12th International Conference on Fluidized Bed Technology
May 23-26, 2017, Krakow

Modelling of indirect steam gasification in circulating fluidized bed reactors

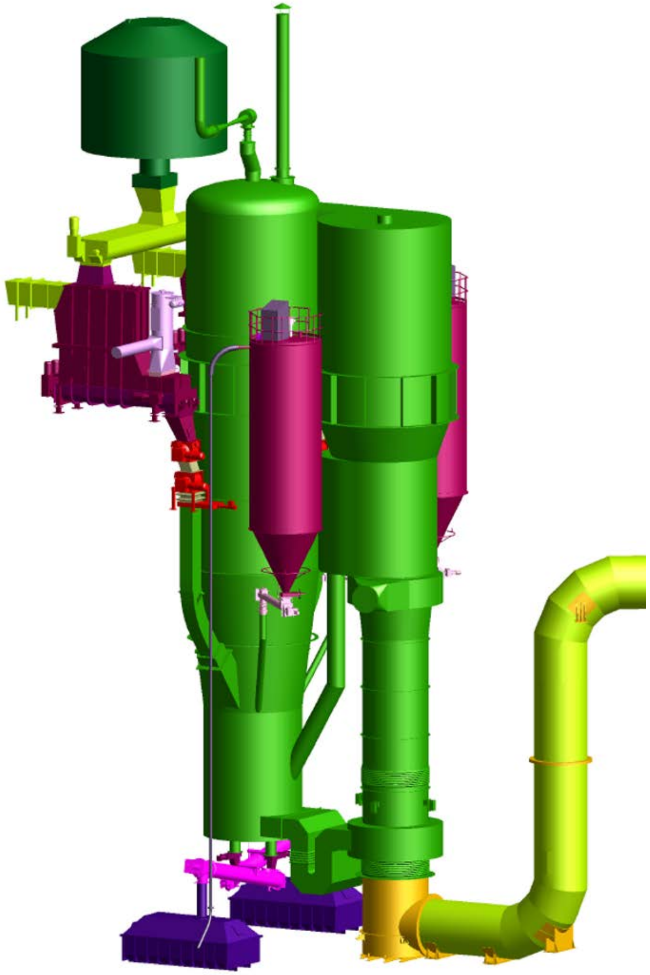
Kari Myöhänen[1], Juha Palonen[2], Timo Hyppänen[1]

[1] LUT School of Energy Systems
Lappeenranta University of Technology

[2] AMEC Foster Wheeler Energia Oy, Finland

Contents

- Indirect steam gasification
- Model description
- Modelling results
- Summary



Design of a 140 MWth air-blown gasifier by AMEC Foster Wheeler

Biomass gasification

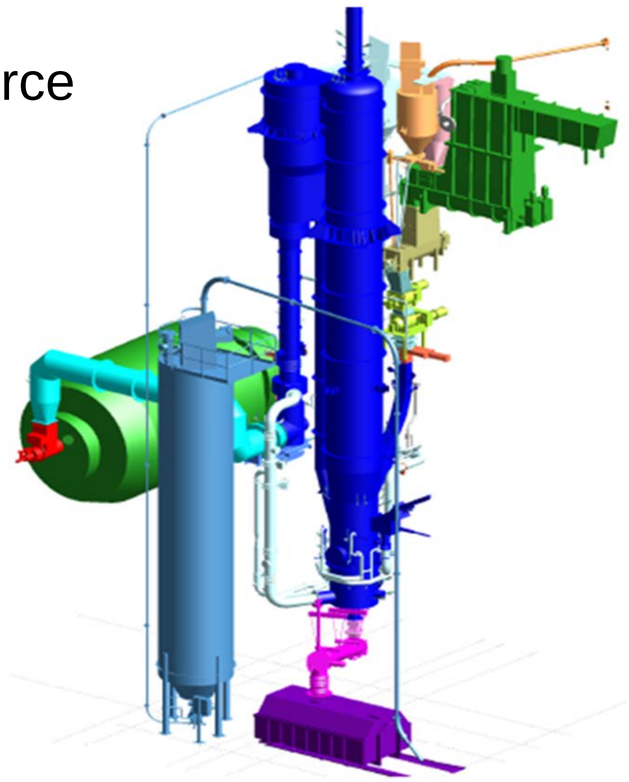
- Renewable, weather independent energy source
  - Gasification

    → Syngas (CO, H_2, CO_2, C_xH_y, H_2O)

      → SNG, FT-diesel, dimethyl ether, methanol, ...

