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Session X

Simulation and exergy analysis of a novel small-scale biomass gasifier: A "Multi-Box" application

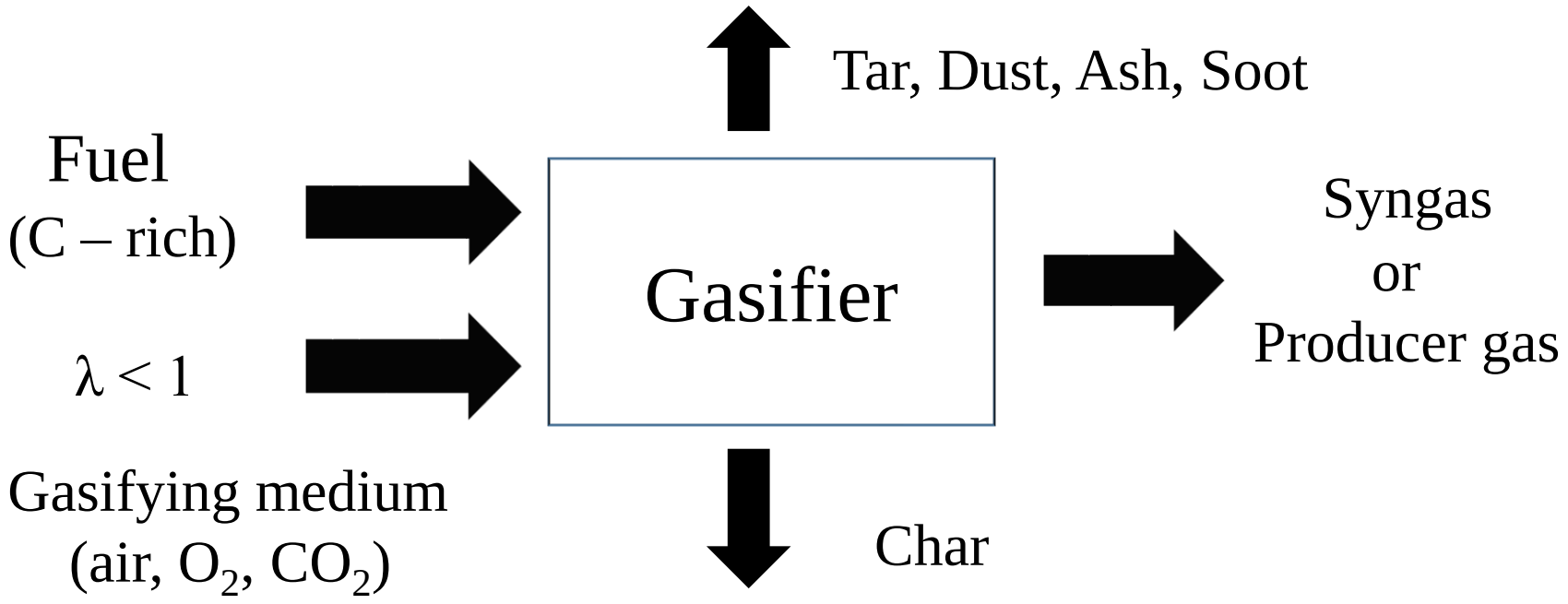
Stergios Vakalis, Francesco Patuzzi, Dario Prando, Konstantinos Moustakas and Marco Baratieri

5th International Conference on Sustainable Solid Waste Management

21–24 June 2017 www.athens2017.uest.gr

Concept of gasification

Gasification is a thermal process which under sub- stoichiometric conditions “packs” energy into chemical bonds



Small- scale biomass gasifiers

- Biomass Gasifiers during WW2
- > 1 m. small scale gasifiers
- Simple to use – but poor quality!

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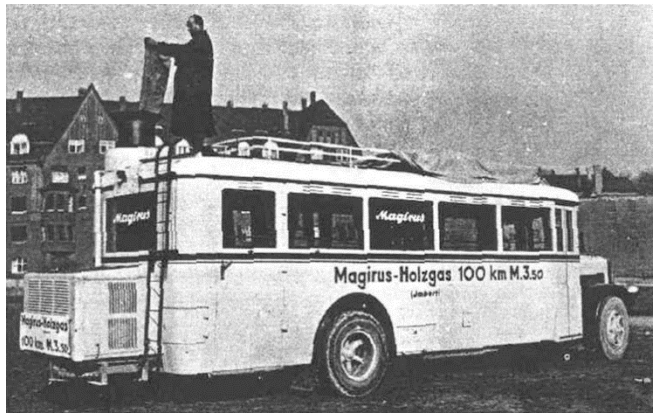
- No latter commercial applications due to petrol abundance



