Three-dimensional simulation of sorbent enhanced gasification

FLEDGED Workshop

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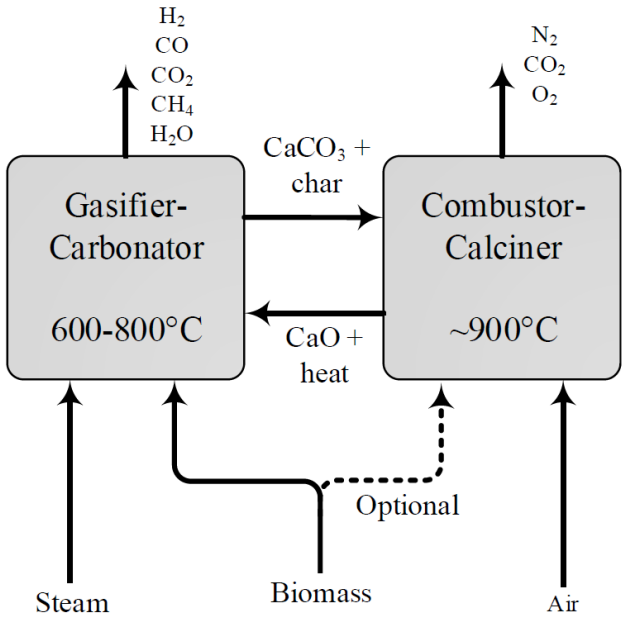
LUT University

Introduction

- FLEDGED:
  Flexible Dimethyl ether production from biomass gasification with sorption enhanced processes
- Modelling activities by LUT:
  - 1D pilot-scale modelling
  - 1D large-scale modelling
  - 3D large-scale modelling

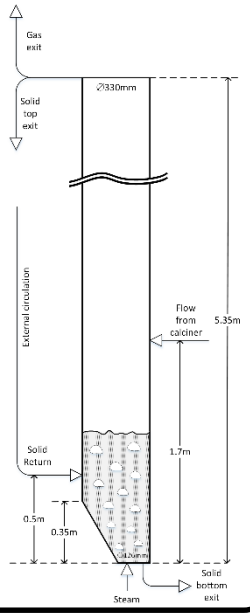


- Focus of this presentation: 3D modelling of a 100 MWth SEG unit.
  - OP1: reference case (M = 2.0)
  - OP10: high temperature case (M = 0.8)

SEG modelling by LUT

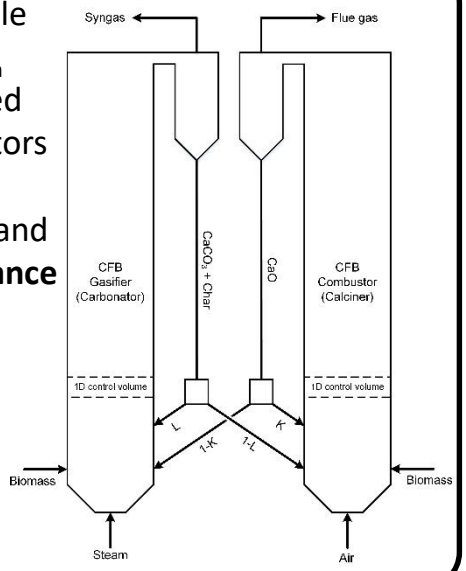
1D pilot-scale model

- Pilot-scale BFB gasifier
- USTUTT geometry
- **Submodel validation studies**



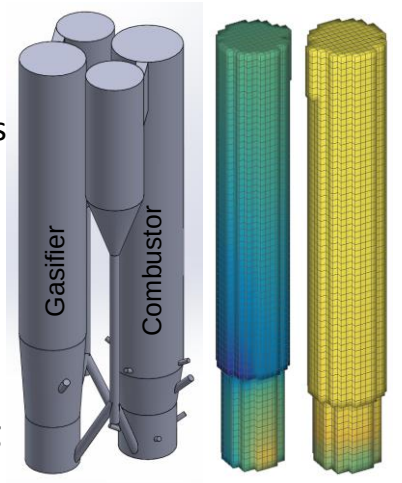
1D large-scale model

- Large-scale 100MW$_{th}$
- Connected CFB reactors
- Scale up and **performance studies**



3D large-scale model

- Large-scale CFB model
- Connected CFB reactors
- **Detailed studies to support reactor design and engineering work**



- Main submodels developed & validated in the project:
  - Fuel decomposition (incl. tar), combustion and gasification reactions.
  - Multiphase flow.
  - Sorbent (limestone) reactions.
  - Homogeneous reactions (e.g. shift conversion).

