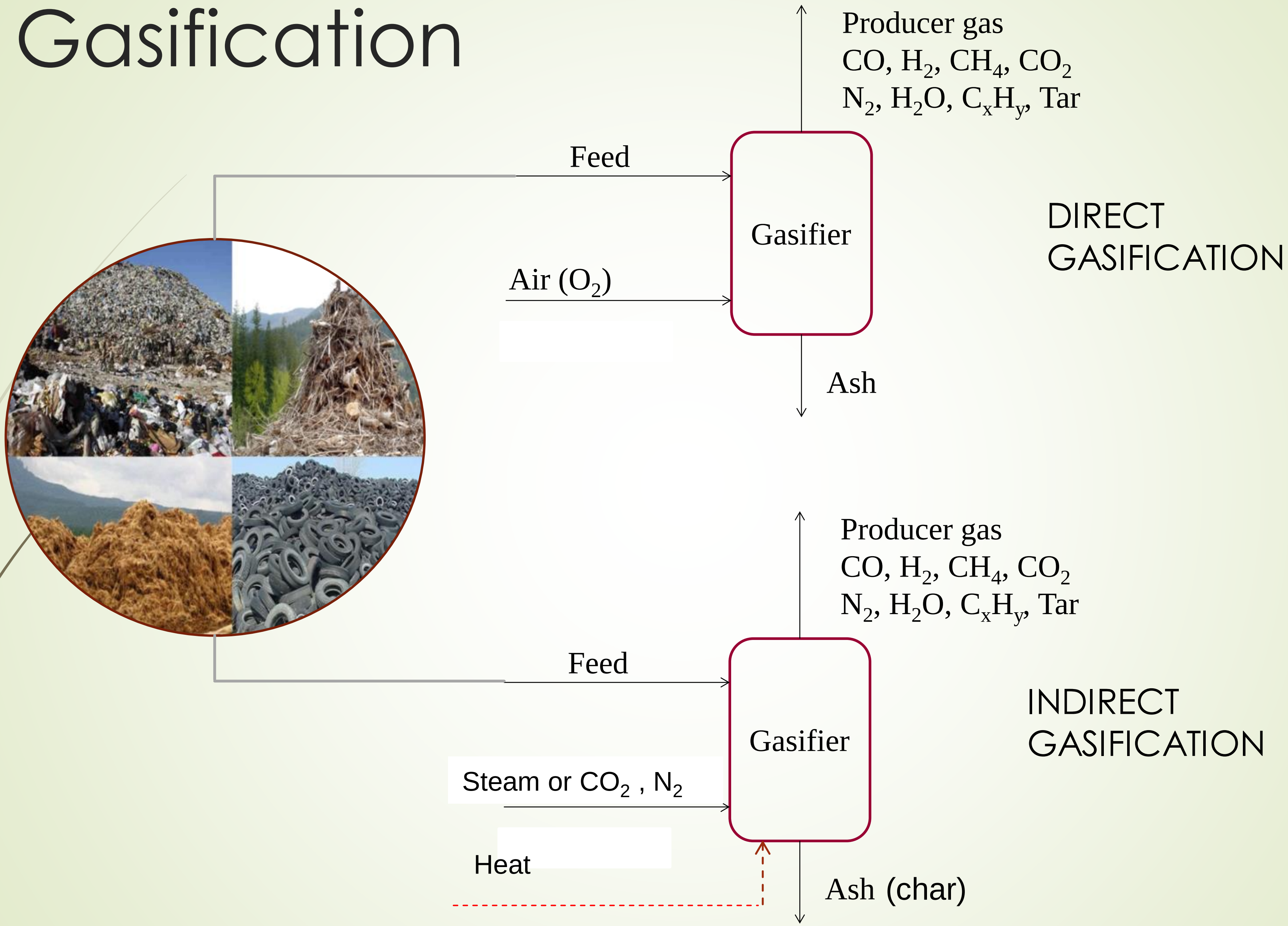
Two stage pyrolysis/split product gasification of refused-derived fuel (RDF)

Juma HAYDARY*, Patrik ŠUHAJ

Slovak University of Technology in Bratislava

Gasification



Challenges for waste and biomass gasification

STU FCHPT

Technical challenges:

- Highly heterogeneous feed with variable composition
- Produced gas tar content and content of other contaminants
- Conversion efficiency in some gasifiers
- Requirement for specific turbine and combustion engine design

Economic challenges:

- High capital costs of gasification plants, particularly given the low capital investment required for natural gas combined cycle

Social challenges:

- Poor public-perception and understanding of the technology
- Complex permitting issues for any type of thermal waste processing technology

Gas tar content

- Complex mixture of condensable hydrocarbons and their derivates
- Causes fouling, corrosion and catalyst poisoning in downstream processing units

- Allowed gas tar content depends on its use propose
- For a fuel quality gas used in gas engines:
  - 1-ring (M< 110 g/mol)<1500 mg/MJ
  - 2-ring (110< M< 152 g/mol)<200 mg/MJ
  - 3-ring (152< M< 200 g/mol)<3 mg/MJ
  - 4-rings and more(200<M g/mol) not allowed

