BEST
Bioenergy and Sustainable Technologies

NOx Modelling and Emission Reduction

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Outline / Introduction

- Current models for biomass combustion
- Realized projects for small scale furnaces
- Ongoing development
  - New technology with low oxygen concentration in the fuel bed
- Areas of model improvement
  - Gas phase reaction modelling
  - Volatiles release behaviour
- Example of current development
- Summary / Outlook

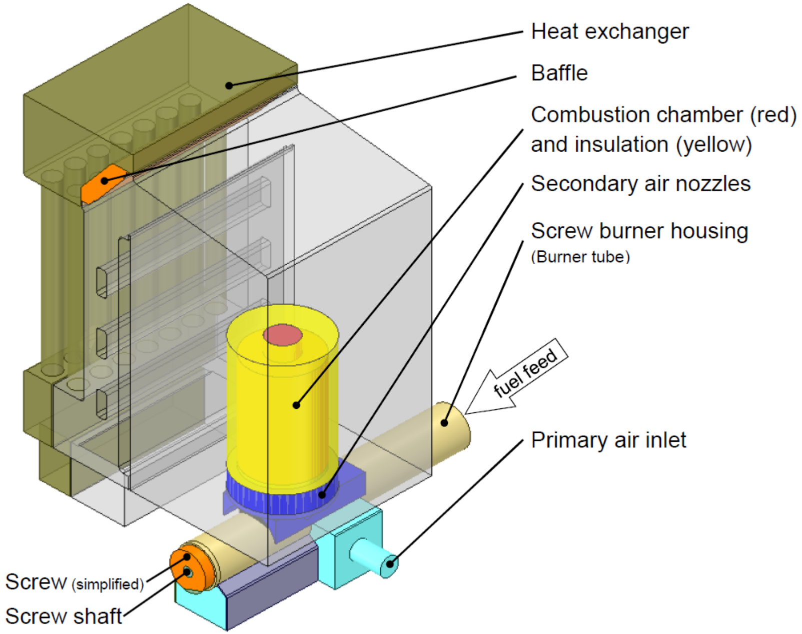
Current models for biomass combustion

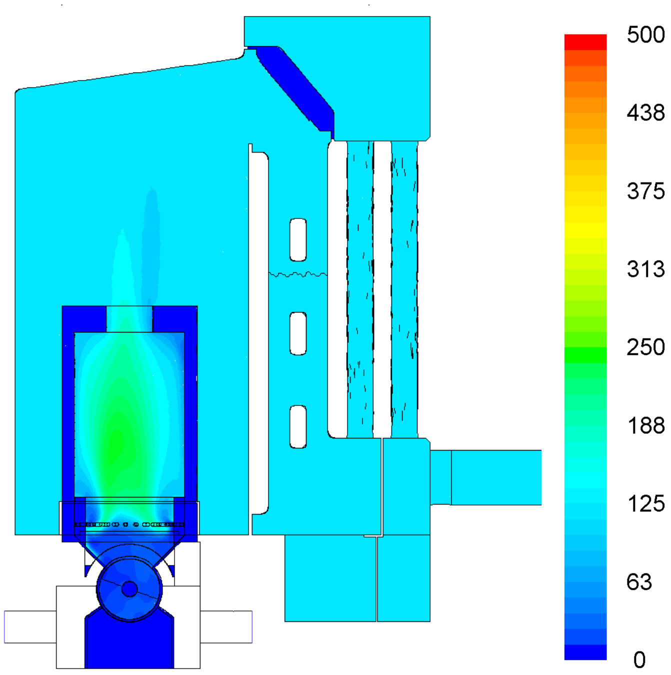
used at BEST research

- Our current models are developed for typical reducing conditions in the fuel bed $(\lambda_{prim} = 0.6 - 0.9)$ of furnaces with air staging.
- The gas phase reactions are modelled via a skeletal reaction mechanism (29 species, 104 reactions).
- The solid biomass is modelled as a discrete phase via representative particles.
- The thermal degradation of the representative particles is realized via a layer approach, where each layer represents a distinct process (drying, pyrolysis, char burnout).
- The models are applied for small and large scale furnaces (30kW – 40MW).