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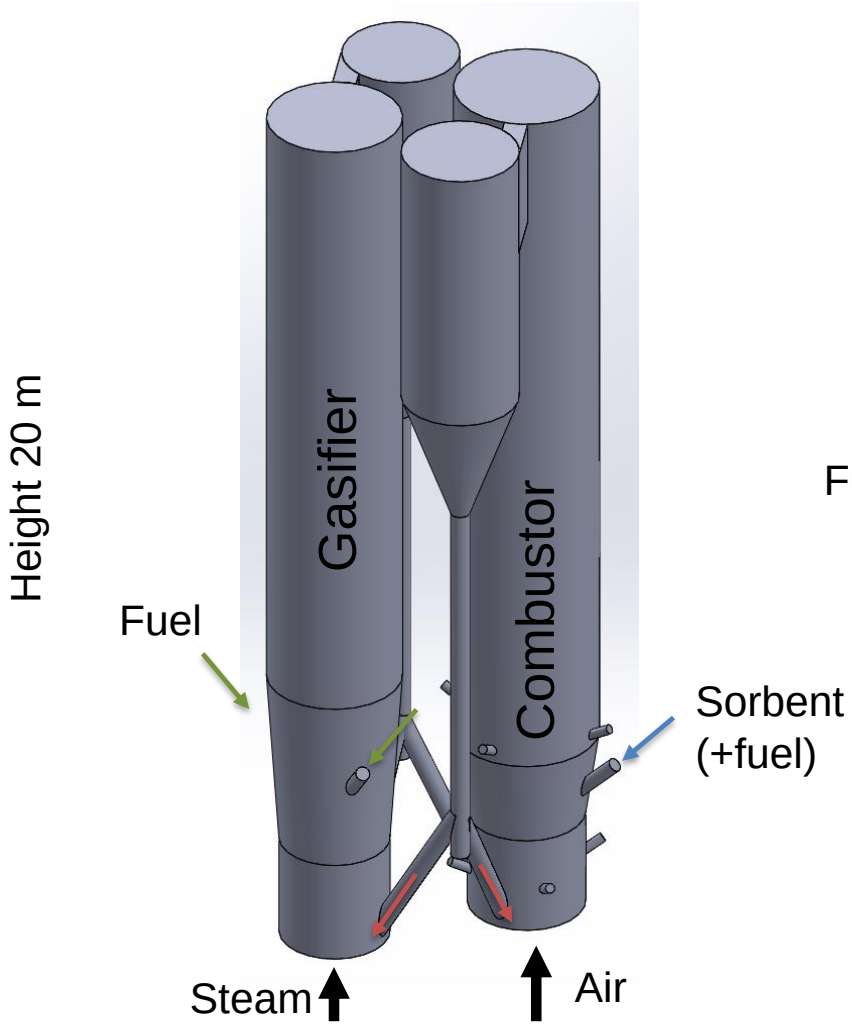
