aixprocess

Simulation Services

Digital Solutions

Engineering Services

The ModeliNG Company

Successful Process Decarbonization in Cement Industry with Barracuda Virtual Reactor Computational Engineering

Martin Weng, M.Schumacher, R.Lakshmanan

Aixprocess at a glance

- **established 2001**
  by Dr. Martin Weng, Markus Hufschmidt, Michael Modigell
- **located in Germany**
- **~ 25 staff**
- **Specialists for high temperature process engineering, combustion**
- **> 1000 engineering & modeling projects**
- **> 400 worldwide customers**

Engineering Services

- CFD process simulation
- *SolidSheet* process modeling
- process optimisation

Digital Solutions

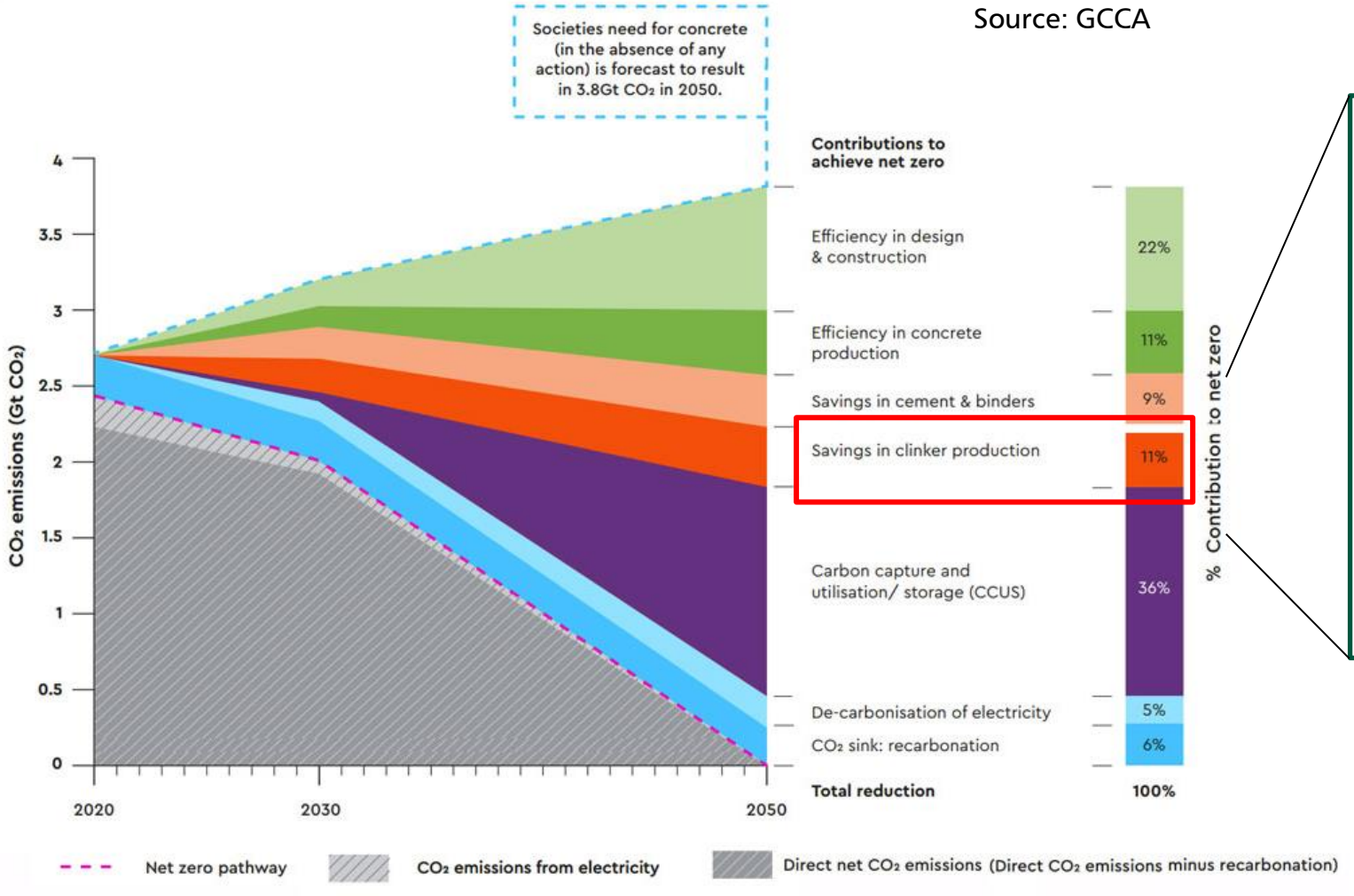
- **aixProM** Data Management
- **aixProM** RealTime Optimiser
- **aixProM** Big Data Analytics

