

# Numerical Analysis of Interaction between a Reacting Fluid and a Moving Bed with Spatially and Temporally Fluctuating Porosity



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**01. (X)DEM-CFD COUPLING**  
XDEM-OpenFOAM direct coupling

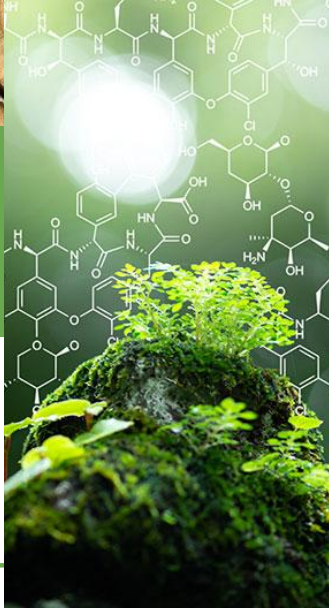
**02. BIOMASS CONVERSION APPROACH**  
Concept and modelisation

**03. MODELING SETUP**

**04. PRELIMINARY RESULTS**

**05. SUMMARY**  
Conclusion and future directions





## INTRODUCTION

Biomass combustion is widely used for generating electricity in geothermal plants. The combustion process, is very complex and requires advanced techniques to minimize harmful gas emissions.

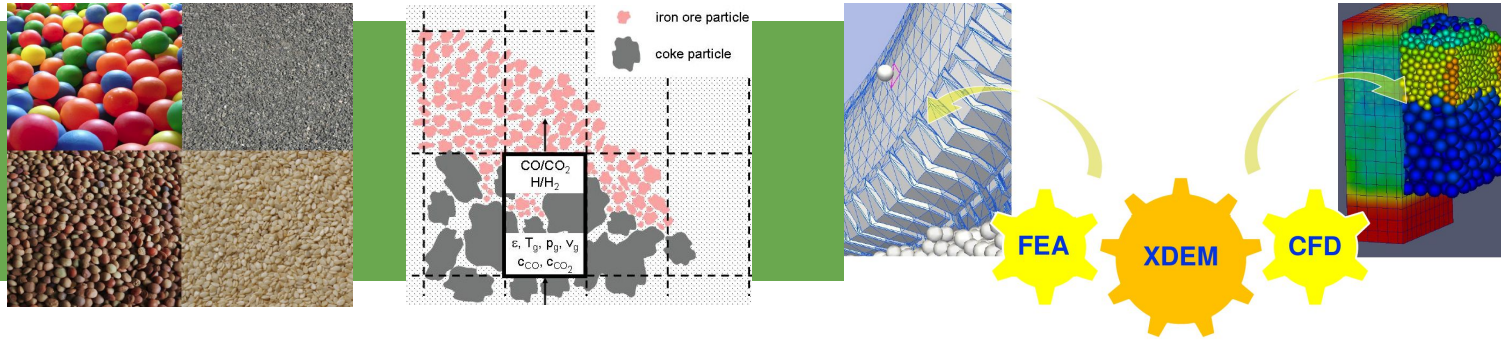
Efficiency and performance within a combustion chamber can be studied from a physical and numerical model to predict the combustion productivity and to reduce the costs of experiments.