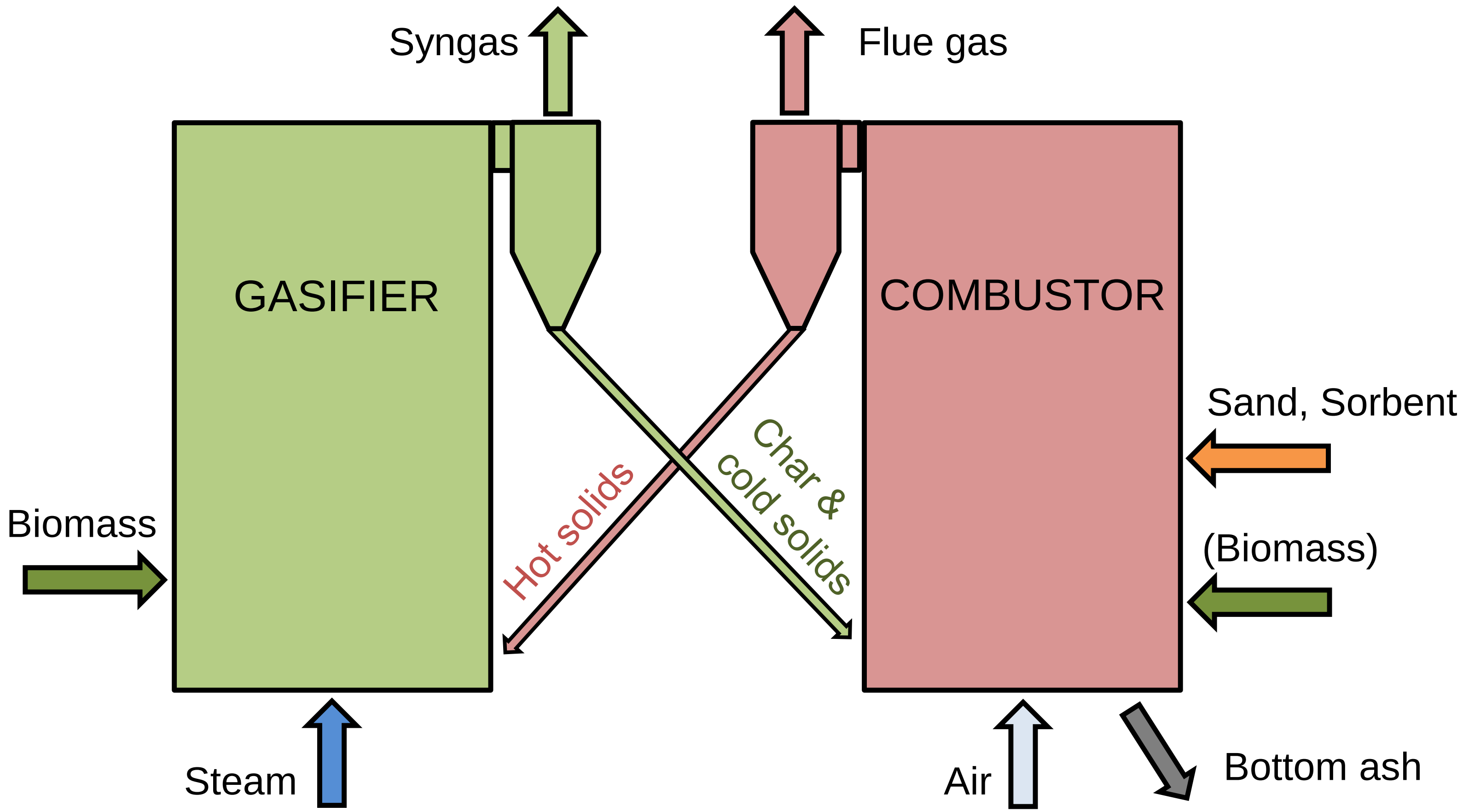
- Modelling needed to support development of new process concepts and scale-up.

- Target of study:
  development of modelling tool
  for comprehensive simulation
  of interconnected CFB processes
  for indirect gasification.



