Humusoft Collaboration:
CFD Simulation for the Efficient H2S Removal

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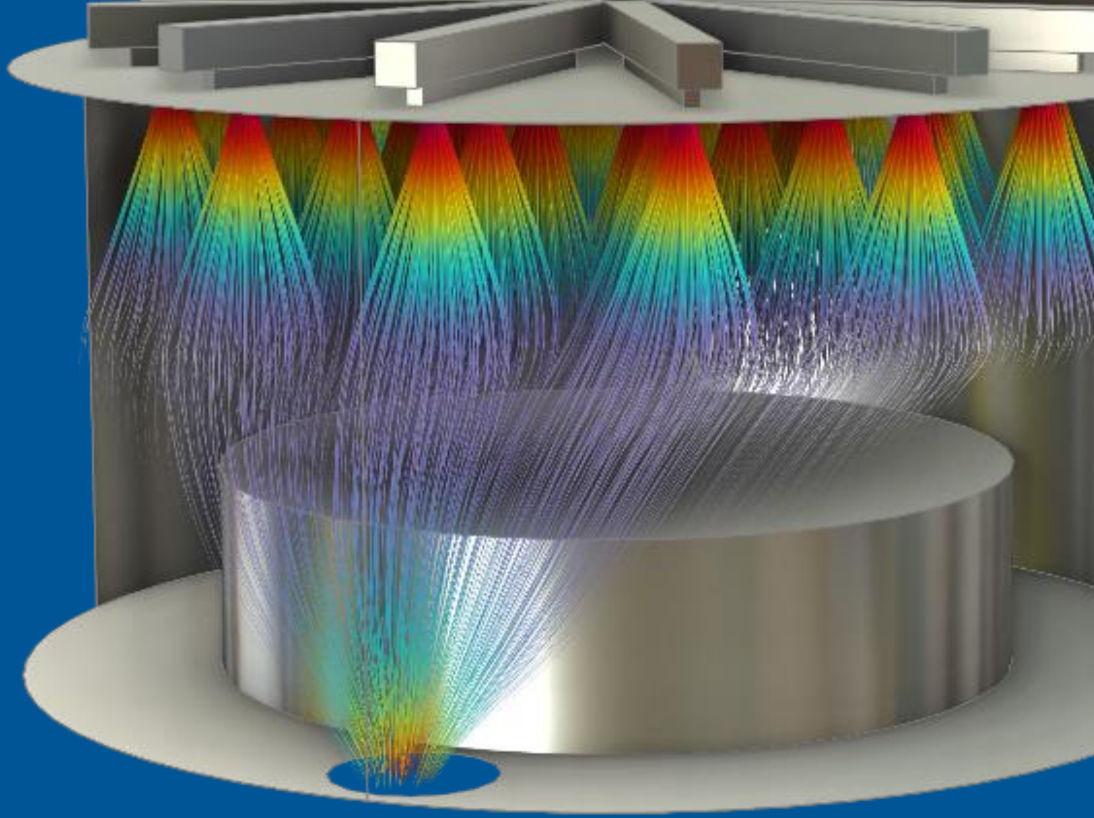

The Biogas Production Challenge