Products

- cyclones
- Barracuda Virtual Reactor
- **aixProM** smart-sensors

GCCA's net zero pathway for Cement industry

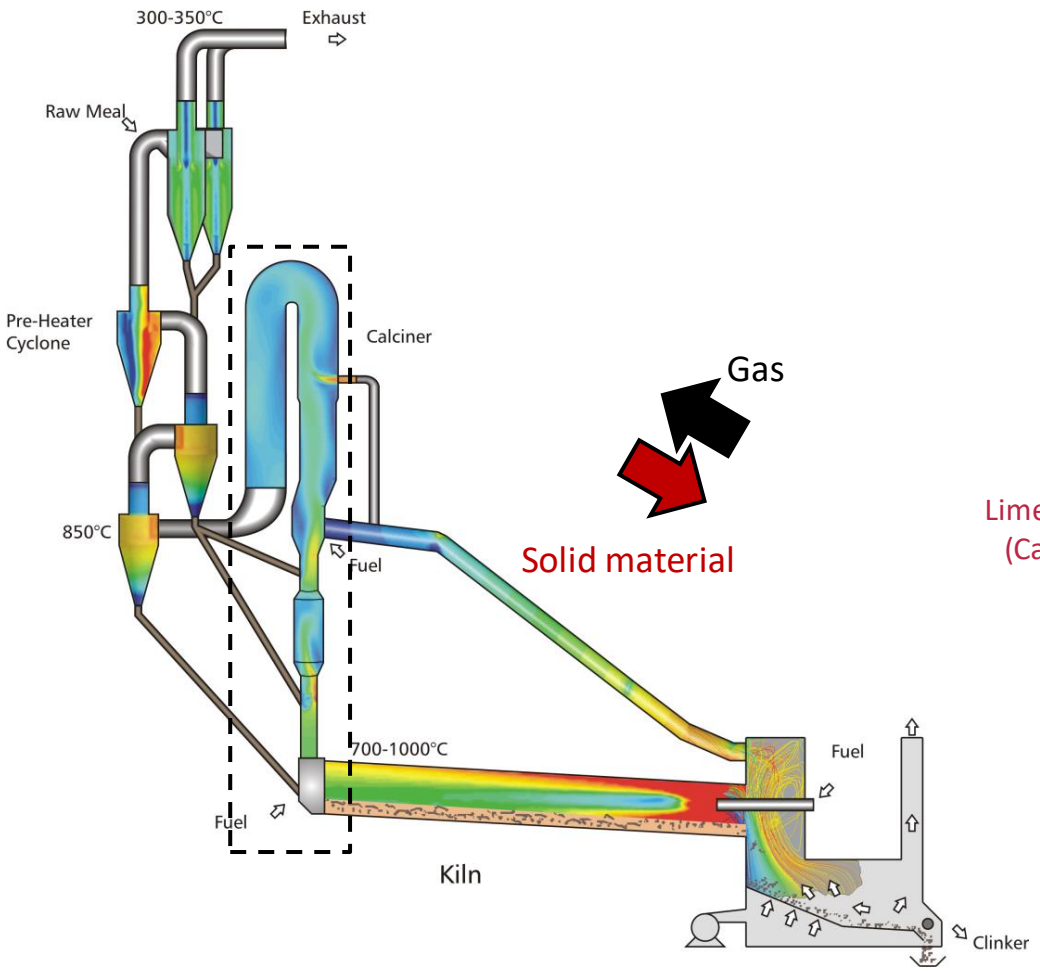
Source: GCCA

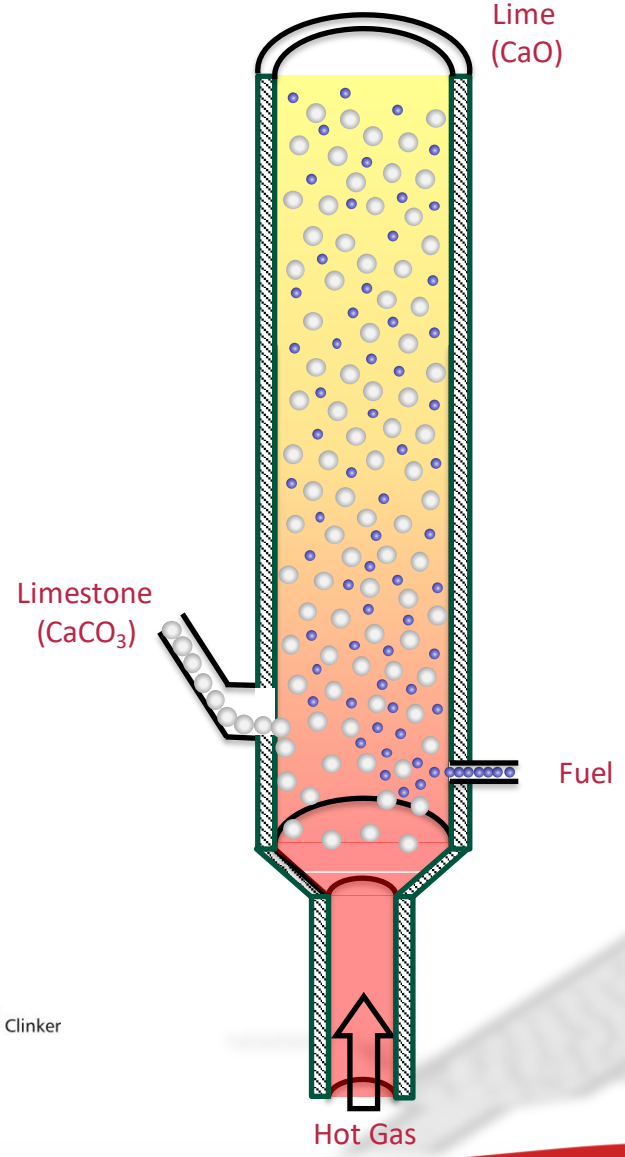


Substitution of Fossile Fuels

Enhancement of Thermal Efficiency

Basic Principle of Cement production and Calciner operation





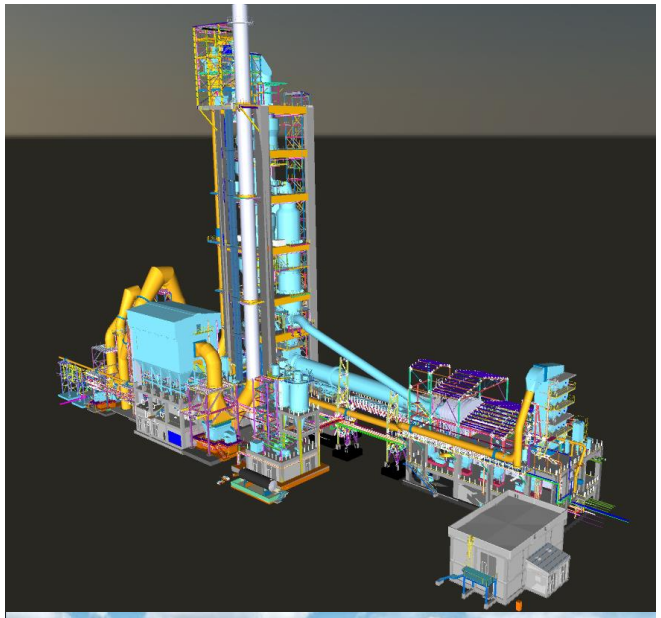
Calcination Reaction

$$CaCO_3 \xrightarrow{Q} CaO + CO_2$$

Fuel Combustion

$$\text{Solid Fuel} \xrightarrow{Q} CO_2 + H_2O$$

Decarbonization of Cement Production – A Use Case

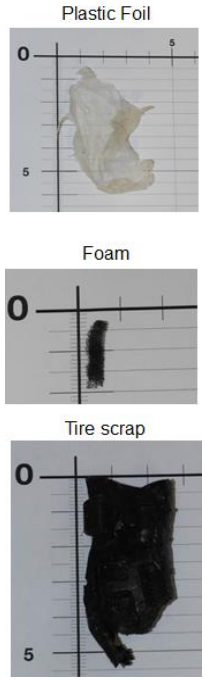


Ecocementos plant in Río Claro

- Located in Colombia
- Commissioned in 2019
- Clinker Production 1.5 Mt/yr
- CO_2 emissions ~1.4 Mt/yr (estimated)

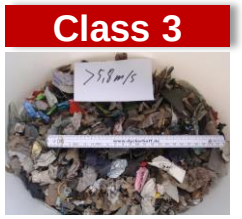
- Reduction of Carbon footprint
- Substitution of Coal by Solid Recovered Fuel (SRF)
- Improvement of Process Performance
  - Keep Plant Productivity
  - Minimize CO emissions
- CFD Process Engineering of a Cost-Efficient Solution
- Get it Right the First Time!

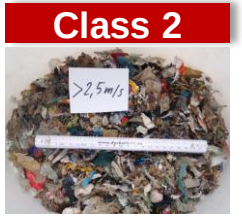
What is Solid Recovered Fuel?

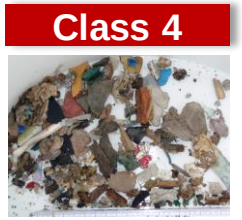


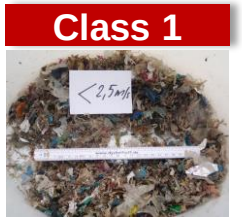
- Very broad particle size distribution
- Non-spherical shape of almost all particles
- Inhomogeneous and varying particle density

