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Modelling and simulation of biomass thermal conversion to hydrogen-rich gas in a short circulating fluidized bed riser

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Talk outline

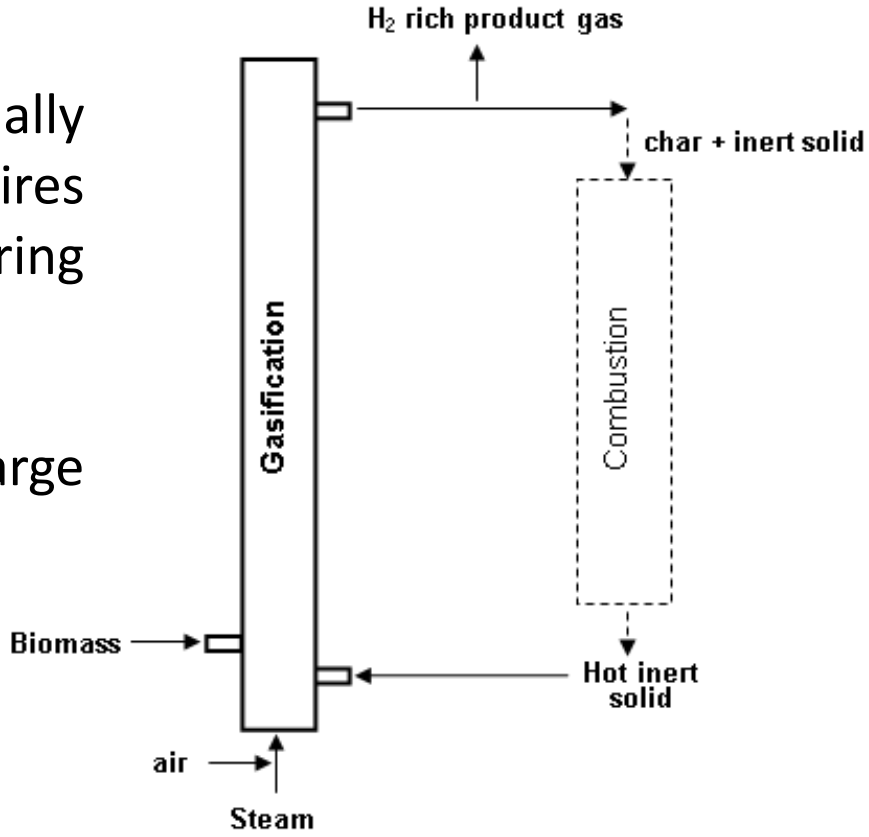
- Introduction and objectives
- Simulation geometry and operating conditions
- Building the model
  - Hydrodynamics
  - reactions
- Results
- Conclusions

Introduction and objectives

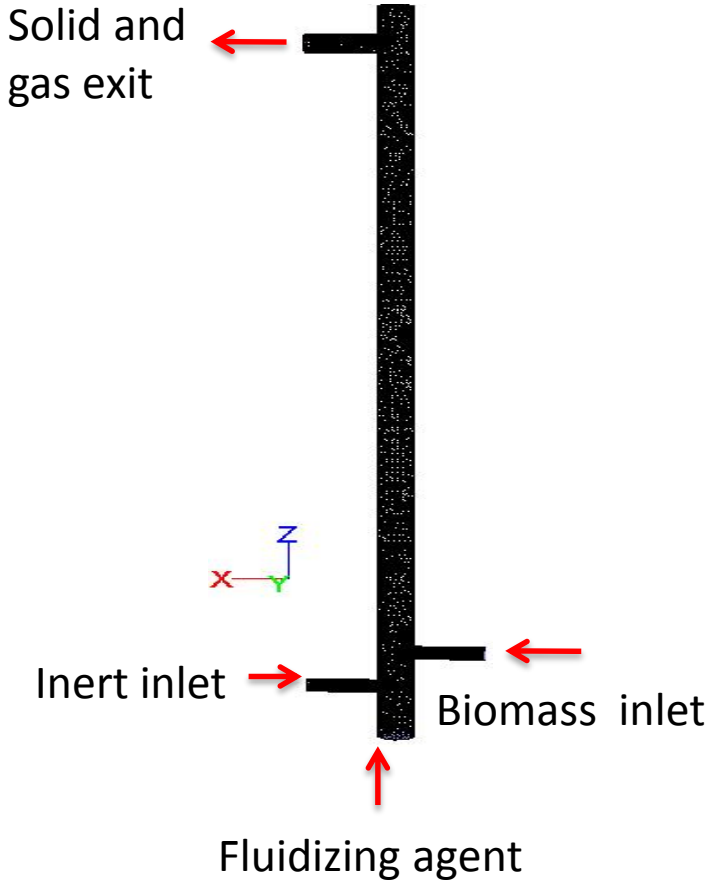
- Develop a three-dimensional computational model to simulate pyrolytic gasification of wood in a CFB riser.

