# Experimental study and Numerical Simulation of the Biomass Pyrolysis and Gasification with MFiX

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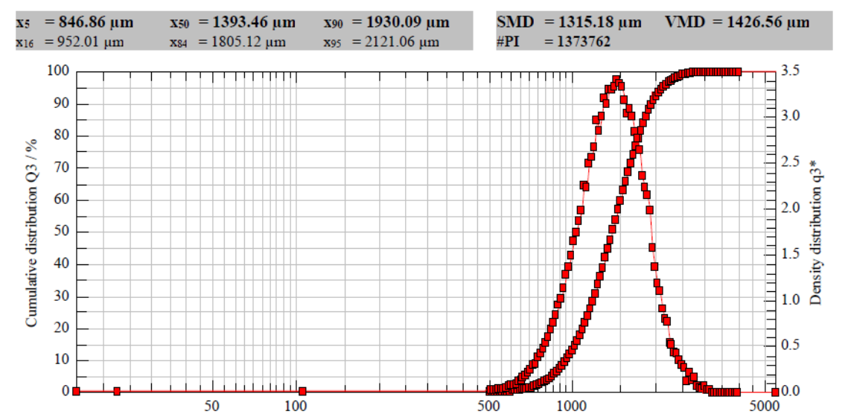
## Objective

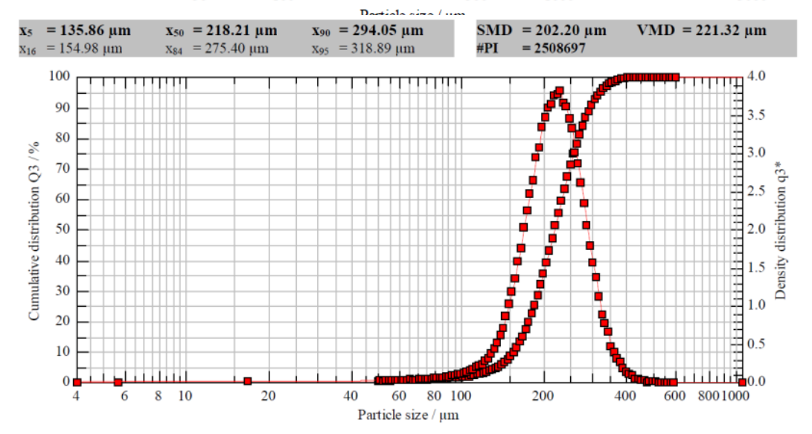
Biomass is a widely available renewable energy source, which could be an alternative fuel source to fossil fuels to alleviate environmental problems. Biomass Pyrolysis and gasification is a promising approach for combined heat and power generation and for the production of various products such as fuels and chemicals. Gas-solid fluidized-bed offers excellent mixing, heat and mass transfer between solid particles and fluidizing gas, thus is one of the most interesting technologies.

## Biomass and sand characterization

The proximate, ultimate and calorimetric analyses of the fuel were carried out at Sotacarbo laboratories according to the international standards. A SympaTEC QICPIC particle analyzer was used to characterize the Cypress biomass and Olivine sand particles at NETL.



| Cypress particles |
|---|
| $D_{32}$=1315.18 μm<br>Sphericity = 0.612 |



| Sand particles |
|---|
| $D_{32}$=202.20 μm<br>Sphericity = 0.739 |
| ρ=3309.6 kg/m3 |