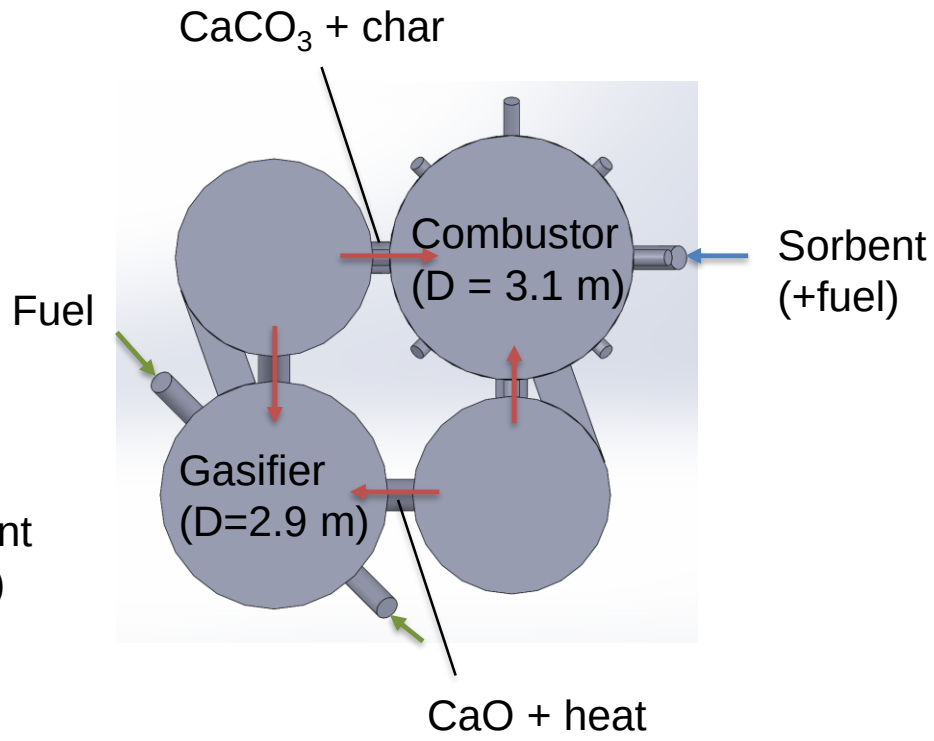
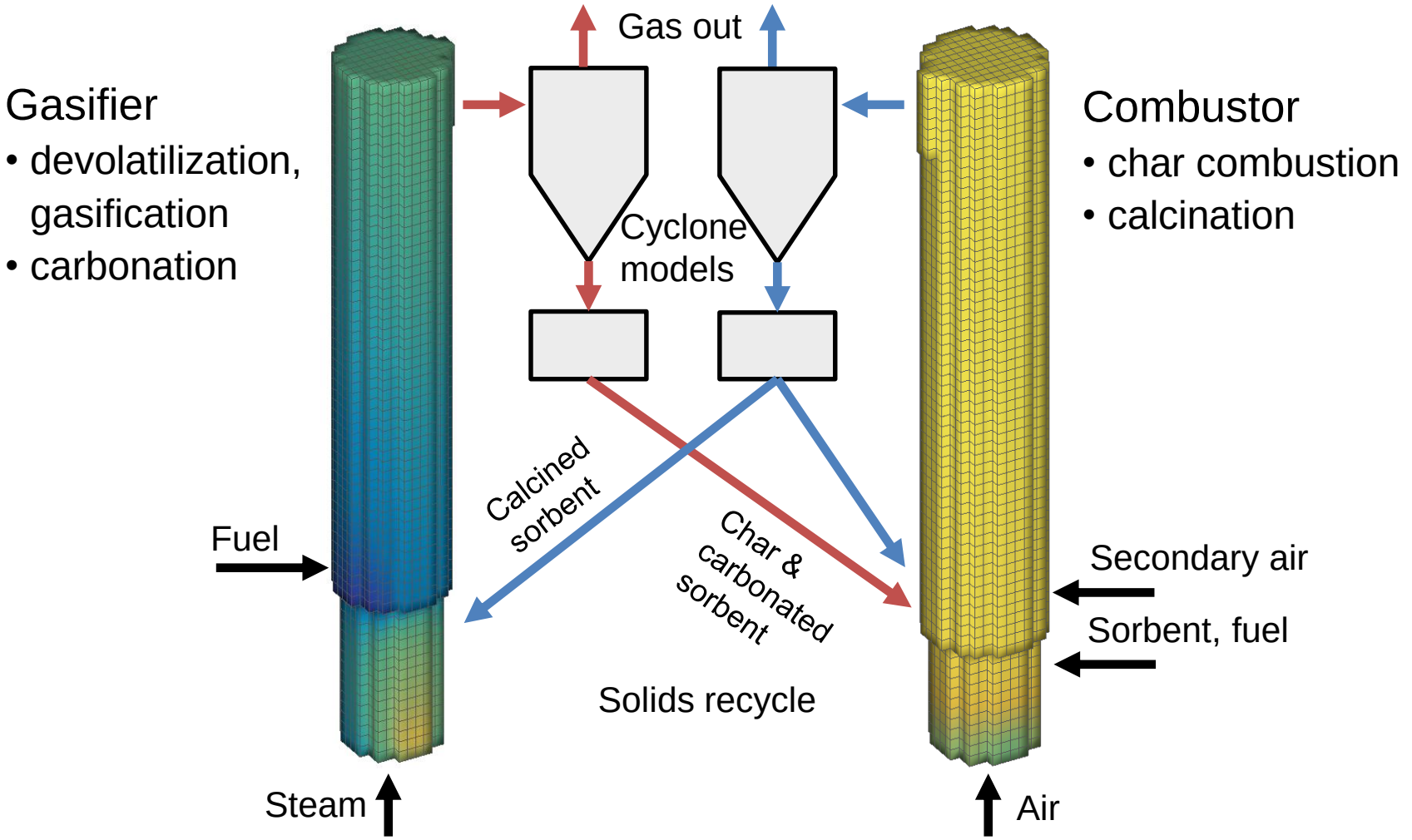
Simplified layout of the 100 MWth SEG unit