- Experimental investigations are usually long and expensive and requires complex and expensive measuring techniques.

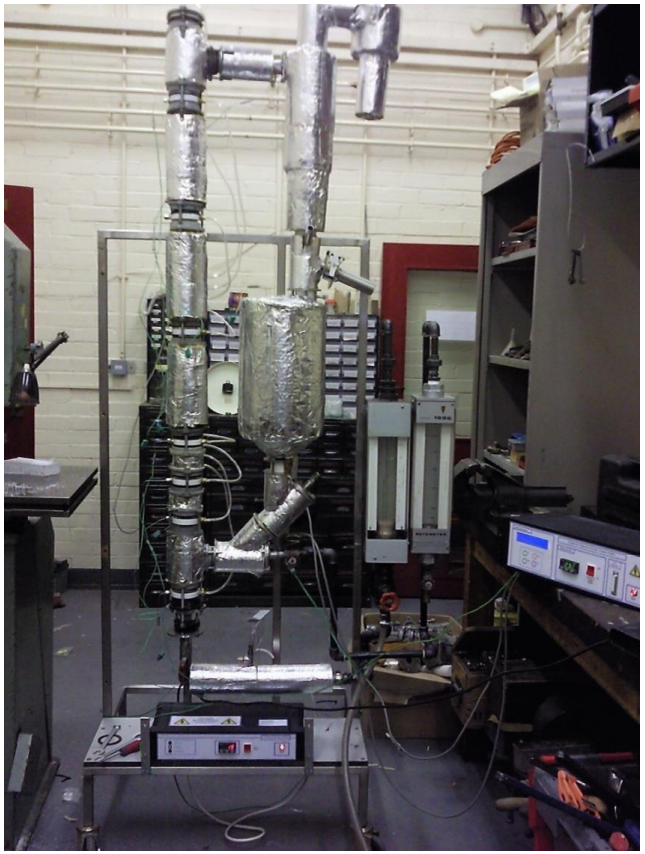
- Gasification processes is usually large scale operations.