Mean values of Proximate, Ultimate (% by weight), and Calorimetric analysis (MJ/Kg)

| | TGA Wet sample | | | | | | | | CHNS Dry sample | | | | | Calorimeter Wet sample | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Name | Moisture [%] | Volatile [%] | Ash [%] | Fixed Carbon [%] | Tot raw | Fixed Carbon (Dry) [%] | Volatile (Dry) [%] | Ash (Dry) [%] | Total C [%] | H [%] | N [%] | S [%] | O [%] | HHV [MJ/Kg] | $LHV_0$ [MJ/Kg] | LHV [MJ/Kg] |
| Cypress | 10,78 | 67,14 | 2,41 | 19,67 | 100,00 | 22,01 | 75,07 | 2,92 | 51,97 | 5,81 | 1,00 | n.d. | 41,22 | 21,00 | 19,49 | 17,12 |
| Ash | 6,58 | 14,50 | 37,81 | 41,11 | 100,00 | 43,97 | 15,54 | 40,49 | 53,30 | 1,61 | 0,39 | n.d. | 44,70 | n.a. | n.a. | n.a. |

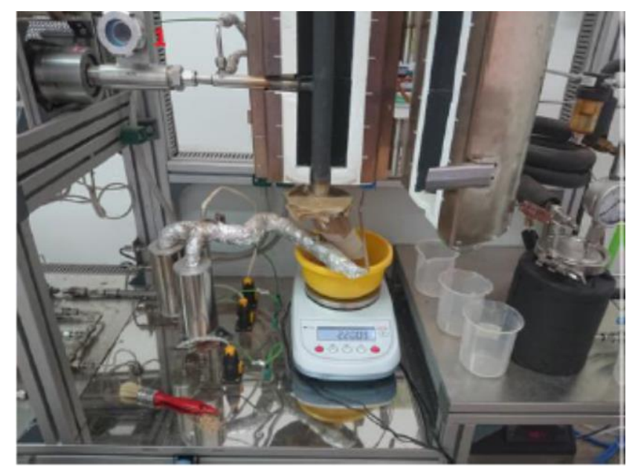
## Pyrolysis Reaction Kinetics from TGA

Pyrolysis kinetics was measured through thermogravimetric analysis at Sotarcarbo and the pyrolysis reaction kinetics were obtained through Flynn-Wall-Ozawa (FWO) method.

$$\frac{d\alpha}{dt} = k(T)f(\alpha)$$
$$k(T) = A\exp\left(\frac{-E}{RT}\right)$$
$$f(\alpha) = (1-\alpha)^n$$
$$\alpha = \frac{m_0 - m_t}{m_0 - m_f}$$

$n$ = is the order of reaction, 7.2
A = (1/s) pre-exponent factor, 2E+19
E = (J/mole) activation energy, 212180
R = (J/mole-K) gas constant
$m_0$ = initial sample weight
$m_t$ = sample weight at any time
$m_f$ = final sample weight