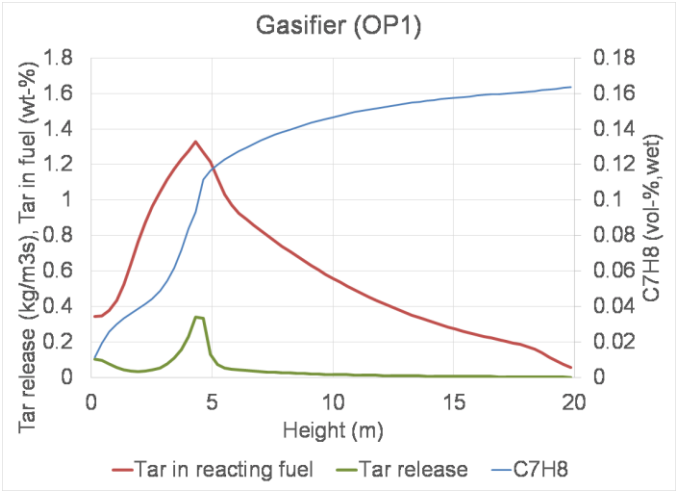


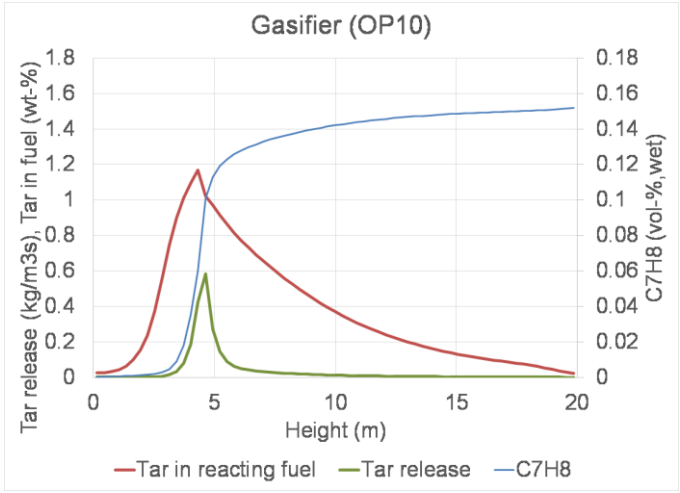
3D model frame



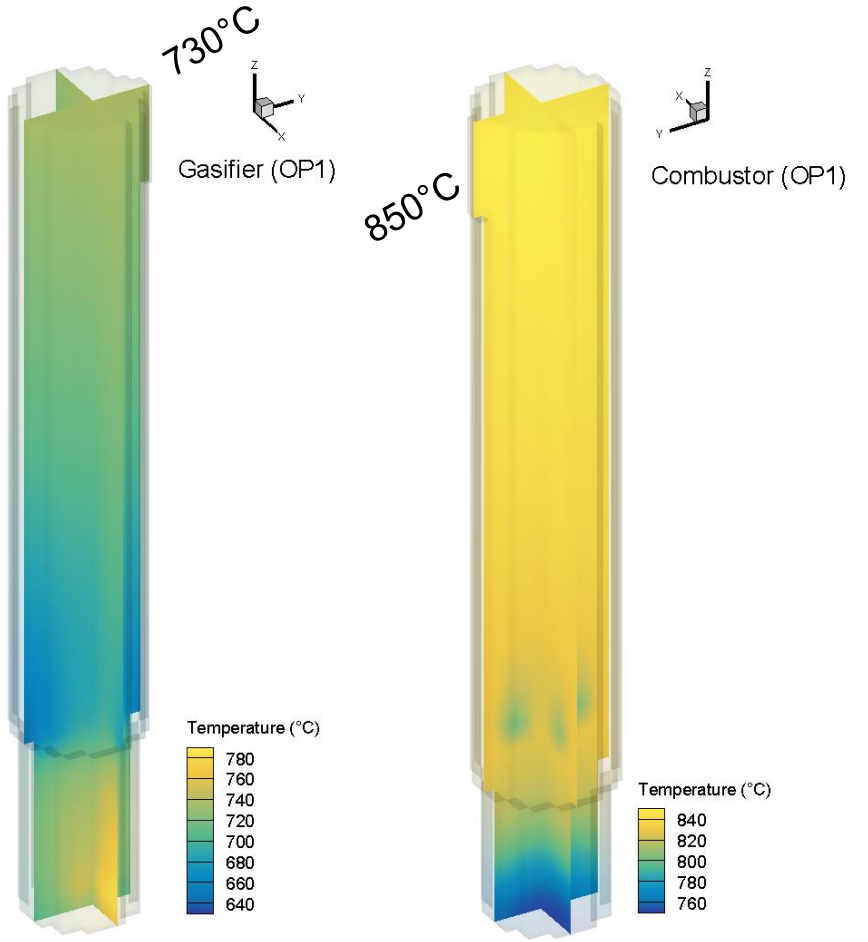
Modelling of tar

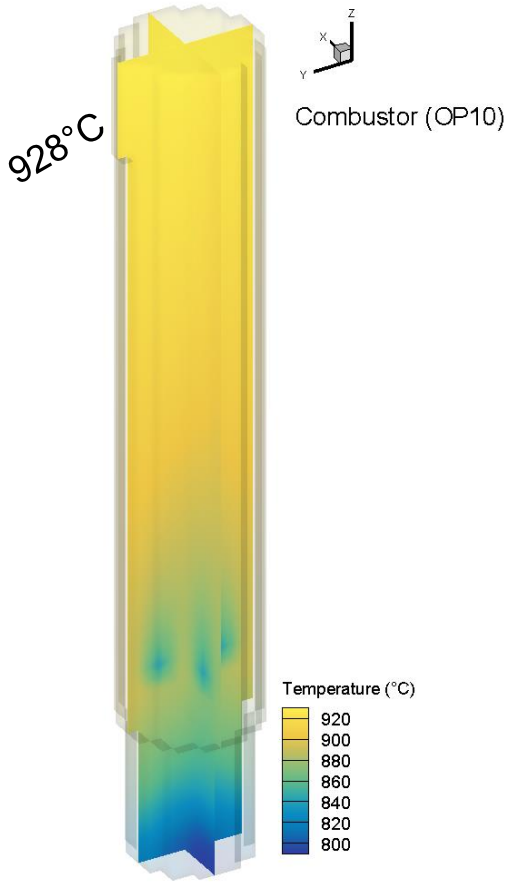
- Tar released to gas phase mainly at the bottom of the gasifier
    - Local maximum at the feeding point.
- At top of the reactor, the unreacting solid fuel is mainly char.
- With higher gasifier temperature, the tar release is faster.