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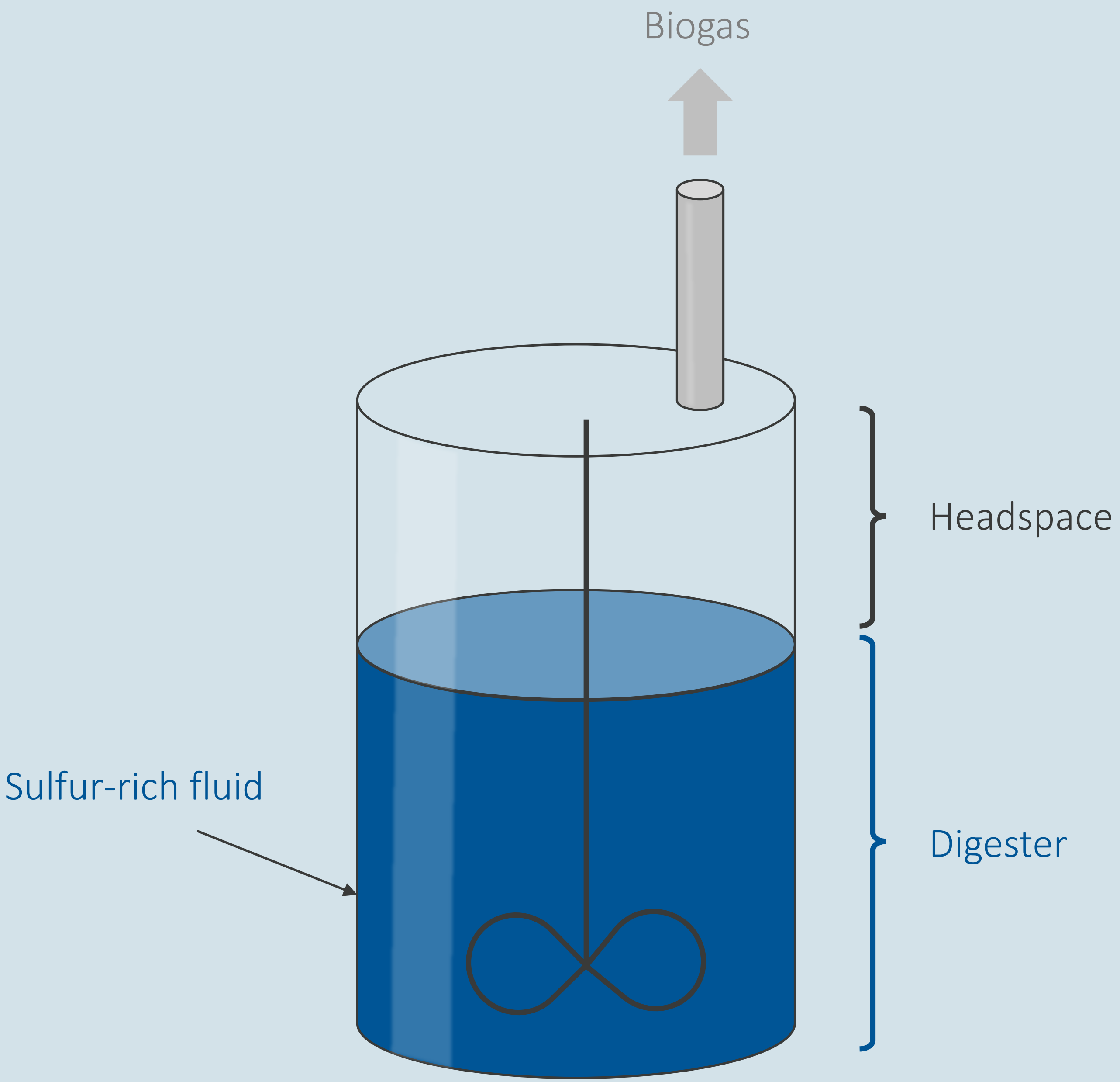
- Anaerobic digestion of organic matter
  - Sludges from urban wastewater treatment plants, agricultural resources or animal waste