Simulation geometry- *a relatively short CFB riser*



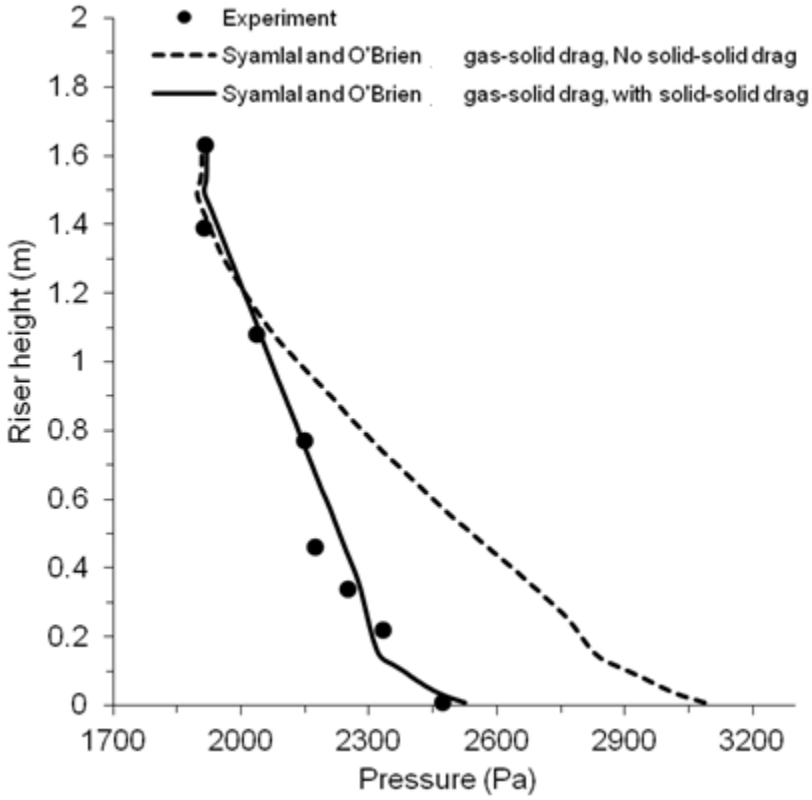
Simulation geometry

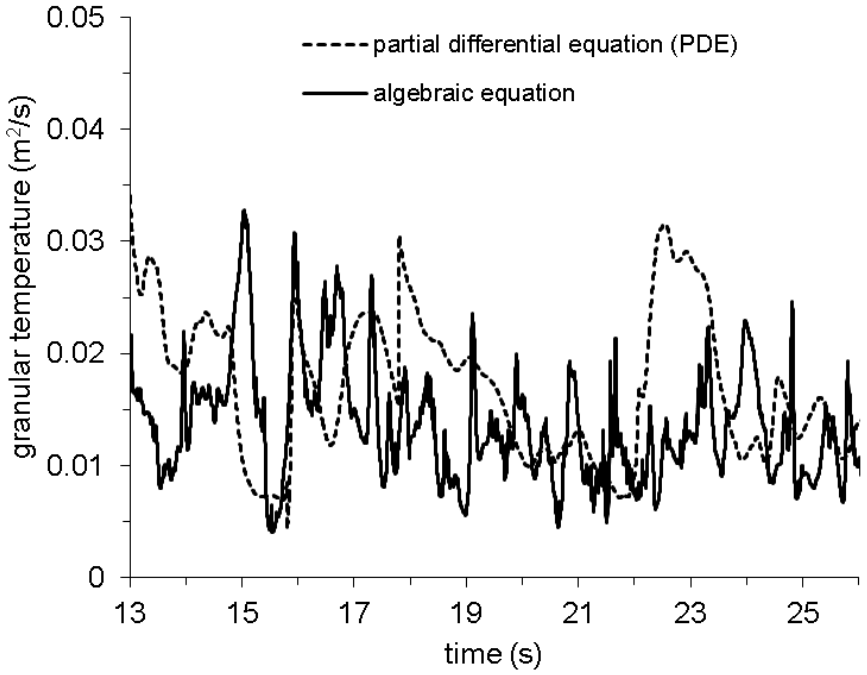


Cold flow experiment

Building the hydrodynamic model

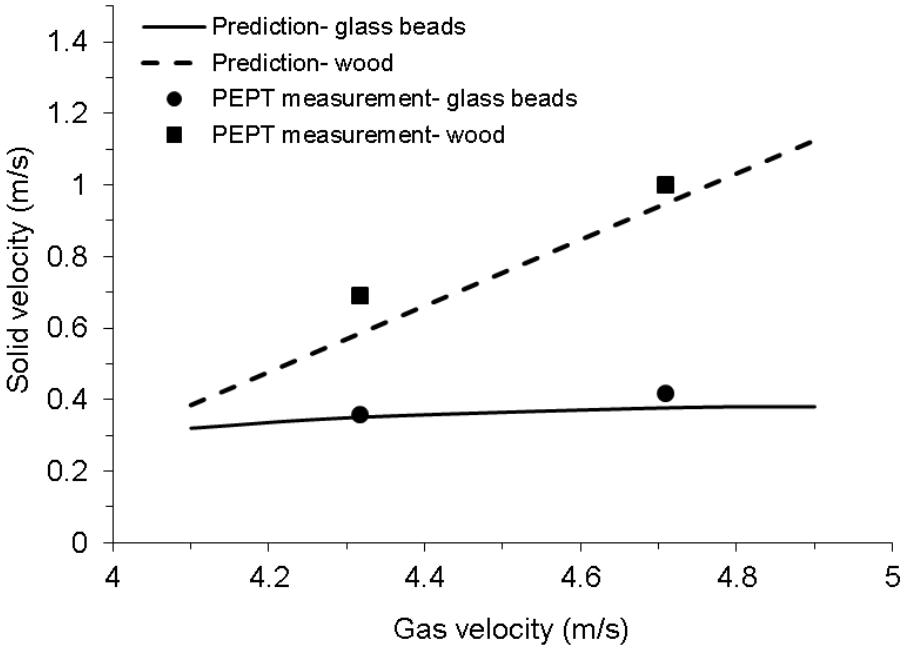
- Develop a valid model for polydispersed solid mixture using the two-fluid model with equations from the KTGF- using Fluent





Experimental validation: using PEPT system

Positron Emission Particle Tracking (PEPT)



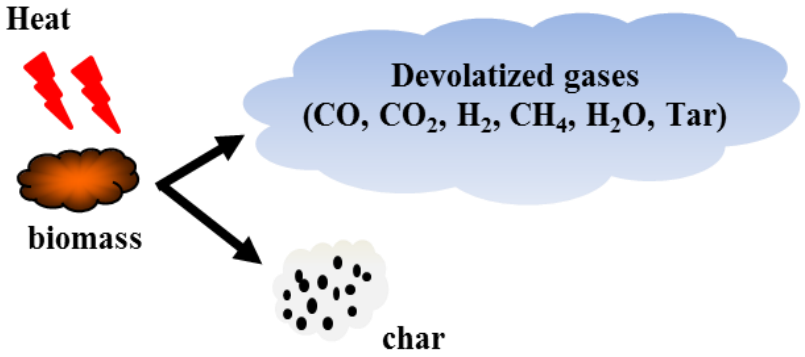