Morphologic charaterization of SRF

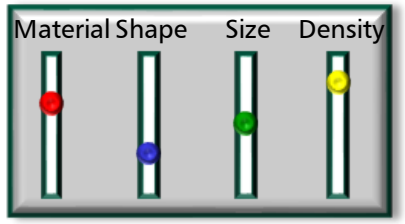


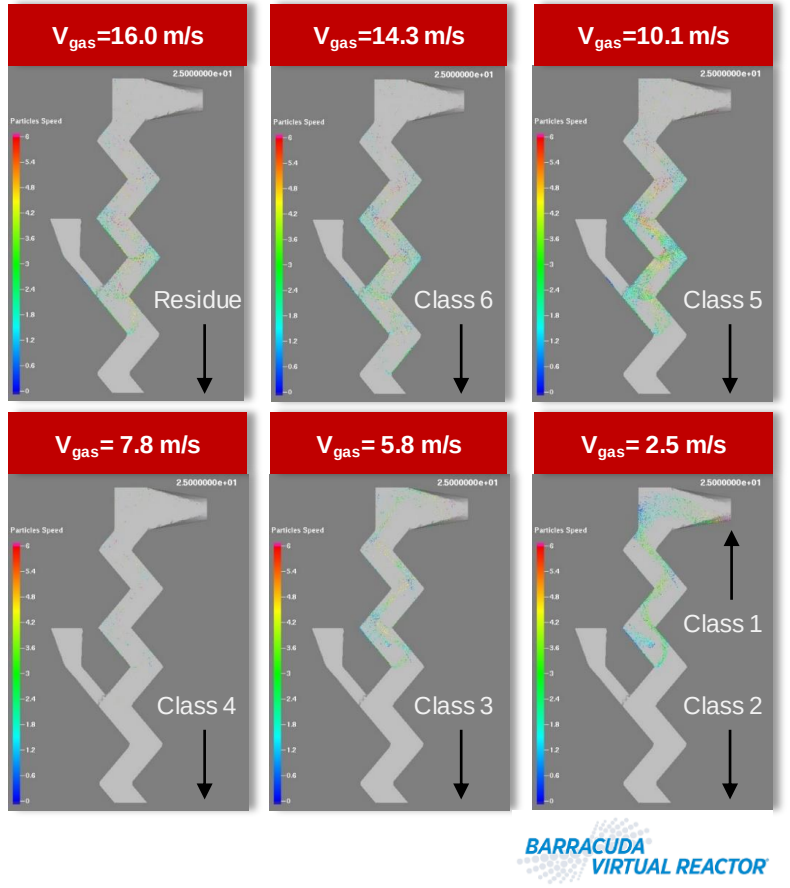






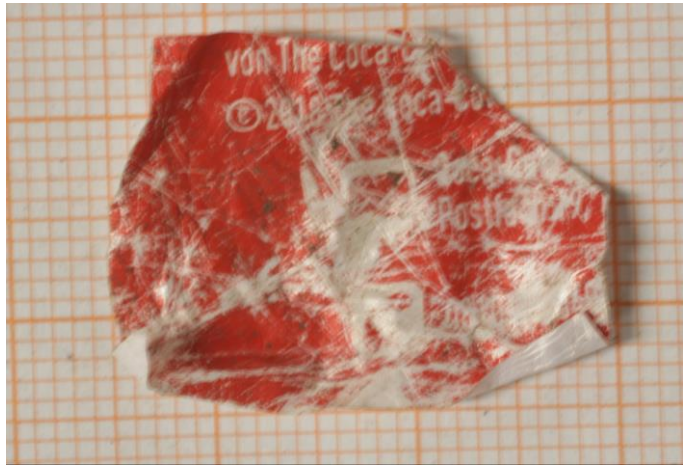
Model parametrization

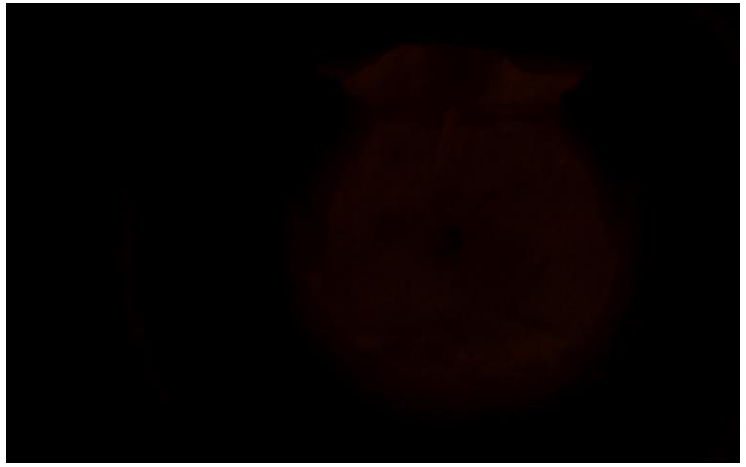


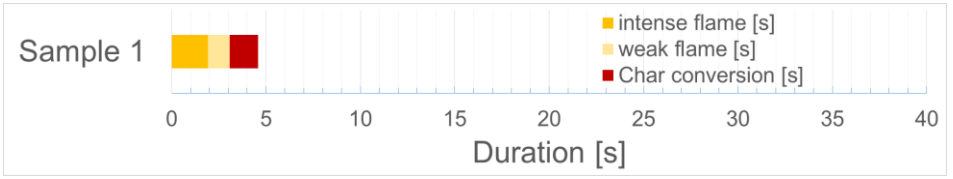


BARRACUDA VIRTUAL REACTOR

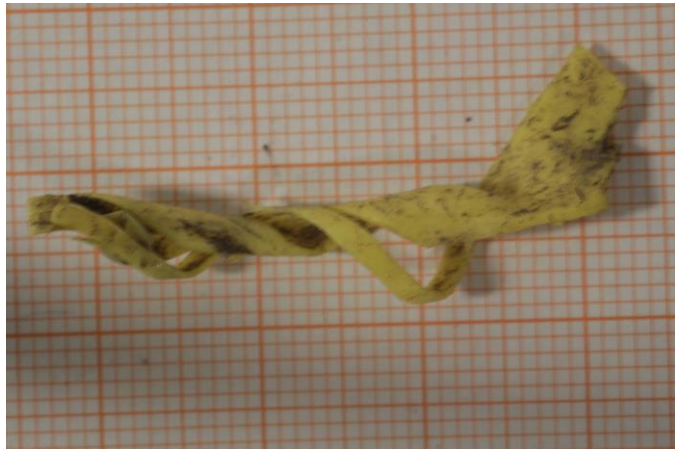
Combustion behavior of SRF Particles

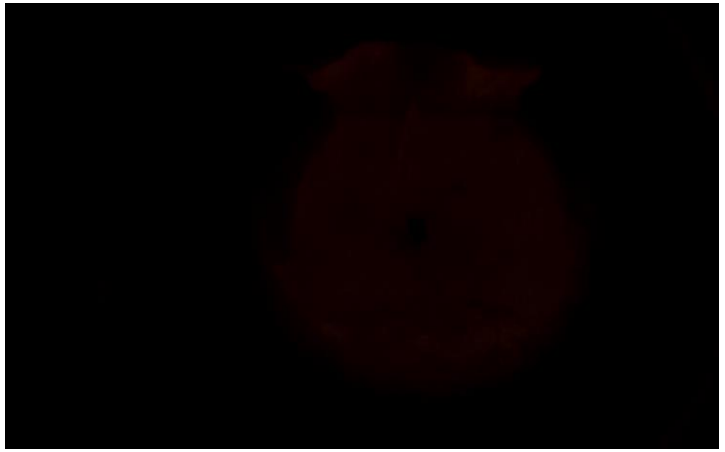


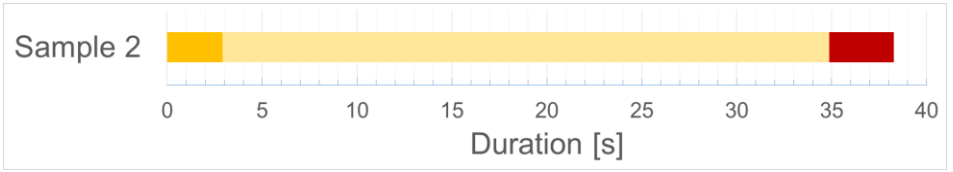




Type: 2D
Size: 25 x 25 mm
Weight: 12 mg

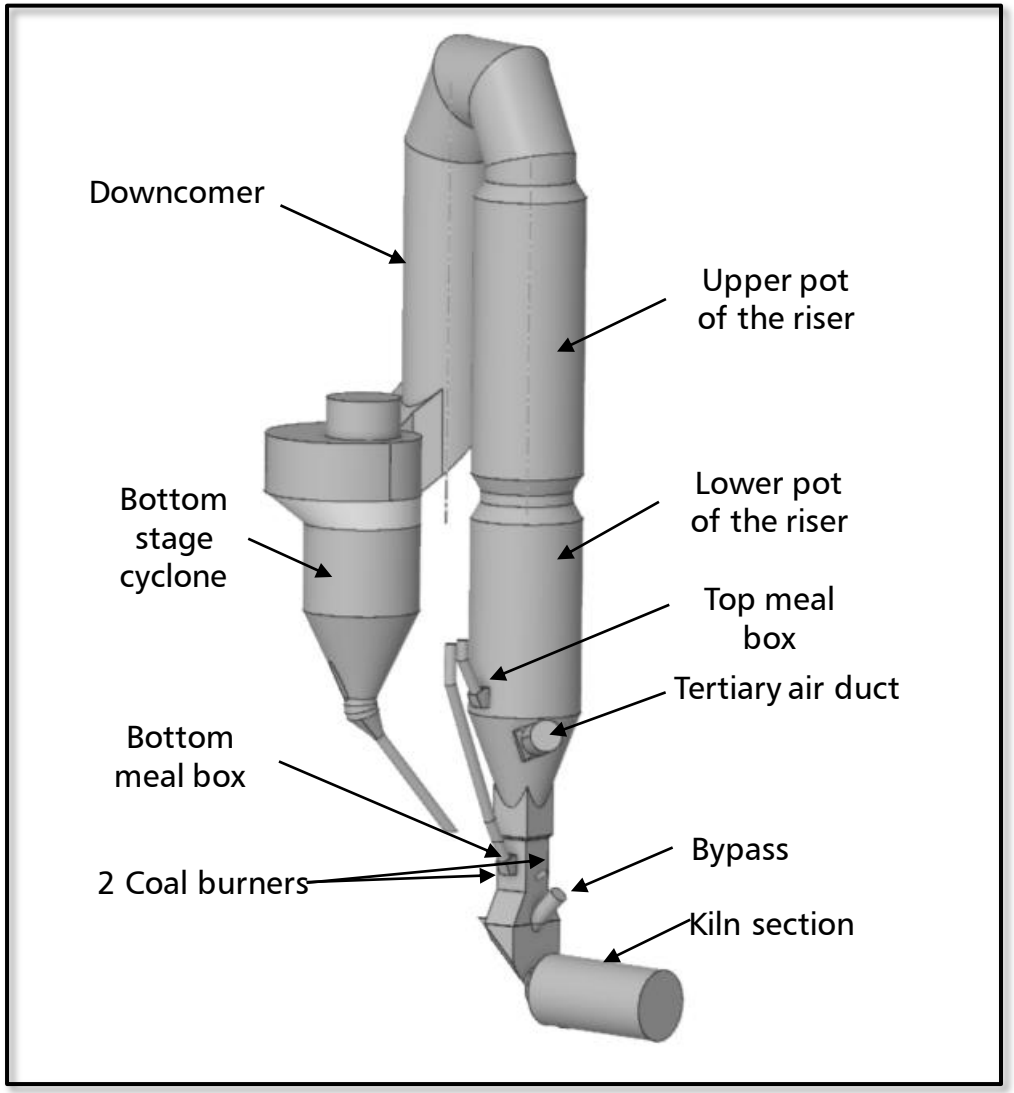






Type: 3D
Size: 30 x 5 mm
Weight: 140 mg

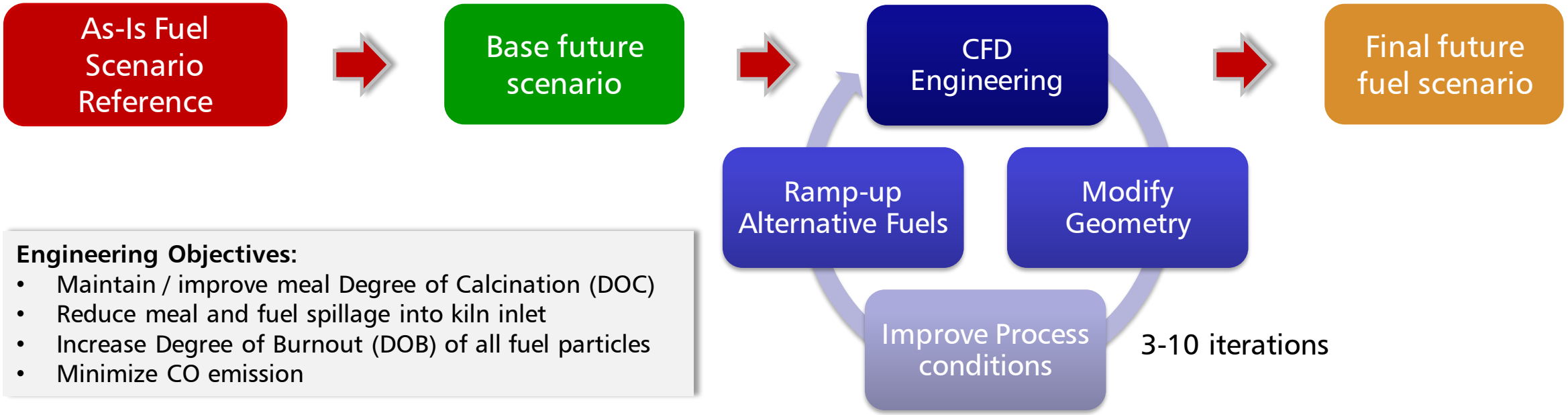
Barracuda Model SetUp



Calciner CFD Modeling	
CFD solver	Barracuda v21.1.0
Mesh	~ 500k cells
Barracuda models	• Mass, species and energy balance • Fluid particle heat transfer • Fluid walls heat transfer • Meal and fuel particles drag • Meal agglomeration • Turbulence model BARRACUDA VIRTUAL REACTOR
