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Yassir Makkawi

*European Bioenergy Research Institute (EBRI), School of Engineering and Applied Science, Aston University*

Mohamed Hassan

*EBRI*

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

**Yassir Makkawi and Mohamed Hassan**

**European Bioenergy Research Institute (EBRI)**  
Aston University, Birmingham B4 7ET, United Kingdom

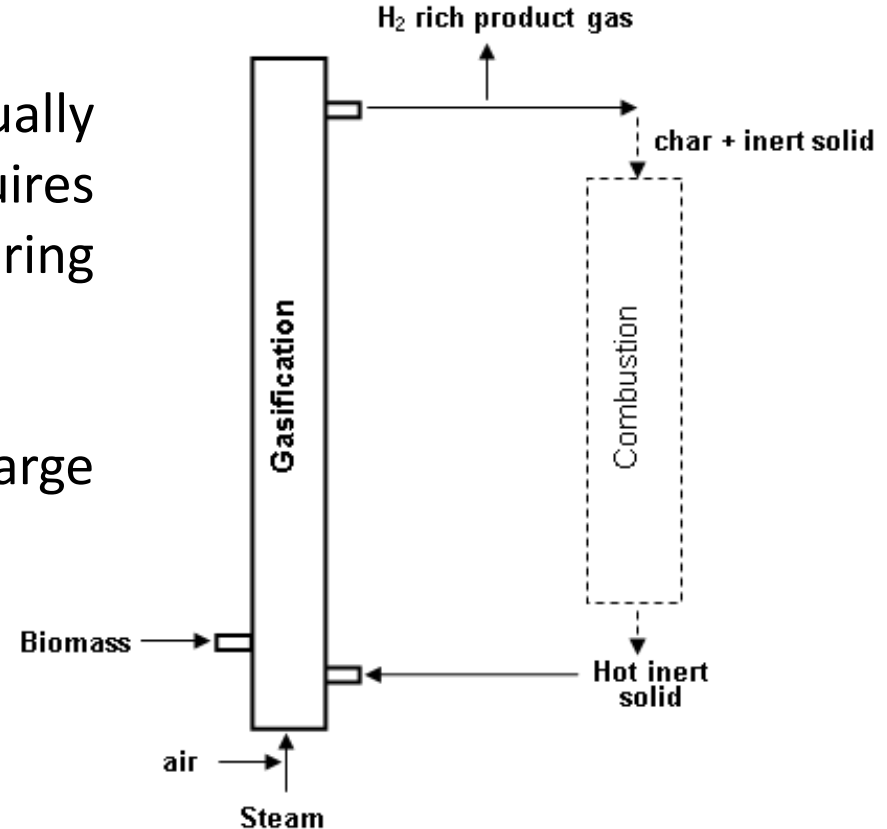


## Talk outline

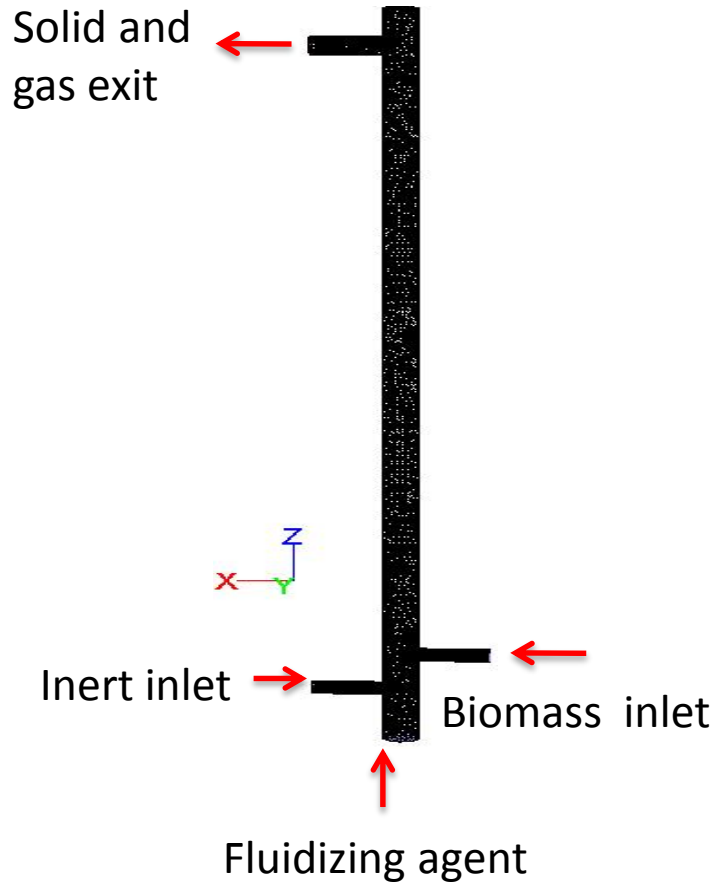
- Introduction and objectives
- Simulation geometry and operating conditions
- Building the model
  - Hydrodynamics
  - reactions
- Results
- Conclusions