## Experimental setup and operational conditions



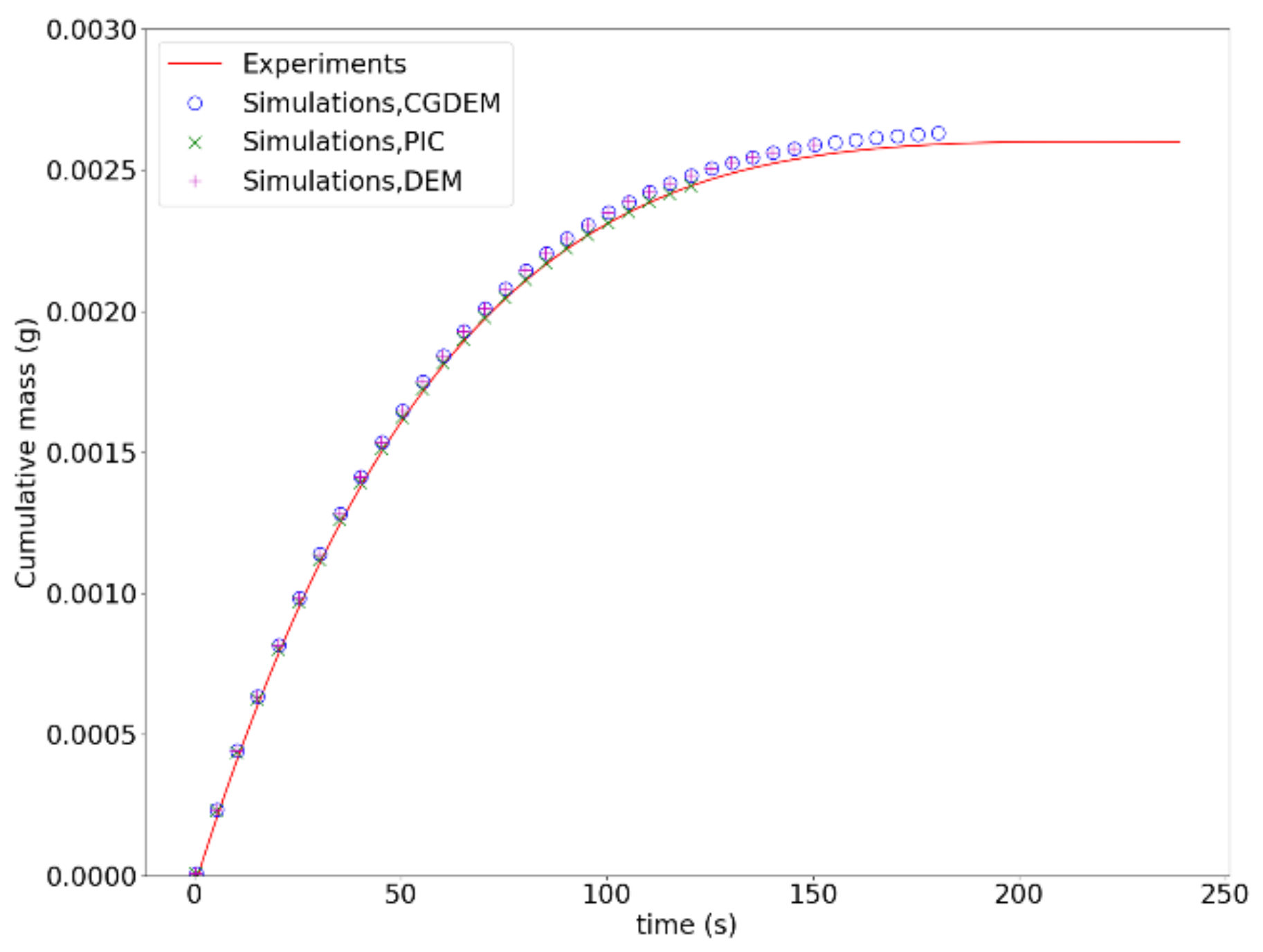
| Parameter | Value |
|---|---|
| Reactor temperature | 800°C |
| Nitrogen pre-heating | 350°C |
| Nitrogen flow (gasification agent) | 1.5 Nl/min |
| Flow rate of the nitrogen in the feeding system | 100 Nml/min |
| Temperature of the nitrogen in the feeding system | 25°C (not controlled) |
| Temperature of the condenser | 5°C |

