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on Sustainable Solid Waste Management

Utilization of char from biomass gasification for onsite energy production

Introduction and modelling of a secondary reactor

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Main objectives of this presentation

- Introduction to small scale gasification and gasification by - products
- Proposing a solution
- Modelling and analysis

Fundamentals of small scale gasification

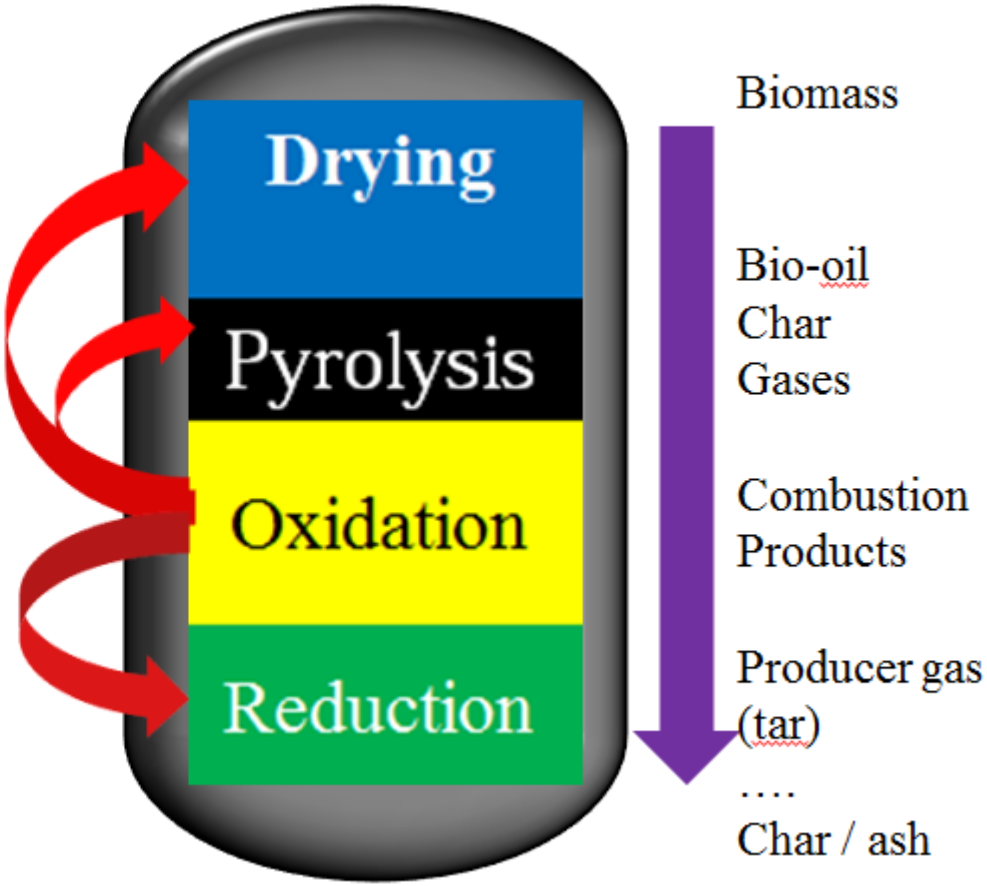
Basic reactions

Boudouard
$C + CO_2 \rightarrow 2CO$

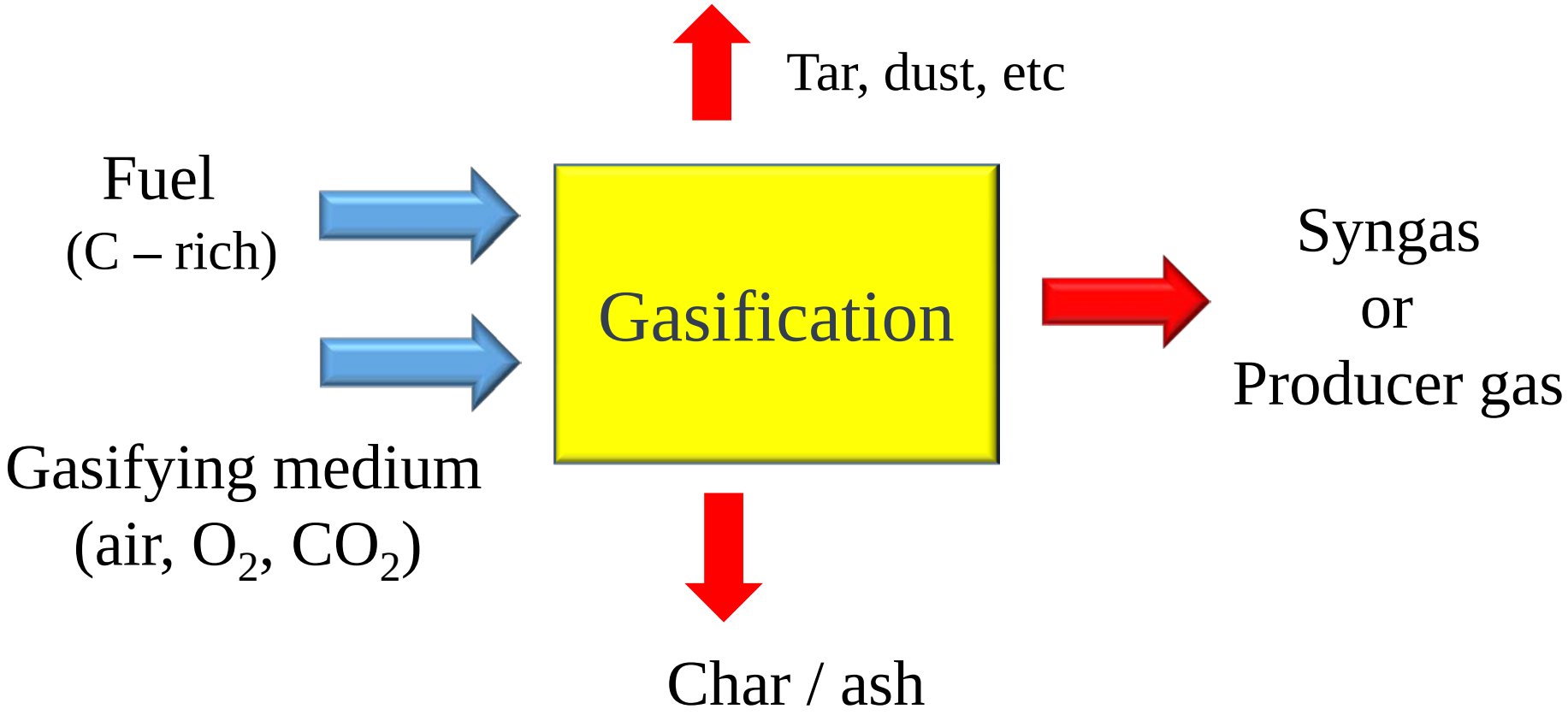
Water gas reaction
$C + H_2O \rightarrow CO + H_2$