Realized projects with the current models

30 kW screw burner with combustion conditions





Contours of NOx [ppm dry]

Ongoing development

for low oxygen concentrations in the fuel bed - I

- The combustion of cheap fuels with higher nitrogen contents and new legal regulations require a further reduction of NOx and particulate emissions for biomass furnaces.
- For small scale furnaces secondary measures are currently too expensive.
- Therefore new technologies which apply cheaper primary measures are under development → double air staging with flue gas recirculation (FGR)

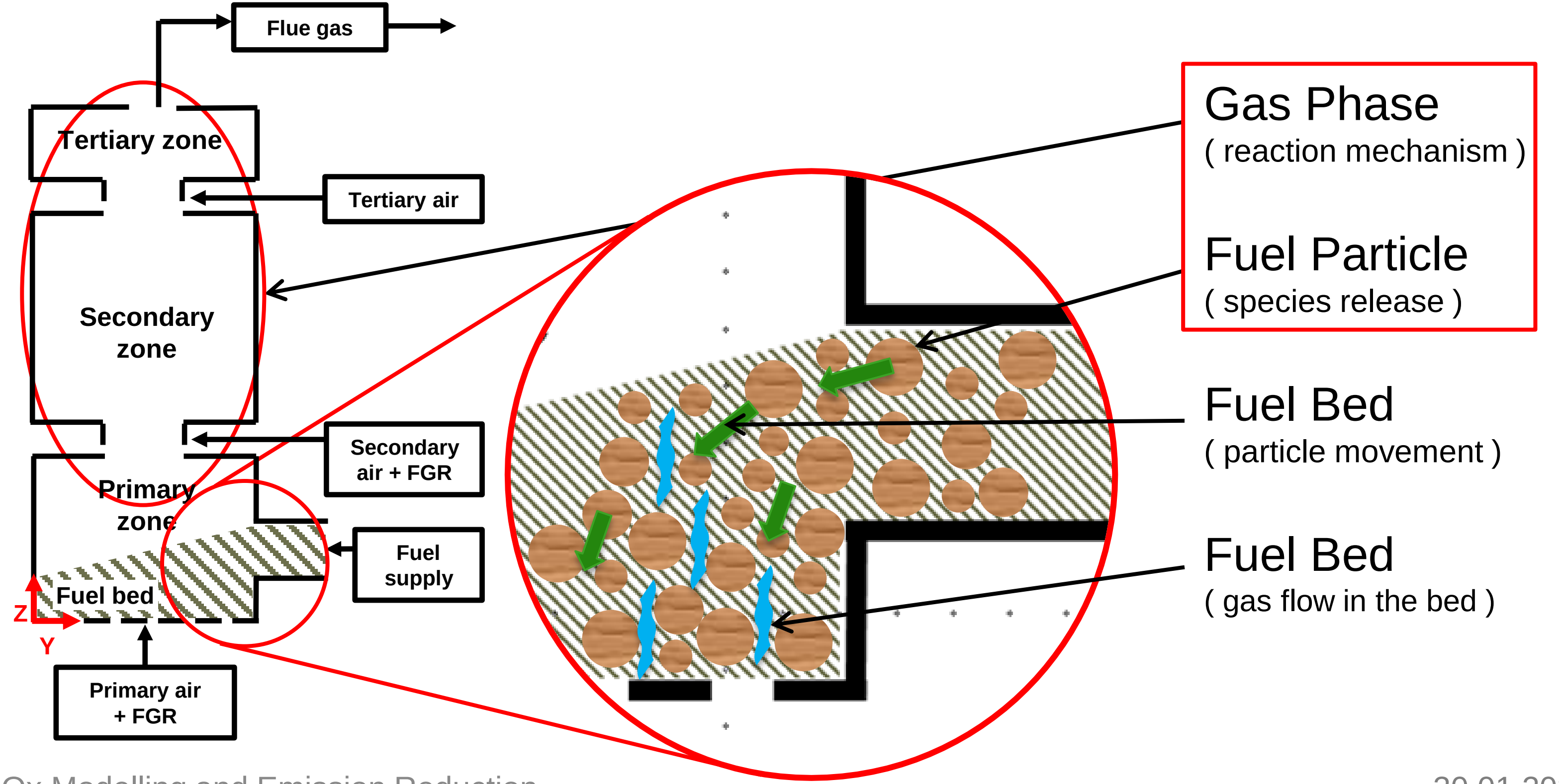
Ongoing development

for low oxygen concentrations in the fuel bed - II

- Advantages:
  - Reduced particulate matter (fine dust) emissions and slag formation due to lower fuel bed temperatures
  - Reduced NOx emissions due to reducing conditions in the primary and secondary combustion zone
- Disadvantages:
  - Tar formation and cracking has to be considered → higher reaction times are needed
  - Soot formation and decomposition has to be considered
  - Increased fuel bed height → slow response, sluggish combustion