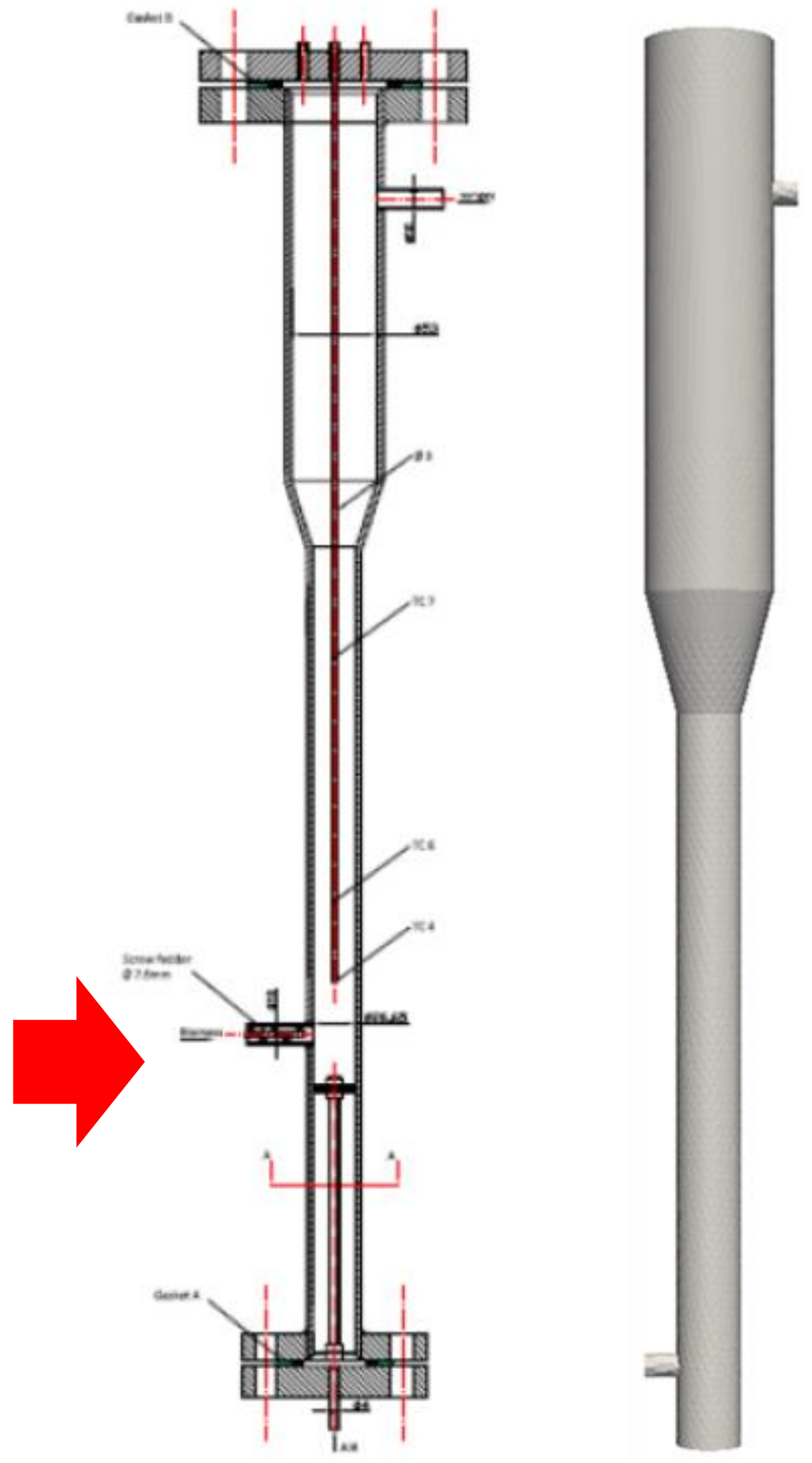
## Numerical simulation of the Biomass Pyrolysis

Based on mass balance between proximate analysis, the biomass yield and measured gas composition at the exit of reactor, the pyrolysis of the biomass follows:

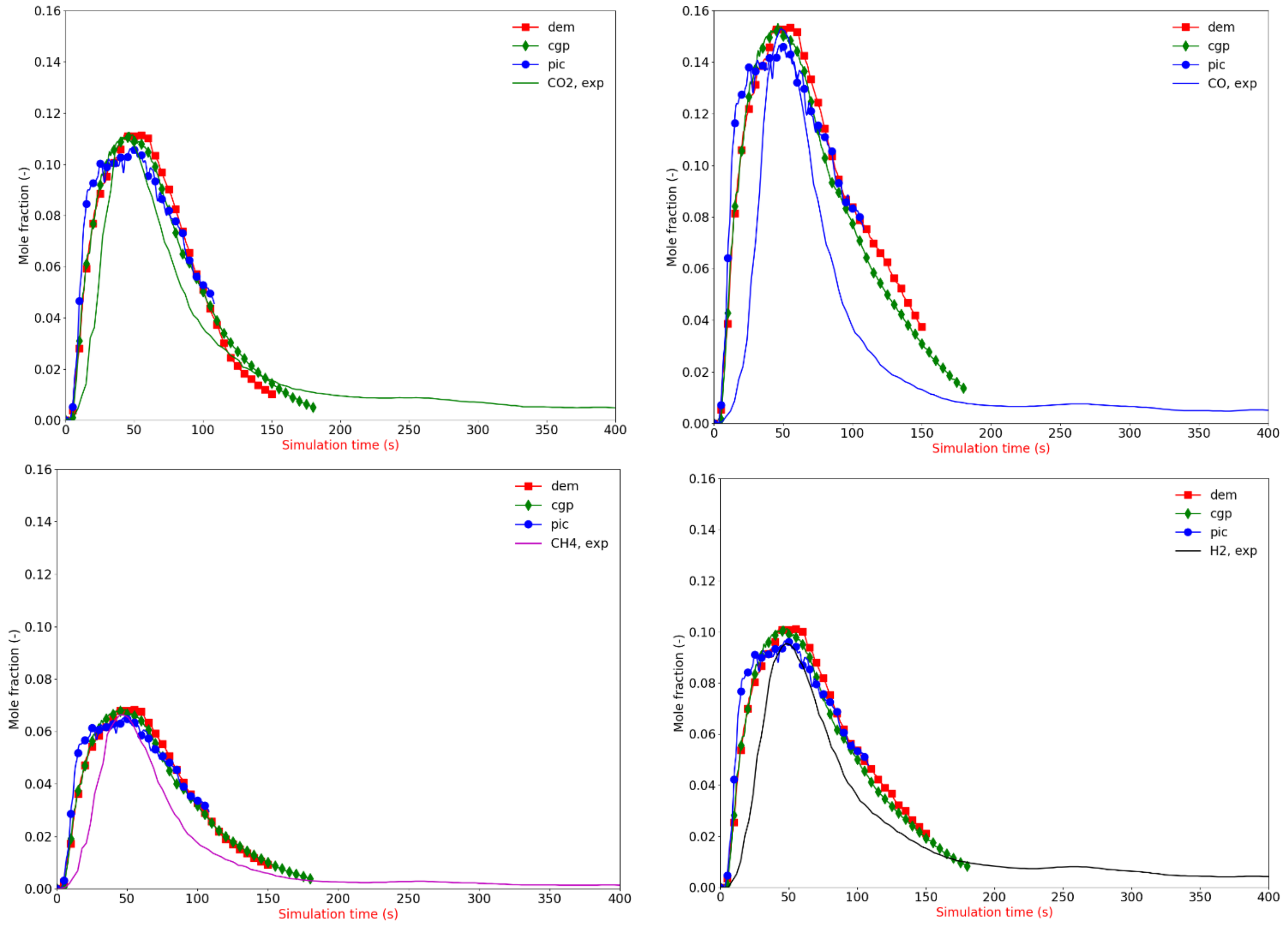
$$\text{Biomass} \rightarrow 0.2281\text{CO} + 0.1657\text{CO}_2 + 0.1493\text{H}_2 + 0.1012\ \text{CH}_4 + 0.2399\ \text{Char} + 0.1158\ \text{Tar}$$