## Introduction and objectives

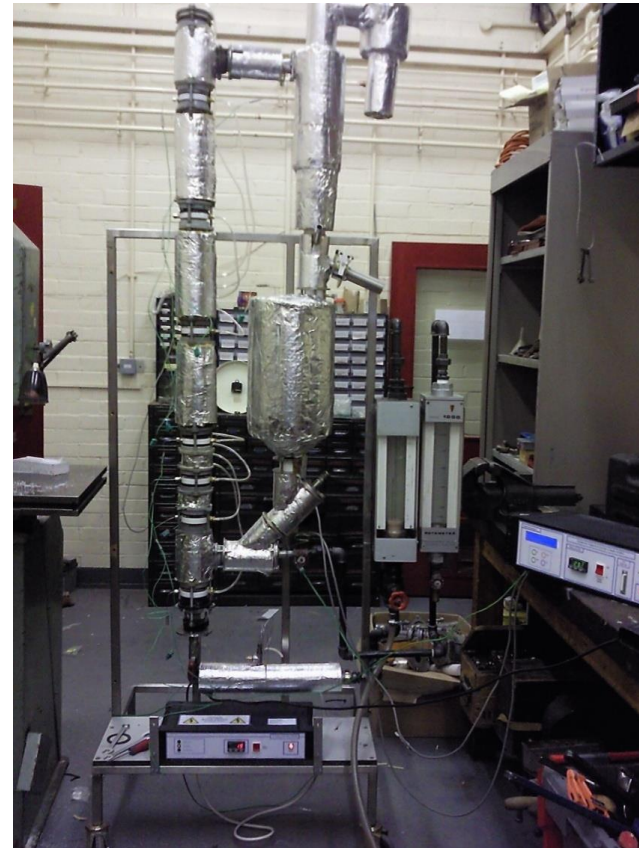
- Develop a three-dimensional computational model to simulate pyrolytic gasification of wood in a CFB riser.
- Experimental investigations are usually long and expensive and requires complex and expensive measuring techniques.
- Gasification processes is usually large scale operations.