In-house models	• Meal calcination • Core and shell alternate fuel • Fuel particle core to shell conversion • Fuel particle moisture evaporation and condensation • Devolatilisation • Volatile oxidation • Char oxidation • CO oxidation aixprocess The Modeling Company

CFD Process Engineering

	As - Is fuel scenario	Future fuel scenario
Hard coal	13,000 kg/h	5,888 kg/h
SRF	-	4,500 kg/h
Tyre chips	-	2,500 kg/h
Thermal Substitution rate (TSR)	0%	55%



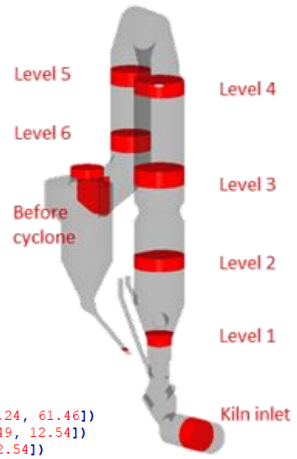
Engineering Objectives:

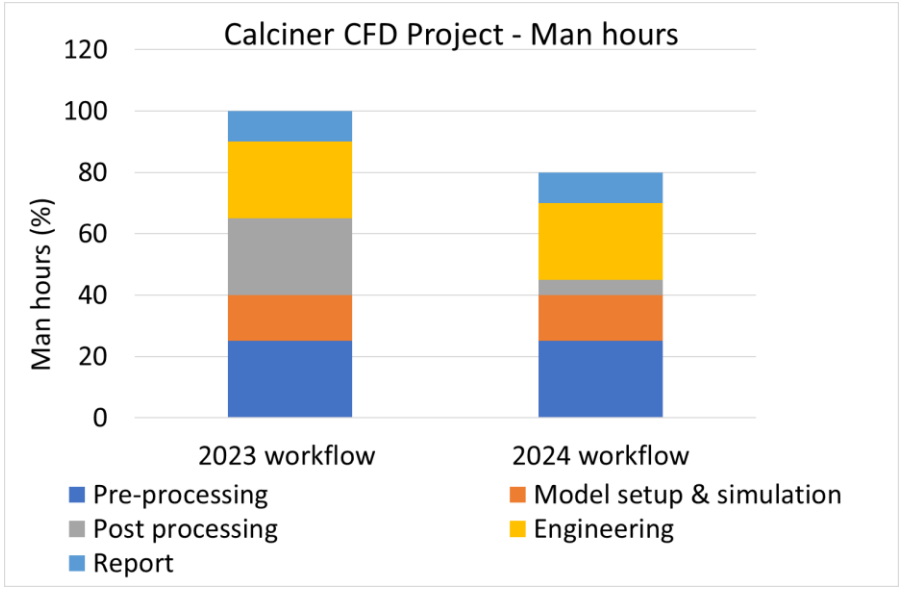
- Maintain / improve meal Degree of Calcination (DOC)
- Reduce meal and fuel spillage into kiln inlet
- Increase Degree of Burnout (DOB) of all fuel particles
- Minimize CO emission