Cumulative mass of biomass inlet





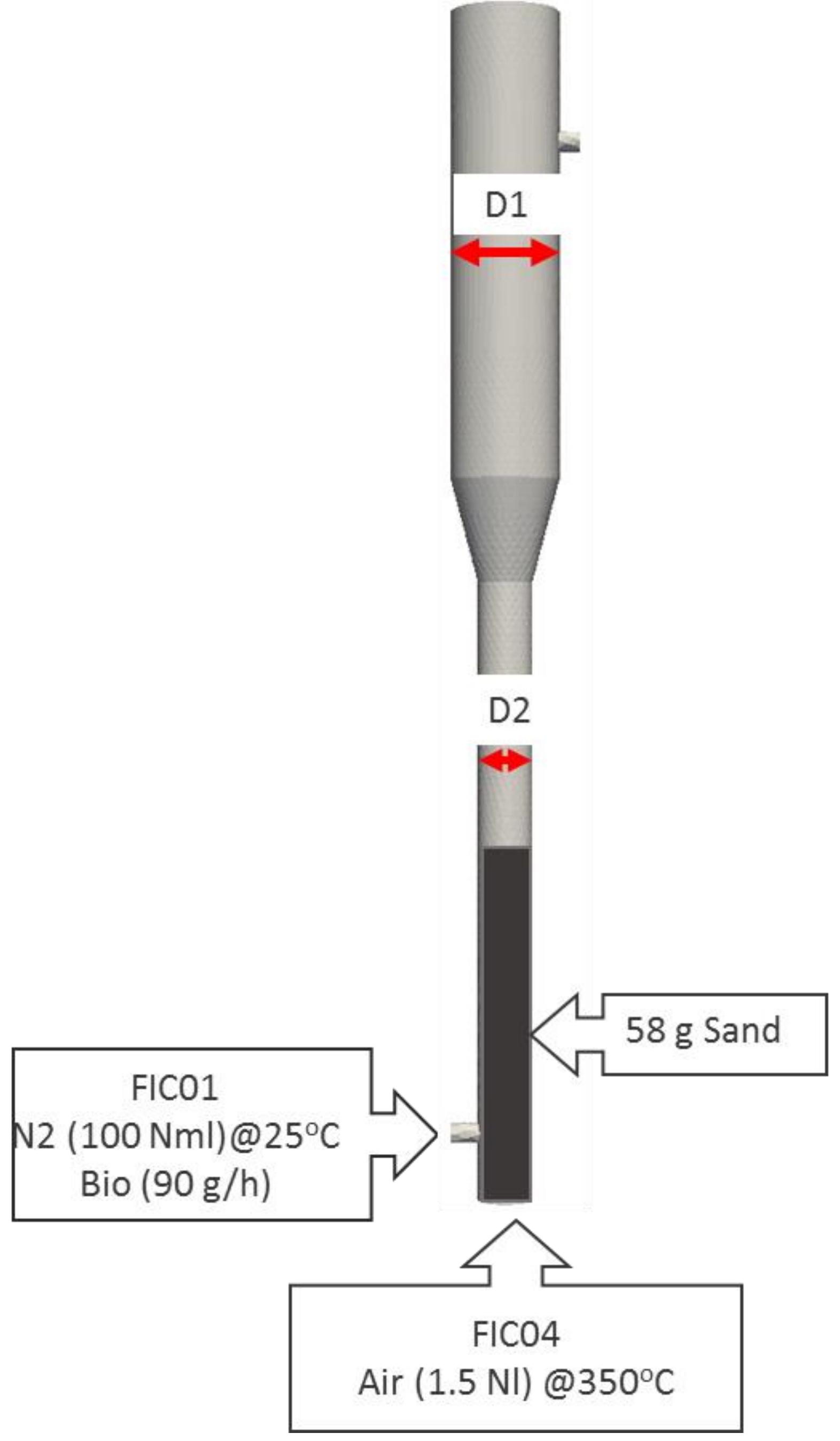
## Comparison between experiment and simulation