# Simulation geometry- *a relatively short CFB riser*



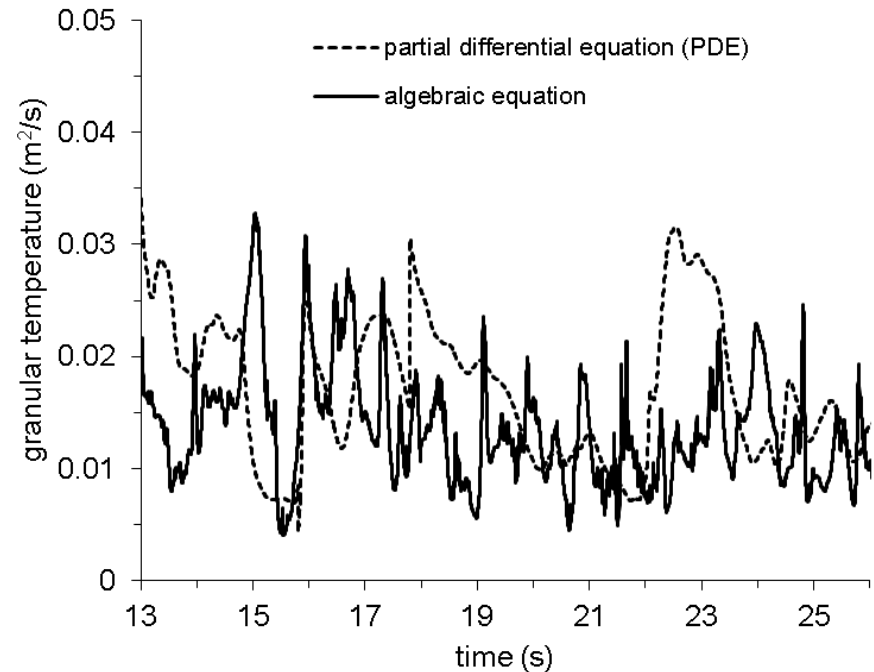
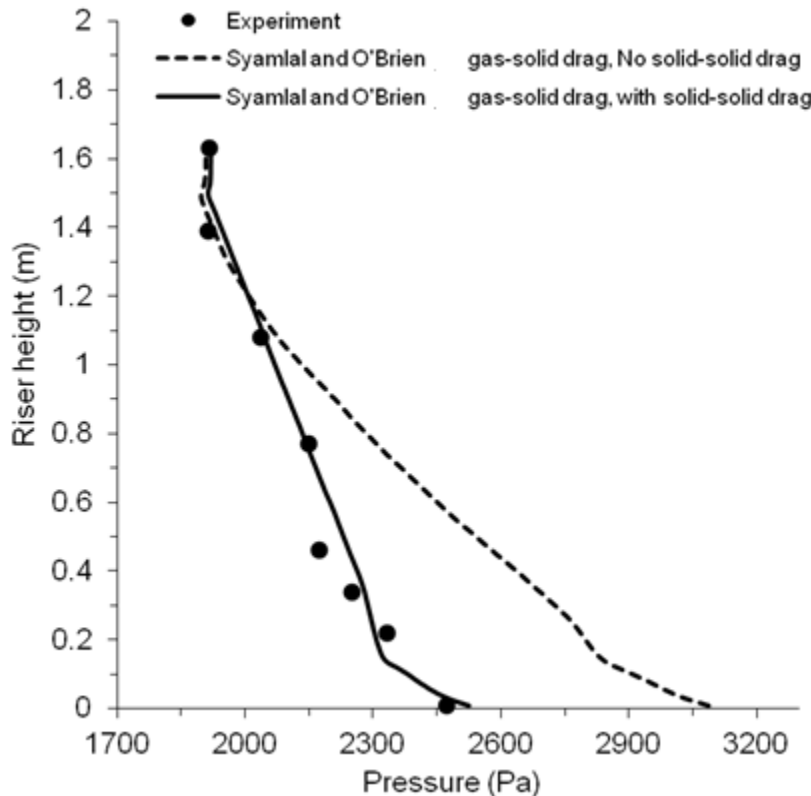
Simulation geometry