Modern small scale biomass gasifiers

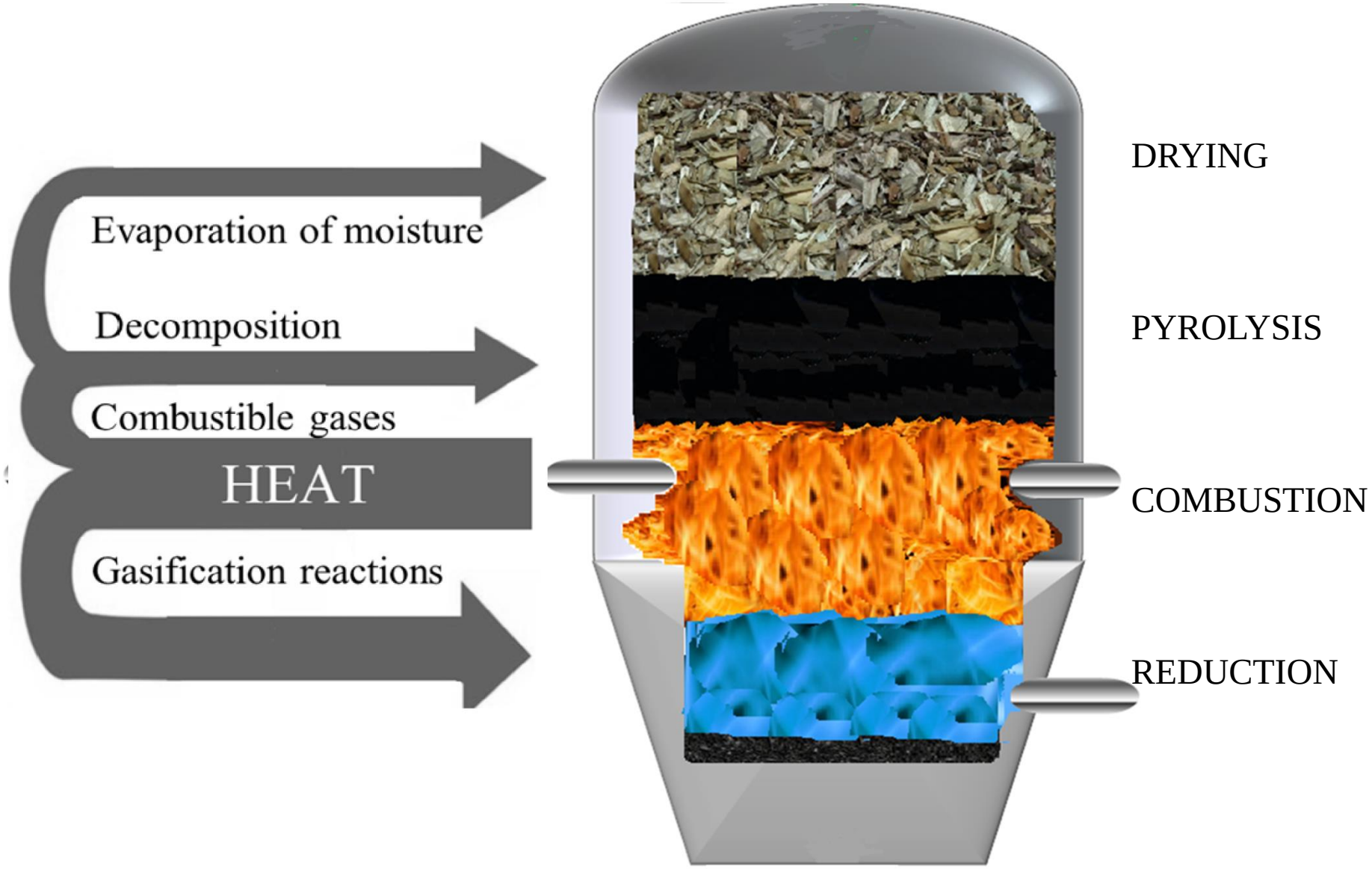
- Novel designs have been able to produce gas of higher quality and heating value.
- The increased electrical efficiency along with the high subsidies have triggered a resurgence of small scale biomass gasifiers during the last years.

Friday 23rd (13.30) - SESSION XVII

The “NEXT GENERATION” project: valorization alternatives for char from small scale gasification

By Prof. Baratieri

How to model a downdraft gasifier?