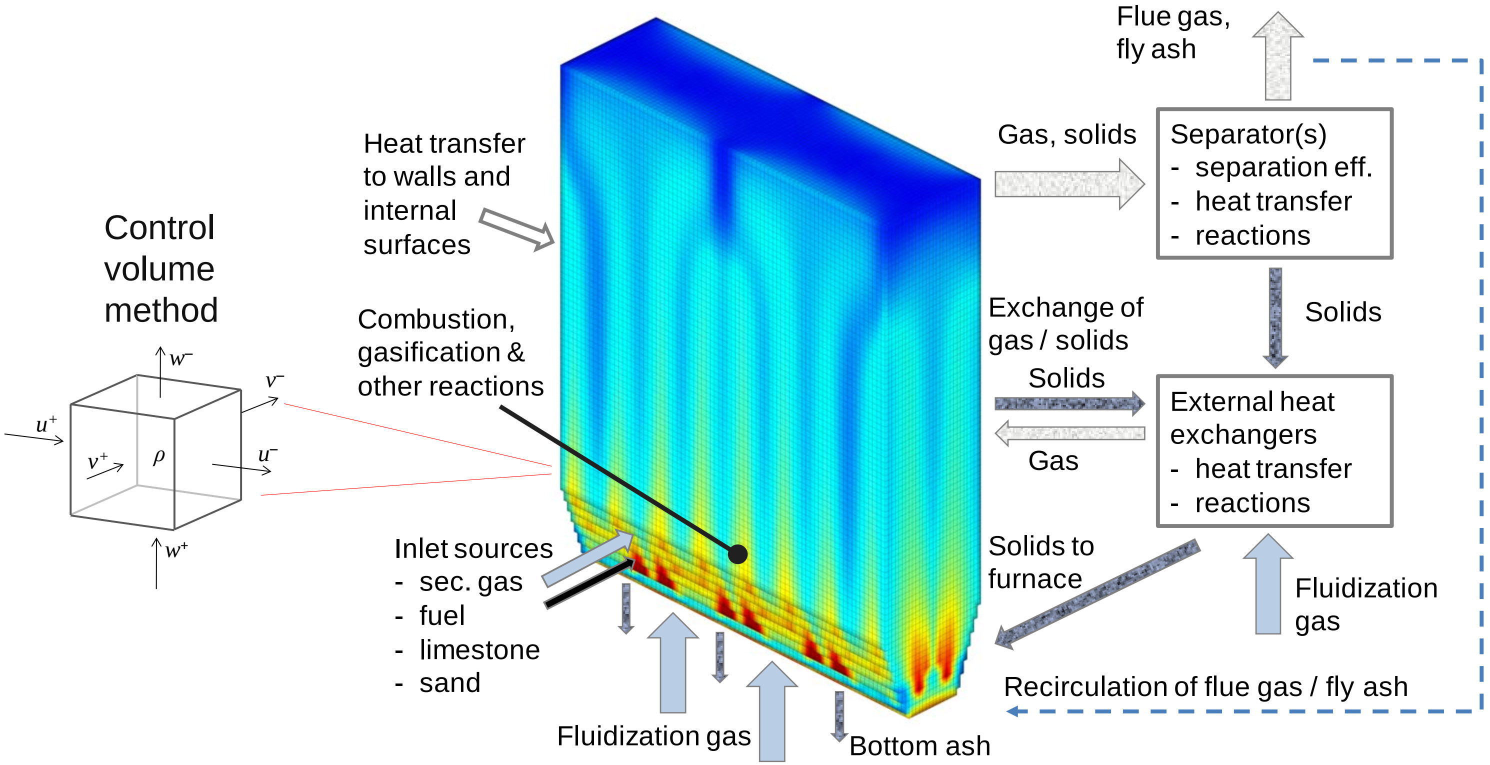
12 MWth lime kiln gasifier,
Stora Enso mill, Varkaus, Finland.

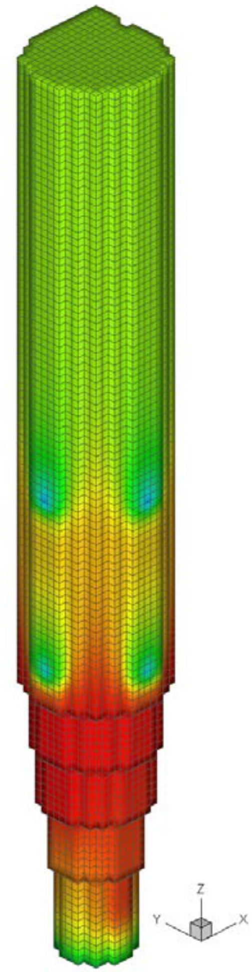
Indirect steam gasification



Three-dimensional model (CFB3D)