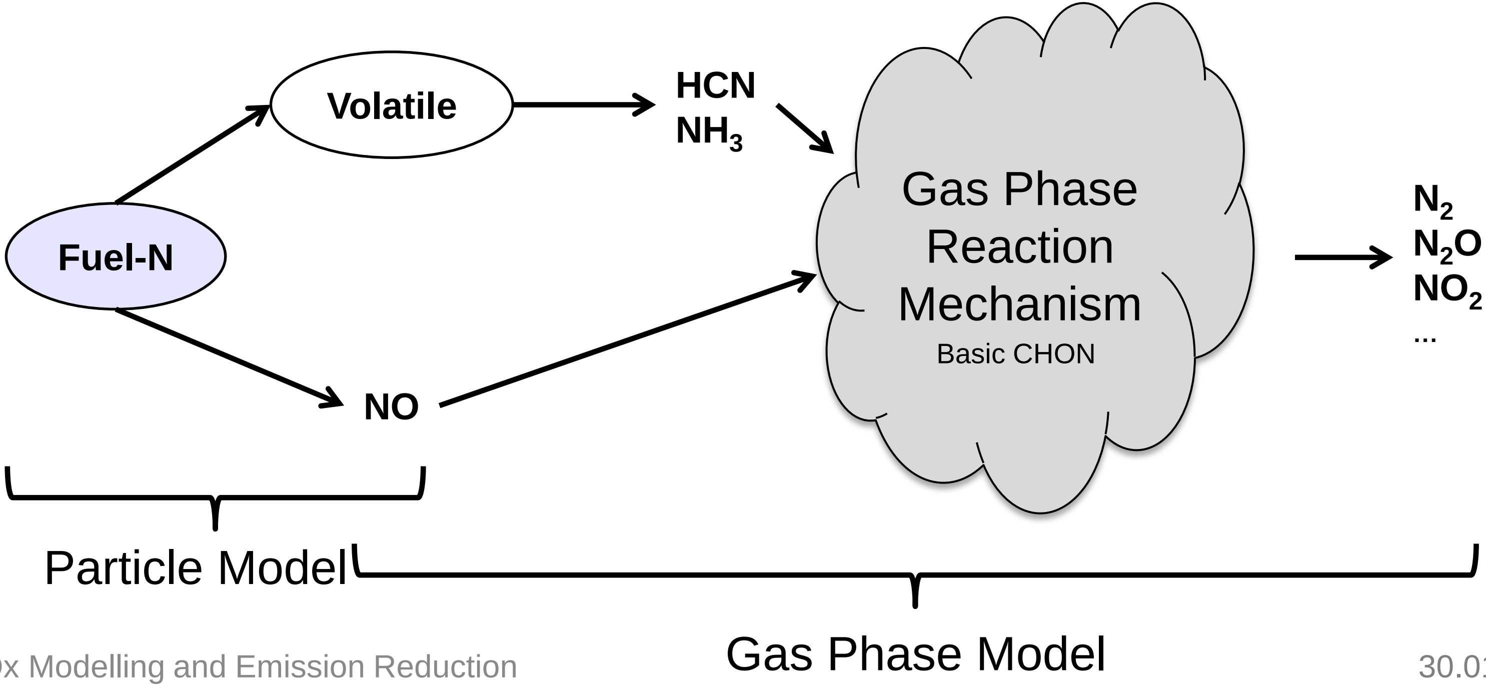
Areas of model improvement

for low oxygen conditions in the fuel bed