Fundamentals of downdraft gasification

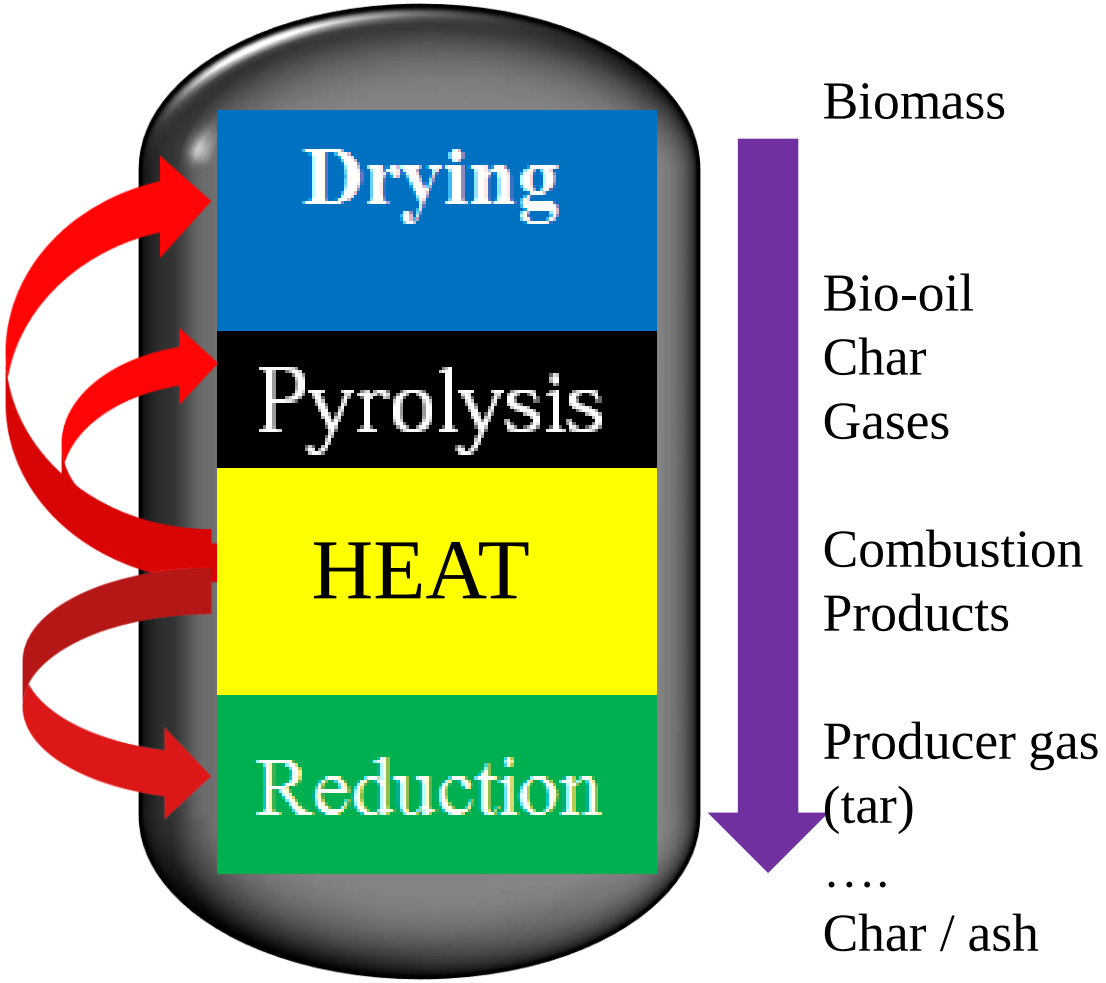
<u>Basic reactions</u>

Boudouard
$C + CO_2 \rightarrow 2CO$

Water gas reaction
$C + H_2O \rightarrow CO + H_2$

Methanation reaction
$C + 2H_2 \rightarrow CH_4$

Shift gas conversion
$CO + H_2O \leftrightarrow CO_2 + H_2$



Status-quo of thermodynamic modelling

- Most models are single stage/ black box
- A few models follow the zone separation stages
- The products are not representative of reality
- None of these models is able to return methane and char yields of any measureable significance
- Realistic modelling values are usually a result of extensive ¨calibration¨

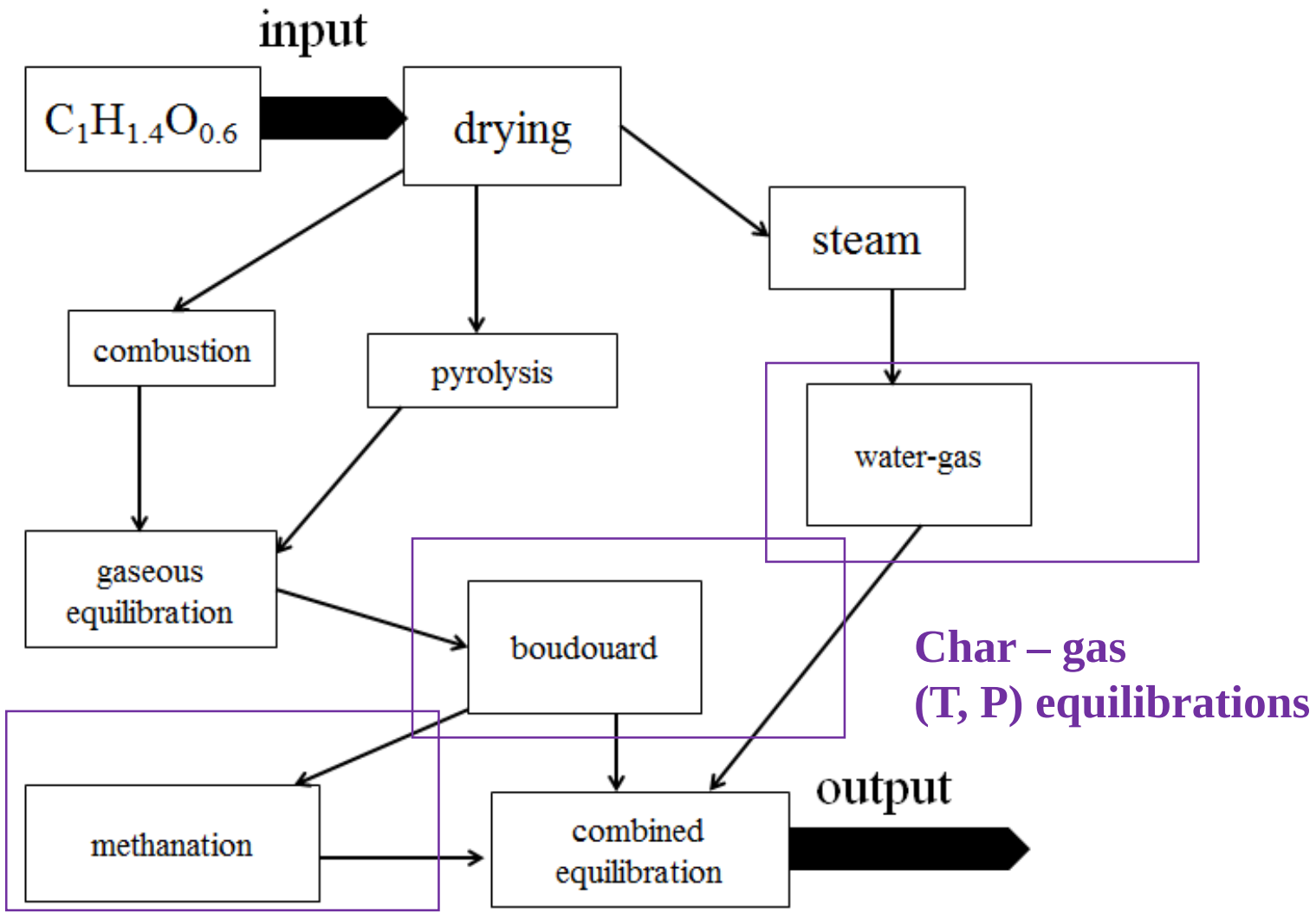
Introducing the “Multi-box”