Comparison of experiment and predictions

Building the reaction model

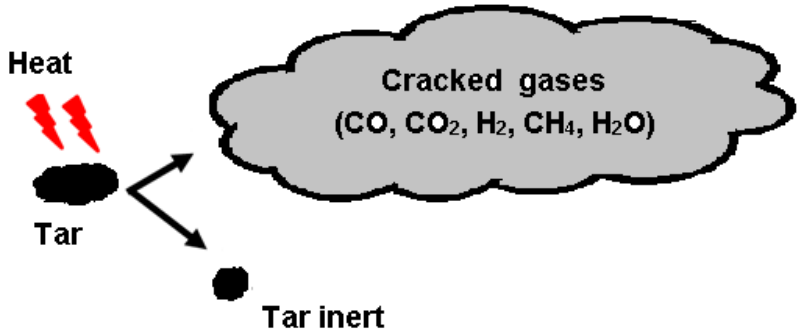
- **Drying**
  - Modelled from mass transfer principles:

$$\dot{m} = \epsilon_l \rho_l \frac{T - T_{sat}}{T_{sat}}$$

- **Devolatilization and tar cracking**



$$\hat{r}_{vol} = -k_{vol}\, C_{vol}$$



$$\hat{r}_{tar} = -k_{tar}\, C_{tar}$$

- **Partial combustion and gasification reactions**
  - Combustion reactions
  - Heterogeneous reactions
  - Homogenous reactions