Temperature profiles





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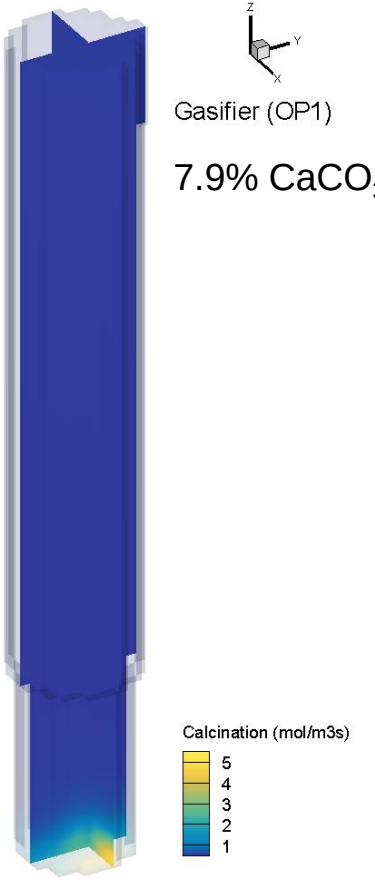
Calcination profiles

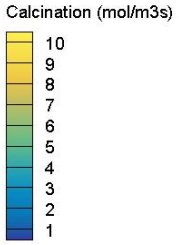


Gasifier (OP1)

7.9% $CaCO_3$

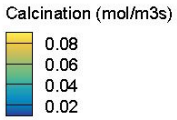
Combustor (OP1)

1.7% $CaCO_3$



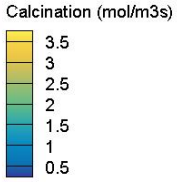
Gasifier (OP10)

1.6% $CaCO_3$

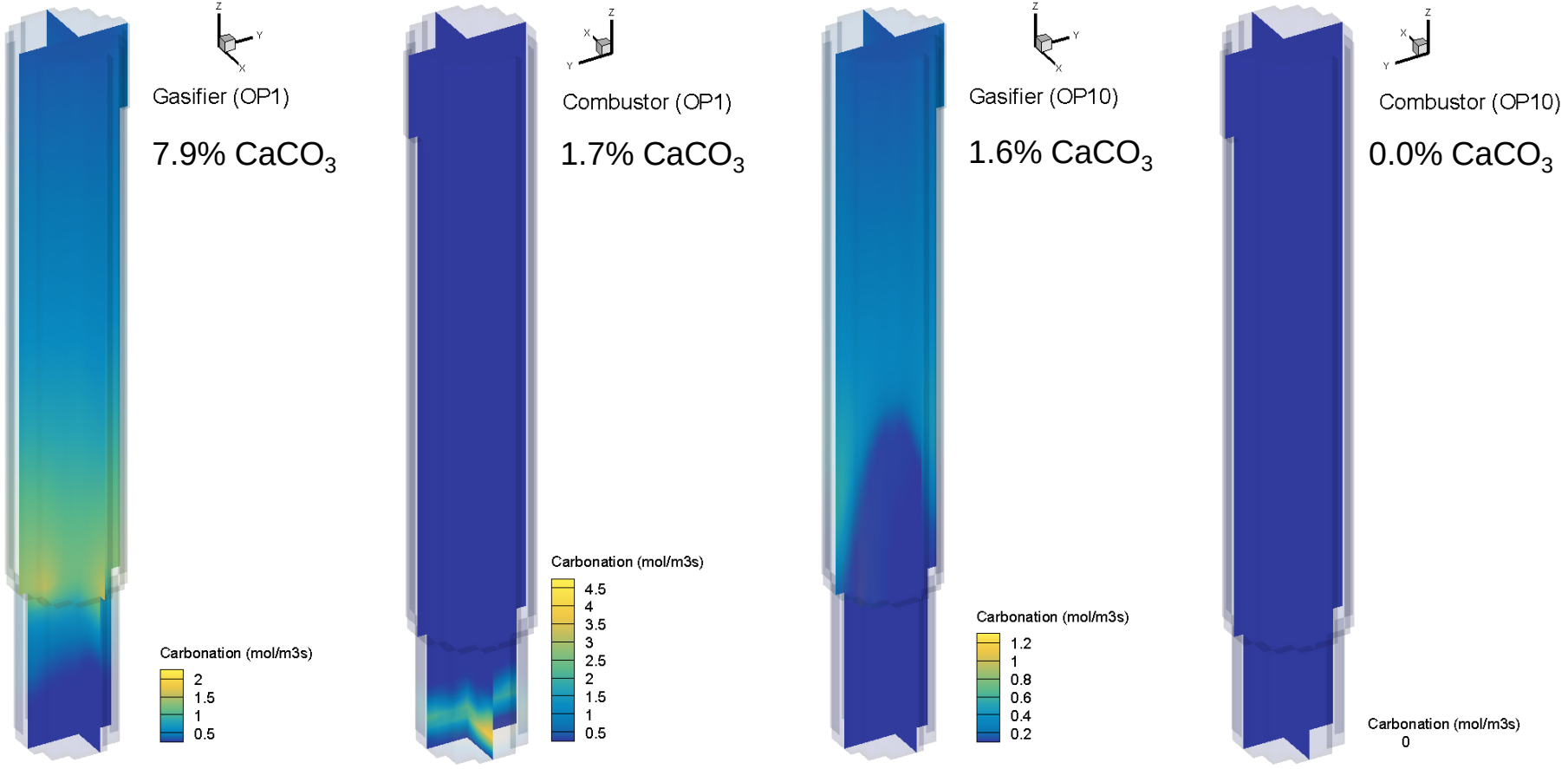


Combustor (OP10)