S. Vakalis, F. Patuzzi, M. Baratieri (2016). Thermodynamic modeling of small scale biomass gasifiers: Development and assessment of the "Multi-Box" approach. Journal: Bioresource Technology 206; 173-179.

Thermodynamic Model

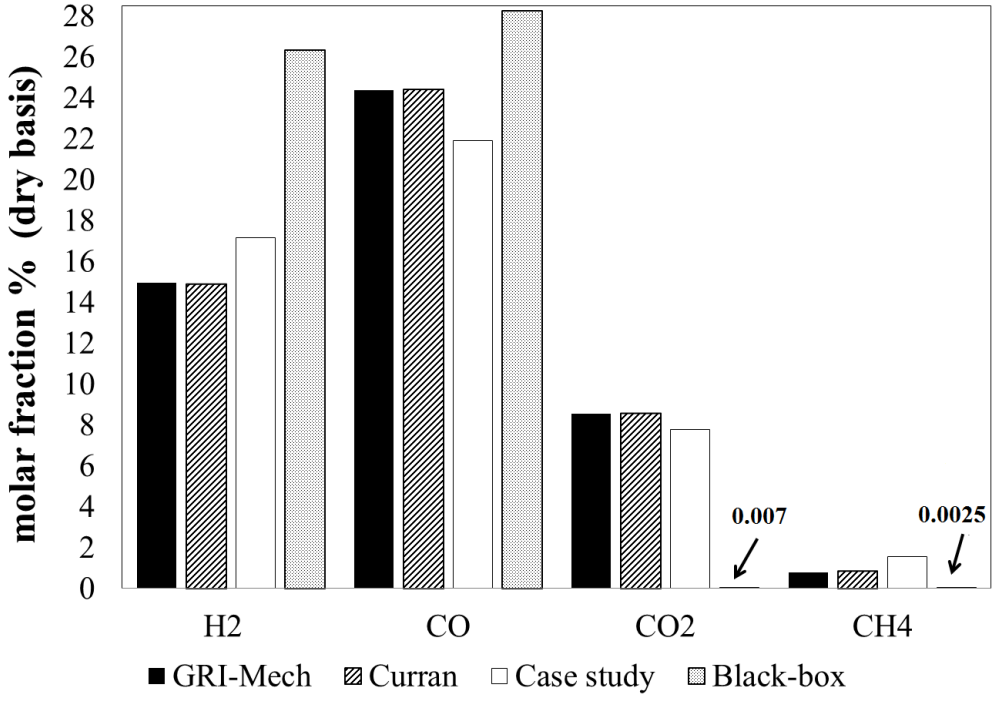
- Matlab - Cantera environment
- Villars–Cruise–Smith (VCS) algorithm
- 2-phase equilibrium model
- GRI-Mech 3.0
  - Also Curran mechanism

Developing the “Multi – Box”