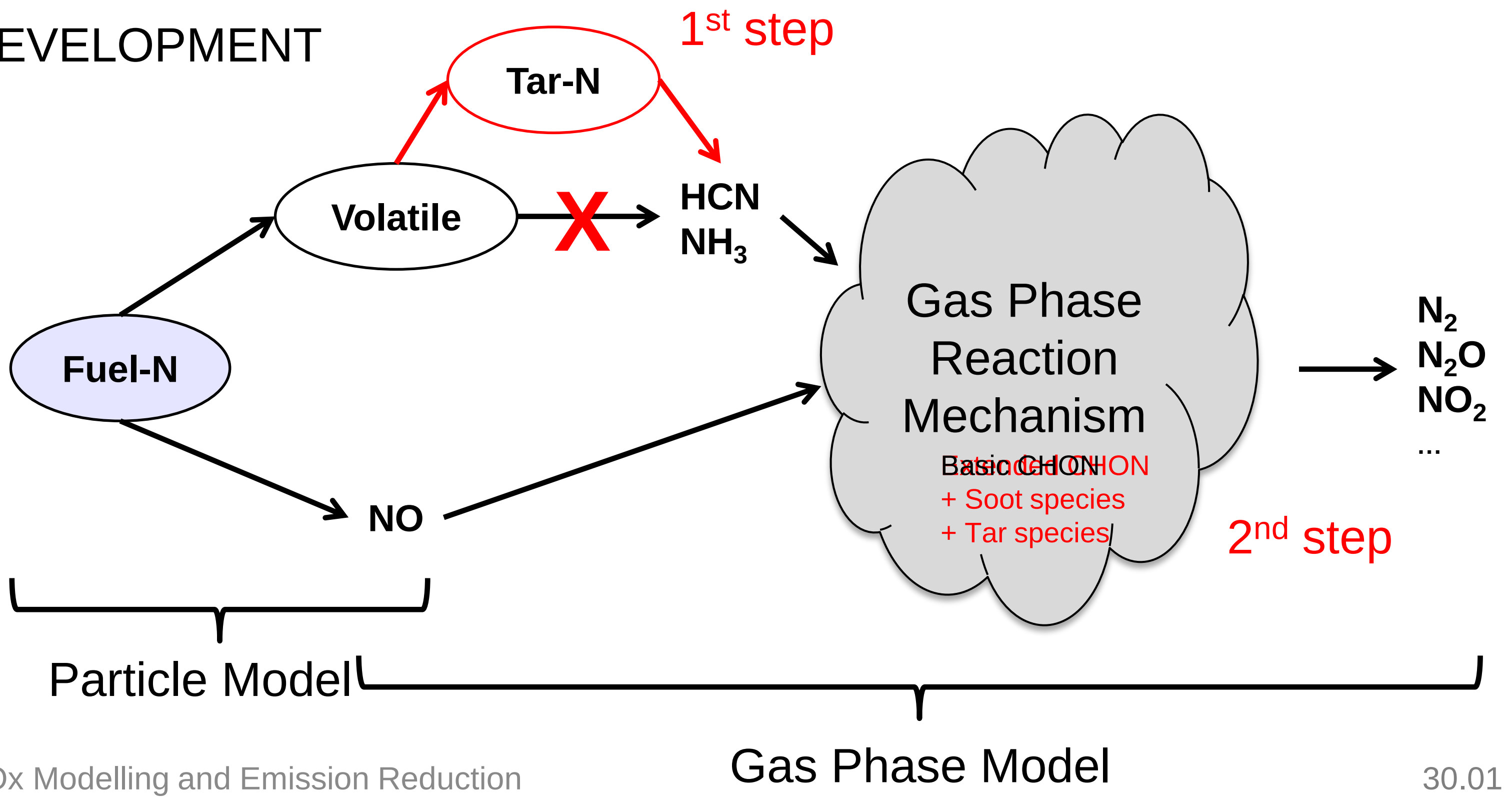
Modelling the gas phase
reaction mechanism – applied in projects