Tar removal tehnologies

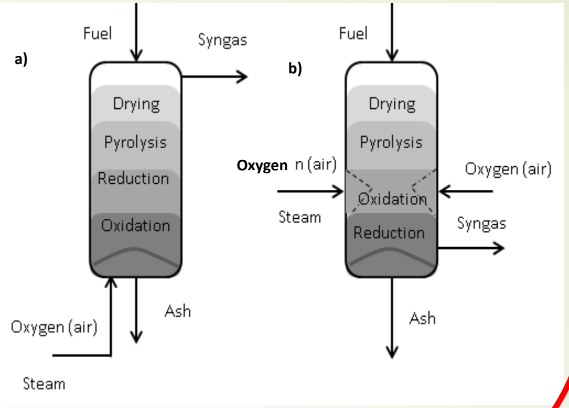
Generally two approaches:

- **Primary methods**
  - Proper selection of gasification technology and operating parameters (temperature, gasifying agent, equivalence ratio, residence time, catalyst)
- **Secondary methods**
  - Physical methods
    - Wet cleaning
    - Organic scrubbers
    - Ventury scrubbers
    - Electrostatic precipitator (ESP)
    - Solid bed filters, etc.
  - Chemical methods
    - Thermal cracking
    - Thermo-catalytic cracking — Using cheap available catalysts
    - Catalytic hydrocracking

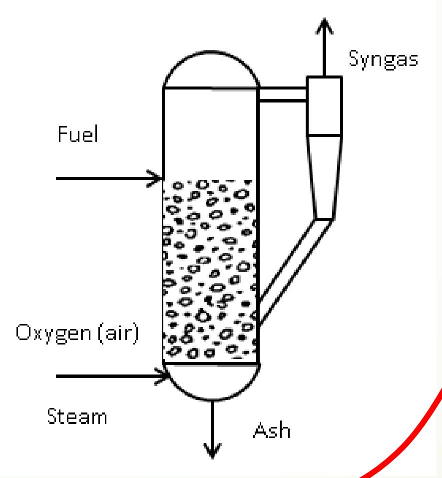
Gasifiers

STU FCHPT

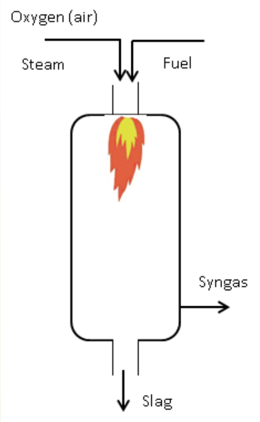
- Fixed bed (moving bed) → Updraft / Downdraft



- Fluidized bed → Bubbling / Circulating



- Intrained flow



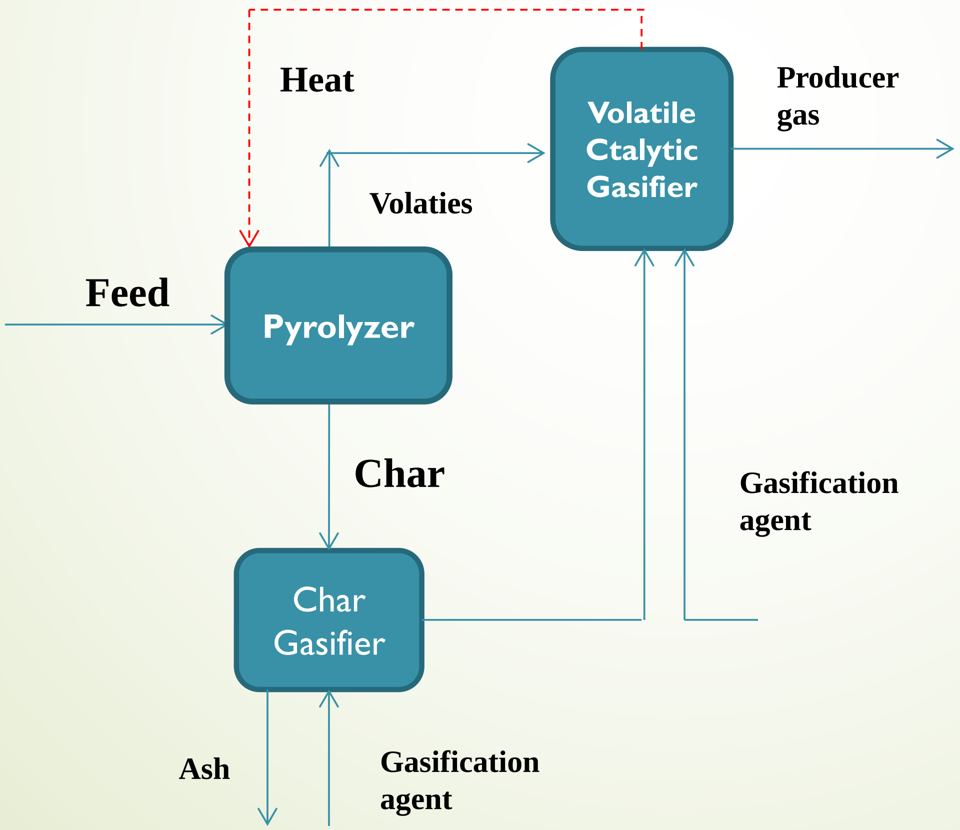
Commercialised
In Coal Gasification

Newer technologies:

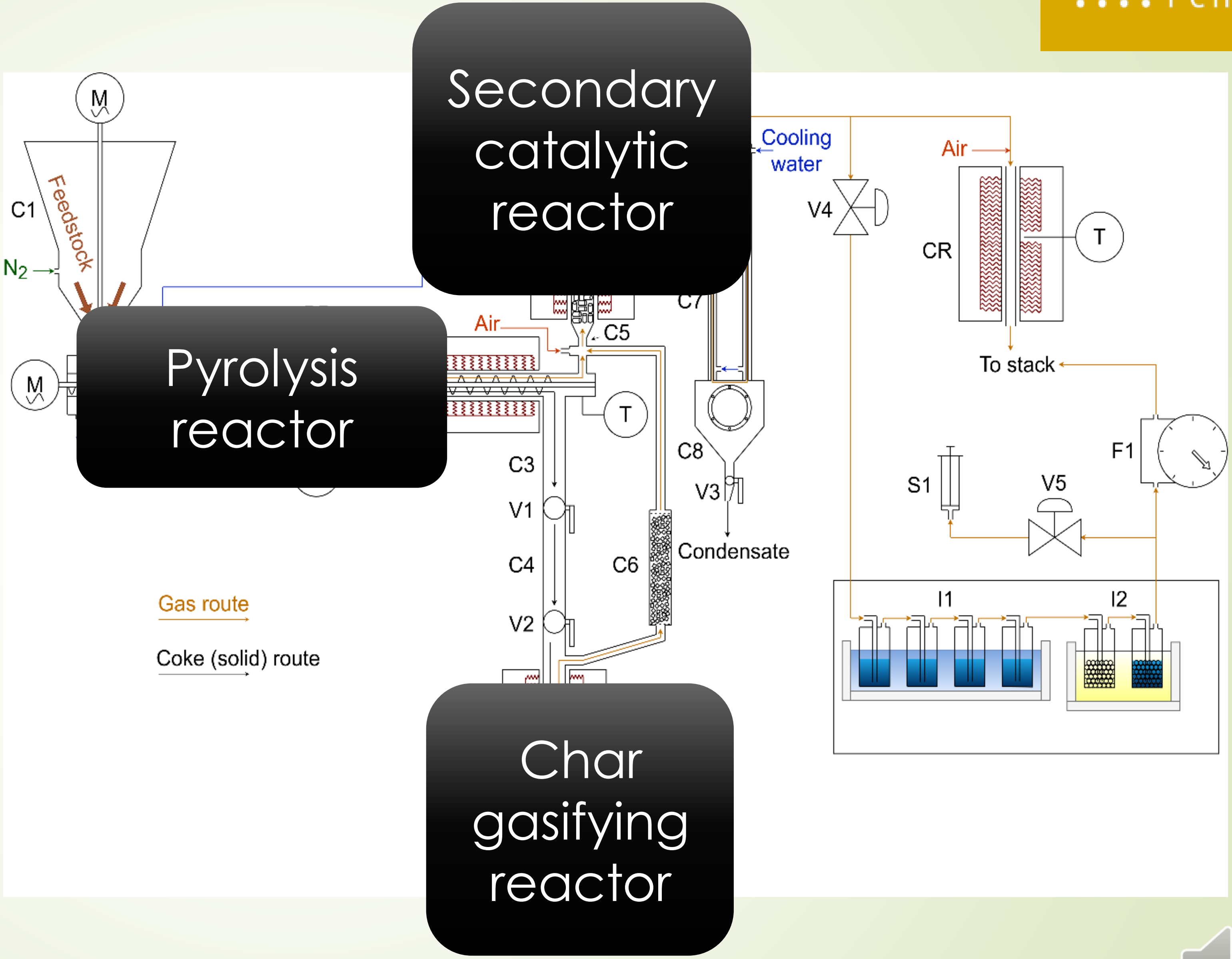
- Plazma → Dry feed / Slurry feed
- Multistage gasifiers
- Others

Two stage pyrolysis/split product gasification (PSPG)

Big potential for complete conversion of highly heterogeneous waste solid mixtures to a low-tar combustible gas