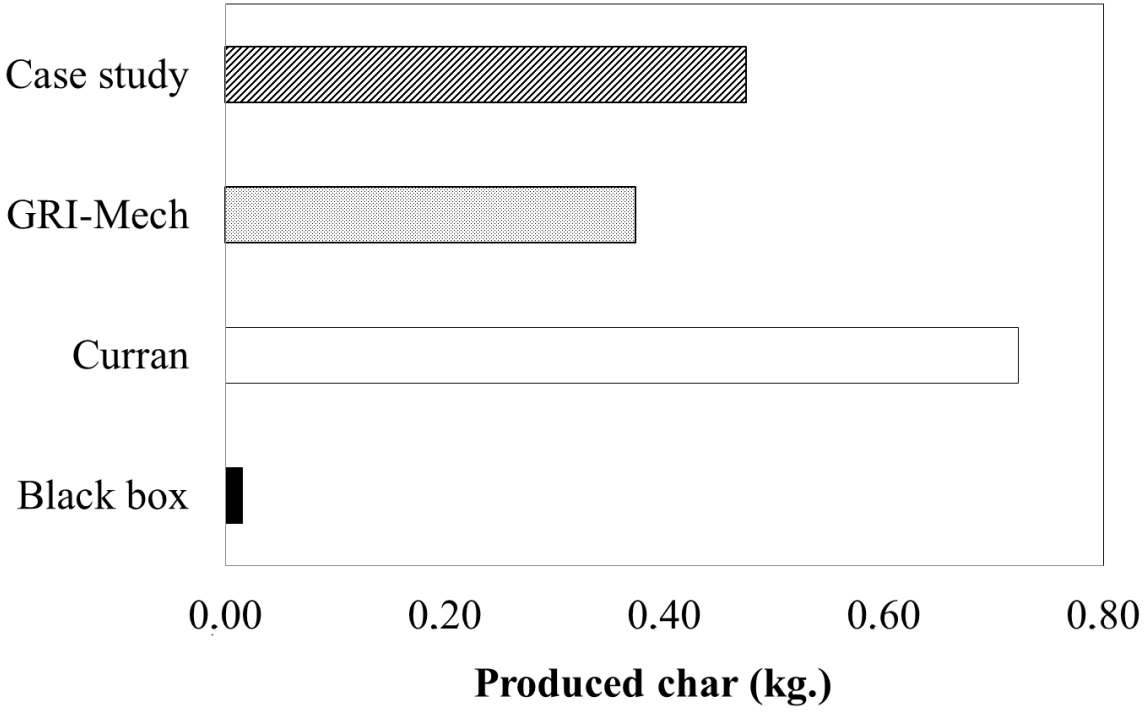


Results and validation

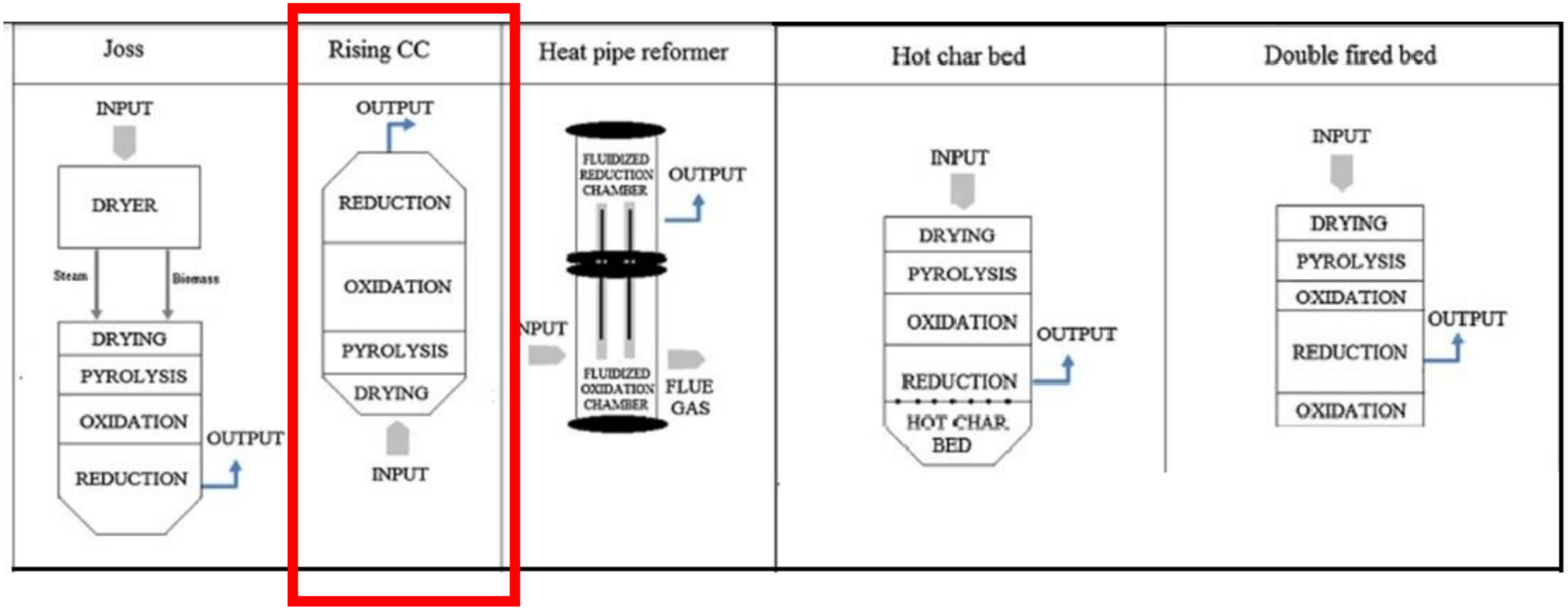
Producer gas



Char yield

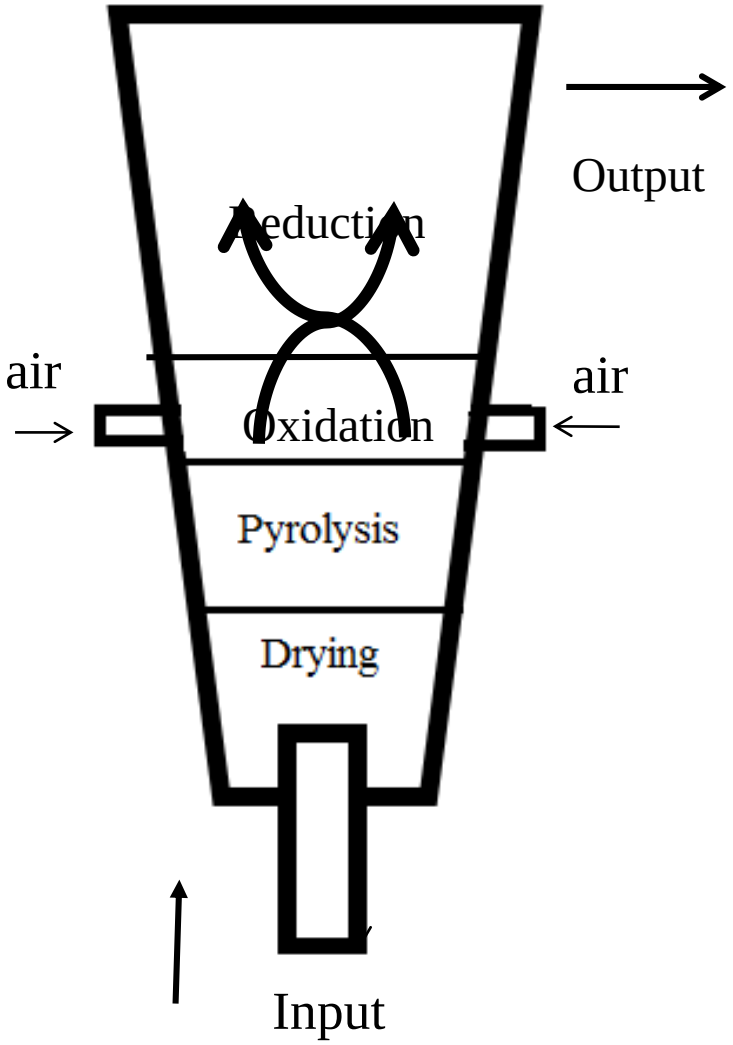


Novel small scale gasifiers