APPLIED



Modelling the gas phase
reaction mechanism – under development

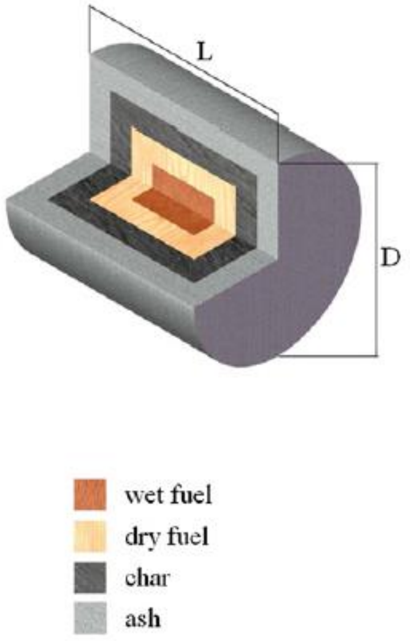
DEVELOPMENT



Modelling the fuel particles

species release

- The layer approach for the representative particles is adopted.
- The currently applied models are developed for combustion conditions.
- The intra particle transport processes, reactions and species release have to be adapted to describe the gasification conditions in the bed:
  - The char gasification reactions have to be adapted and extended

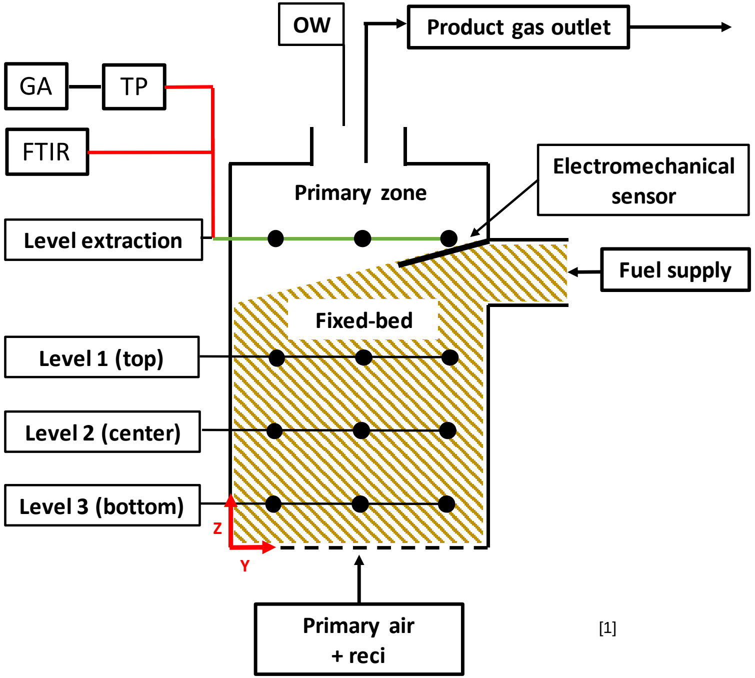


Example of current development

small scale application - experimental test run

Operating conditions

- Fuel: spruce wood chips
- Moisture content: 8.04 m.%w.b.
- Fuel-N: > 0.1 m.%d.b.
- Fuel flow rate: 6.78 kg/h w.b.
- Primary air ratio: 0.2
- Secondary air ratio: 0.8
- Total air ratio: 1.8



[1]