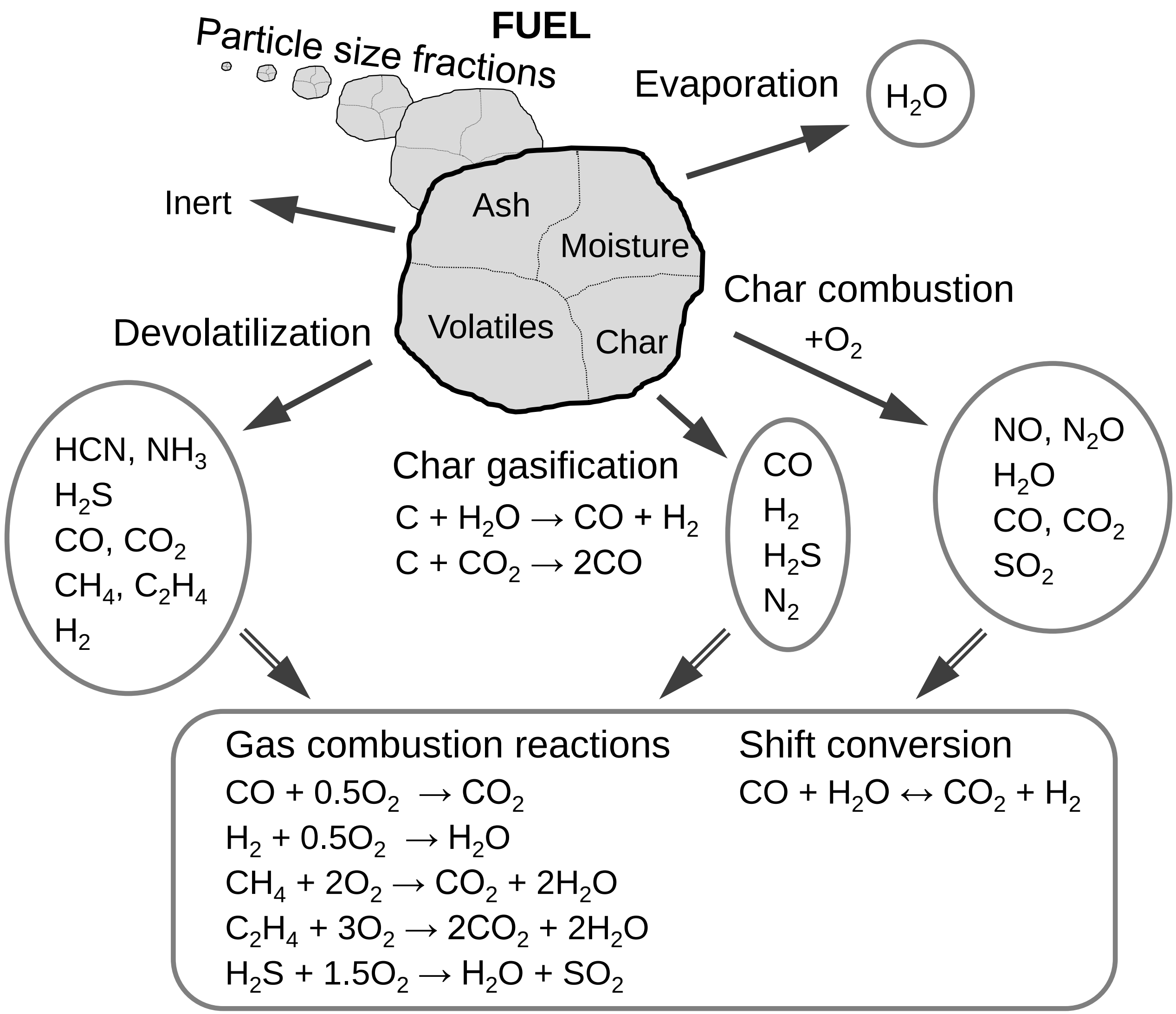
- In-house Fortran-code developed at LUT.
- Steady-state, semi-empirical engineering model.
- Applied for air/oxygen fired combustion, gasification, and calcium looping in bubbling and circulating fluidized bed processes.