  - Biogas contains a small amount of Hydrogen Sulfide (H2S) which is toxic and corrosive



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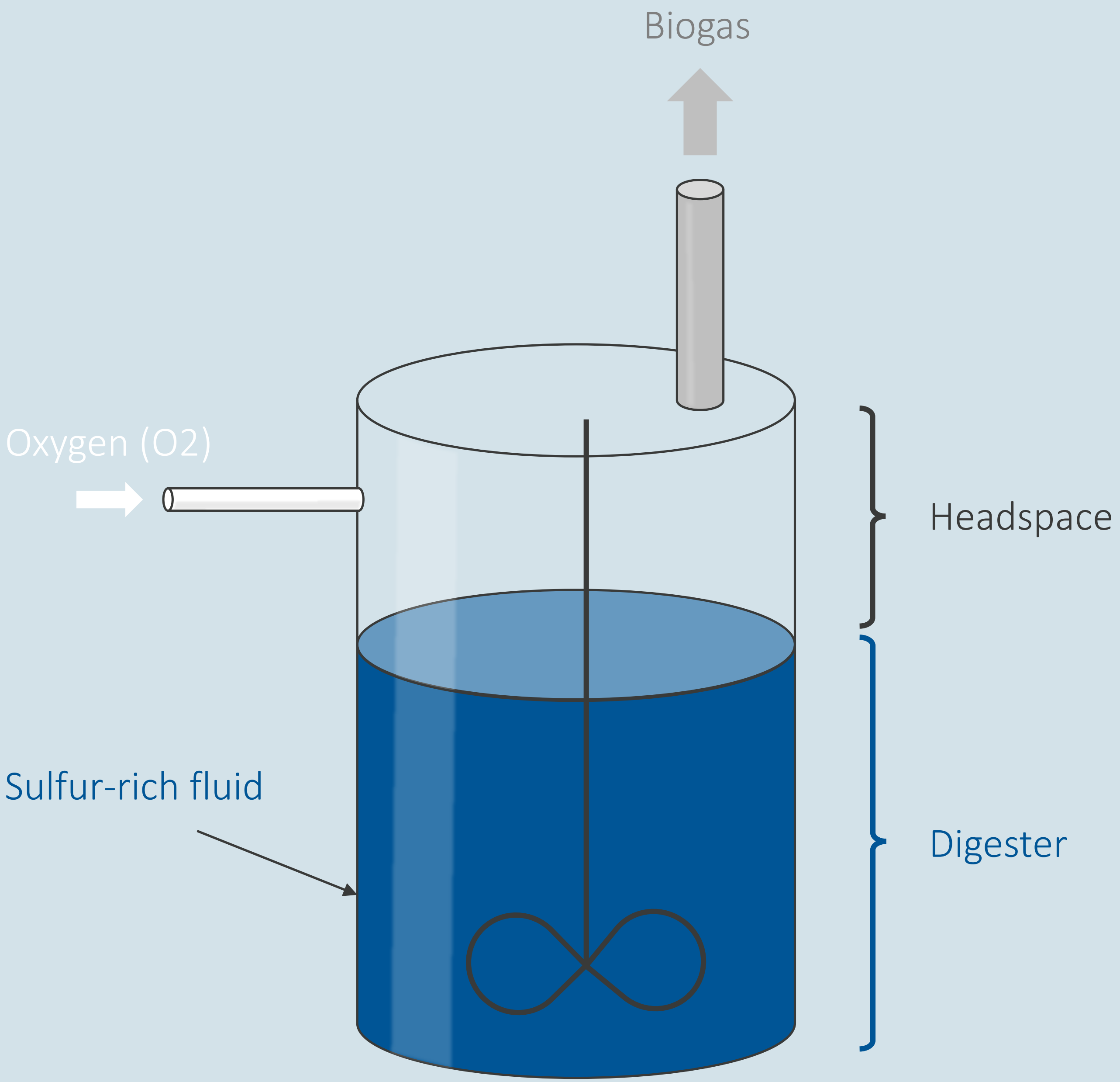
  - Inflow of Oxygen to facilitate growth