Automated Postprocessing

- Calciner CFD postprocessing typically involves numerous particle types (due to many meal inlets, many fuel inlets, many fuel species and many fuel species class)
- Creating postprocessing template for evaluation of meal calcination and each fuel burnout across the calciner is complicated, time - consuming and highly prone to errors
- Repetitive, tedious and non - value adding tasks for each project
- Calciner CFD postprocessing **completely automated with PyTecplot** python scripting
- PyTecplot also enables detailed data analysis and numerical evaluation of calciner performance with use of python libraries like NumPy
- With automated postprocessing workflow, **~20% man hours saved per project**

```python
from pathlib import Path

from tecplot_automation.automation import Fluid_Variable, Multi_Slice, Particle_Type, Single_Slice, View
from tecplot_automation.main import run
from tecplot_automation.utils import burnout_eqn, complete_eqn, doc_eqn, initiate_level

# Inputs Required.
# Locations
# Simualtion Folder Location
simulation_location = Path("/monsterdata/Projekte/temporary_data/GE22-044-Cemento-Alion-TSR-injection/01-As-Is/Run_5")
# Results Storage Location
results_storage_location = simulation_location / "results"
# To specify additional folder for results storage location (below line)
#results_storage_location= simulation_location / "results" / "test6"


# Steps/Time Duration to PostProcess
starting_step = 750
steps_to_process = 250
# For initial test, start with 3 steps and then check the results.
# For complete post processing the total steps to process to be provided
# example 250 for 10 simulation seconds

# TecPlot Connection
tecplot_portNumber = 7607
# Choose Individual recommended port number available in the Intruction

# If Animation also to be saved use False
# If only numerical results are required use True
only_numericals = False

# views
iso_view = View(name="iso", psi=57.57, theta=-47.72, alpha=0, zoom=None)
front_view = View(name="front", psi=90, theta=-90, alpha=0, zoom=None)
left_view = View(name="left", psi=90, theta=0, alpha=0, zoom=None)

iso_zoom = View(name="iso_zoom", psi=57.57, theta=-47.72, alpha=0, zoom=[16.81, 58.13, -54.24, 61.46])
front_zoom = View(name="front_zoom", psi=90, theta=-90, alpha=0, zoom=[16.81, -0.245, -90.49, 12.54])
left_zoom = View(name="left_zoom", psi=90, theta=0, alpha=0, zoom=[16.81, 85.207, 0.341, 12.54])
#rdf_zoom = View(name="rdf_room", psi=90, theta=50, alpha=0, zoom=[48, -369, -312, 40])
```





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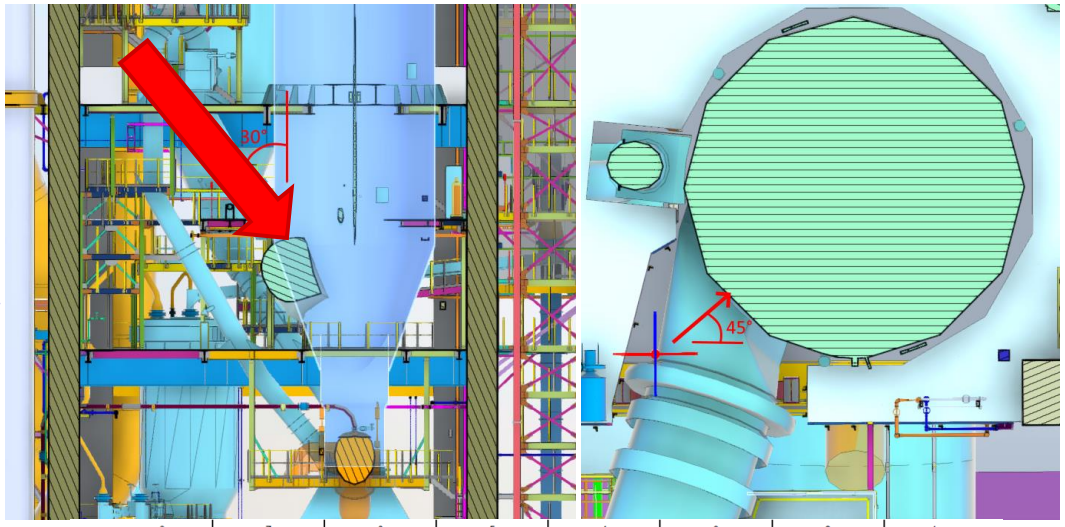
Optimisation Engineering Deliverables

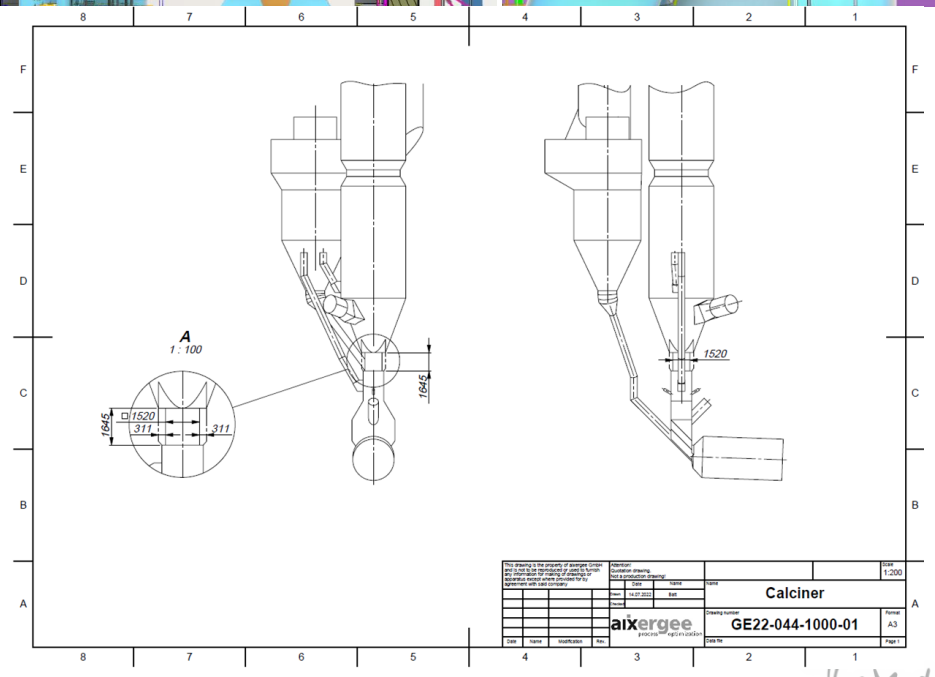
Step 1
Fuel Feeding Engineering

- Feeding location selection
- Feeding concept (pneumatic or gravity)
- Fuel engineering (size and moisture)