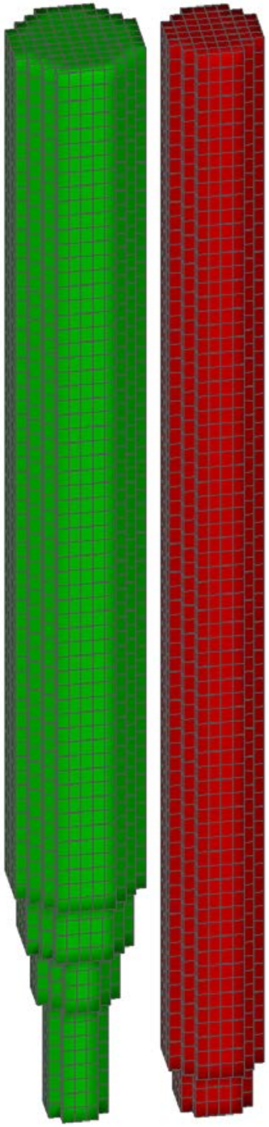
320 MWth gasifier (6 bar,abs)

Modelled reaction system



Geometry and mesh

- Gasifier
  - Fuel input ≈ 12 MWth.
  - Diameter 1.6 m, height 15 m.
  - Fluidized by steam.
  - Woody biomass & secondary steam to level height 1.9 m.
- Combustor
  - Max. fuel input ≈ 2.1 MWth.
  - Diameter 1.4 m, height 15 m.
  - Fluidized by air.
  - Make-up sand, limestone, and secondary air to level 1.1 m.
  - Additional fuel feed to level 0.5 m.
- Reactors coupled in code.