Methanation reaction
$C + 2H_2 \rightarrow CH_4$

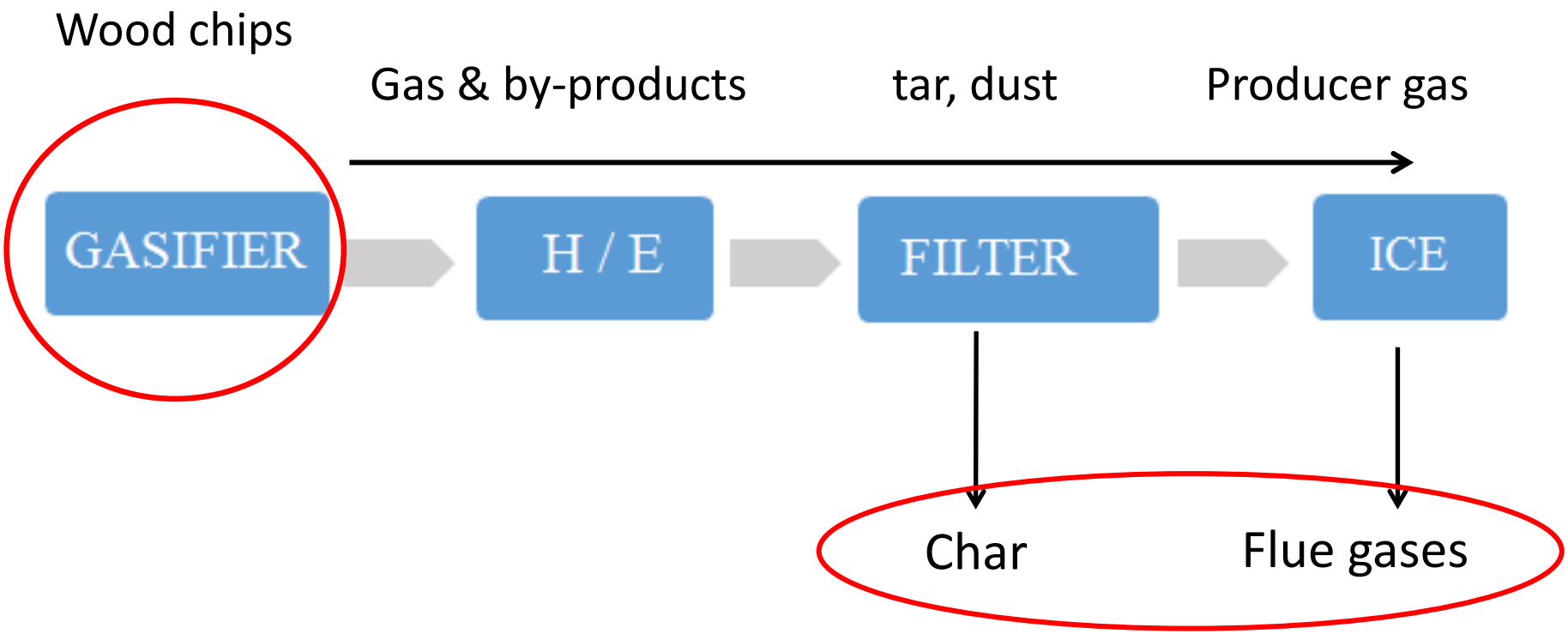
Shift gas conversion
$CO + H_2O \leftrightarrow CO_2 + H_2$



Gasification and by - products



Process scheme



Issues concerning char and flue gases

Char in small gasification typically has a yield from 2 up to 10 % of the initial mass of the feedstock.

Due to the scale restrictions of small scale units, ***organized strategies have not yet been developed.***

ICE emissions are the output stream with the highest mass yield.

In principle, flue gases are discarted to the environment ***without any additional treatment***

Examining a case study

Joos gasifier (45 kWe and 120 kWth)
San Leonardo, Passaria (South Tyrol – Italy)

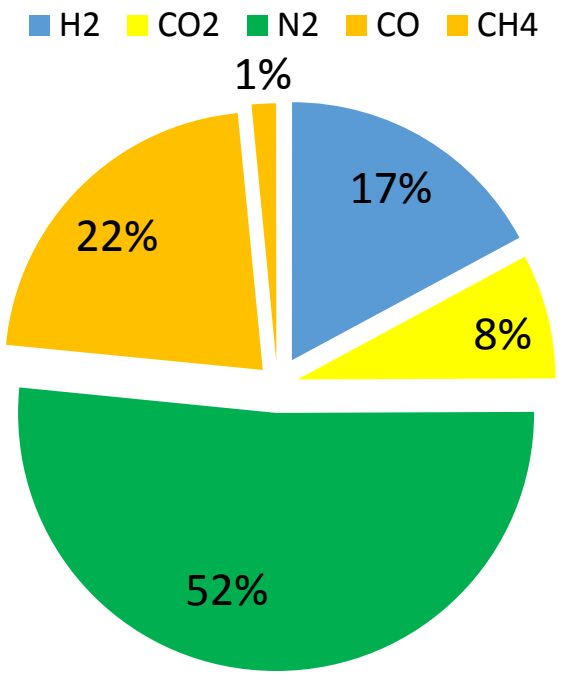
<u>References</u>

S. Vakalis et al. (2015), Monitoring und Analyse von repräsentativen kleintechnischen Biomassevergasern in Südtirol

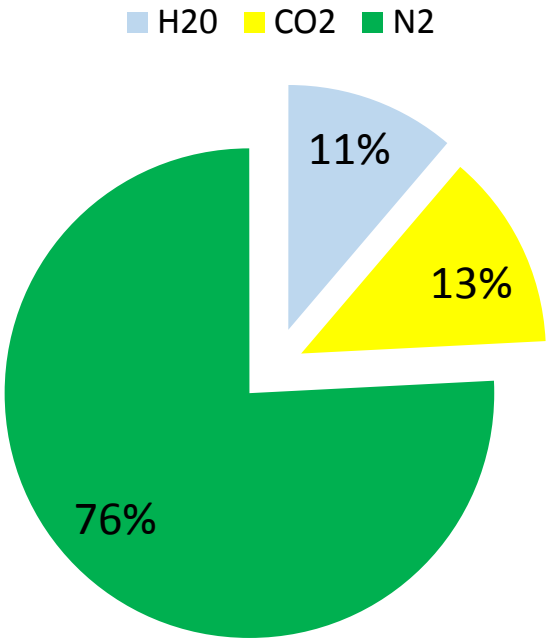
S. Vakalis et al. (2014) Measuring the performance of biomass small scale gasification plants by implementing mass and energy balances.