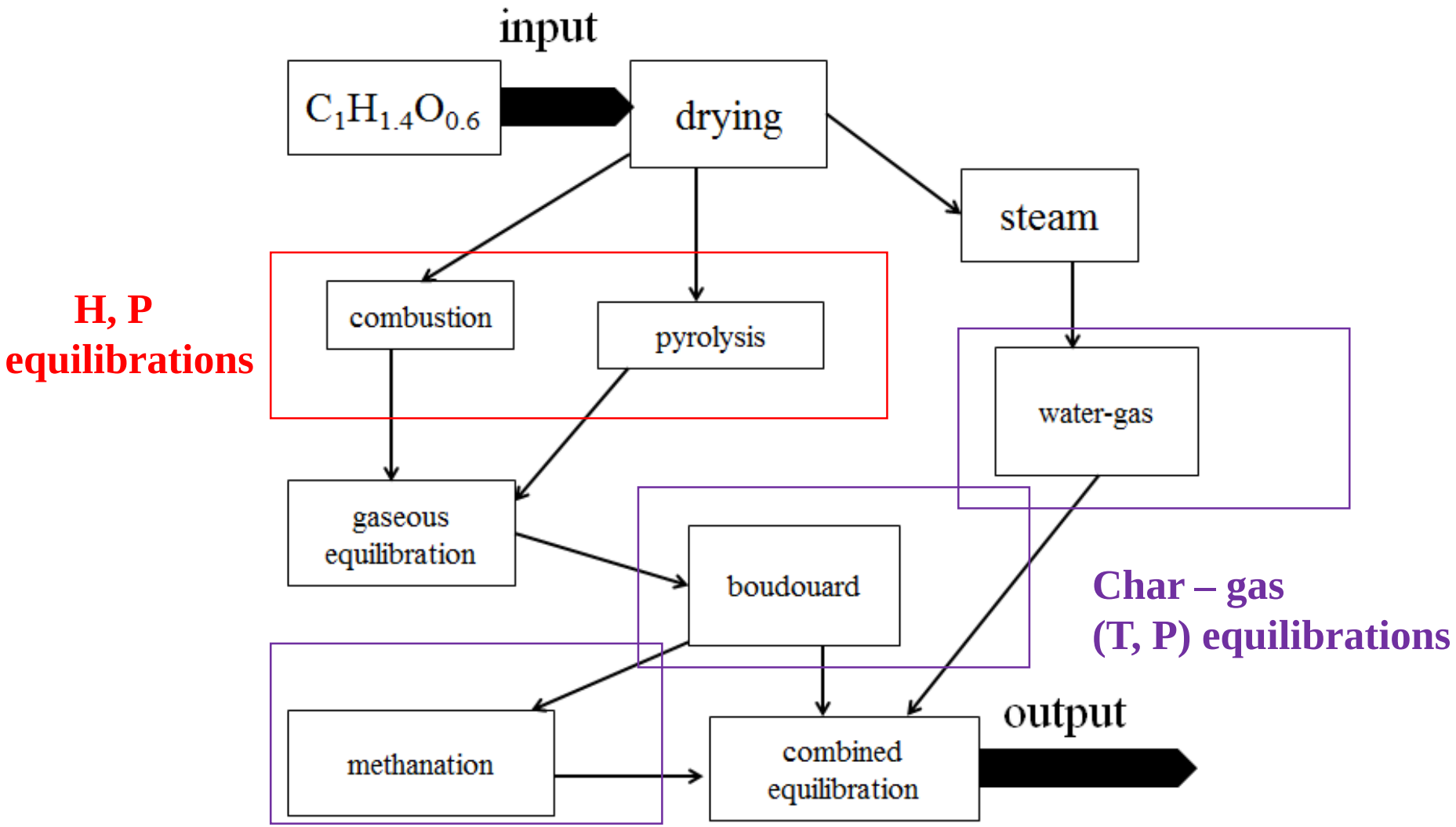
Source: S. Vakalis, M. Baratieri (2015). State-of-the-Art of Small Scale Biomass Gasifiers in the Region of South Tyrol. Journal: Waste and Biomass Valorization 6; 817 – 829.

Characteristics of modelled reactor