# 01

## **(X)DEM-CFD Coupling**

A 2 way coupling with  
XDEM and OpenFOAM

# eXtended Discrete Element Method (XDEM)



## Dynamic

## Conversion

## FEA-coupling

## CFD-coupling

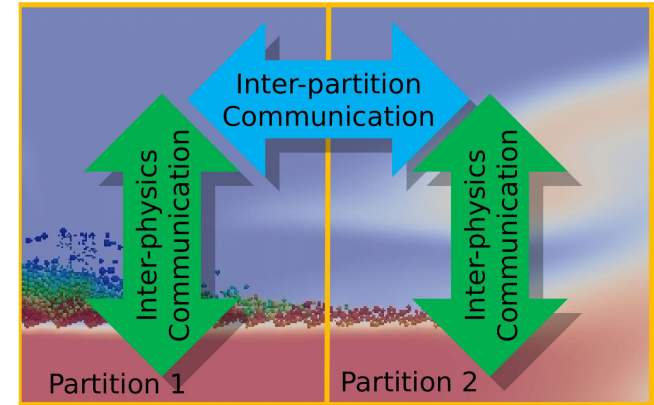
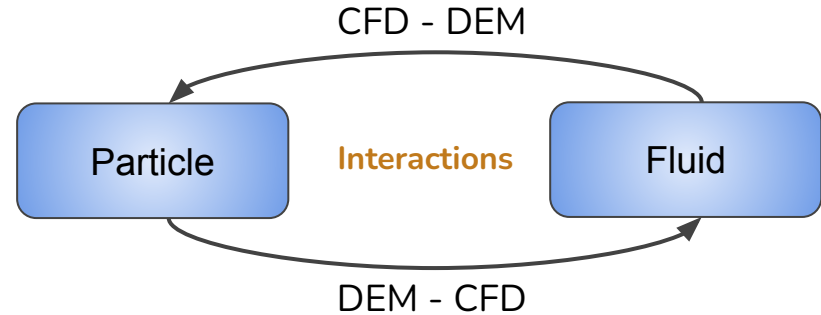
Extended Discrete Element Method:

- Based on the classical Discrete Element Method (DEM) to describe motion of granular materials (discrete phase)
- Extended by
  - Thermodynamics for particles
  - An interface to Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA)
- Coupling to external commercial/OpenSource software

## 2-Way coupling

2-way coupling approach:

- (X)DEM for:
  - wood particles motion (Lagrangian approach)
  - Conversion (thermodynamics state)
- OpenFOAM for gas phase (Eulerian approach)