Joos gasifier

Producer gas composition



Flue gas composition



Char/ash composition: 35 % of the final yield consists from ash. (also: 64 % carbon, 1% Hydrogen)

Further optimization “incentives”

- Energy efficiency of 71.25 %
- Nonetheless, auxiliaries demand 17% of the energy to operate
  - (i.e 3.45 % of initial)
- Economic gains of 28 cents/ kWe over 70 % of efficiency *
- High temperature heat exchangers have high heat losses
- High exergy dissipation in autothermal gasifiers

*for italy: Ministry of Economic Development, 'Italian Energy Efficiency Action Plan 2011

Process scheme

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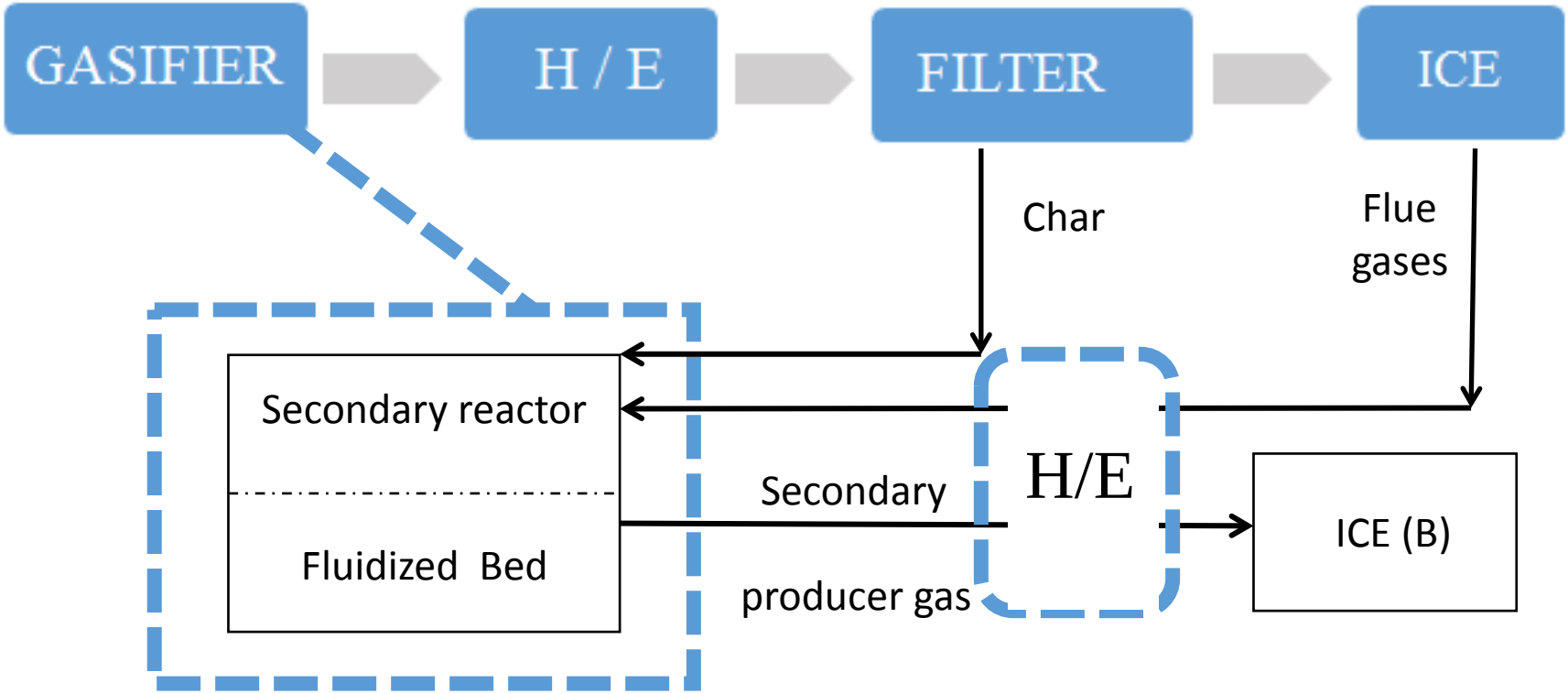


