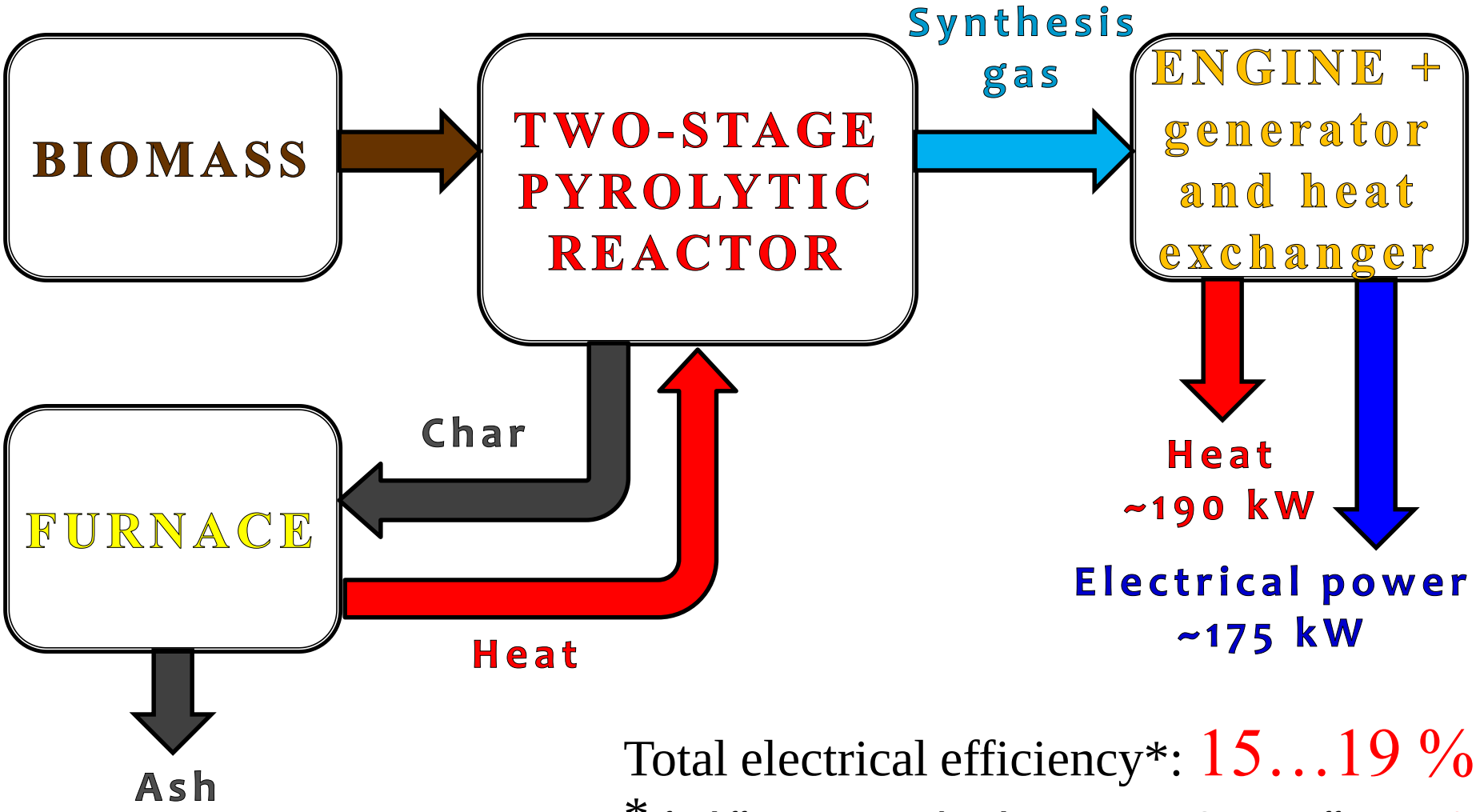
Capacity up to: 300 kg/h (m.c. 48 %)

Gas yield per 1 kg of biomass: 0,73 m^3

Lower heating value: 11,2 MJ/m^3

Energy conversion efficiency: ~ 68 %

CHP plant scheme



Total electrical efficiency*: 15…19 %

* for different scenarios, based on gas-piston IC engine efficiency 28 %, taking into account own unit needs in electric power (from 10 to 30 %).

Conclusions and future works

Experimental data characterizing the dependence of the specific yield of non-condensing gases, their chemical composition, the calculated value of the lower heating value and the specific content of tar on the processing parameters was presented. It was shown that the most optimal cracking temperature for wood chips and bark processing is from 1000 to 1050 °C. The advantages of this mode were observed for all gas characteristics:

- high specific gas yield up to 1.5 m^3/kg due to effective conversion of water steam,
- total volume fraction of combustible components more than 98 %, low concentration of CO_2,
- high LHV up to 12.5 MJ/m^3,
- low specific tar content (less than 20 mg/m^3).

Mini-CHP power plant capacity of 300 kg/h of initial wet biomass with estimated electrical efficiency of 15 – 19 % was developed.

Thank you!

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