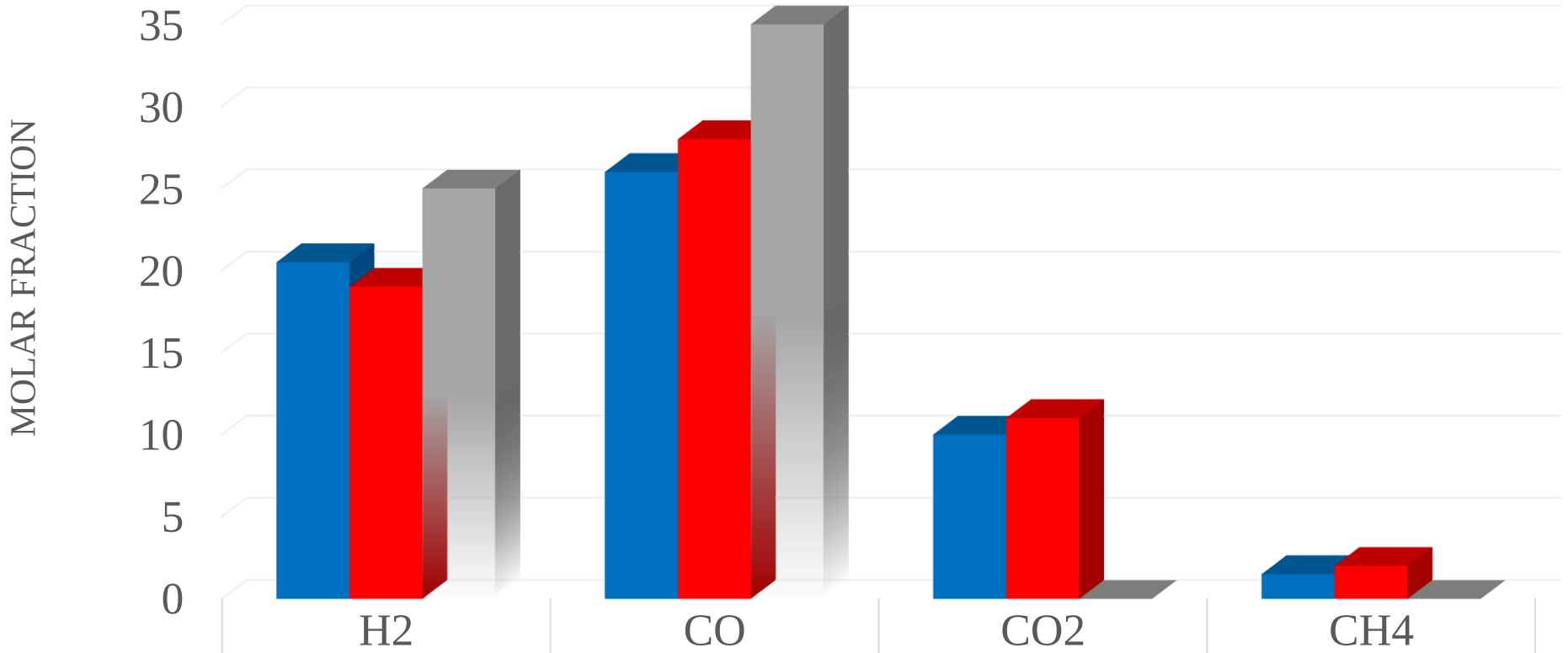


- 180-190 kW_{el} / 220-240 kW_{th}
- Rising Co – current
- Bottom fed (Pellets)
- Vortex above oxidation zone
- Char is slightly ‘fluidized’
- Dual-fuel engine