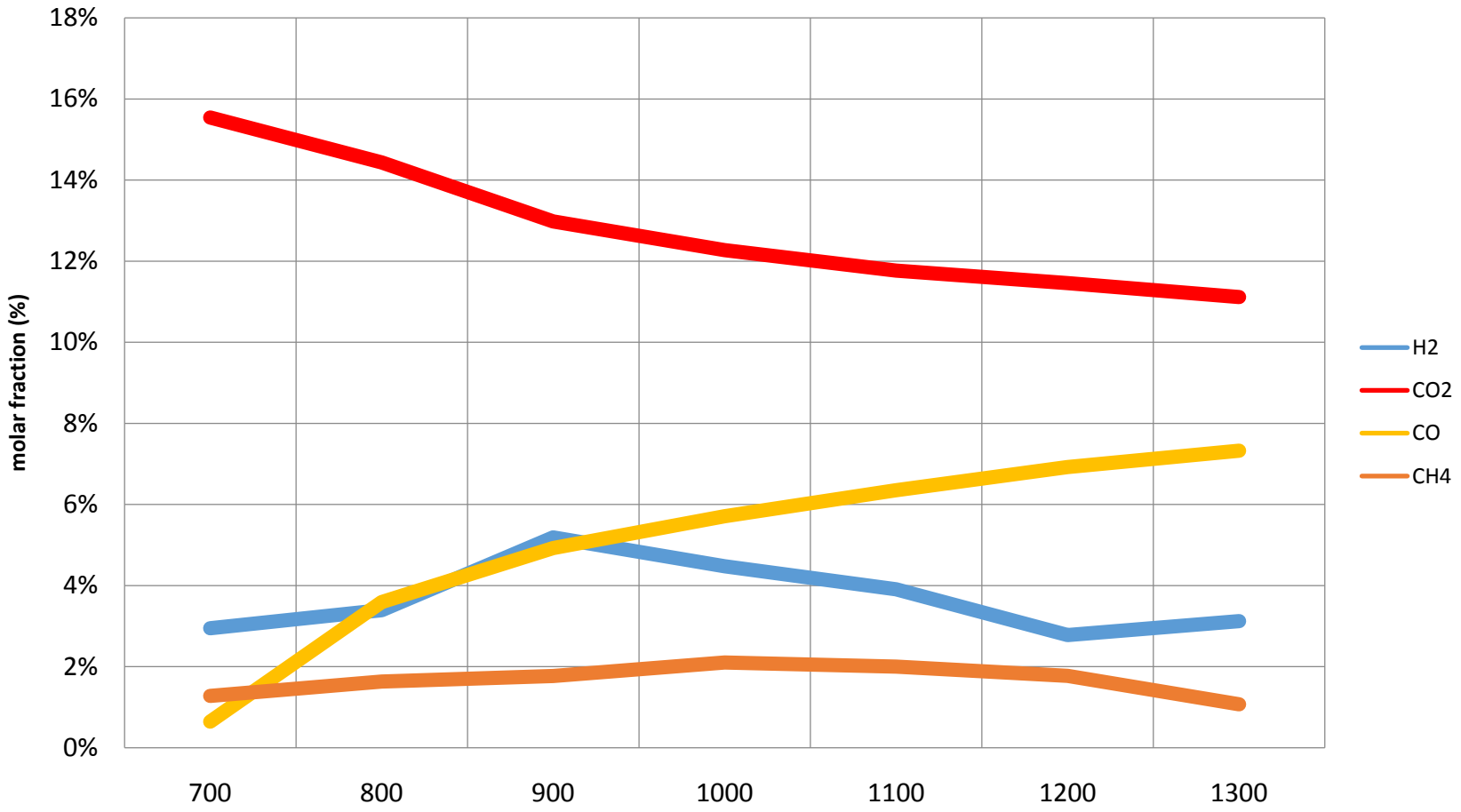
Application of a Thermodynamic Model

- Matlab - Cantera environment
- Villars–Cruise–Smith (VCS) algorithm
- Zero dimensional, adiabatic
- 2-phase equilibrium model
- Multiple gasifying agents
- Fluidized bed gasifiers
- Model validated in 12 gasifiers