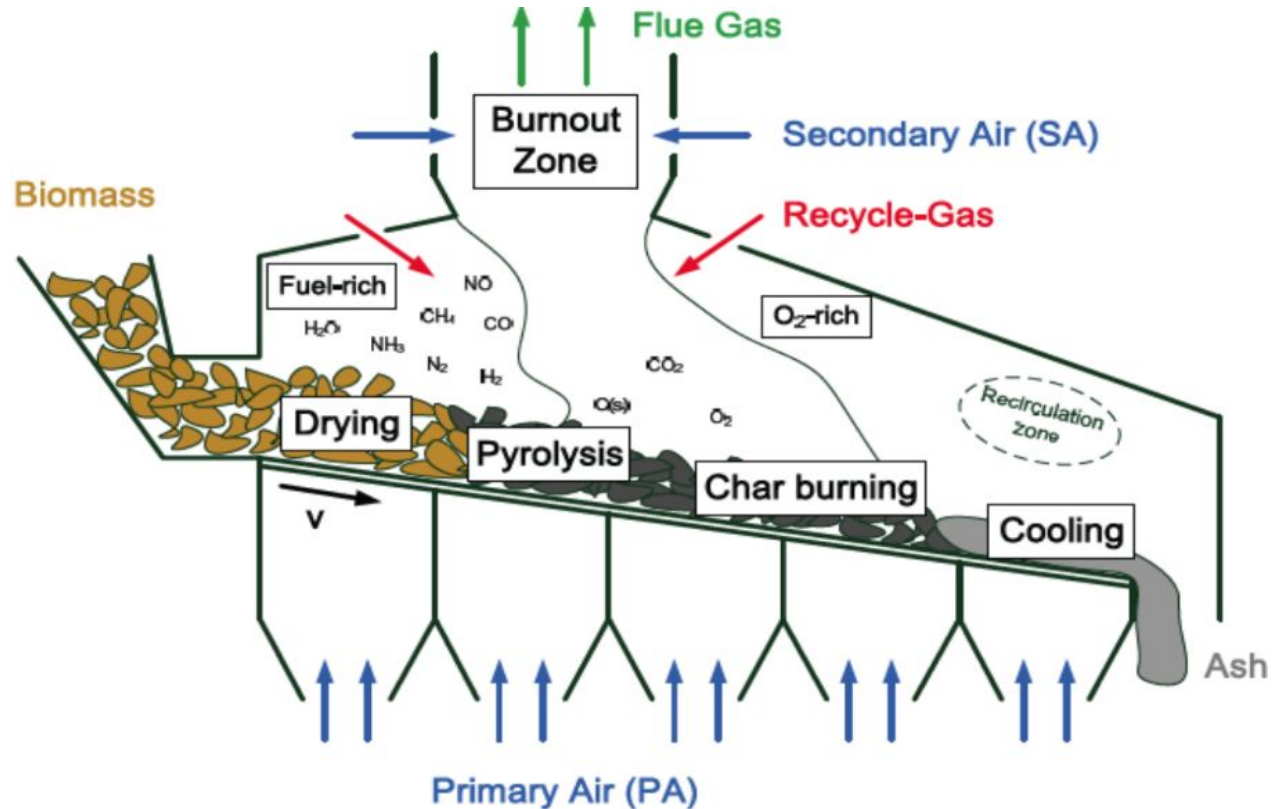
# 02

## **Biomass conversion approach**

Concept

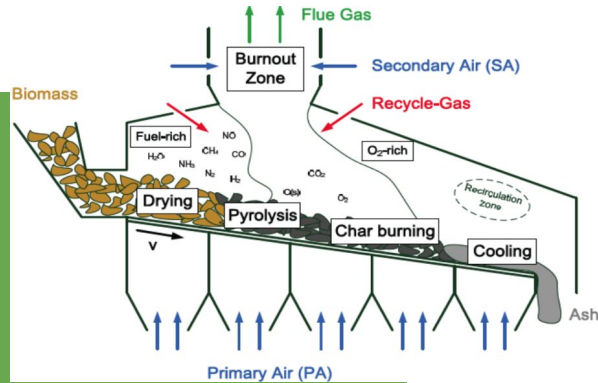


# BIOMASS





# BIOMASS DECOMPOSITION



Name	Enel Green Power "Cornia 2"
Power	16MW combustion chamber
Location	Italy

## DRYING

Evaporation of bound water

## PYROLYSIS

Wood => Char, CO, CH<sub>4</sub>, H<sub>2</sub>, Tar

## CHAR BURNING

Char => CO, CO<sub>2</sub>

## COOLING

Ash remains

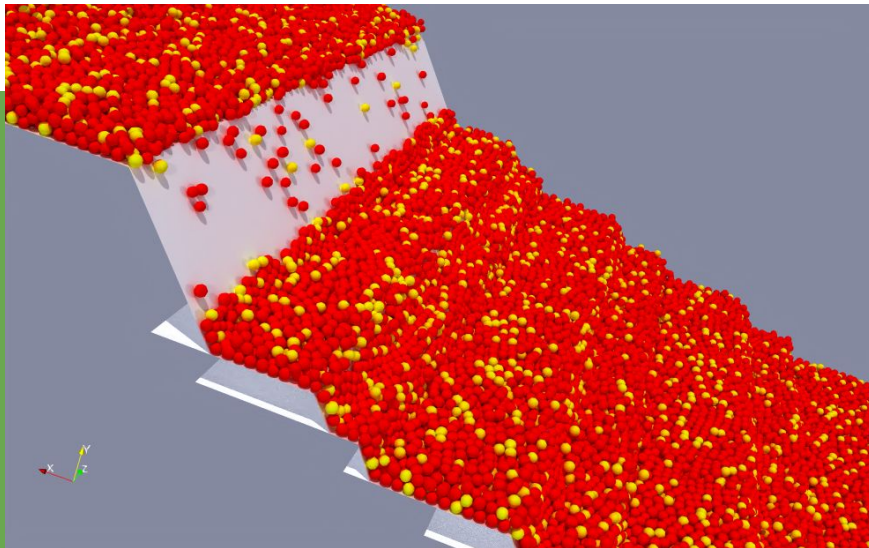
# 03

## Modeling Setup

Biomass

# SIMULATION SETUP

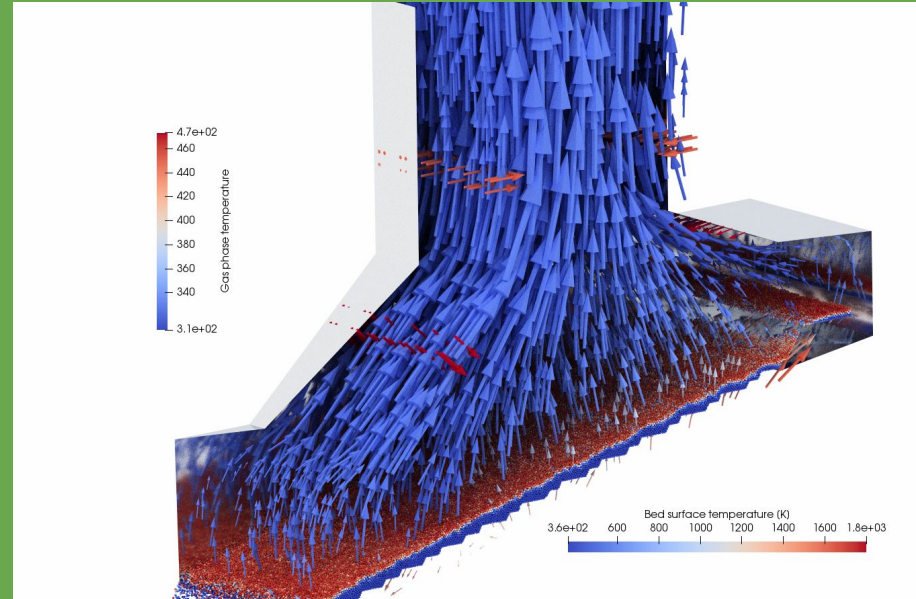
- piecewise motion set to the moving steps of the grate (period=90 sec., 80% forward – 20% backward, phase shift of 30 sec. between the tree step series)



- Spherical wood chips (red) ( $D_p=30\text{ mm}$ )
- Spherical agricultural residues (yellow) ( $D_p=30\text{ mm}$ )

# NUMERICAL APPROACH

- Coupling of XDEM-OpenFOAM
- Multi-phase, multi-scale and multi-species approach
- DEM for particles motion on forward acting grates
- XDEM  $\rightarrow$  thermal conversion(Radiation + Conduction + Conversion)
- CFD for gas flow in void space of moving bed
- Interaction between solid and gas phase through
  - Heat transfer
  - Mass transfer
  - Momentum transfer
- Simultaneous coupling between solid and fluid phase