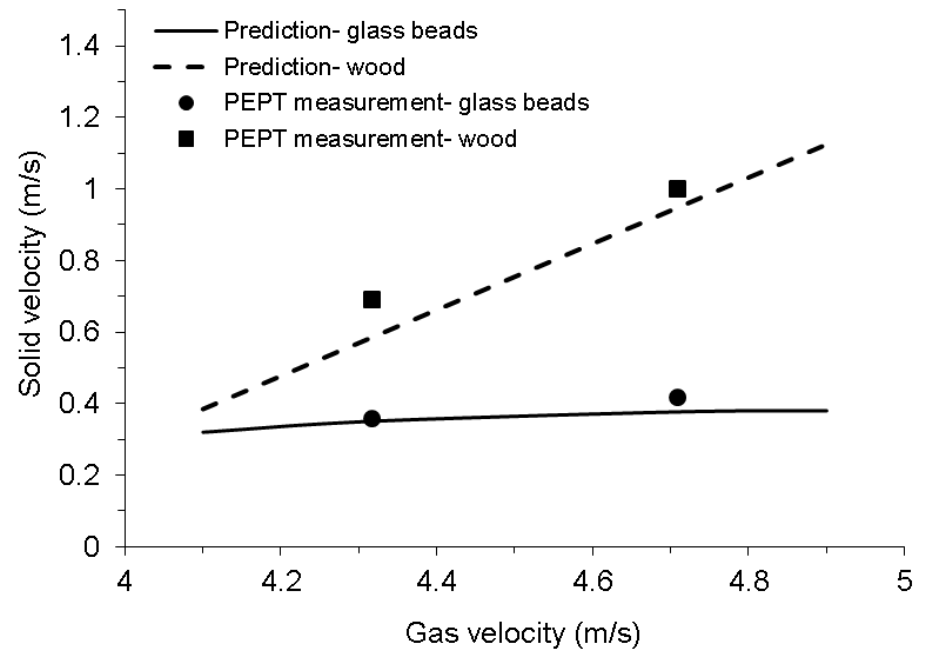
Cold flow experiment

# 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**



Comparison of experiment and predictions

Positron Emission Particle Tracking (PEPT)

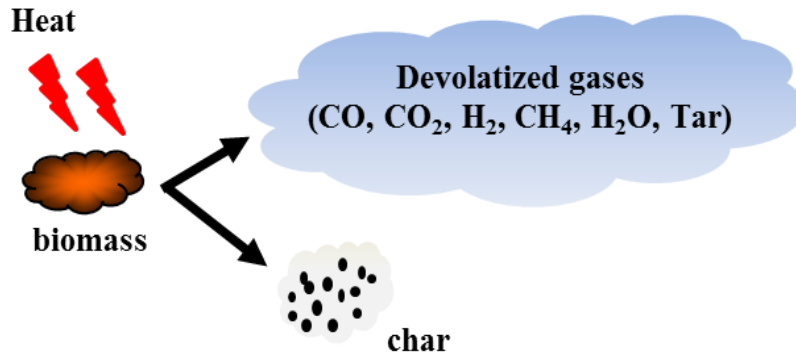
# Building the reaction model

## ➤ Drying

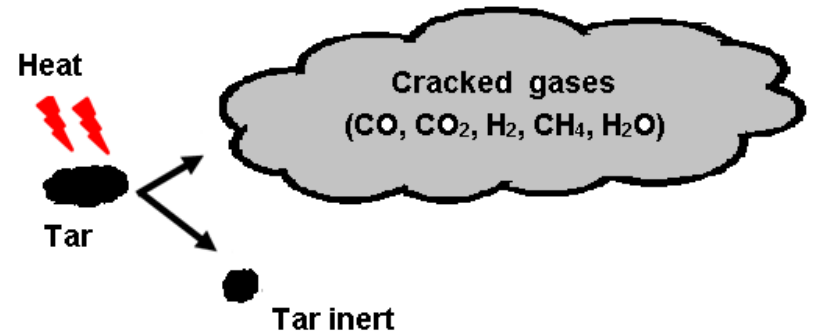
➤ Modelled from mass transfer principles:

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

## ➤ Devolatilization and tar cracking



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



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

## ➤ Partial combustion and gasification reactions

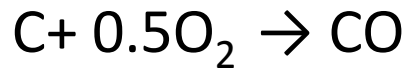
- Combustion reactions
- Heterogeneous reactions
- Homogenous reactions