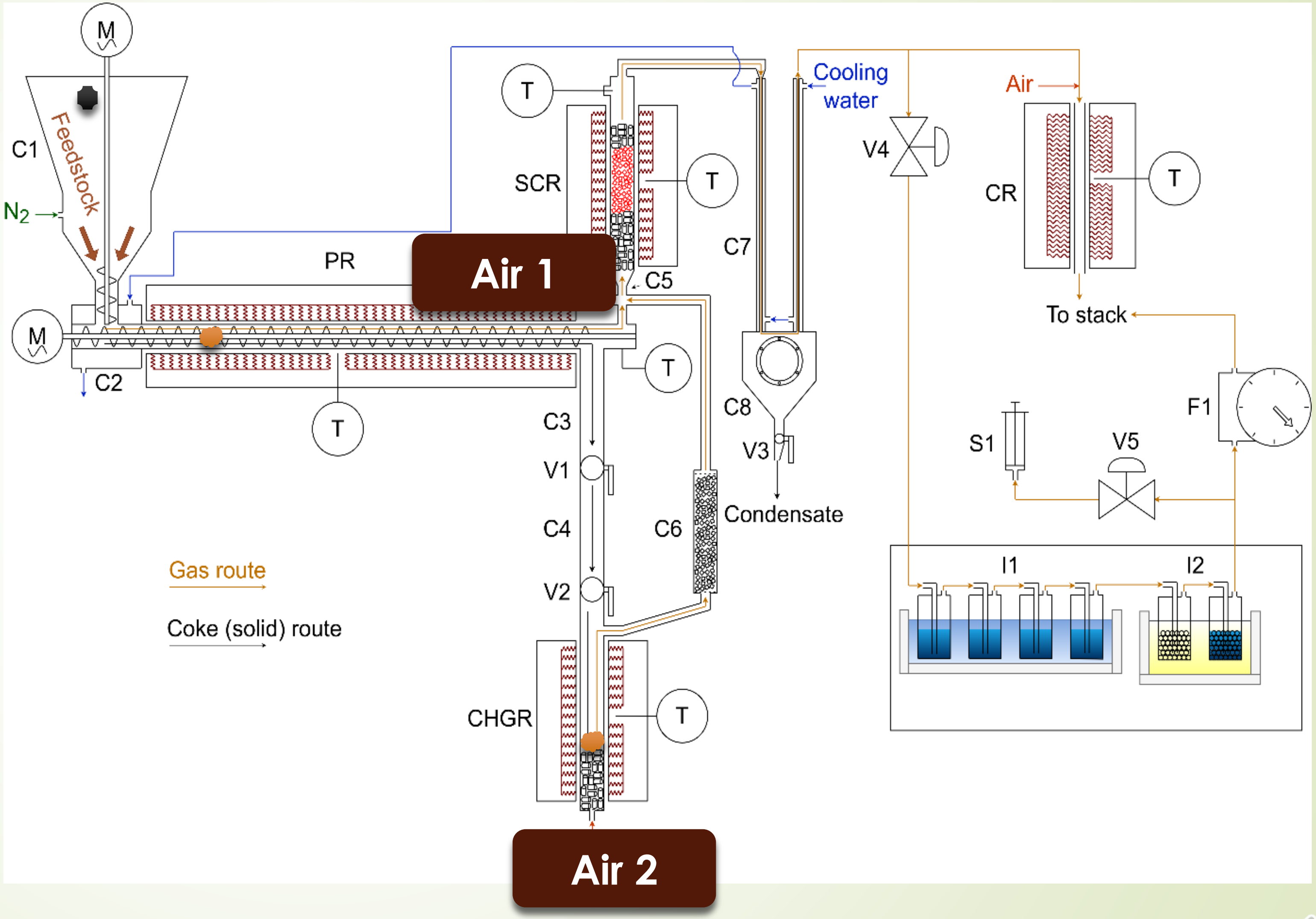


PSPG

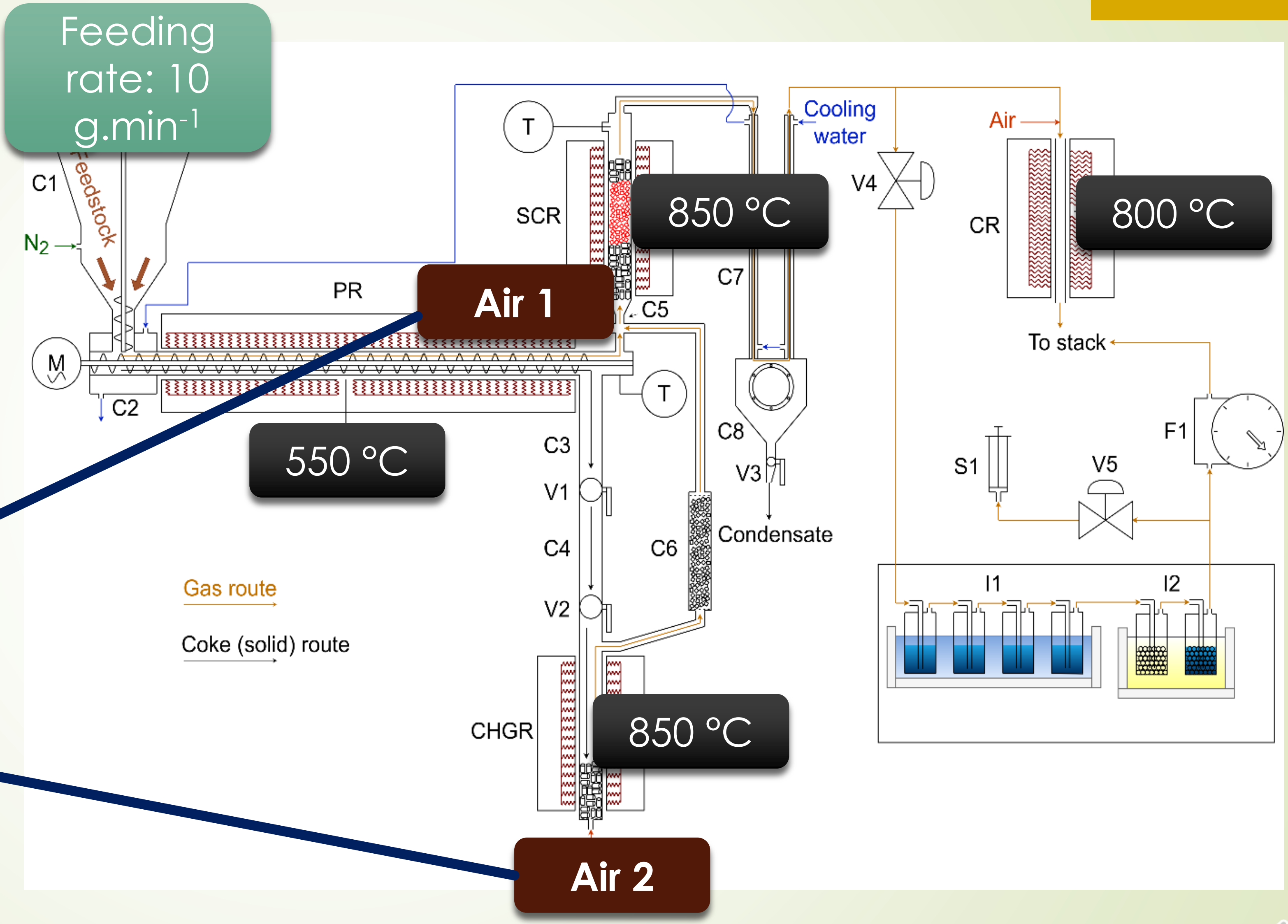


Šuhaj, P., Husár, J., Haydary, J., & Annus, J. (2022). Experimental verification of a pilot pyrolysis/split product gasification (PSPG) unit. *Energy*, *244*, 122584.

PSPG


M
C1
Feedstock
N2
PR
Air 1
SCR
T
C5
C7
Cooling water
Air
V4
CR
To stack
C2
C3
V1
C4
C6
V2
C8
V3
Condensate
F1
S1
V5
I1
I2
Gas route
Coke (solid) route
CHGR
Air 2

RDF pelets
1.4 – 2.0 mm



Equivalence ratio

$$ER = \frac{Air\ 1 + Air\ 2}{Air_{stochiometric}}$$

Air split ratio

$$AS = \frac{Air\ 1}{Air\ 1 + Air\ 2}$$