Building the reaction model- *continue*

- **Combustion reactions**

$C + 0.5O_2 \rightarrow CO$ ⟸ $R = \frac{f P_{O_2}}{1/k_1 + 1/k_2}$

$2CO + O_2 \rightarrow 2CO_2$ ⟸ $R = k * C_{CO} C_{O_2}^{0.25} C_{H_2O}^{0.5}$

- Heterogeneous gasification reactions

$C + 2H_2 \rightarrow CH_4$ ⟸ $R = -k_f * C_{H_2}$

$C + CO_2 \rightarrow 2CO$ ⟸ $R = -k * C_{CO_2}$

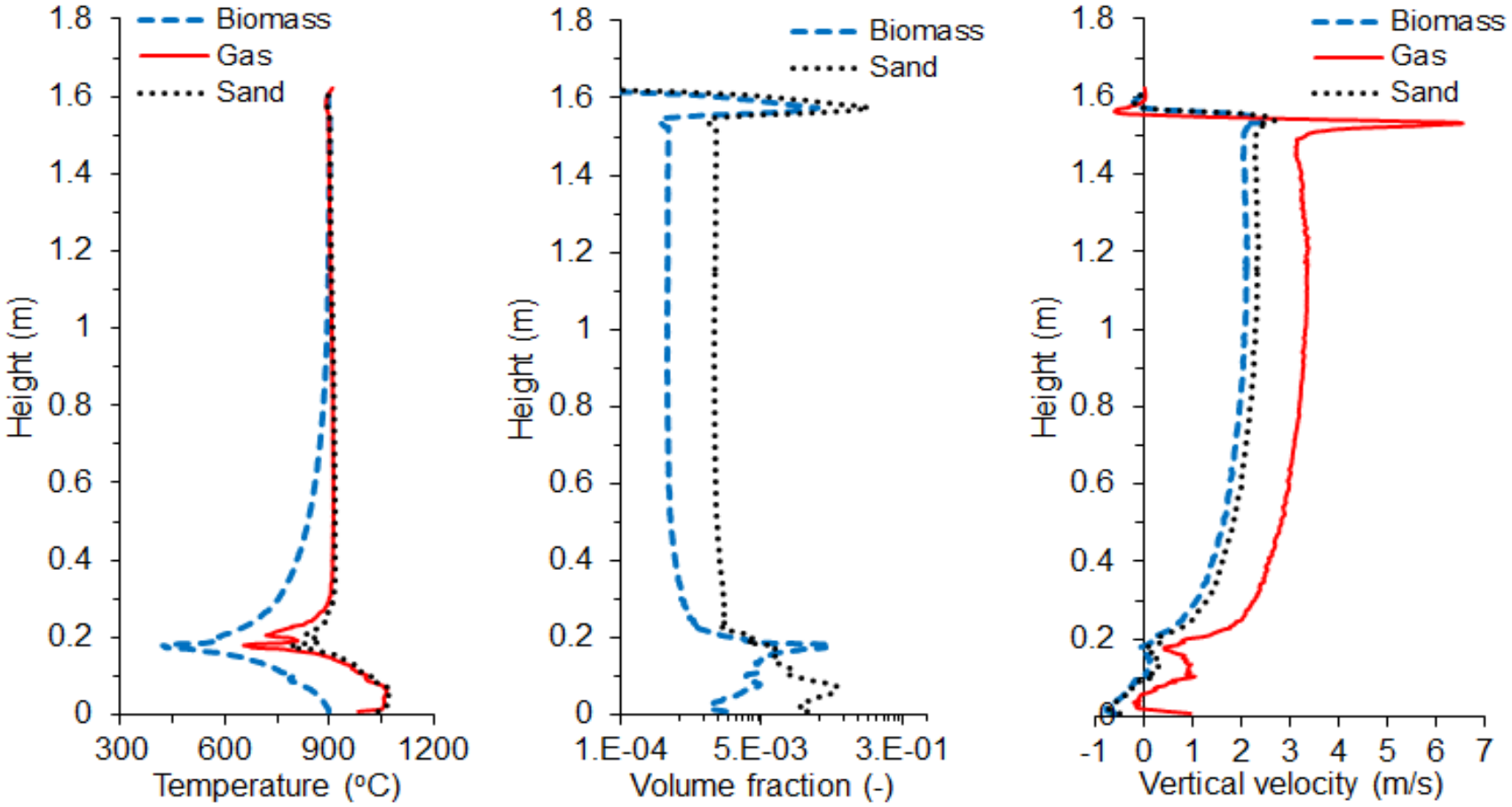
$C + H_2O \rightarrow CO + H_2$ ⟸ $R = -k * C_{H_2O}$