0.0% $CaCO_3$



Carbonation profiles



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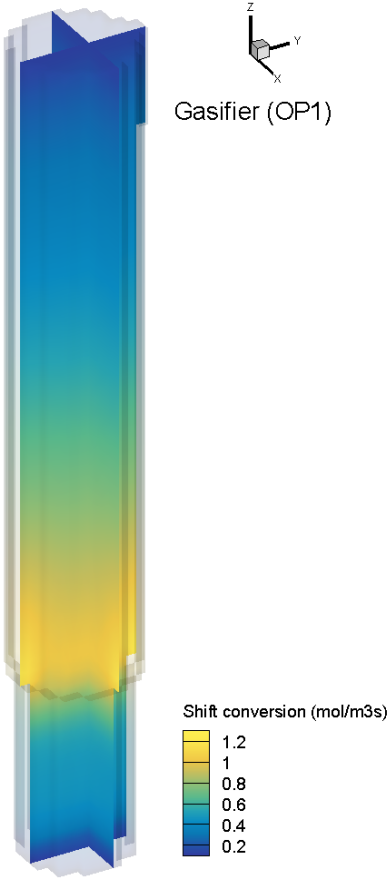
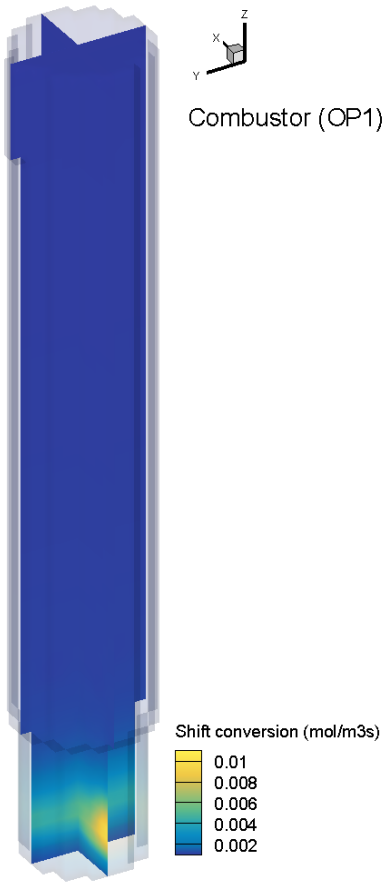
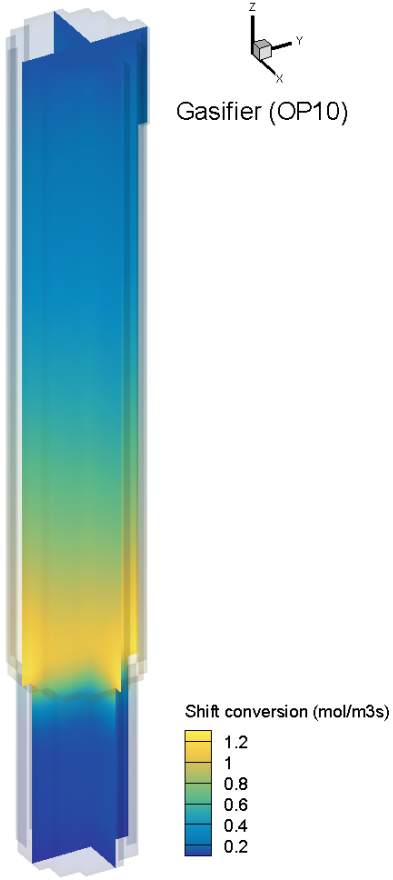
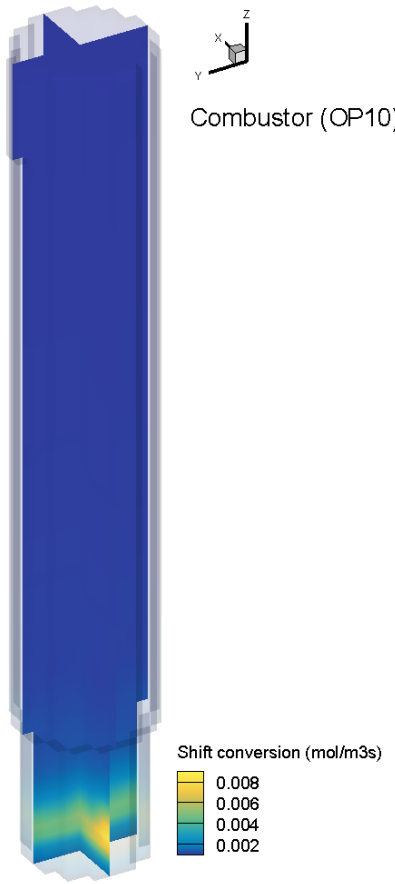
Shift conversion profiles ($CO + H_2O \leftrightarrow CO_2 + H_2$)