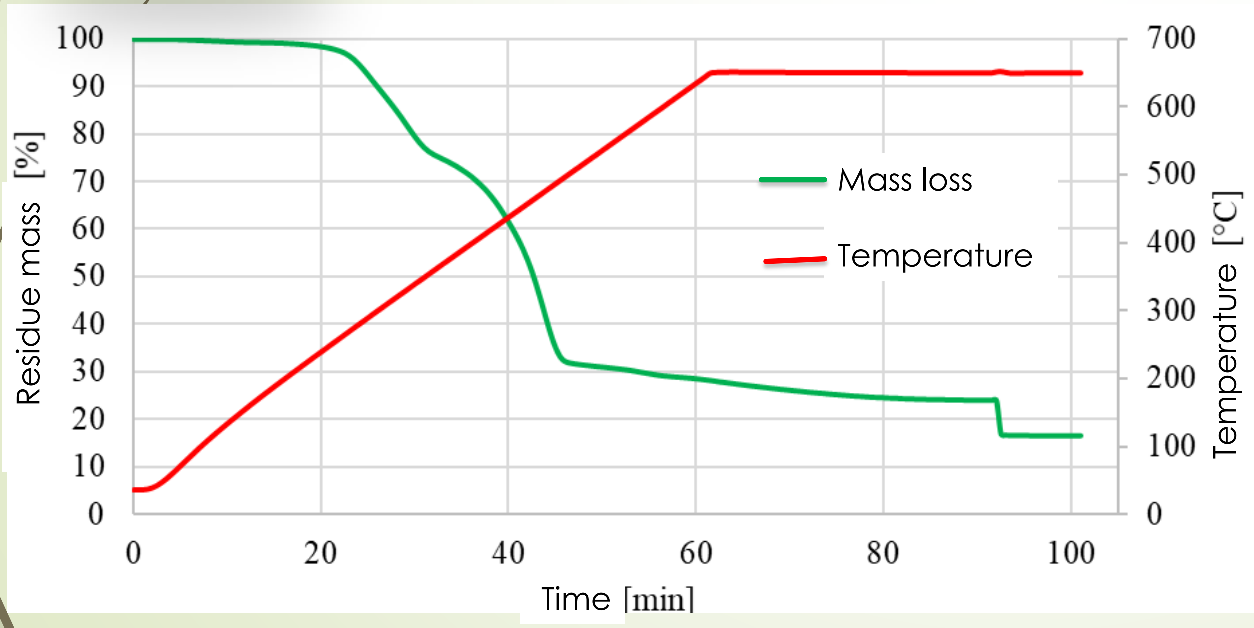
Raw materials

RFD pellets (diameter 5mm, average height: 10mm

(RDF)

Hammer mill screen

Pellet machine



Parameter	Value
Nitrogen (wt. %)	0.50
Carbon (wt. %)	55.3
Hydrogen (wt. %)	7.90
Sulphur (wt. %)	0.45
Chlorine (wt. %)	0.89
Oxygen[1] (wt. %)	18.85
Ash (wt. %)	16.00
Moisture[2] (wt. %)	0.50
Volatile matters (wt. %)	77.5
Fixed carbon (wt. %)	6.00
Lower heating value (MJ.kg^{-1})	23.85

Catalysts characterized and used

Pristine and Ni-impregnated beta zeolite

Catalyst	S_{BET}, $m^2\ g^{-1}$	v_p, $cm^3\ g^{-1}$	d_p, nm
Pristine	511	0,772	16,4
Impregnated	485	0,716	15,6