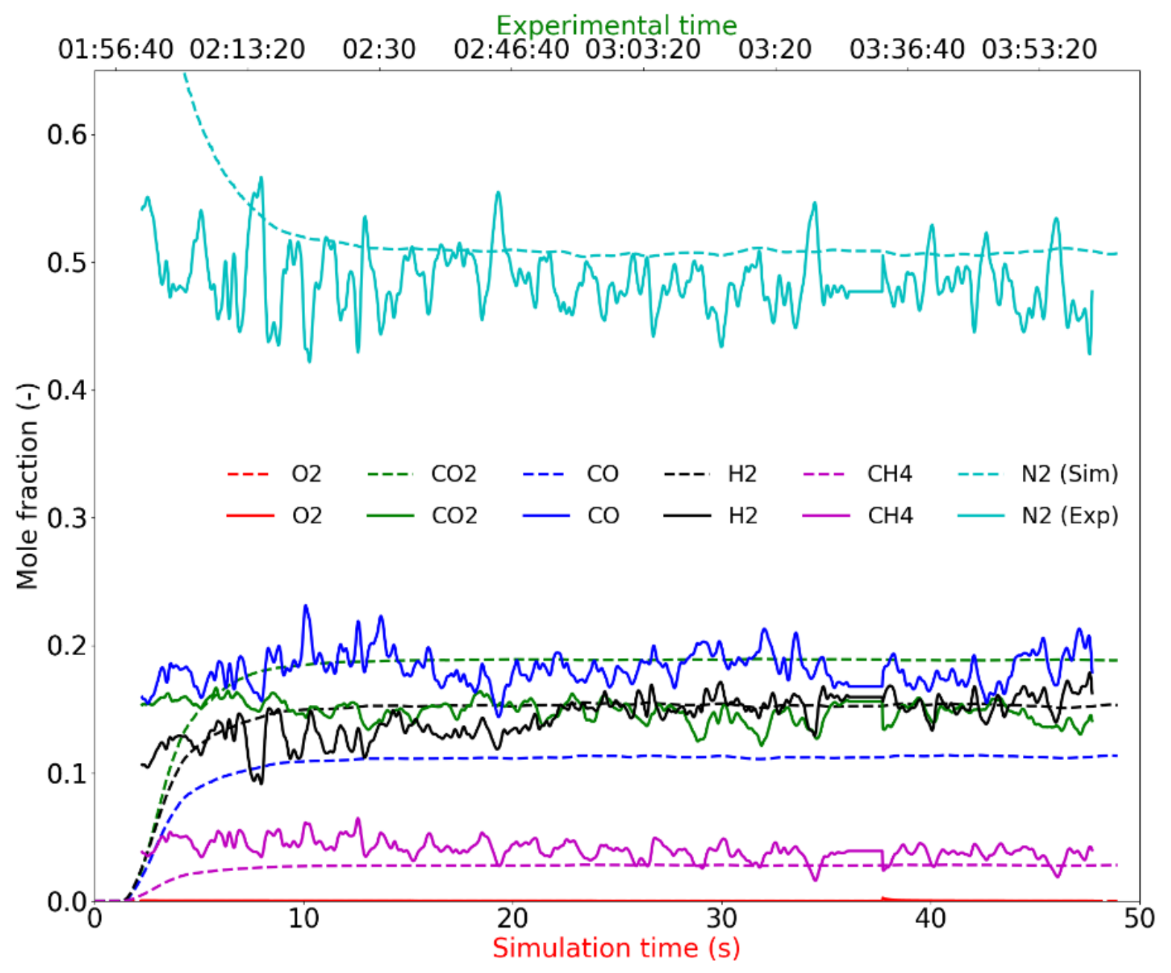
Detailed comparison between the instantaneous pyrolysis vapor between experiment and simulation, which shows that 3 different methods (MFiX-DEM, MFiX-CGDEM, MFiX-PIC) predicted the same results.