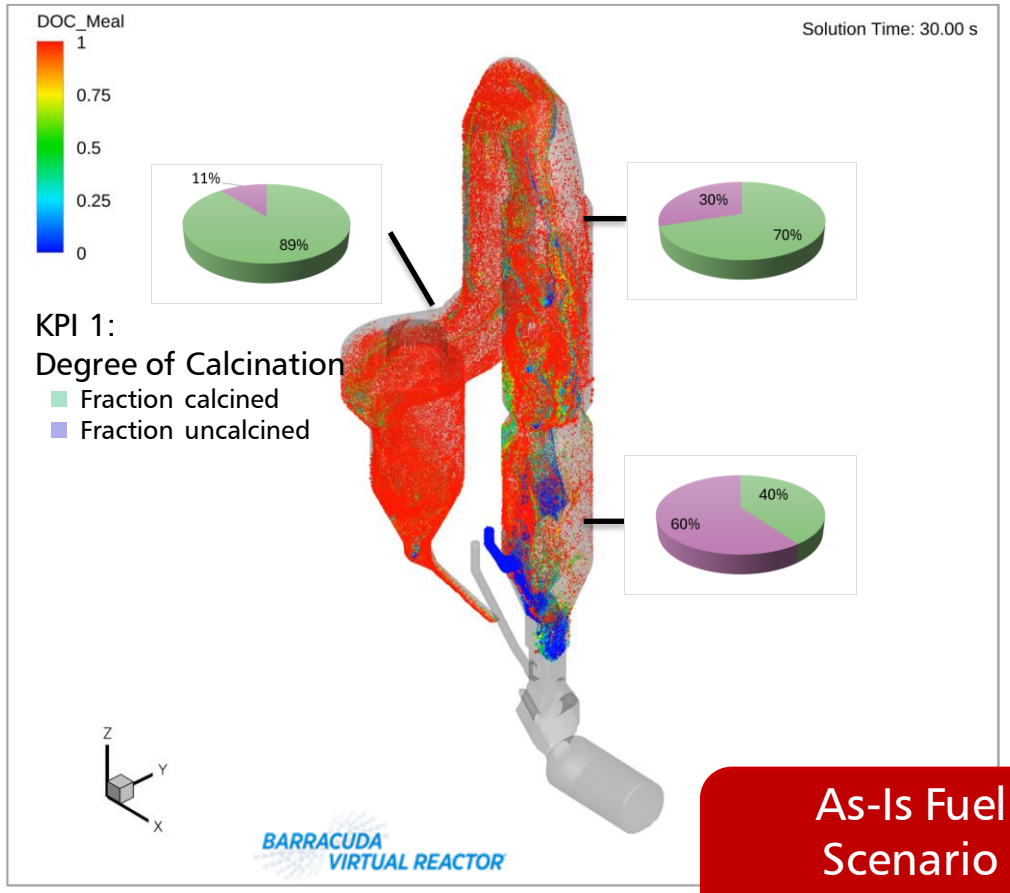


Step 2
Process Engineering

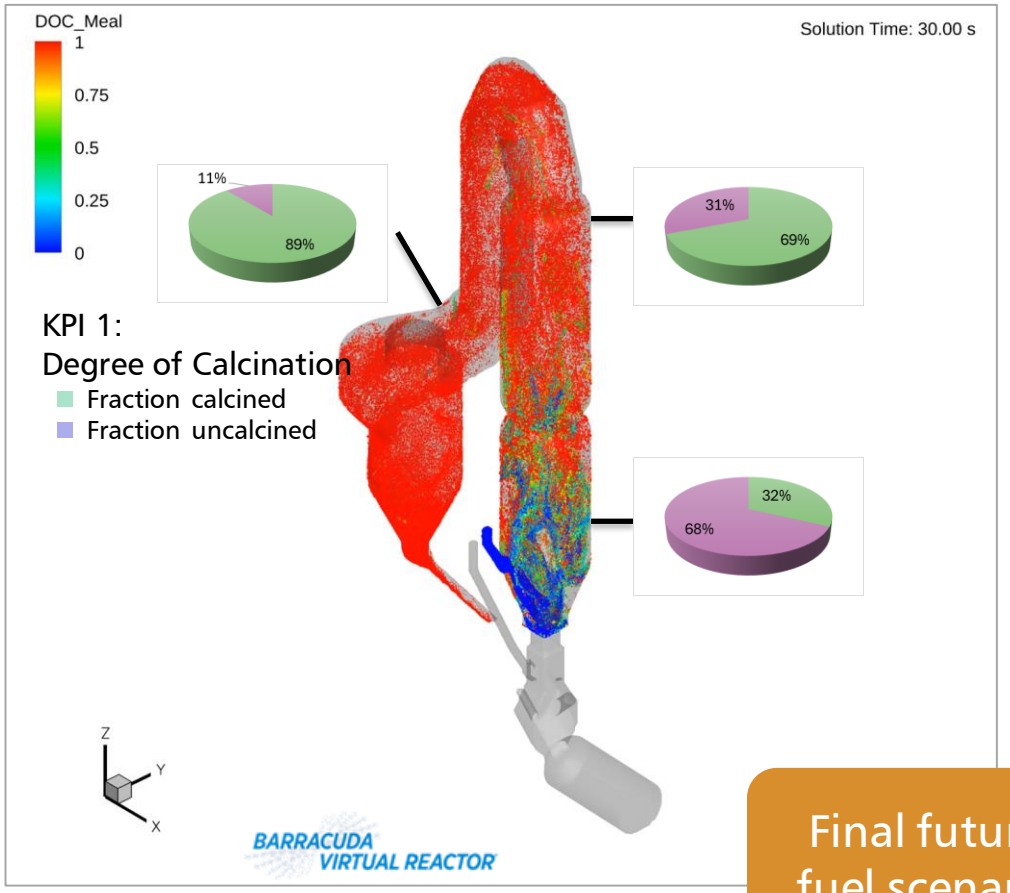
- Thermal efficiency enhancement
- Elimination of process deficiencies
- Enhancement of process stability