Methods of characterisation:

Method

- Analysis of pore structure and specific surface area
- Thermogravimetric (TG) analysis
- X-ray diffraction (XRD) analysis
- X-ray fluorescence (XRF) analysis
- Scanning electron microscope (SEM) analysis

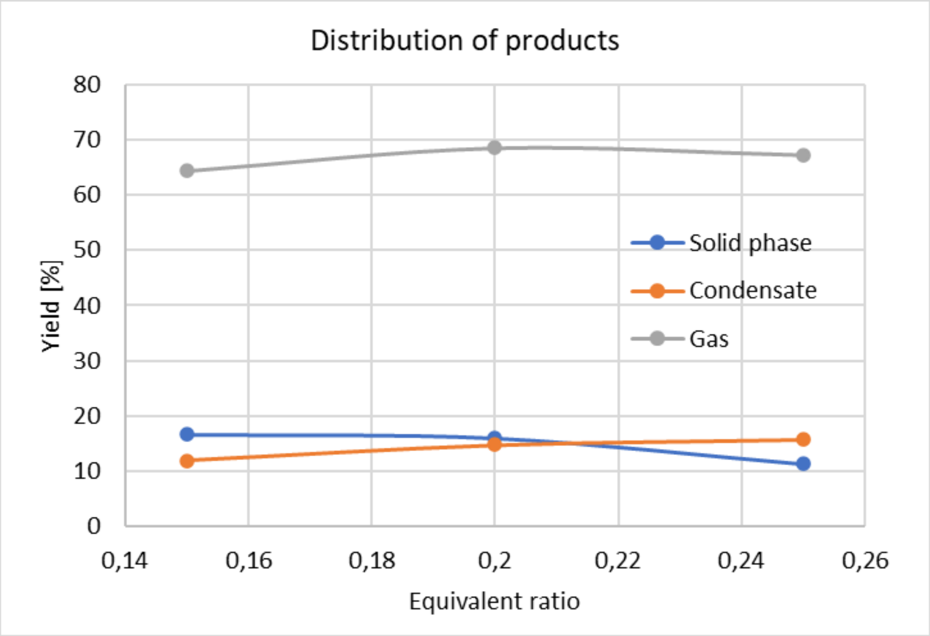
Previously used catalysts

Red clay mineral (RC)
- RC/ Calcined
- RC/Calcined/Ni

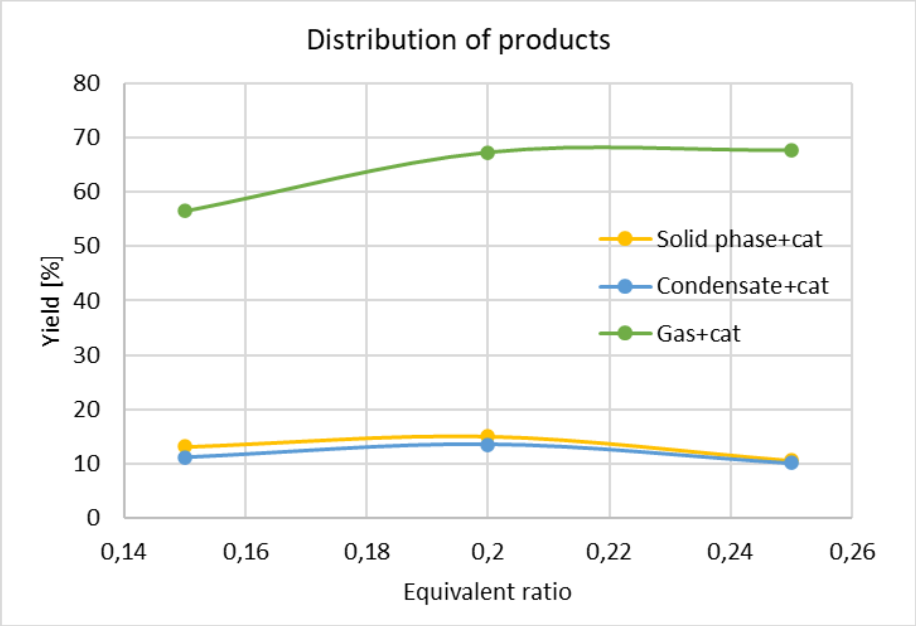
Pyrolytic char
- Carbonized
- Carbonized/Ni