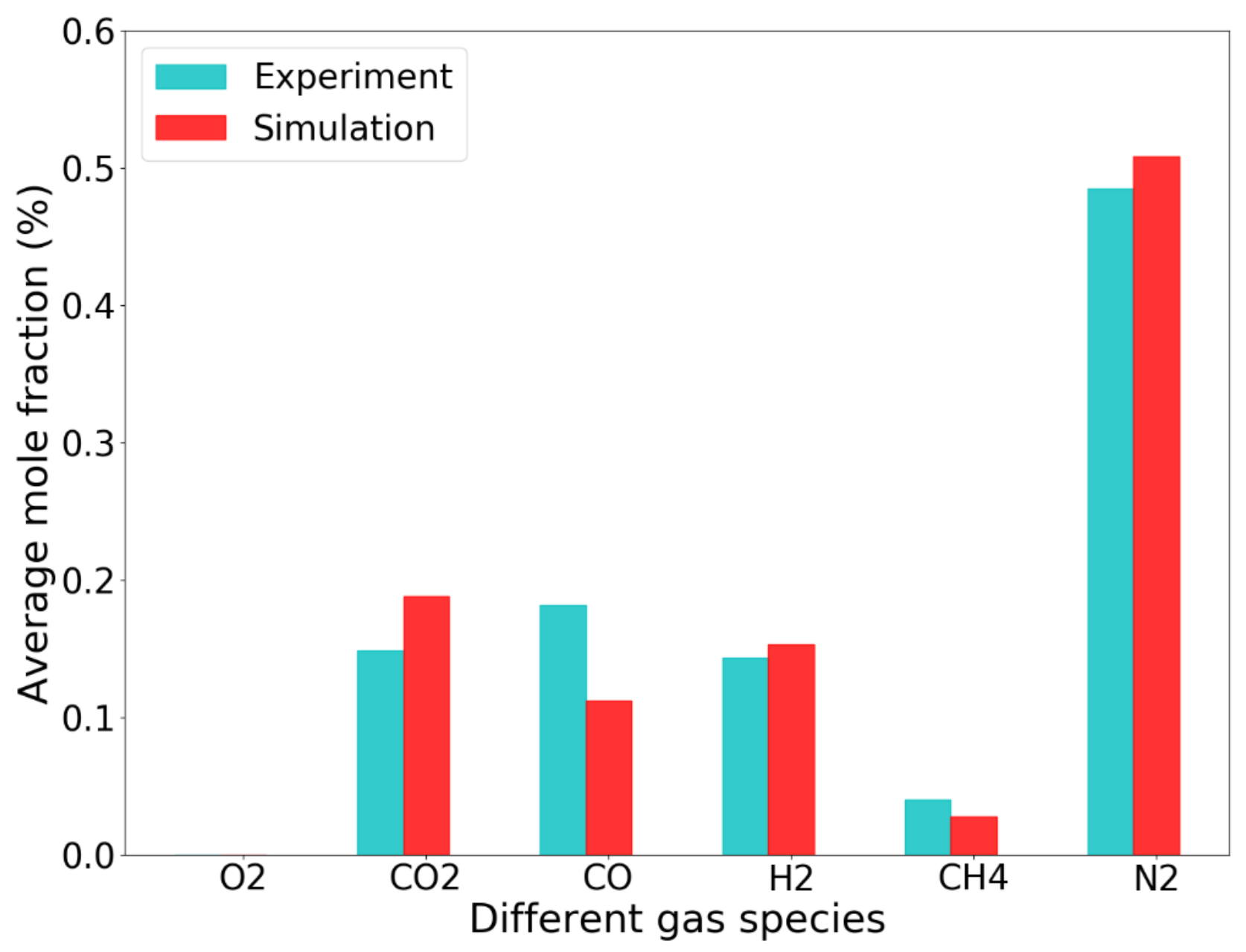
## Numerical simulation of the Biomass Gasification

Simulations are conducted using the U.S. Department of Energy's Multiphase Flow with Interphase eXchanges code, MFIX. The Eulerian-Eulerian, Two Fluid Model in MFiX, (MFiX-TFM) has been used to simulate the drying, pyrolysis, combustion and gasification of the biomass particles. Additionally, homogenous oxidation reactions such as CO, H2 and CH4 oxidation reactions and water gas shift reactions are included. Syngas composition at the outlet of the gasifier is compared with the experimental results.



## Comparison between experiment and simulation





The comparison between the simulation results and the measurements shows very good agreement.

U.S. DEPARTMENT OF ENERGY

MFS NETL Multiphase Flow Science Home of the MFiX Software Suite

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