of Sulfide-Oxidizing Bacteria (SOB)



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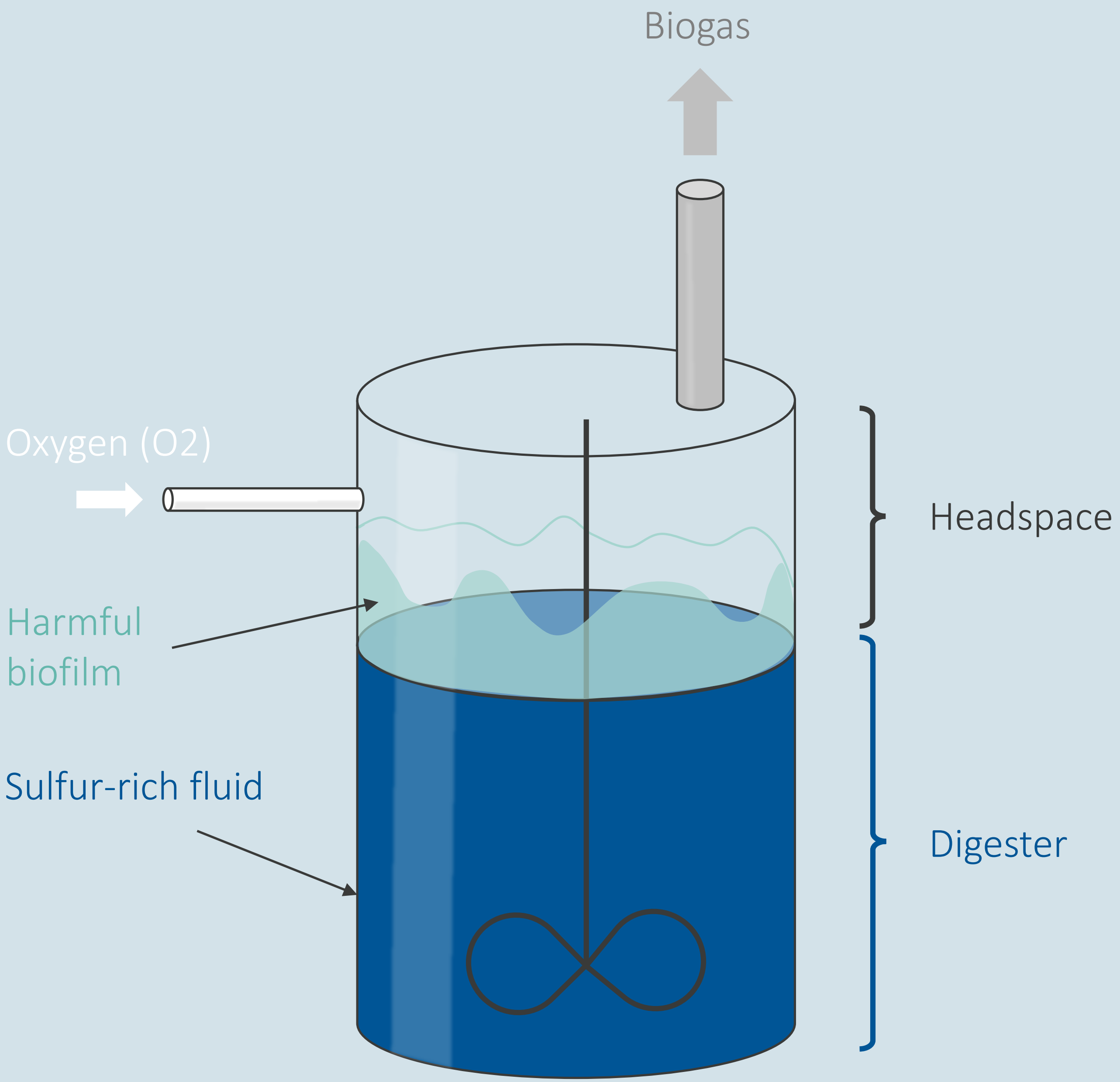

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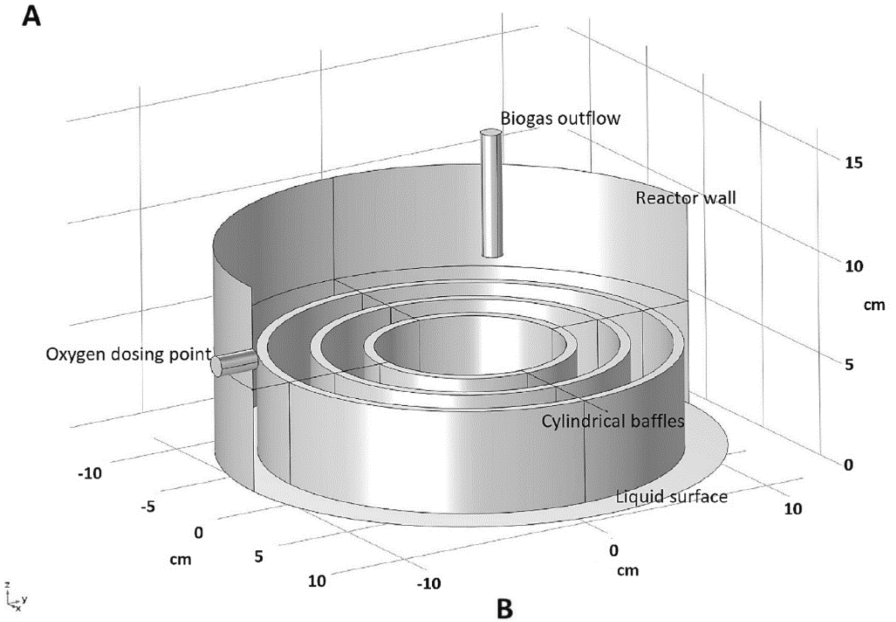