Natural zeolite
- Calcined

Product distribution



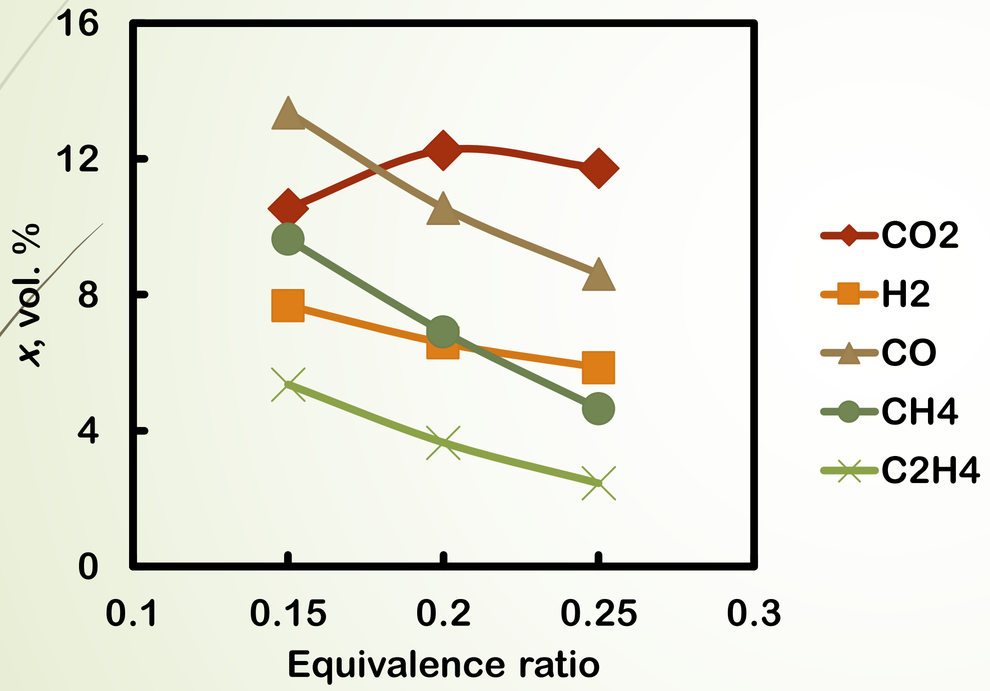
Absence of catalyst



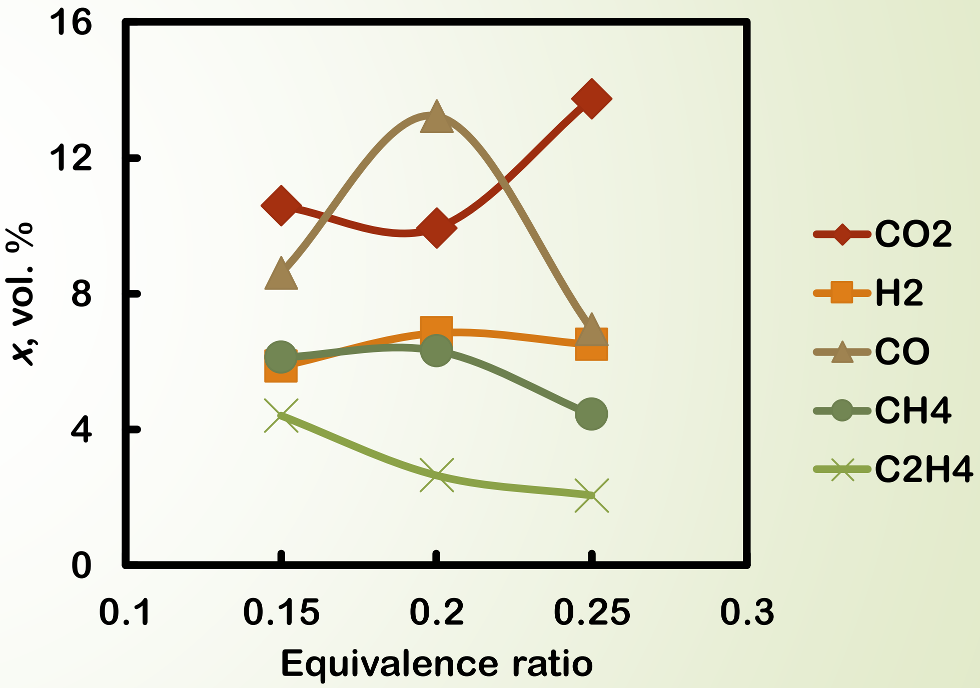
In present of catalyst

Gas composition

Gas LHV: 7-9 MJ/Nm^3



Absence of catalyst

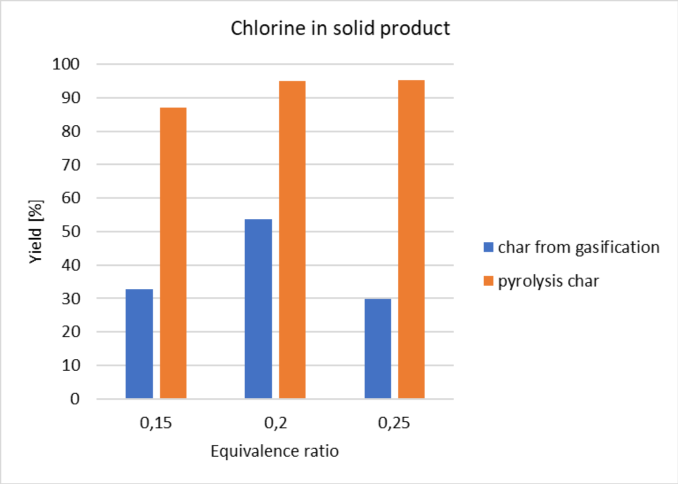


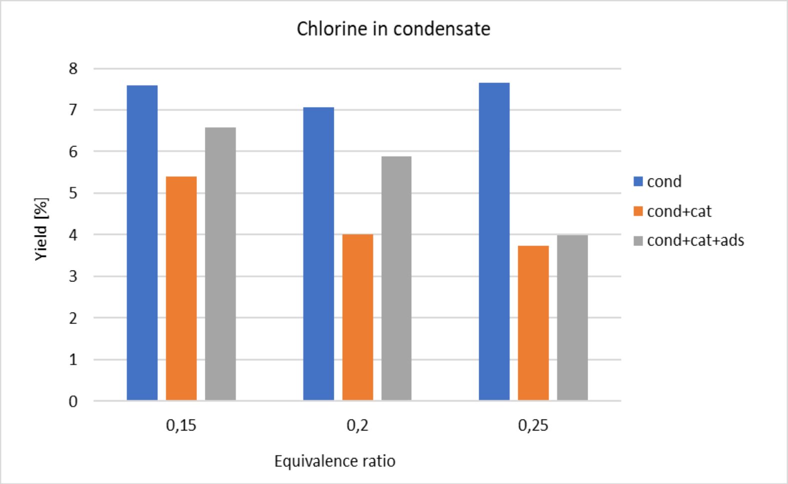
In present of catalyst

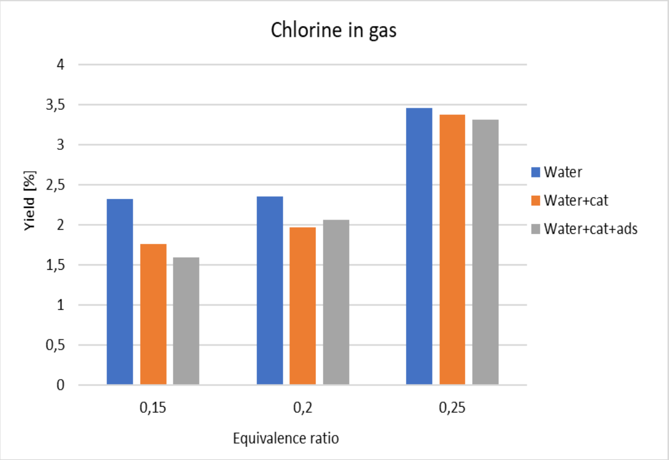
Gas tar content

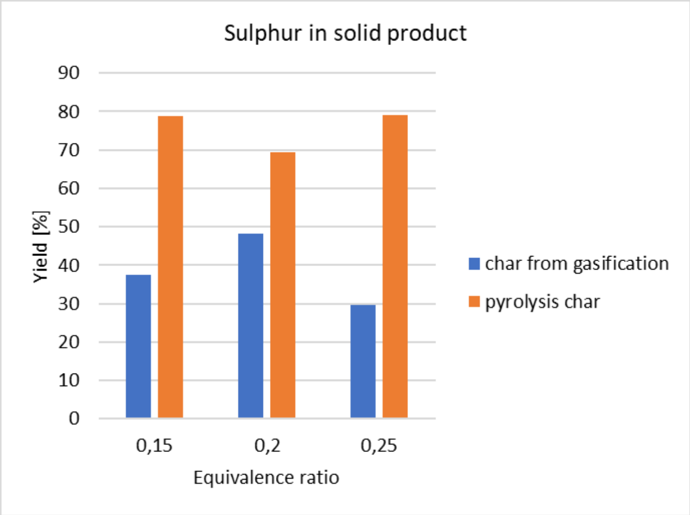
RDF feed	Equivalence ratio	Tar yield [mg/g]	Gas tar content [g/Nm^3]
Without catalyst	0,15	13,06	8,33
	0,20	10,20	5,87
	0,25	4,72	2,42
With cataslyst	0,15	5,32	4,08
	0,20	3,46	1,91
	0,25	4,66	2,44

Distribution of Cl and S



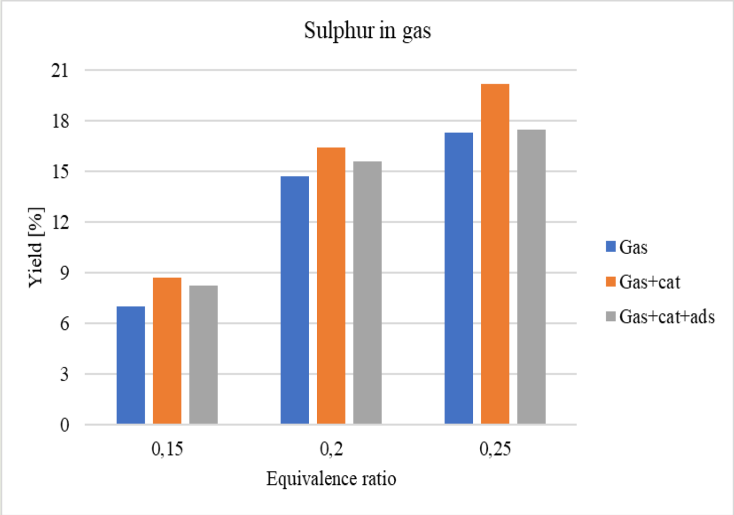






Sulphur in liquid condensate

Belowe the measurable range



Conclusion

- Pyrolysis/Separate Product Gasification (PSPG) unit is efficient in increasing gas LHV, reducing gas tar content and increasing CGE and CCE.
- Combination of a pyrolysis reactor with two gasification reactors for separate pyrolysis product gasification and their mutual integration has been proven as a convenient way to improve waste and biomass gasification performance.
- Catalytic effect of Ni/Beta zeolite was only on the range of catalytic effect of natural clay and char catalyst studied in previous works
- The majority of contaminant like S ad Cl remained in solid char; by increasing the equivalence ration the content of contaminants in gas product increased.