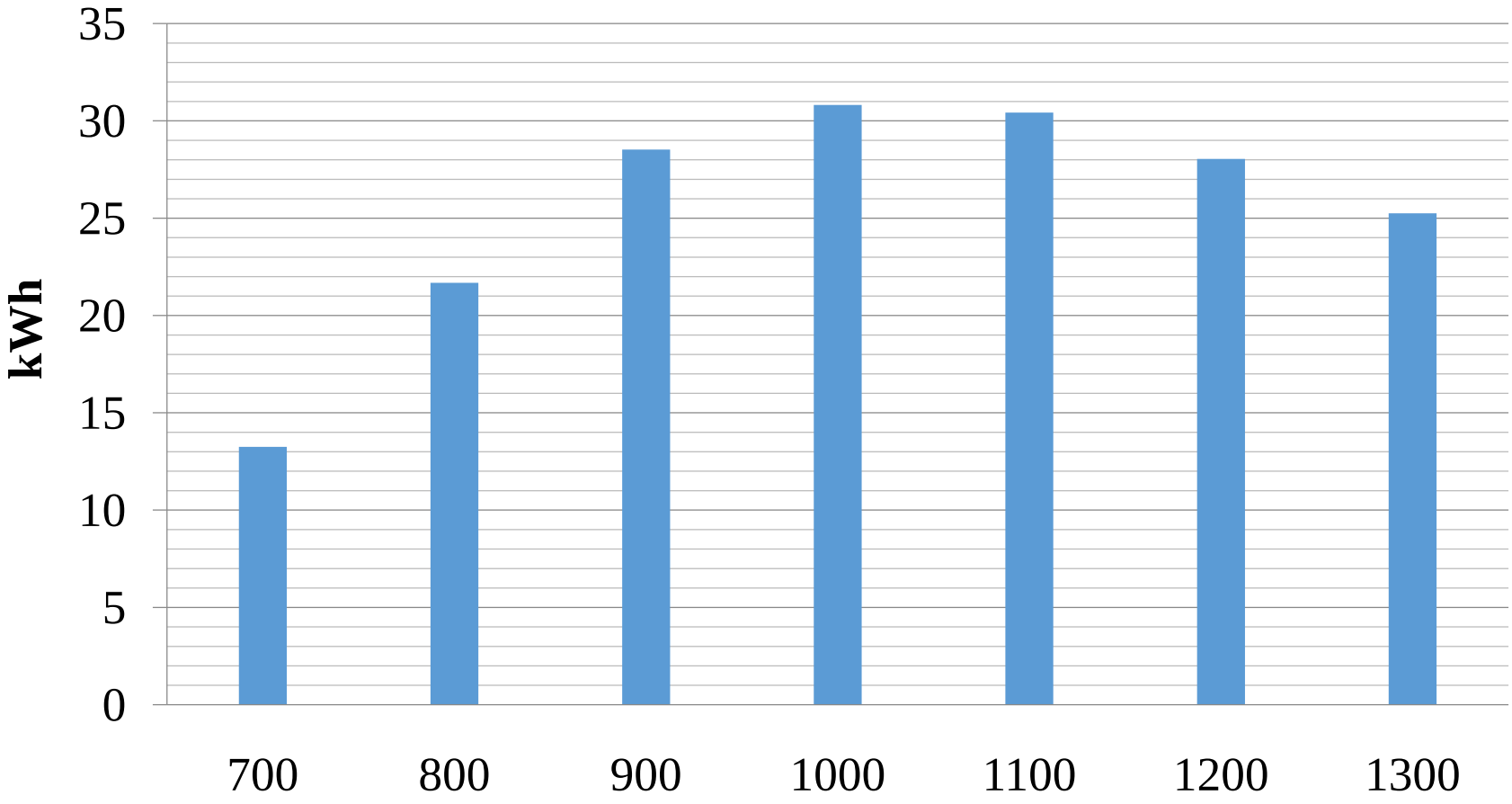
T, P, N

Reference: Baratieri, M., Baggio, P., Fiori, L., Grigiante, M., Biomass as an energy source- Thermodynamic constraints on the performance of the conversion process, Bioresource Technology 99 (2008), pag. 7063–7073