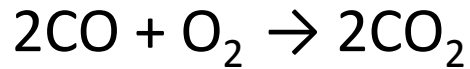


# Building the reaction model- *continue*

## ➤ Combustion reactions

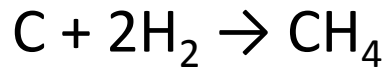


$$R = \frac{fP_{O_2}}{1/k_1 + 1/k_2}$$

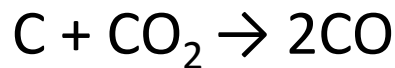


$$R = k * C_{CO} C_{O_2}^{0.25} C_{H_2O}^{0.5}$$

## ➤ Heterogeneous gasification reactions



$$R = -k_f * C_{H_2}$$

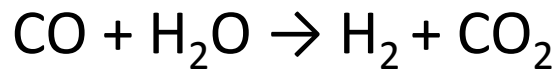


$$R = -k * C_{CO_2}$$

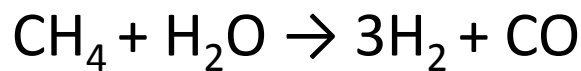


$$R = -k * C_{H_2O}$$

## ➤ Homogenous reactions

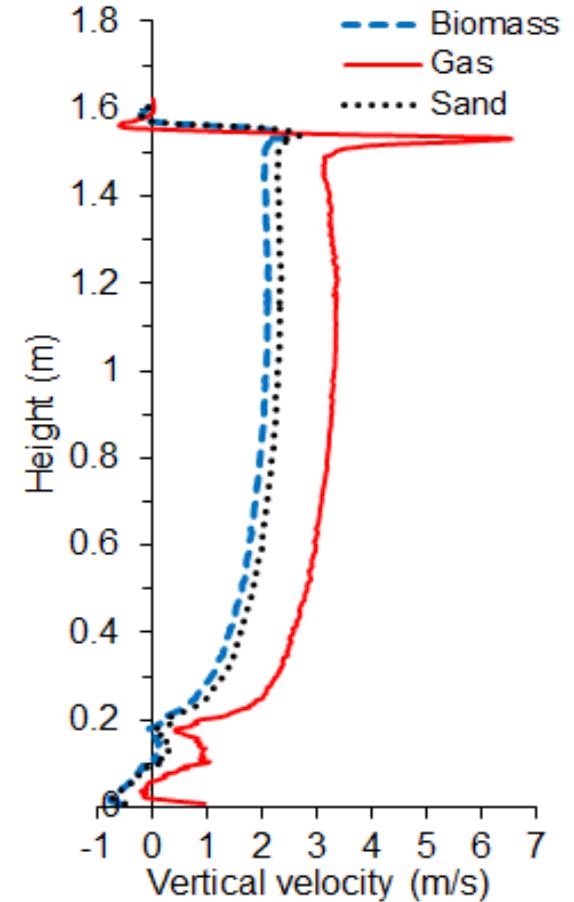
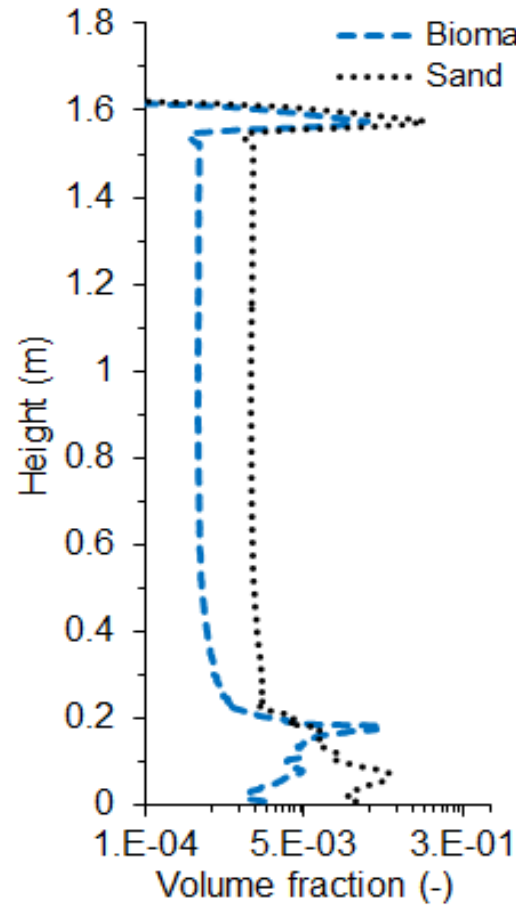
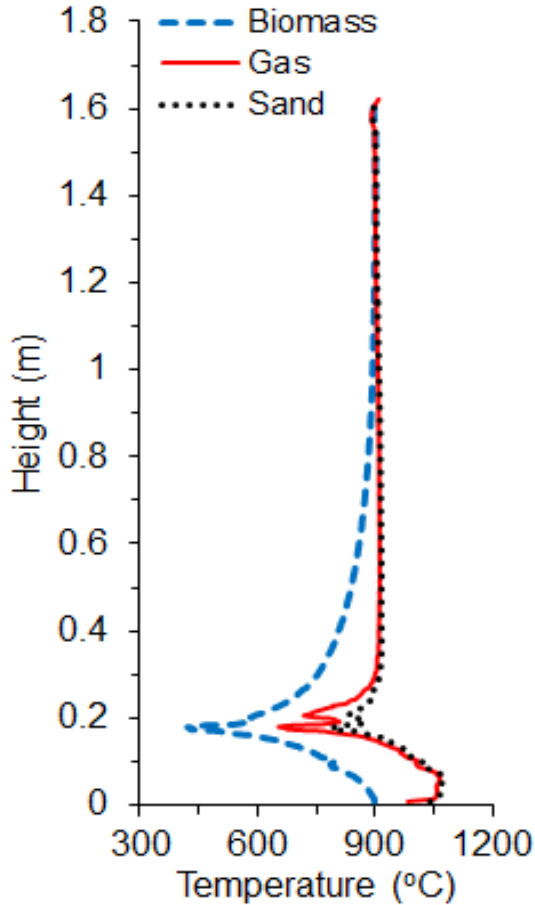