- Homogenous reactions

$CO + H_2O \rightarrow H_2 + CO_2$ ⟸ $R = k_f C_{CO} C_{H_2O} - k_b$

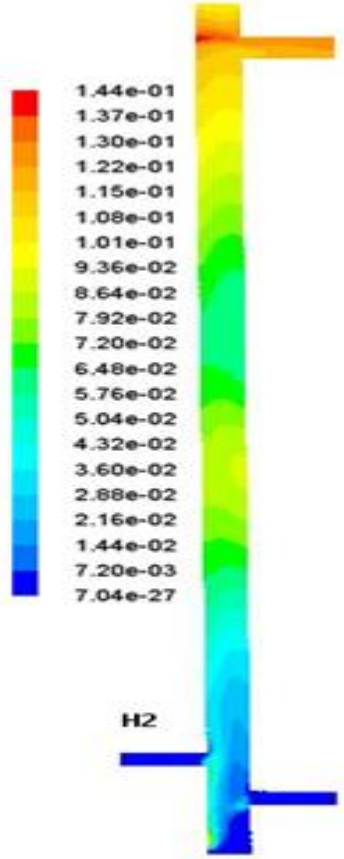
$CH_4 + H_2O \rightarrow 3H_2 + CO$ ⟸ $R = k_f C_{CH_4} C_{H_2O}$

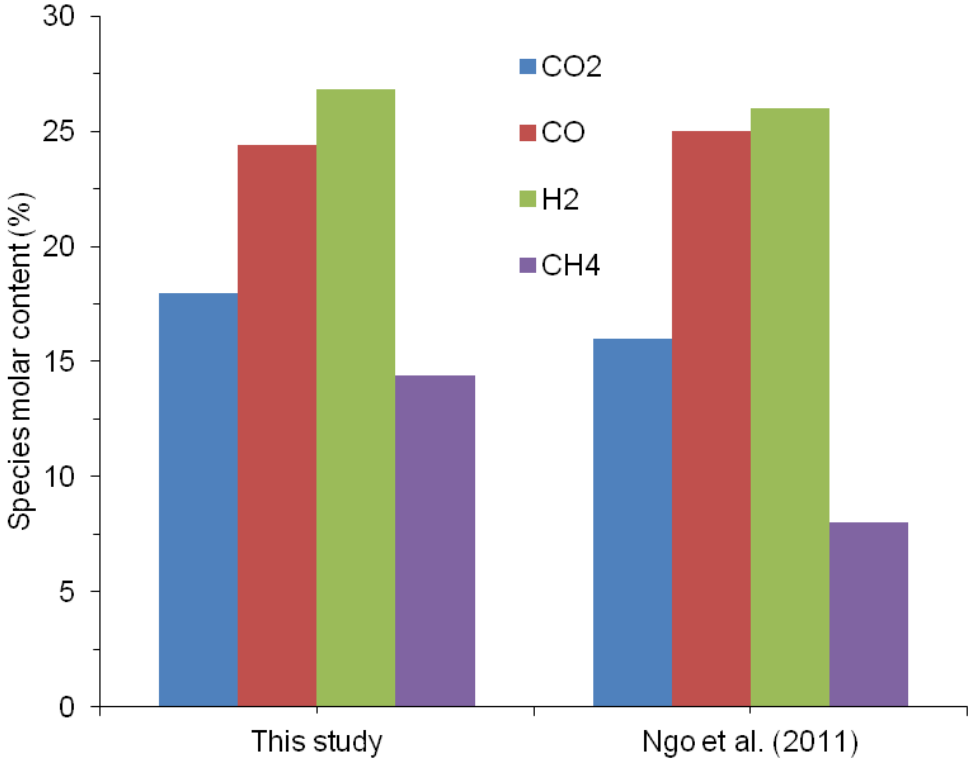
Results: hot flow hydrodynamics



- Gasifier operating at: Inlet sand temperature of 900 °C; ER=0.1; biomass-to-steam ratio of 0.6; biomass feed rate of 2 g/s (7.2 kg/h)