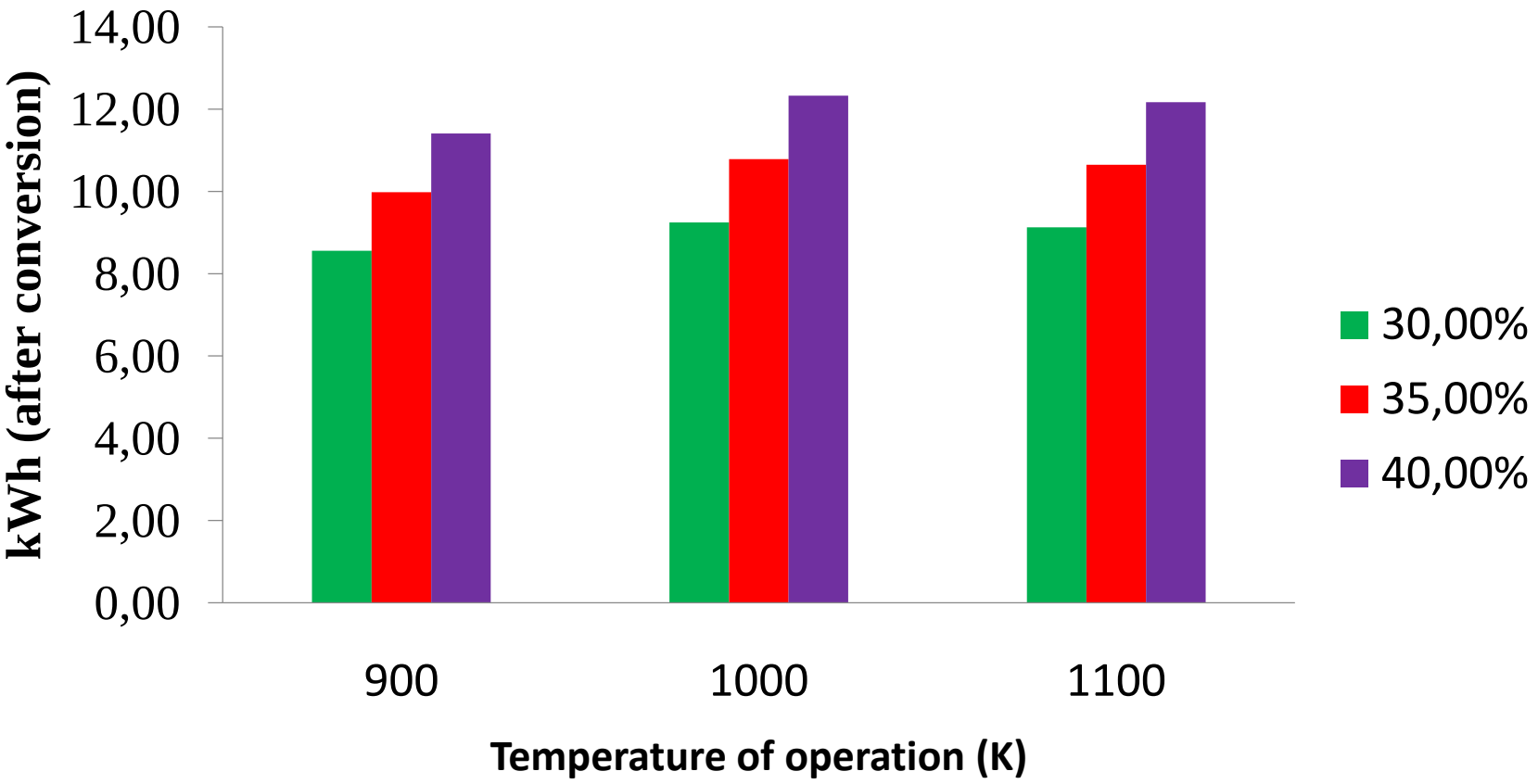
Composition of secondary producer gas (db%)