$$R = k_f C_{CO} C_{H_2O} - k_b$$



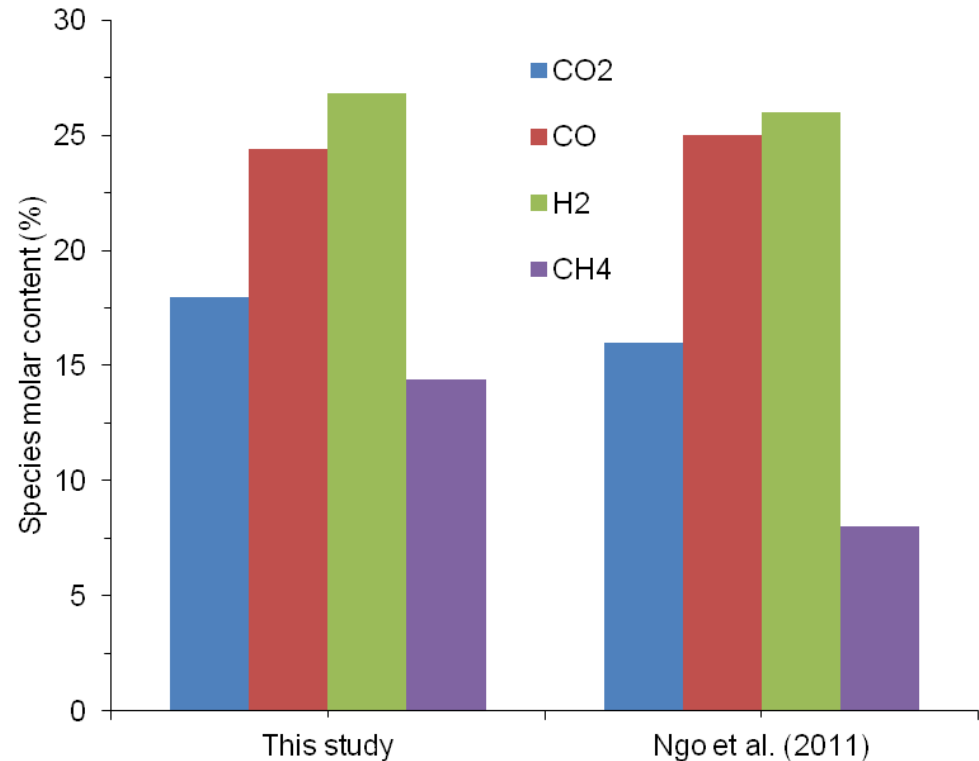
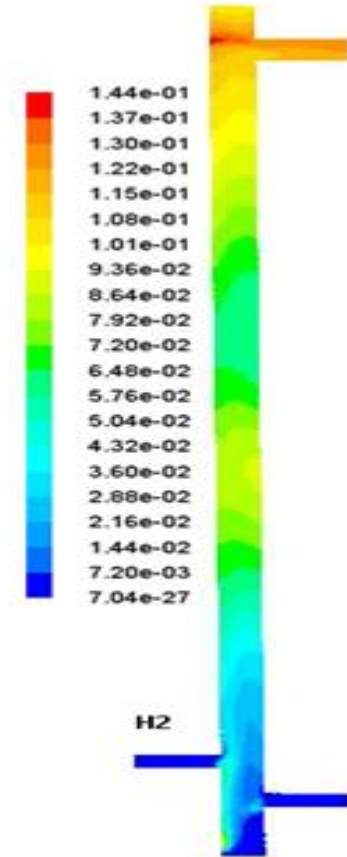
$$R = k_f C_{CH_4} C_{H_2O}$$