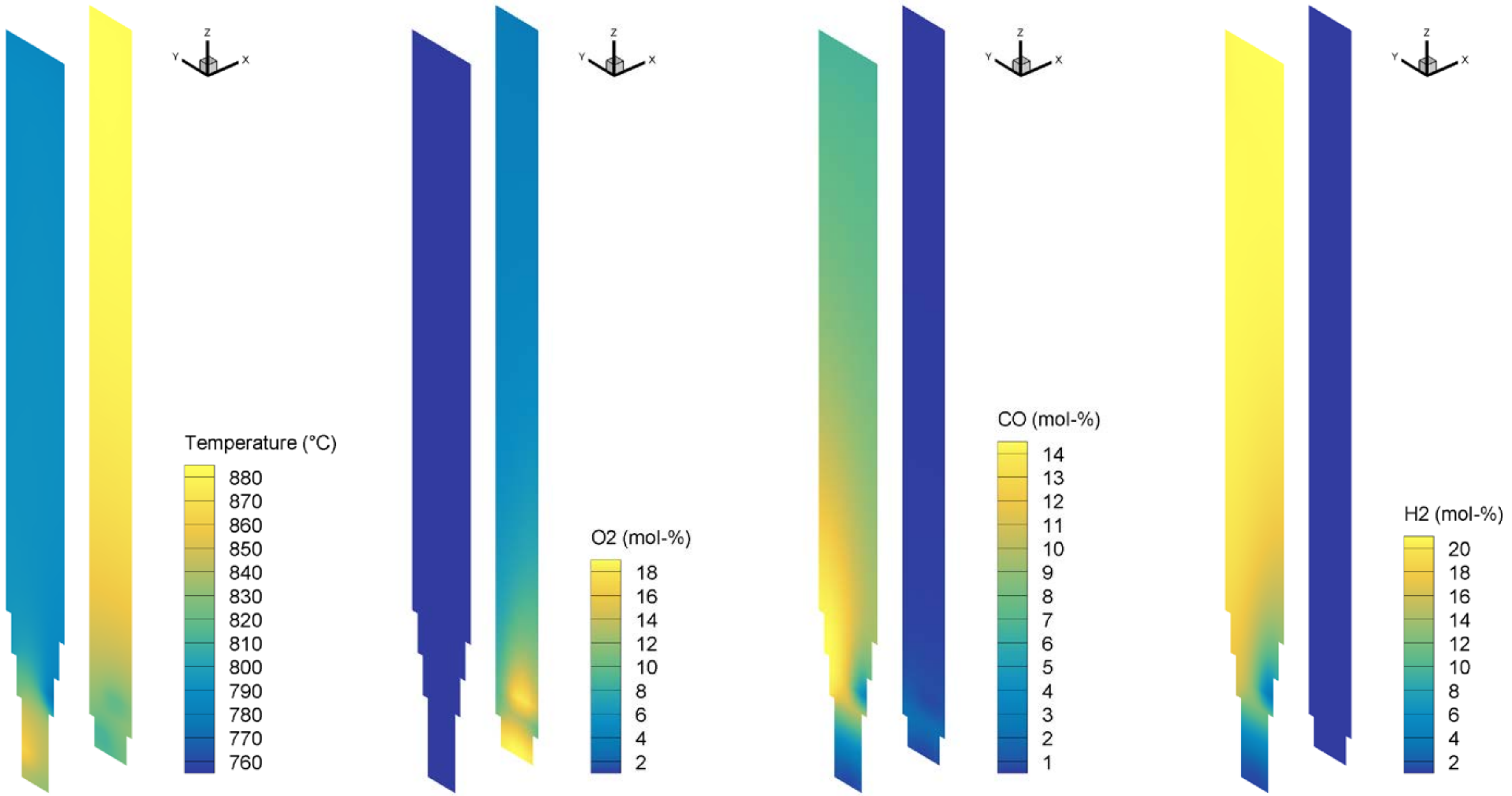


Boundary conditions

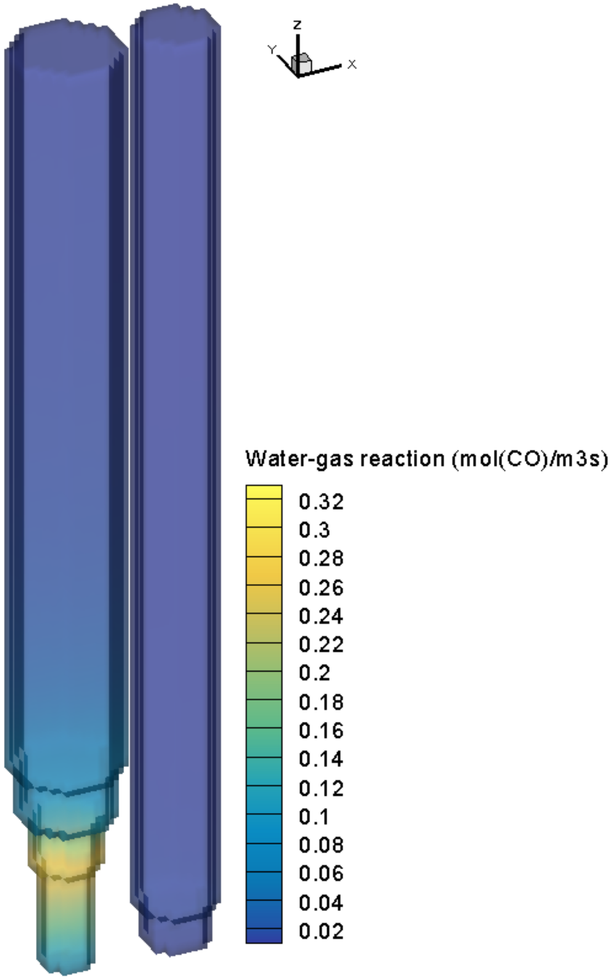
- Fuel = wood based biomass
  - 11% char, 62% volatiles, 25% moisture, LHV 14 MJ/kg,af.
- Four cases with varying fuel feed to combustor (0...2.1 MWth).
- Same excess oxygen in combustor in each case (3.94 %-vol,dry).

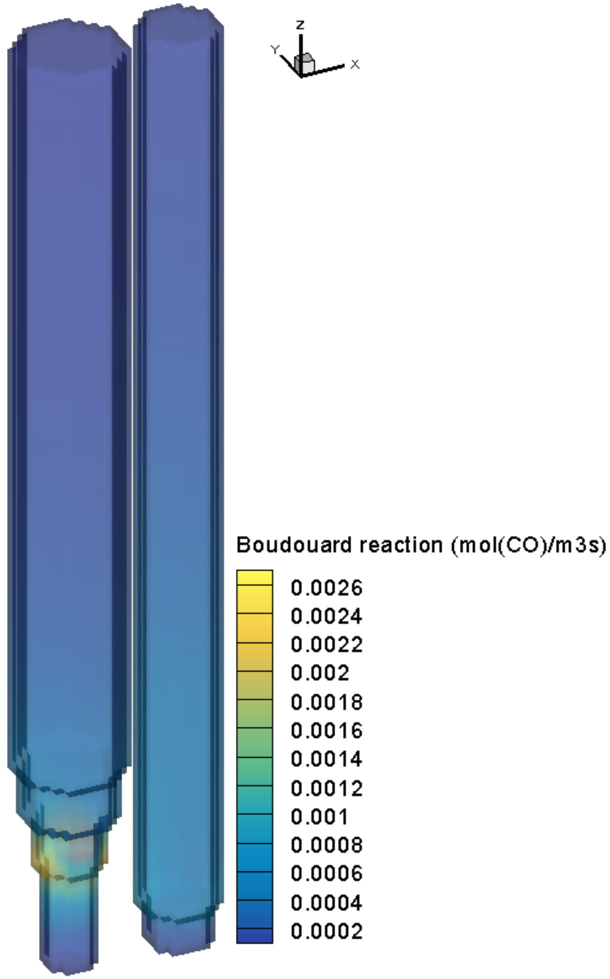
Parameter	Units	Case A01	Case A02	Case A03	Case A04
Steam flow to gasifier	(kg/s)	0.45	...	...	...
Primary steam ratio	(%)	40	...	...	...
Steam temperature	(ºC)	180	...	...	...
Air flow to combustor	(kg/s)	1.84	2.06	1.62	1.38
Primary air ratio	(%)	50	...	...	...
Air temperature	(ºC)	280	...	...	...
Fuel feed to gasifier	(kg/s)	0.9	...	...	...
Fuel feed to combustor	(kg/s)	0.10	0.15	0.05	0.00
Sand feed	(kg/s	0.05	...	...	...
Limestone feed	(kg/s)	0.01	...	...	...
Solid feed temperatures	(ºC)	30	...	...	...