Total Energy Content (LHV) of secondary gas

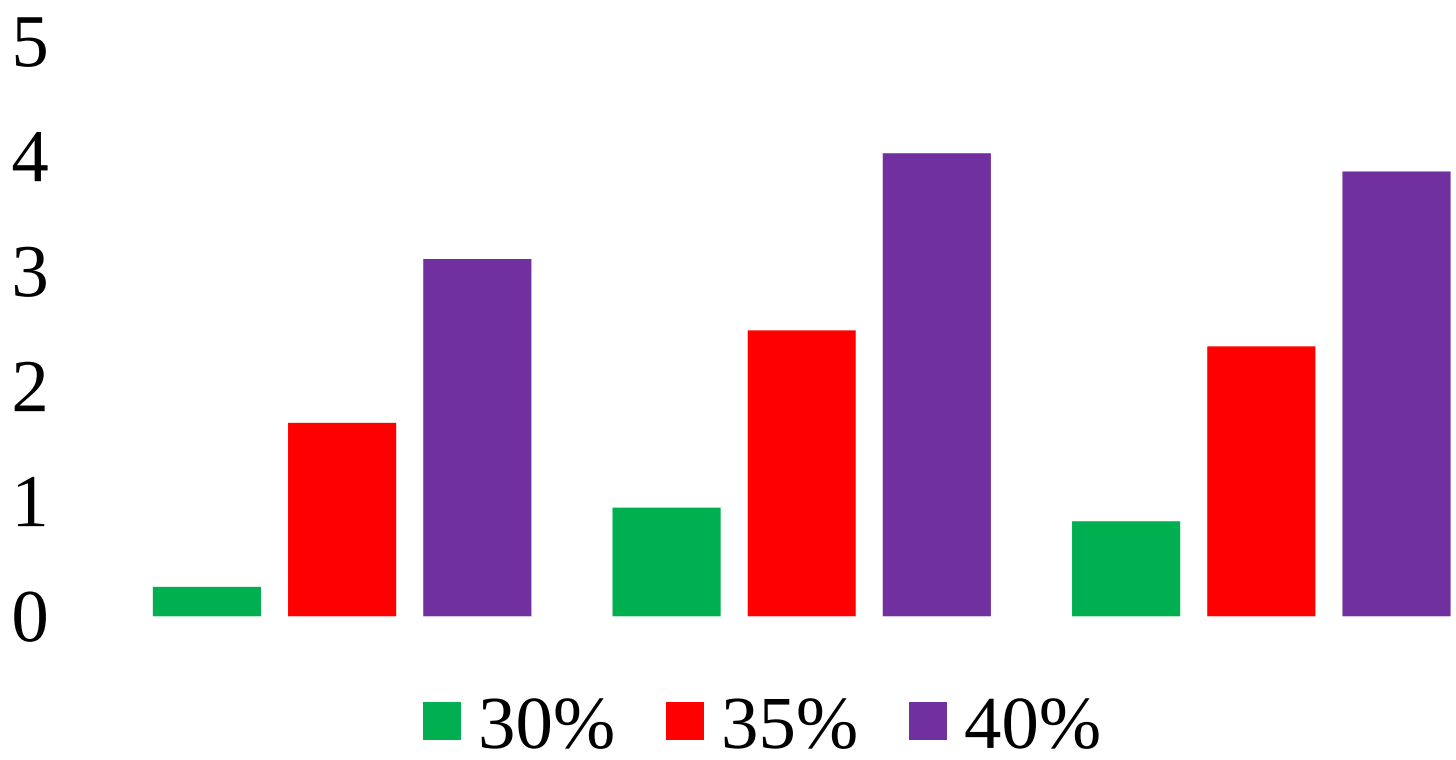


Energy gain after ICE



Balancing the operation of auxiliaries (8.3 kWe)*

900 K	1000 K	1100 K



* With two added pumps (2 x 0.25 kW), blower (0.25 kW) and ICE (B) compressor (1.2 kW)

Comparison of efficiencies

	Standard operation		With reactor	
(for 35% at 1000K)	Gross	Net	Gross	Net
Input (kWh)	198	198	221	221
Electricity	42	34,86	52,79	44,48
Thermal Power	98.05	94.34	98.05	90.34
Total Energy (kWh)	140.05	129.2	150.84	134.82
Energy efficiency	71 %	65 %	76 %	68 %
Exergy efficiency	28.5 %	25.7 %	32.3 %	30.5 %

Conclusions

- Char and emissions from ICE are by-products that are underutilized and no satisfactory management strategies have been developed.
- An apparatus is introduced that utilizes char residue from gasification and emissions from ICE for the production of a gaseous fuel
- Only a marginal change in the heating value is observed at the range between 900 K and 1100 K .
- The additional would on average increase 12% the energy production of the facility.
- Interesting applications at ‘‘dual-fuel engine‘‘ gasifiers

THANK YOU FOR

YOUR ATTENTION !

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