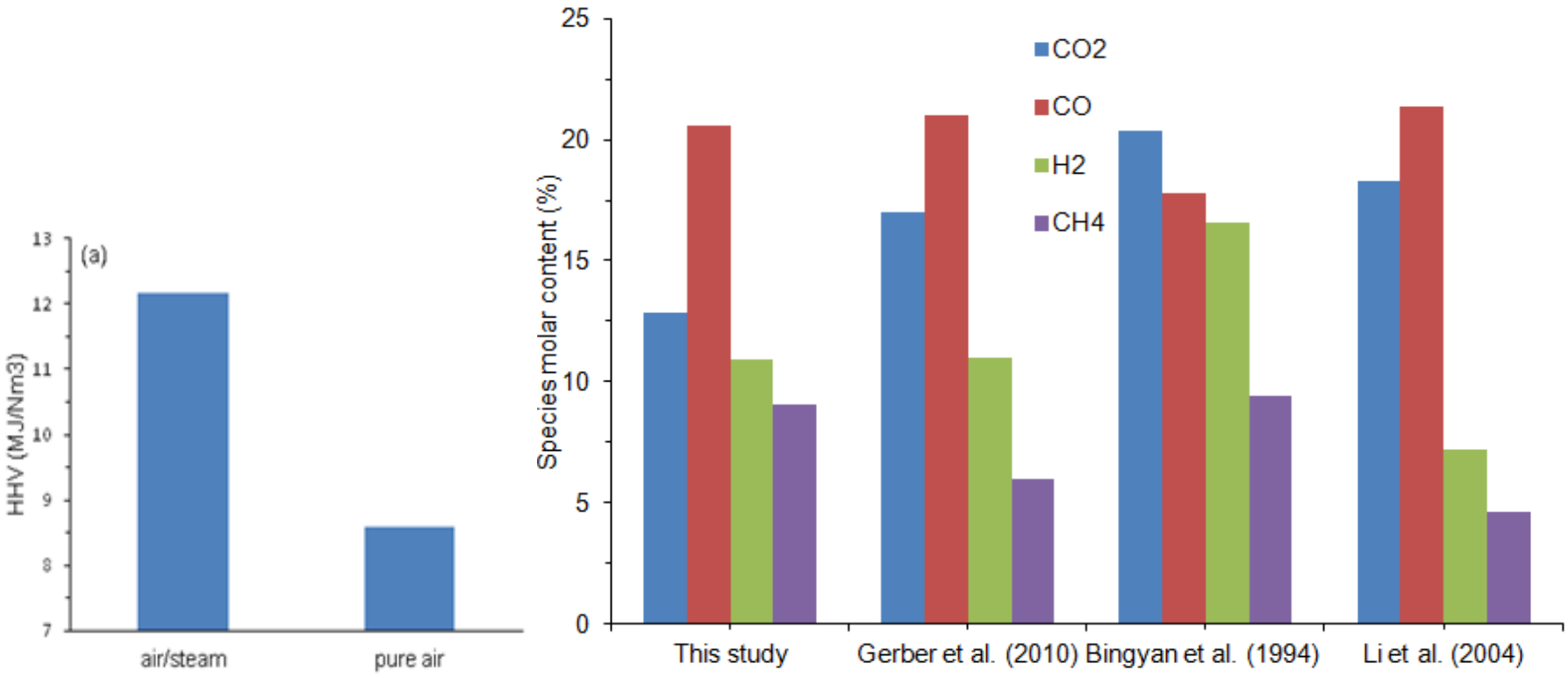
Validation: product gas composition- *steam gasification*





- Example of the hydrogen concentration in the riser.
- Comparison with experimental data of Ngo et al. (2011)