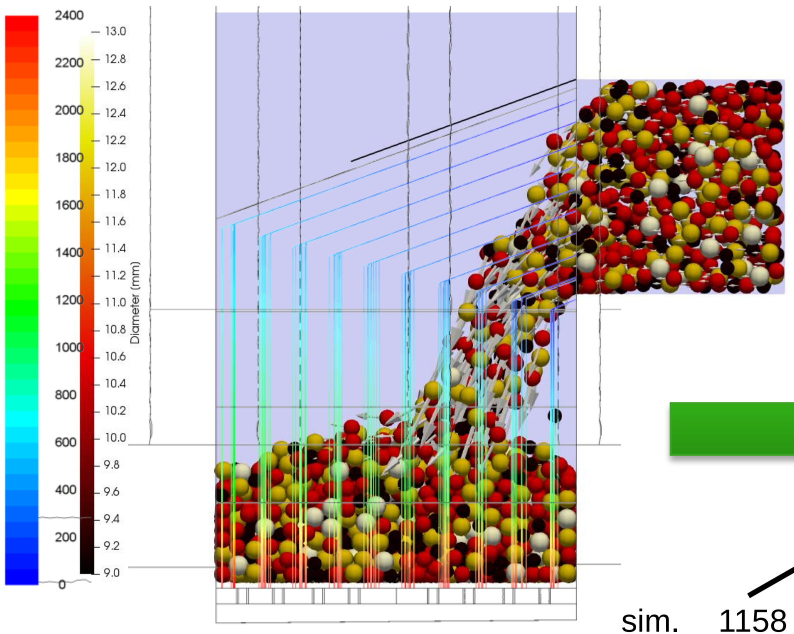
[1] G. Archan et.al., "Detailed Experimental Investigation of the Spatially Distributed Gas Release and Bed Temperatures in Fixed-Bed Biomass Combustion with Low Oxygen Concentration," Proceedings of the 27th European Biomass Conference and Exhibition, EUBCE 2019, Lisbon, Portugal, May 27-30, 2019 , pp. 447–453, 2019.

Example of current development

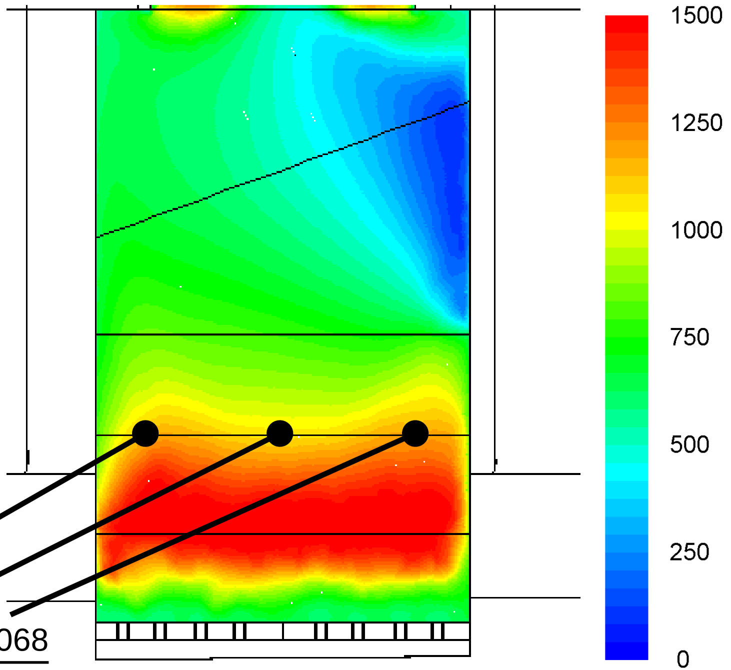
small scale application - modelling process and simulation results

Residence time distribution [s]

Discrete Element Simulation



Temperature distribution [C]



sim.	1158	1064	1068
exp.	928	1057	1037

Summary / Outlook

- The experiments showed promising results and the technology outperforms the state of the art concerning NO_x emissions. [2]
- The current simulation models that are designed for combustion conditions were adapted.
  - Extension of the gas phase reaction mechanism to include tar, C_2H_4 and soot species.
  - Adaption of the intra particle reactions and species release from the particle model.
- These modifications will then give a better match with the measured data and consequently support the understanding of the processes in the plant.

[2] G. Archan et.al., "Experimental analysis and optimization of a new 30 kW multi-fuel low-emission combustion technology," 6th Central European Biomass Conference, CEBC 2020, Graz, Austria, January 22-25, 2020