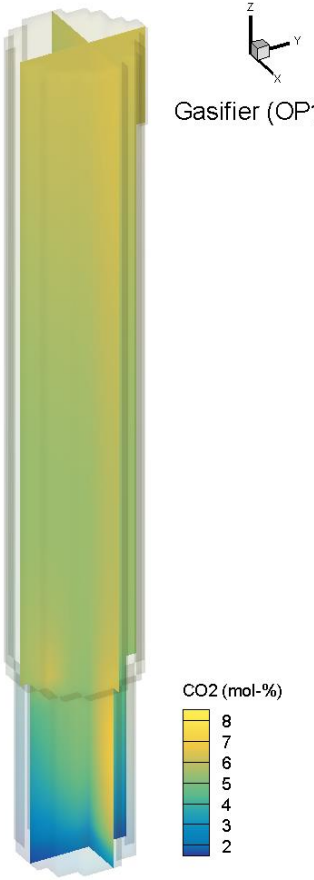




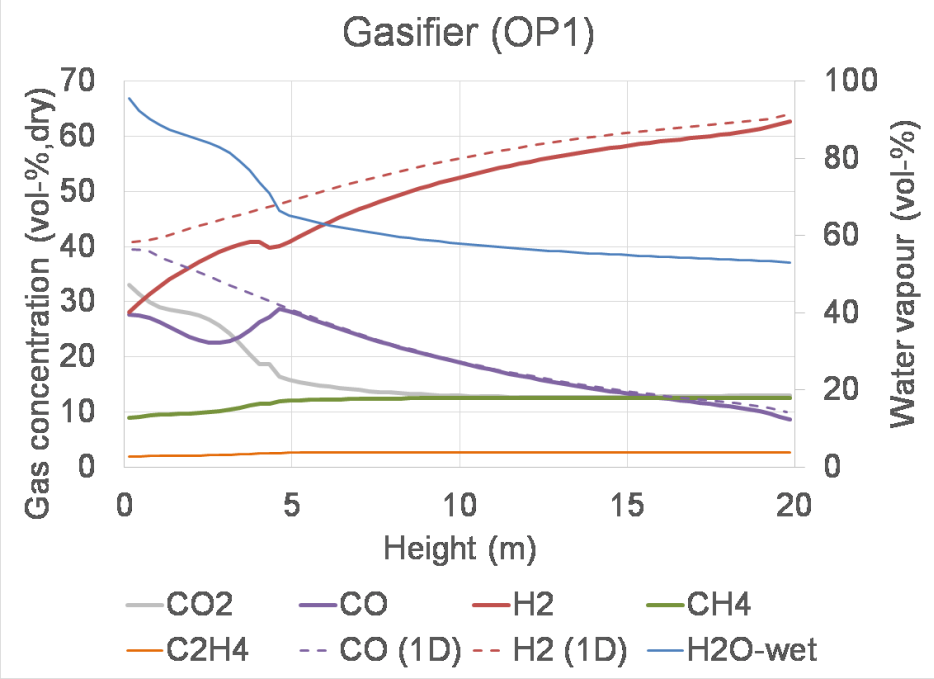


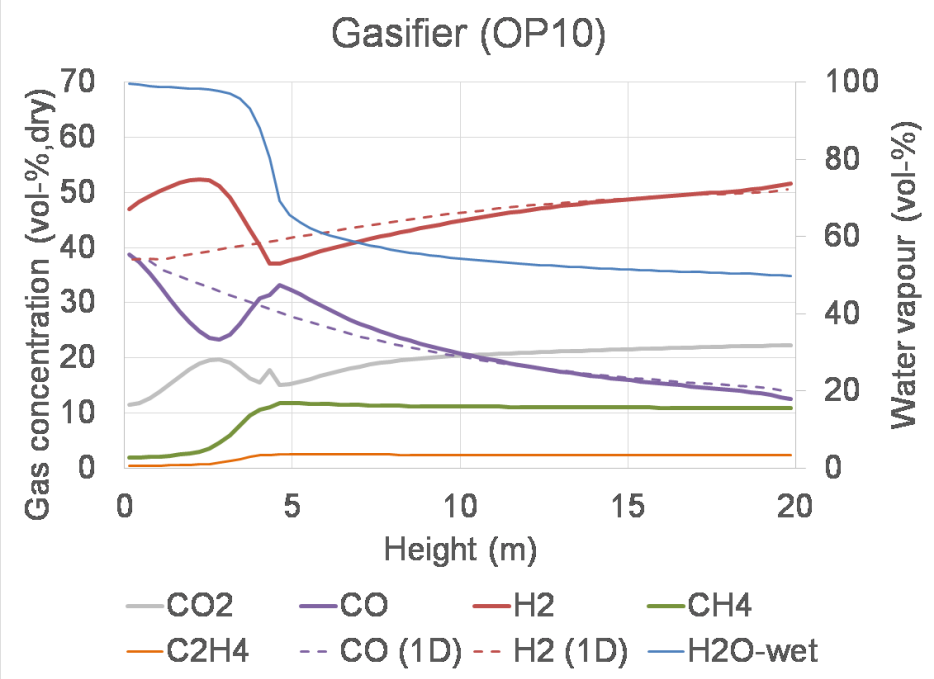


CO_2 profiles



Gas composition profiles of gasifier



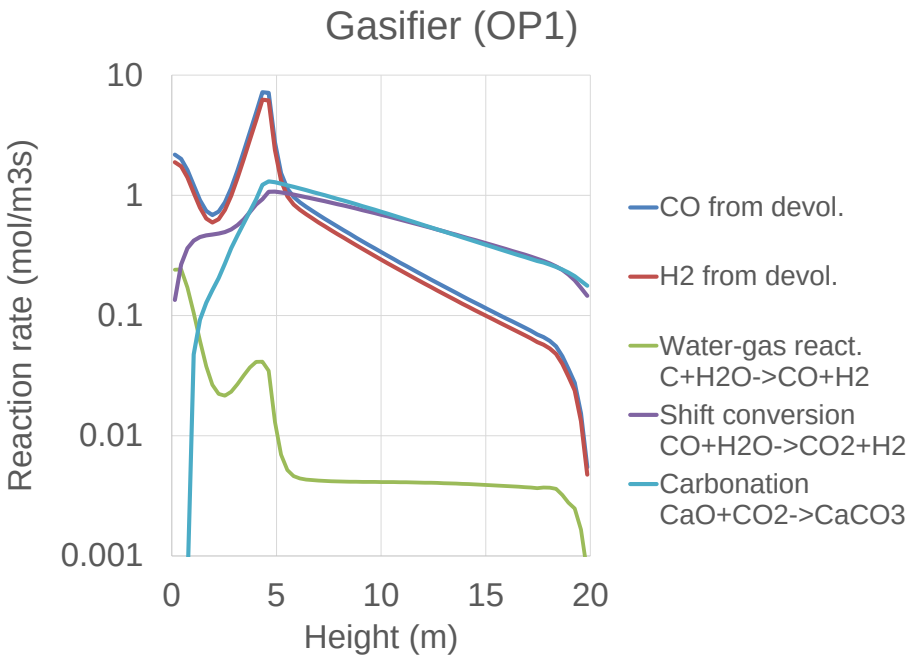


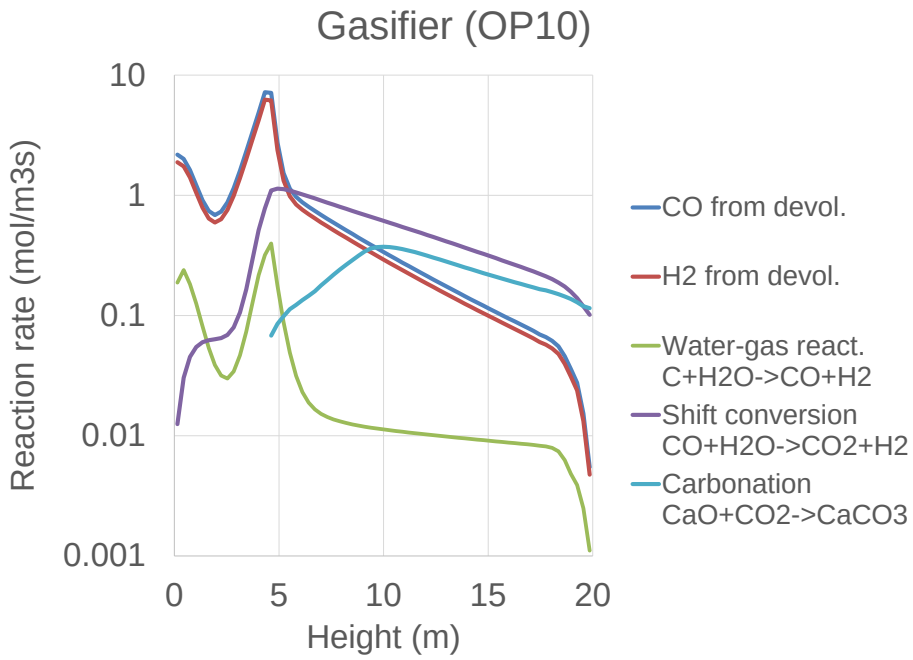
$\mathrm{M} = 2.0$

$\mathrm{M} = 0.8$

$$\mathrm{M} = \frac{H_2 - CO_2}{CO + CO_2}$$

Main reaction profiles of gasifier





Summary

- 1D and 3D models developed for sorbent enhanced gasification.
  - Solution of coupled gasifier-combustor system.
- The 3D-model can be used to study local mixing phenomena inside the reactors.
- The global results were satisfactory: desired producer gas compositions reached.
- The entry points of circulating flow from the adjacent reactor cause local re-calcination and re-carbonation.
- The 3D-model can be utilized for further development of the reactor designs.

Publications related to SEG modelling

- Pitkäoja, A., Ritvanen, J., Hafner, S., Hyppänen, T. and Scheffknecht, G. (2020) *Simulation of a sorbent enhanced gasification pilot reactor and validation of reactor model*, **Energy Conversion and Management** 204:112318. doi:10.1016/j.enconman.2019.112318
- Myöhänen, K., Palonen, J. and Hyppänen T. (2018) *Modelling of indirect steam gasification in circulating fluidized bed boilers*. **Fuel Processing Technology** 171:10-19.
- Pitkäoja, A., Ritvanen, J., Hafner, S., Hyppänen, T. and Scheffknecht, G. *Numerical modelling of sorption-enhanced gasification: Development of a fuel decomposition model*, **Under review in Fuel journal.**
- Ritvanen, J., Myöhänen, K., Pitkäoja, A. and Hyppänen, T. *Modeling of industrial-scale sorption enhanced gasification process: One-dimensional simulations for operation of coupled reactor system*, **To be submitted to Applied Energy**
- Myöhänen, K., Ritvanen, J., Pitkäoja, A. and Hyppänen, T. *Three-dimensional simulations of a 100 MWth sorption enhanced gasification process*, **To be submitted to Fuel journal**

Find out more:	www.fledged.eu
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