Particle Motion – Limestone Meal

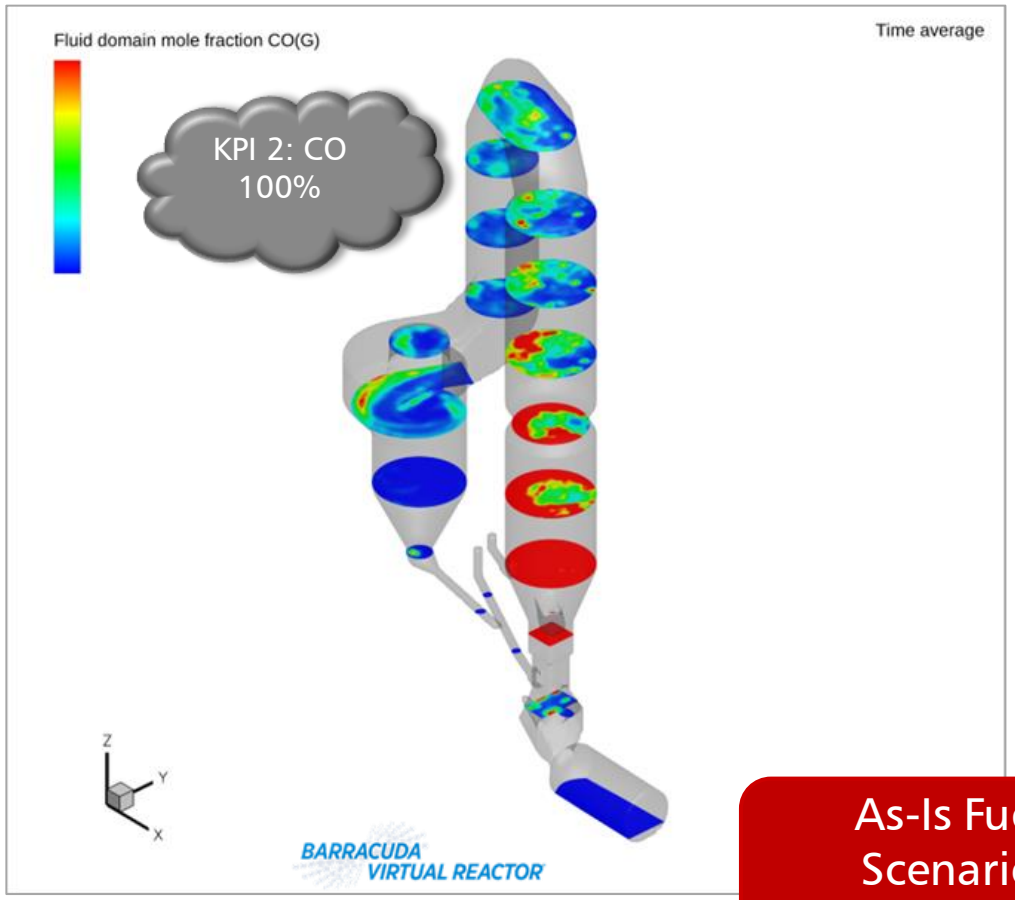


As-Is Fuel Scenario Reference

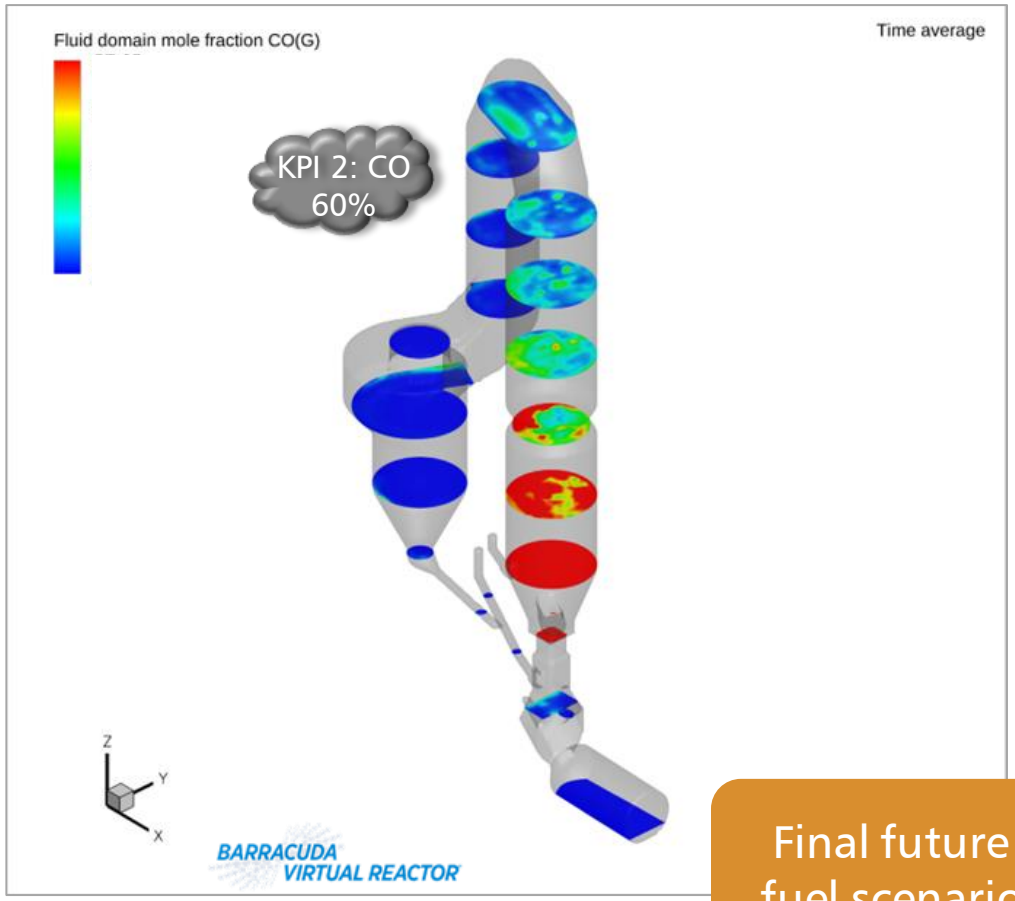


Final future fuel scenario

CO - Emissions

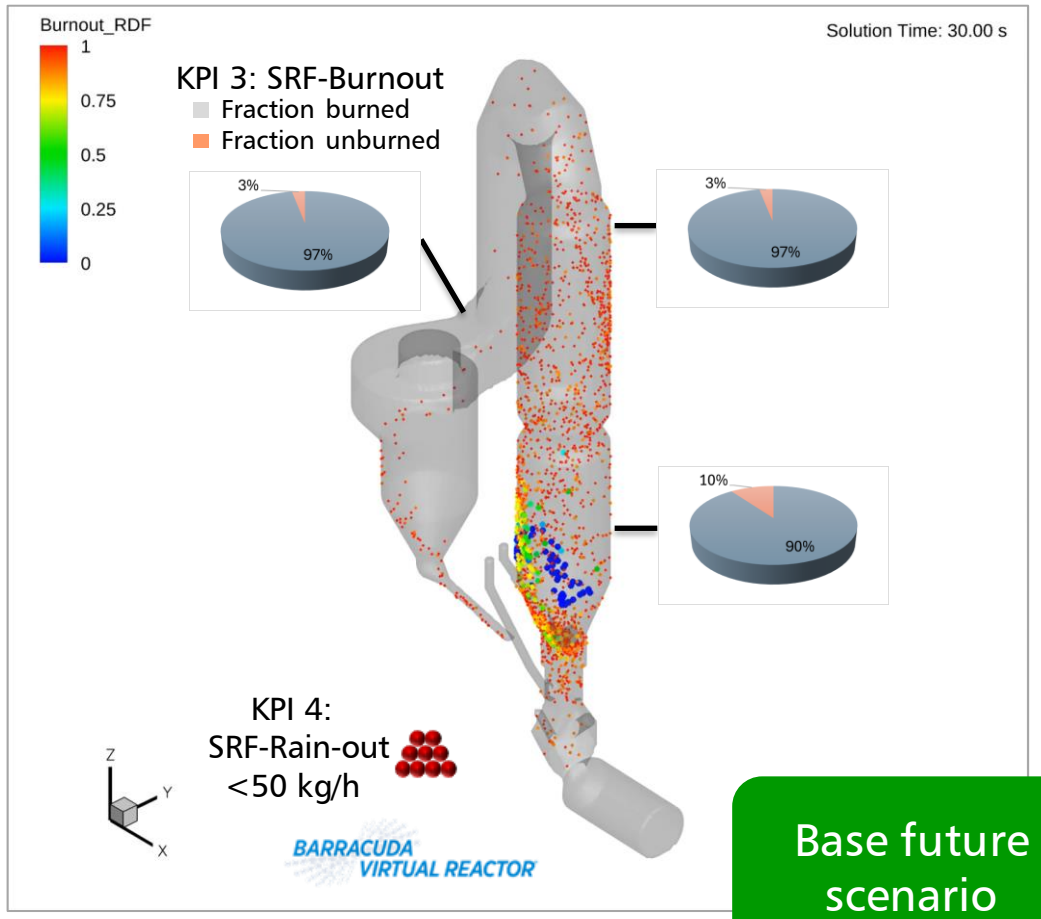


As-Is Fuel Scenario Reference



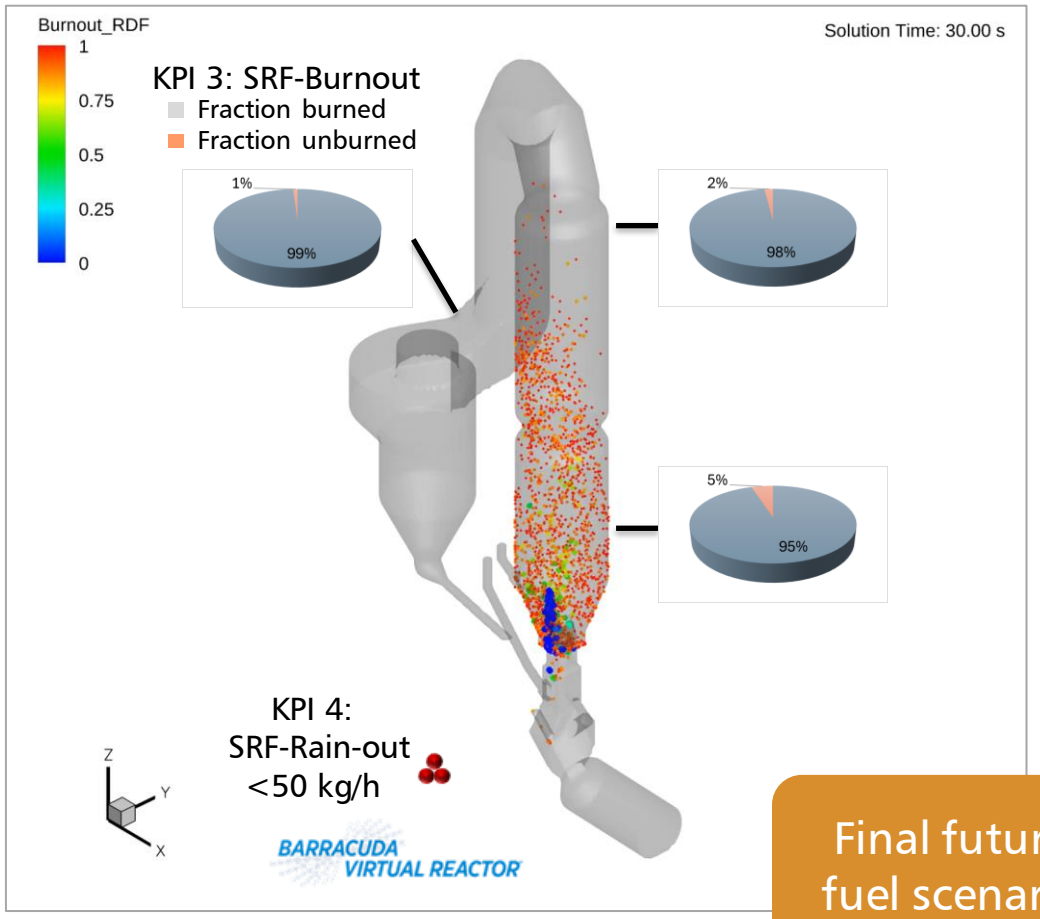
Final future fuel scenario

Particle Motion – SRF



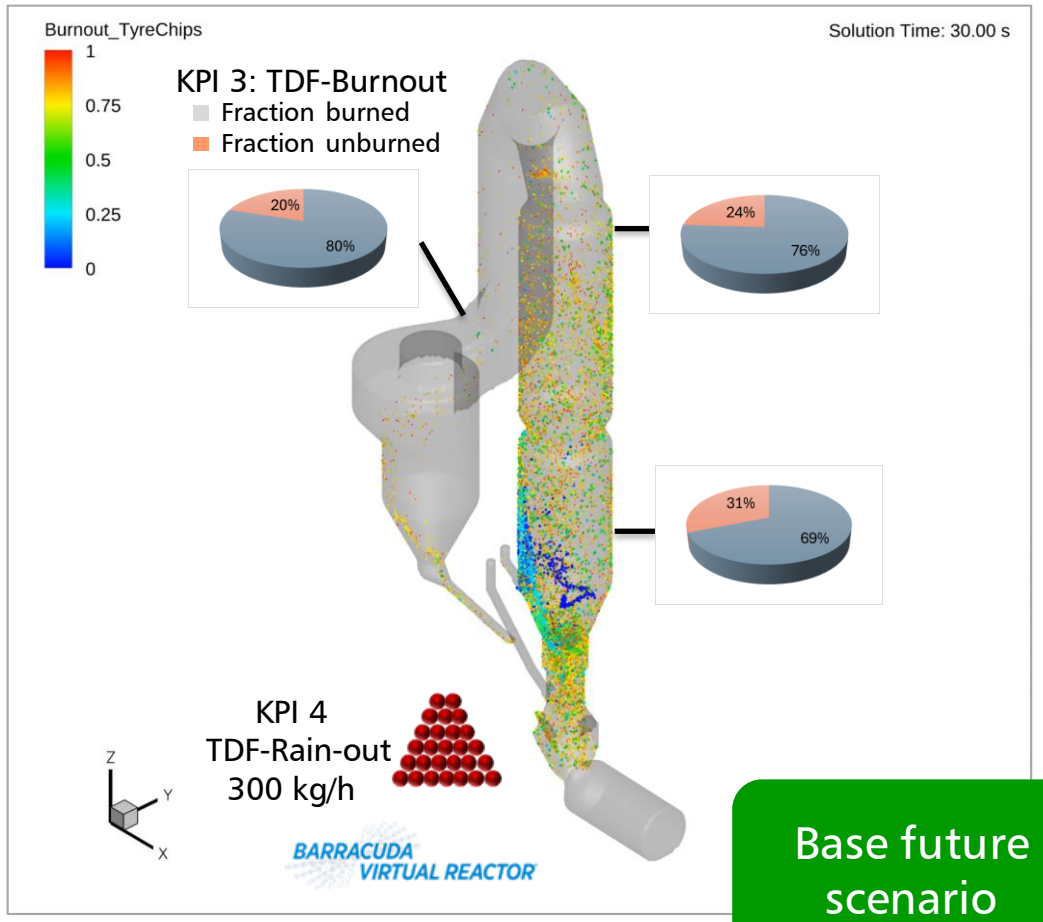
Base future scenario

Final optimisation

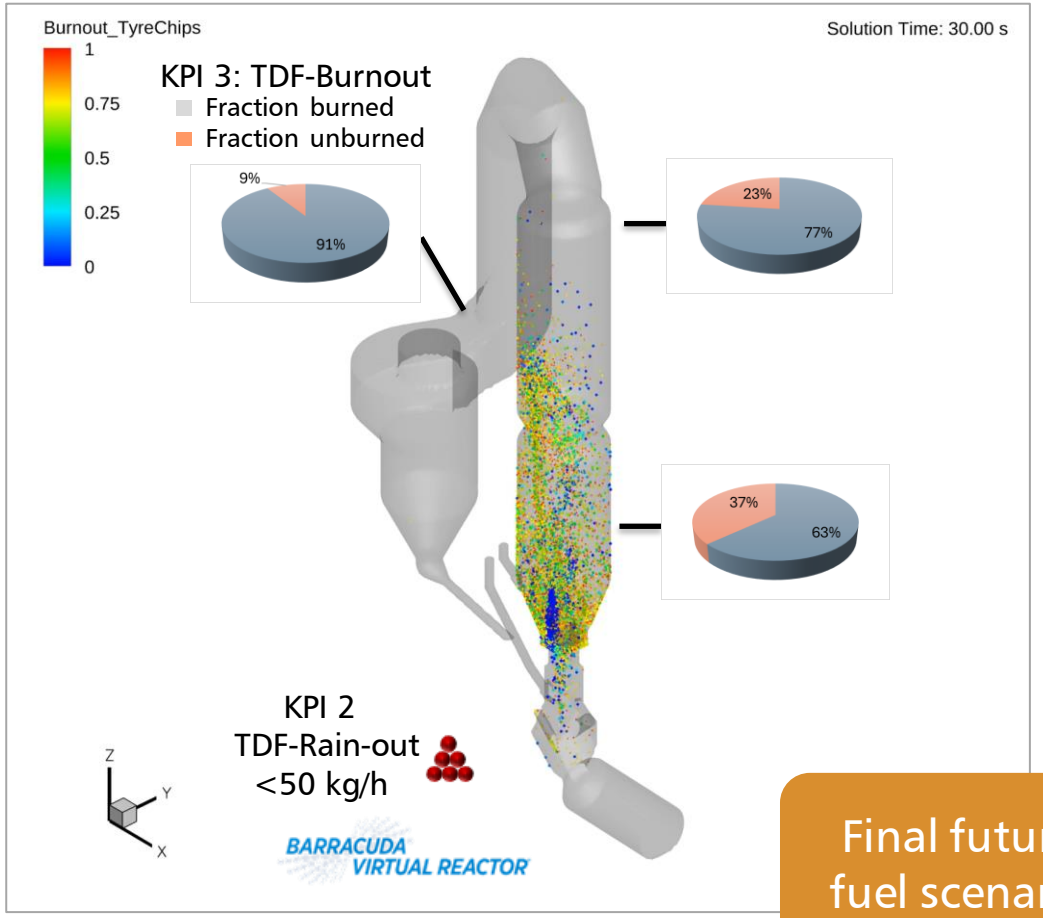


Final future fuel scenario

Particle Motion – Tyre Chips



Base future scenario



Final future fuel scenario

TakeAways

- aixprocess GmbH contributes to cement industry decarbonisation by enhancing cement plant performance using Barracuda Virtual Reactor
- Use case plant was successfully commissioned in Q1/2024
- In particular project 55,000 t/yr coal are substituted by waste derived f corresponding to ~51,000 t/yr CO_2 emission savings from primary fuel
- Barracuda software proves to be a right choice for cement calciner engineering among several other commercial software packages due to its modeling capabilities, numerical stability and computational efficiency
- PyTecplot utility in Tecplot enables us to automate the postprocessing, saving significant man hours and adding value to the clients.
- Apart from cement plants, Barracuda also aid us to design and optimize industrial reactors, fluidized bed reactors etc.,