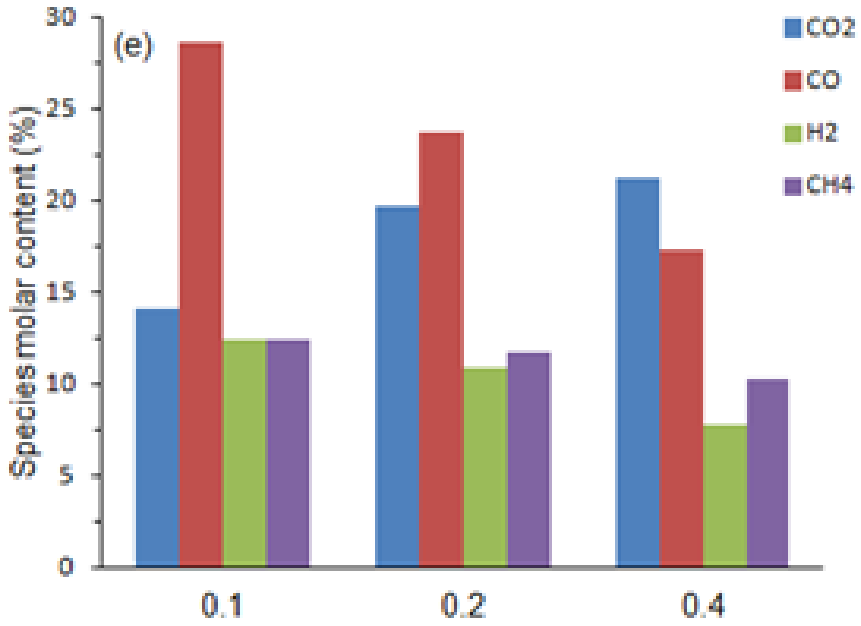
Validation: product gas composition- *pure air case*



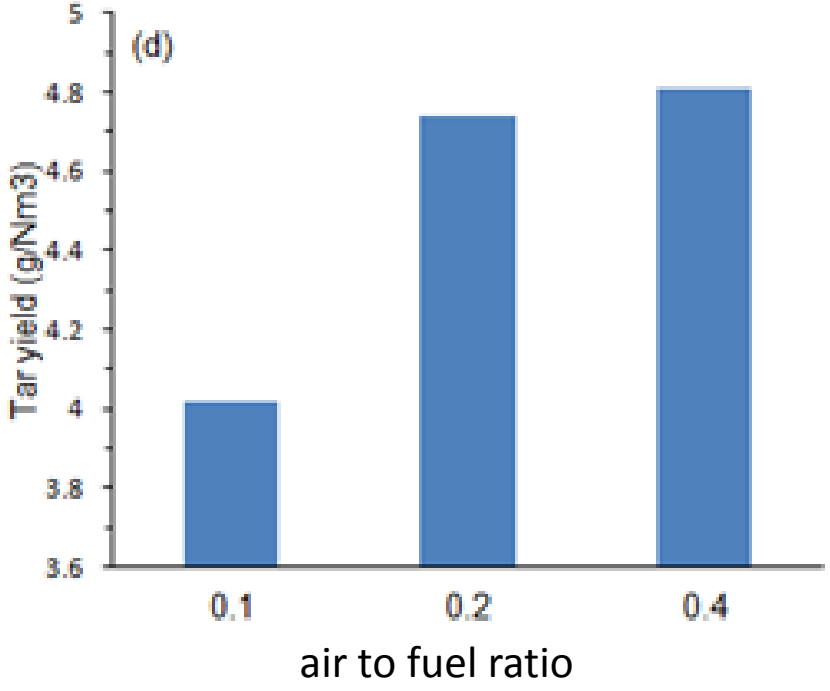
- Air-blown gasifier typical produce gas with higher heating value (HHV) of 4–7 MJ/Nm^3; oxygen- and steam-blown processes result in gases with a HHV of 10–18 MJ/Nm^3

Results: Example of parametric analysis

Gas composition



Tar yield



Conclusions

- A CFD model for biomass gasification in a circulating fluidized bed riser has been developed and validated.
- The predicted flow hydrodynamics agrees well with the experimental data obtained by two different experimental methods.
- The predicted gas quality agrees reasonably well with the available experimental data.