- ~300 000 particles
- 100 000 DEM cells
- 88 000 CFD cells

# 04

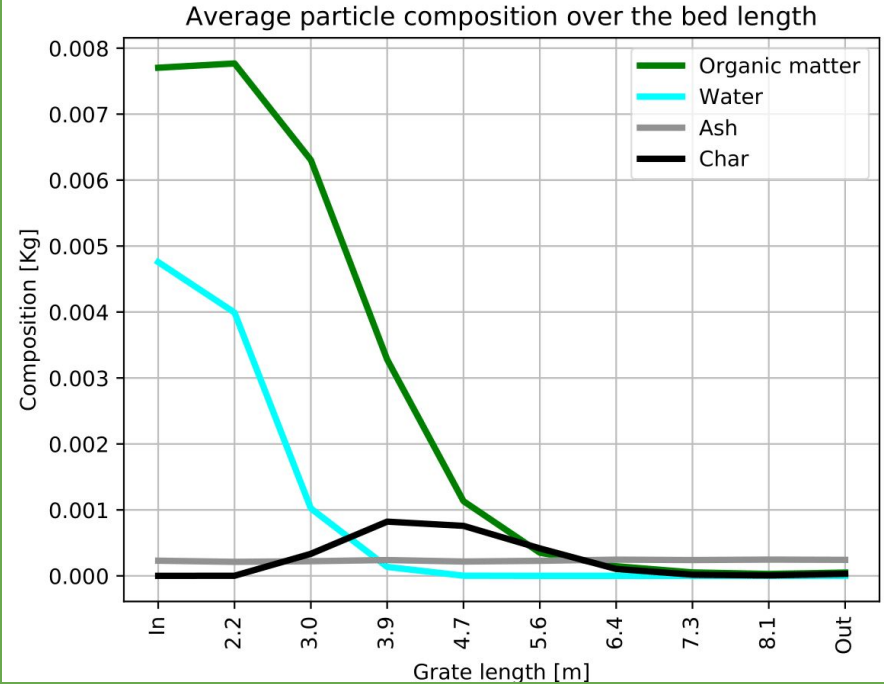
## Preliminary Results

Biomass

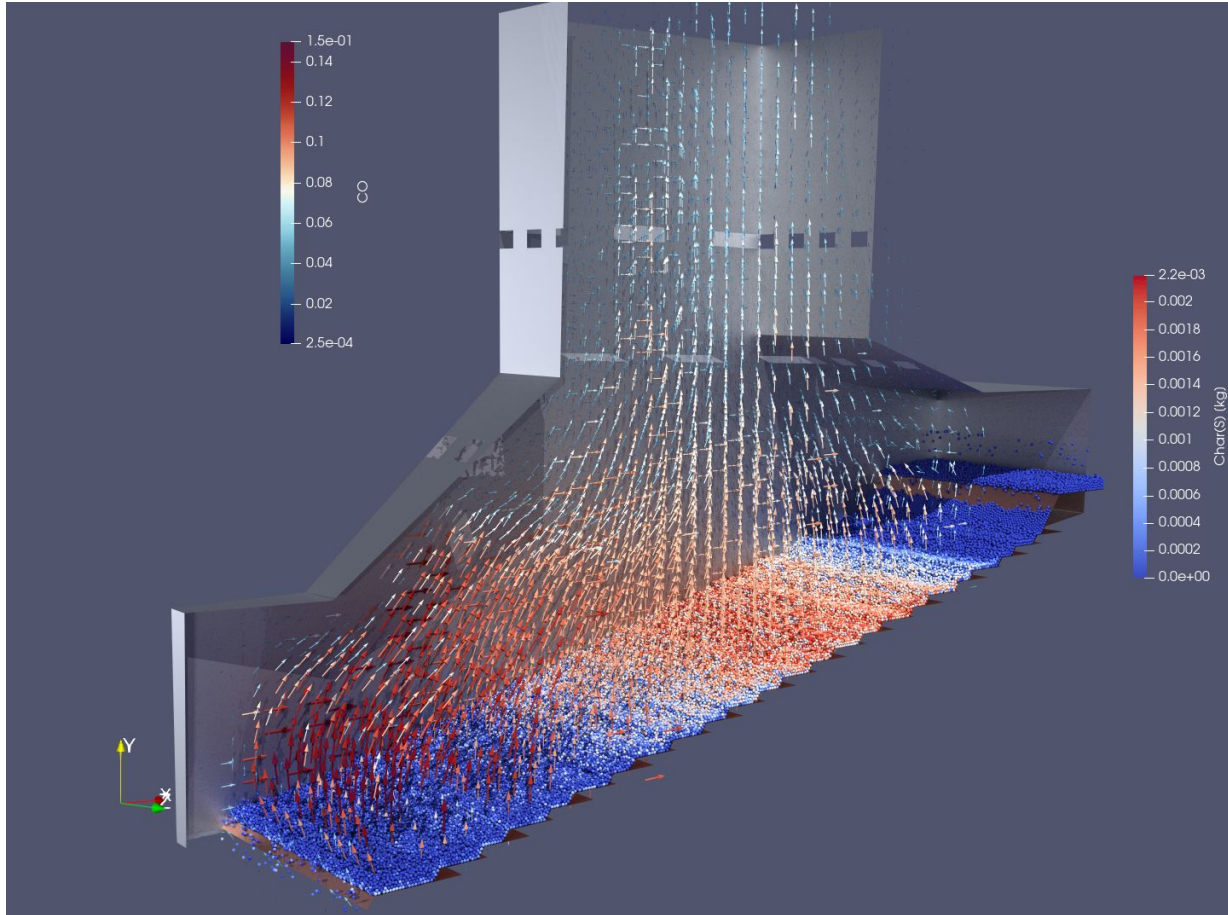
# PRELIMINARY RESULTS

Particle average composition:

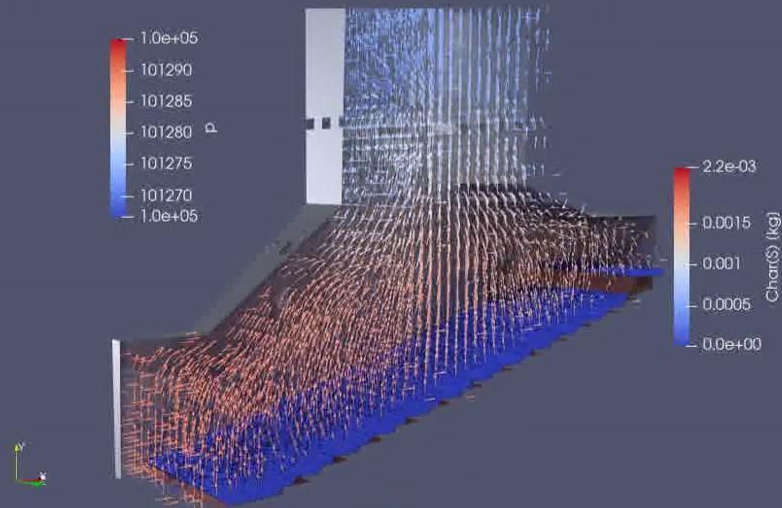
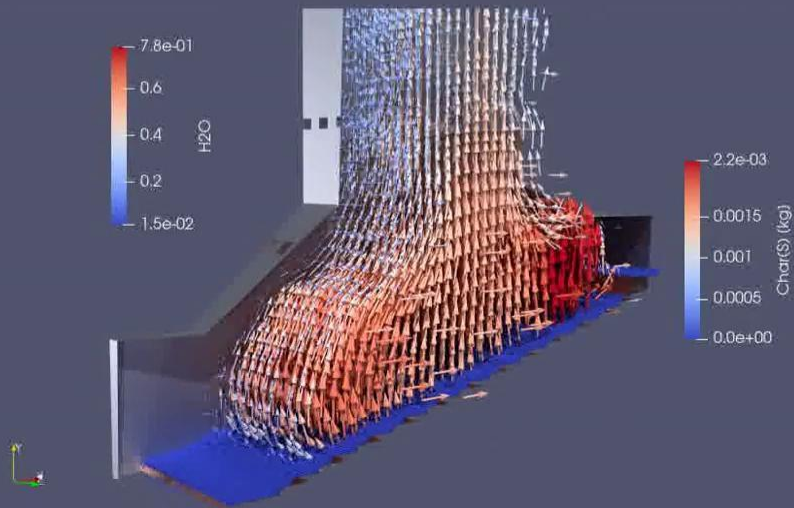
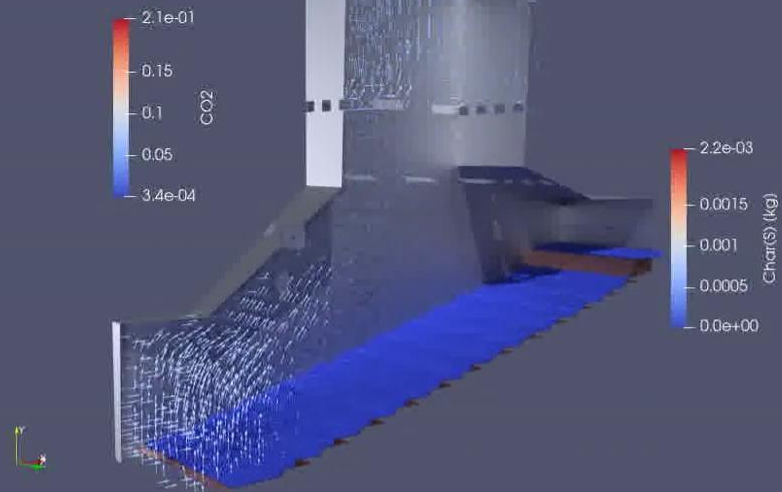
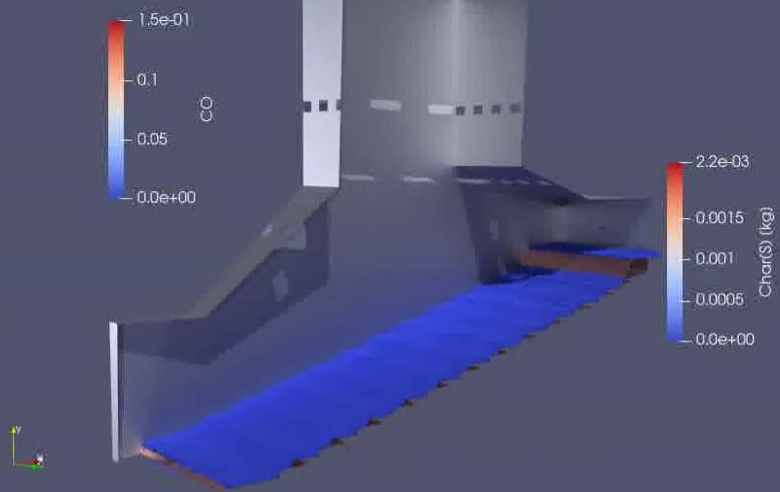
- Drying process (complete)
- Combustion
- Char production+burning