## 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)

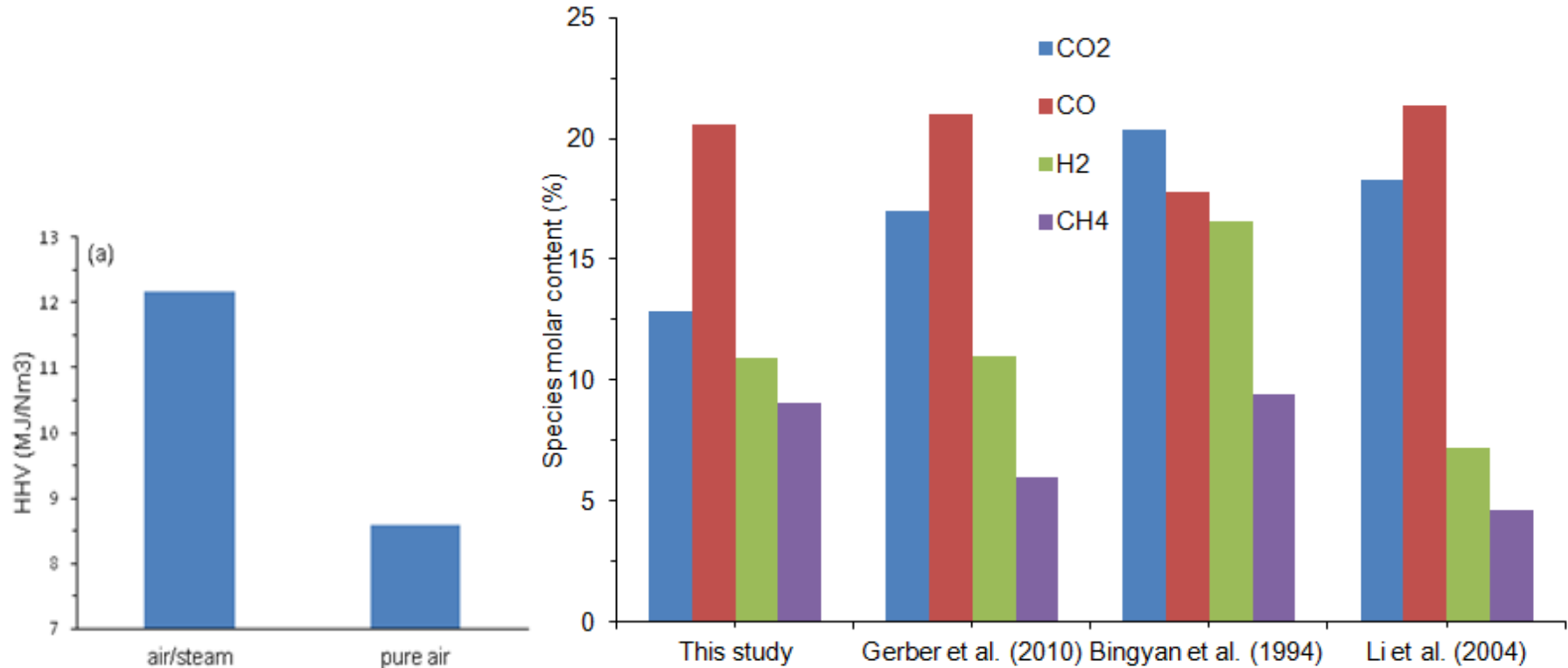
# Validation: product gas composition- *steam gasification*



➤ Example of the hydrogen concentration in the riser.