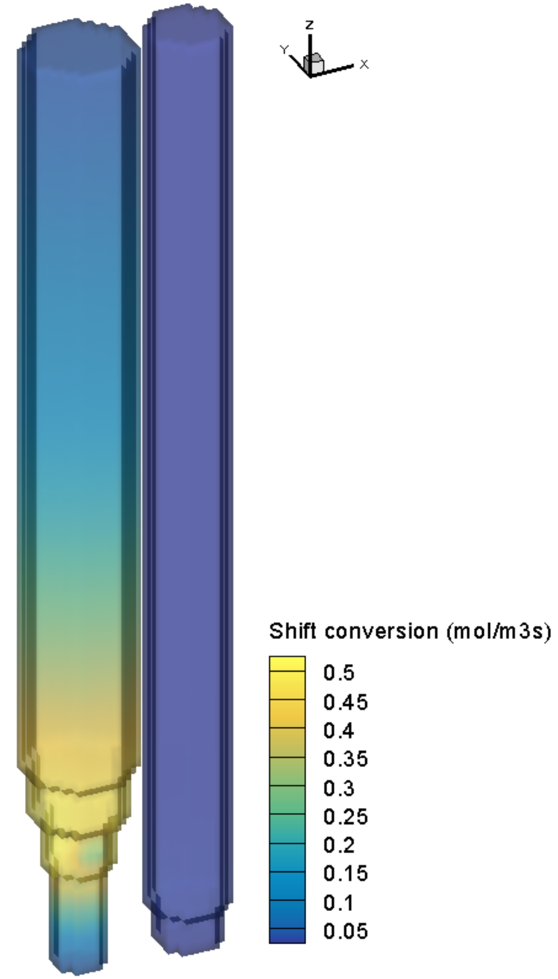
3D-model results at centre-plane, Case A01



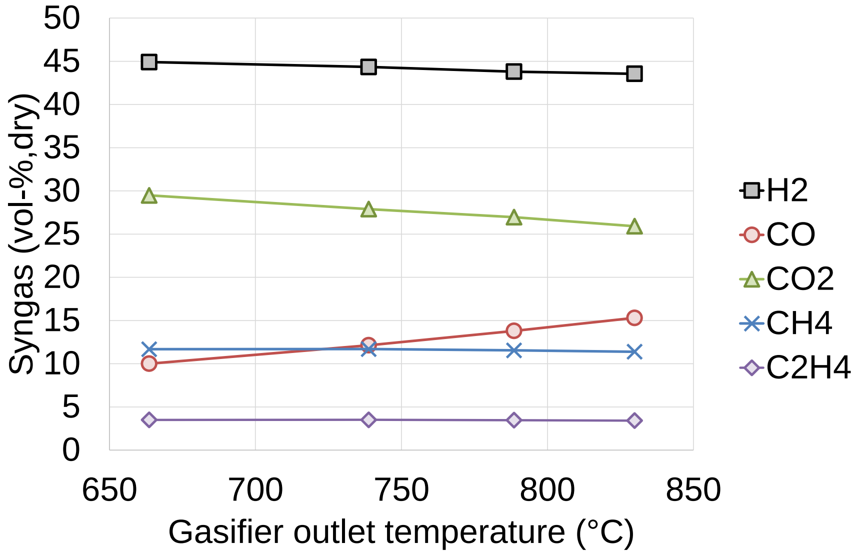
Water-gas & Boudouard reaction and shift conversion (Case A01)