# SPECIES DISTRIBUTION







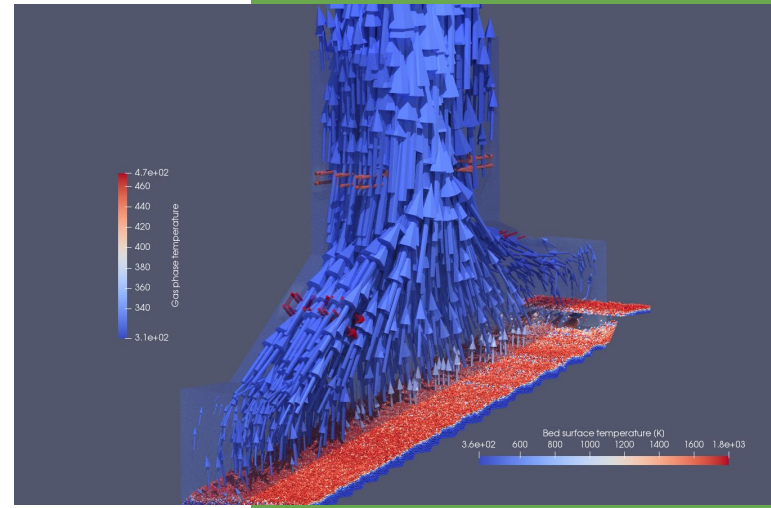
05

# Summary

Conclusion and  
Future directions

# CONCLUSIONS

- Exchange between gas and solid phase through heat-, mass-, and momentum transfer
- Average of 58% of char and 42% of ashes by wt. Unburnt carbon (5% of dried biomass)
- Consistent with sampling data from industrial plant
- Ability to predict gas flux behaviour (recirculation) and thermal field
- Multi-phase flow in general and with a particulate phase in particular is still a challenging domain
- CFD-DEM coupling offers unprecedented insight into the underlying physics



- 3D real plant scale for practical use
- XDEM as a novel and advanced simulation framework for multi-physics applications
- Complete and simultaneous 2-way coupling between particulate and gas phase
- Parallel implementation and flexibility (MPI+OpenMP)
- Combination of algorithms e.g. ROM in conjunction with HPC reach into industrial applications

# FUTURE DIRECTIONS

- Thermal load and temperature of structure (Walls, Grates thermal load)
- Improved radiation heat transfer
- Improved Graphical User Interface (GUI)
- Advanced algorithms for moderate HPC power



# THANKS!

Dr. Alban ROUSSET

University of Luxembourg

**LuXDEM Team**



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<http://luxdem.uni.lu/>



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