➤ Comparison with experimental data of Ngo et al. (2011)

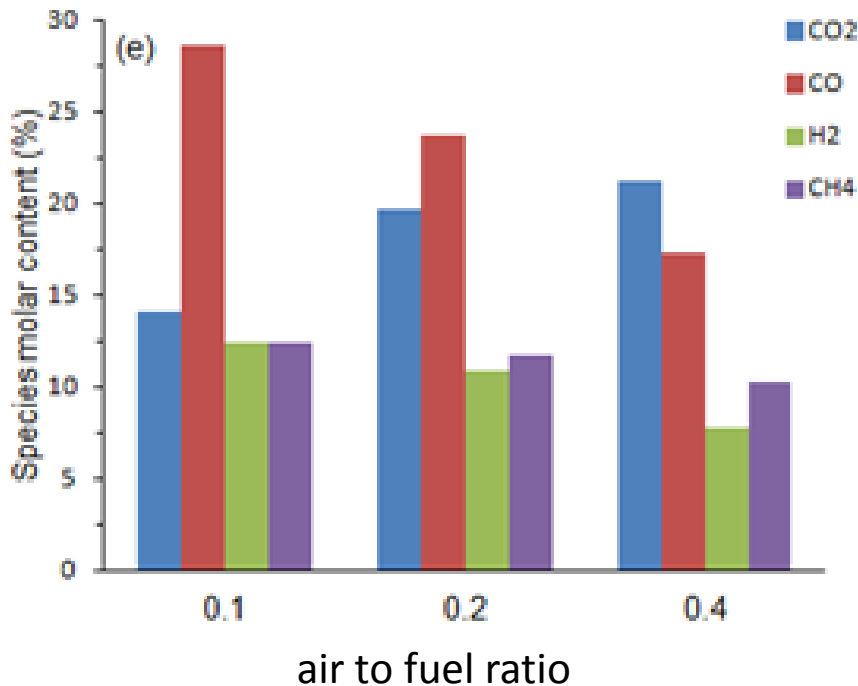
# Validation: product gas composition- *pure air case*



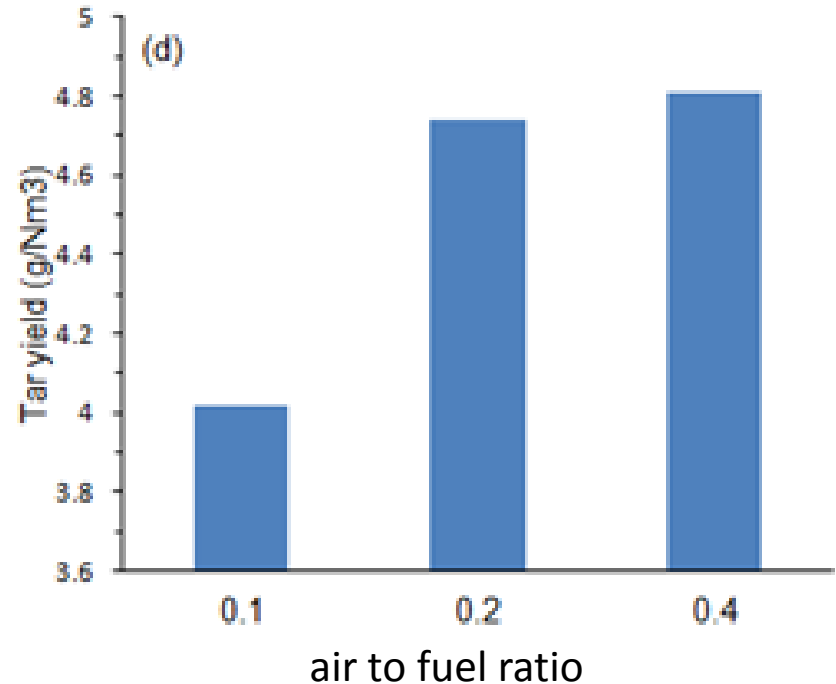
- ❖ Air-blown gasifier typical produce gas with higher heating value (HHV) of 4–7 MJ/Nm<sup>3</sup>; oxygen- and steam-blown processes result in gases with a HHV of 10–18 MJ/Nm<sup>3</sup>

# 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.