Adjusting the “Multi – Box”

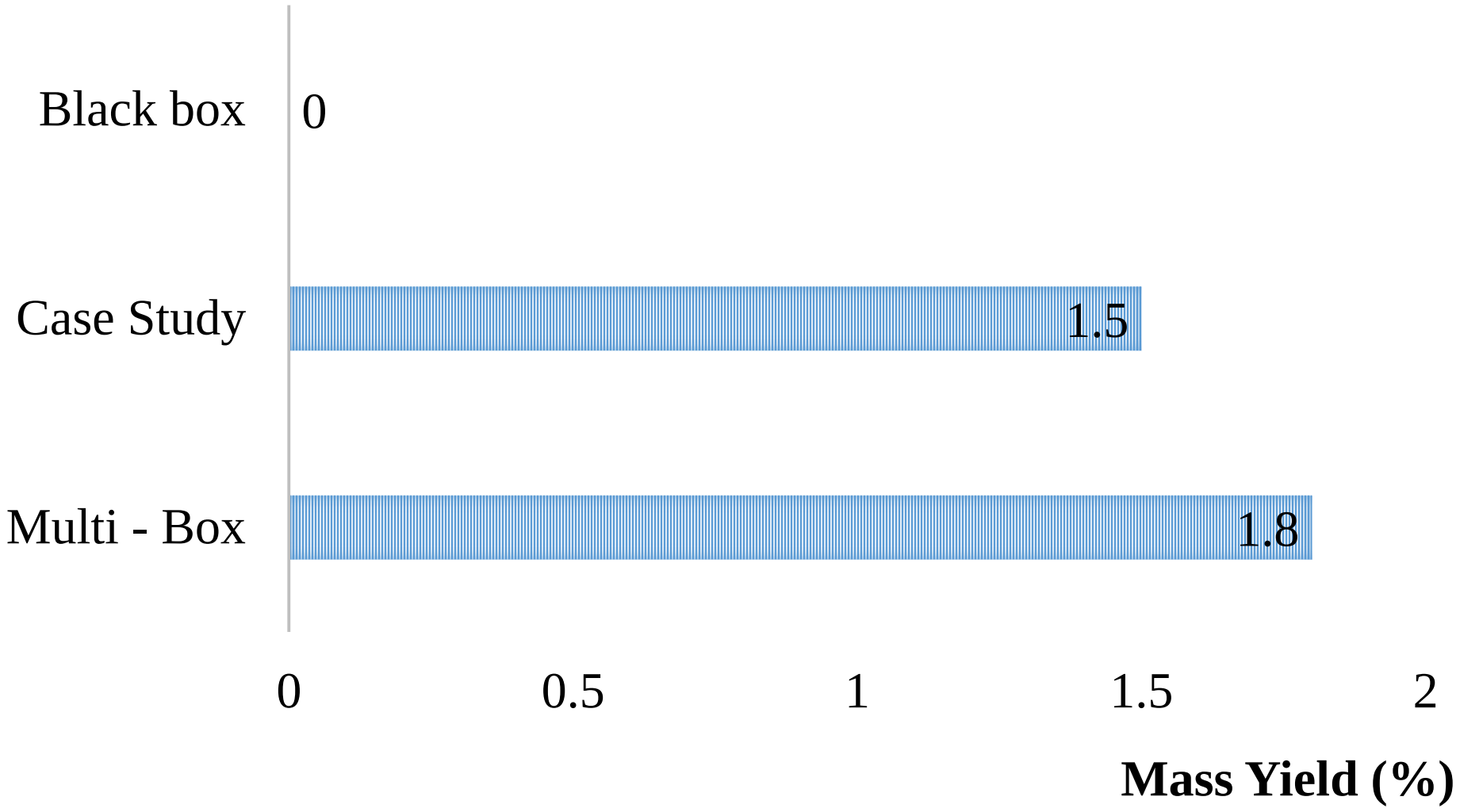


Results - (Gas composition for ER: 0.22)



	H2	CO	CO2	CH4
Multi-Box Model	20.5	26	10	1.5
Case Study	19	28	11	2
Black Box model	25	35	0	0

Results - (Char Yield for ER: 0.22)



Conclusions

- Creation of a multi –stage & process based model
- Results much closer to case study than black – box models
- Adjustment of combustion & pyrolysis boxes modelling
- ¨Multi-Box¨ addresses successfully the issues of methane concentration and char yield

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THANK YOU FOR YOUR ATTENTION

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