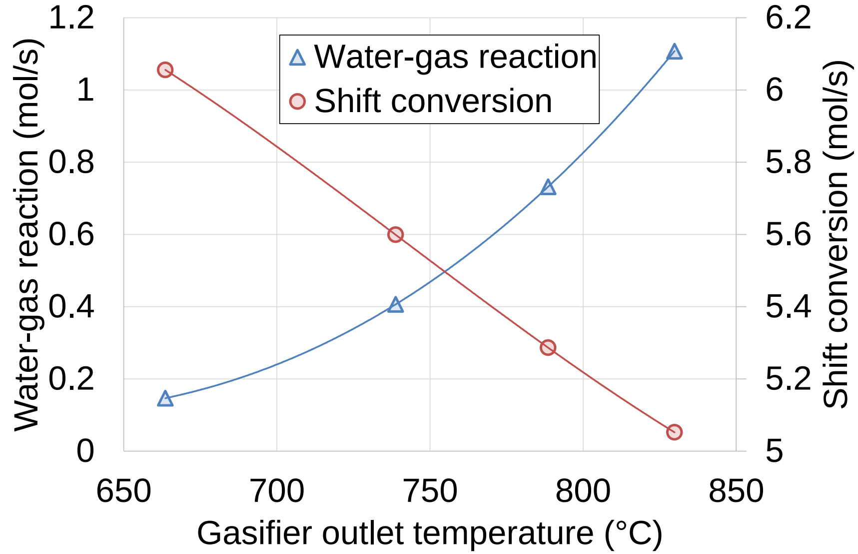






Syngas composition as function of temperature





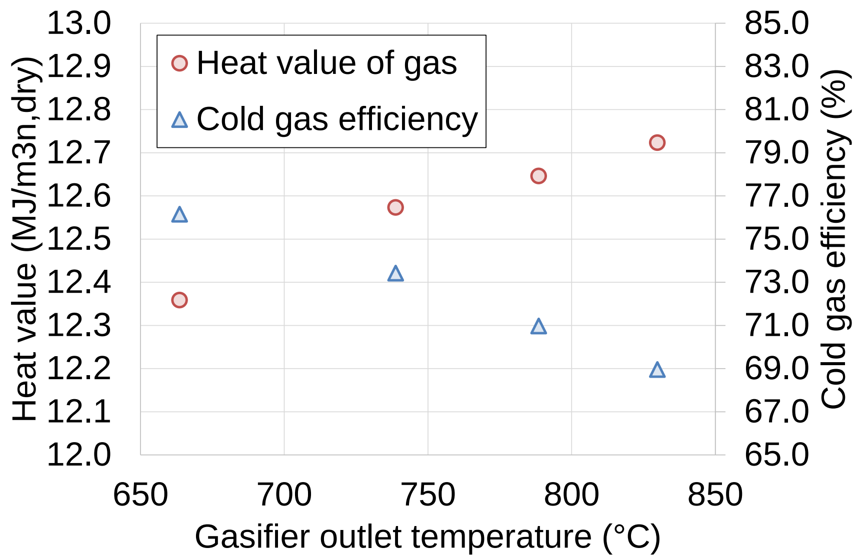
Increasing water-gas reaction ($C + H_2O \rightarrow CO + H_2$) → Higher CO & H_2

Decreasing shift conversion ($CO + H_2O \rightarrow CO_2 + H_2$) → Higher CO, lower CO_2 & H_2

Net effects as function of temperature:

- H_2 ≈ constant
- CO increasing
- CO_2 decreasing

Heat value of syngas and cold gas efficiency



$$\eta_{CG} = \frac{q_{v,gas} Q_{gas,LHV}}{\sum q_{m,fuel} Q_{fuel,LHV}}$$

Higher temperature → Higher gas yield from char
→ Increasing heat value of gas
(Opposite effect when compared with air- or oxy-fired gasification)

The increase in heat value of gas is smaller than the increase of fuel input
→ Decreasing cold gas efficiency

Summary

- Indirect steam gasification system with interconnected CFB reactors was successfully simulated by a semi-empirical model approach.
- Process can be operated without additional fuel feed to combustor.
- Effects of increasing the fuel feed to combustor:
  - Higher gasification temperature.
  - Slightly higher heat value of syngas.
  - Lower cold gas efficiency.
- Future targets:
  - Validation of model parameters based on measurement data.
  - Modelling of sorbent enhanced gasification (FLEDGED-project).

Thank you for your attention!

kari.myohanen@lut.fi
www.fledged.eu

FLEDGED

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727600