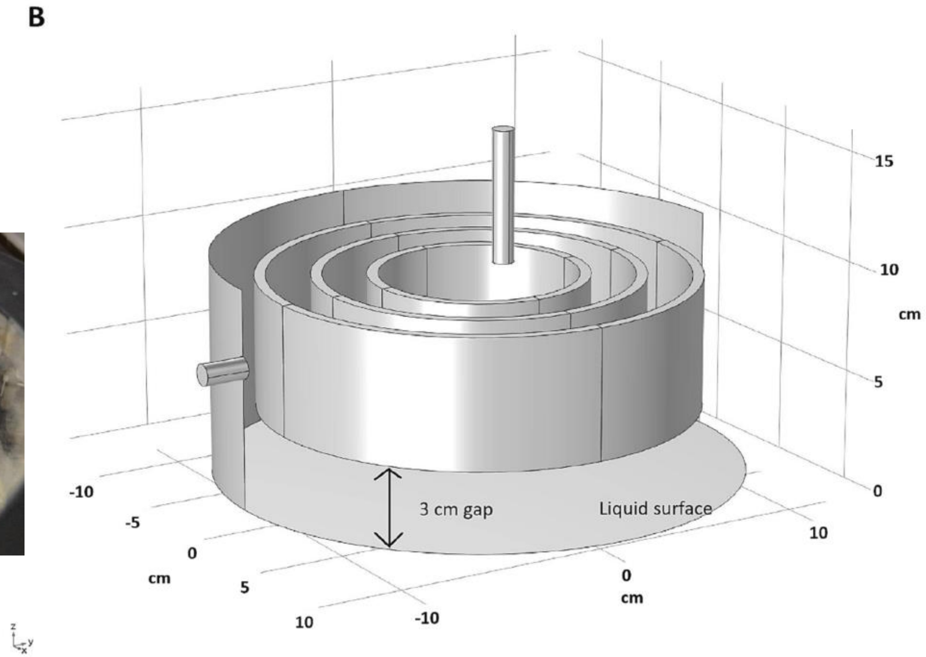
How to Protect Digester‘s Headspace?

„By modifying headspace geometry biofilm growth can be directed to designated areas, reducing harmful effects on the reactor“

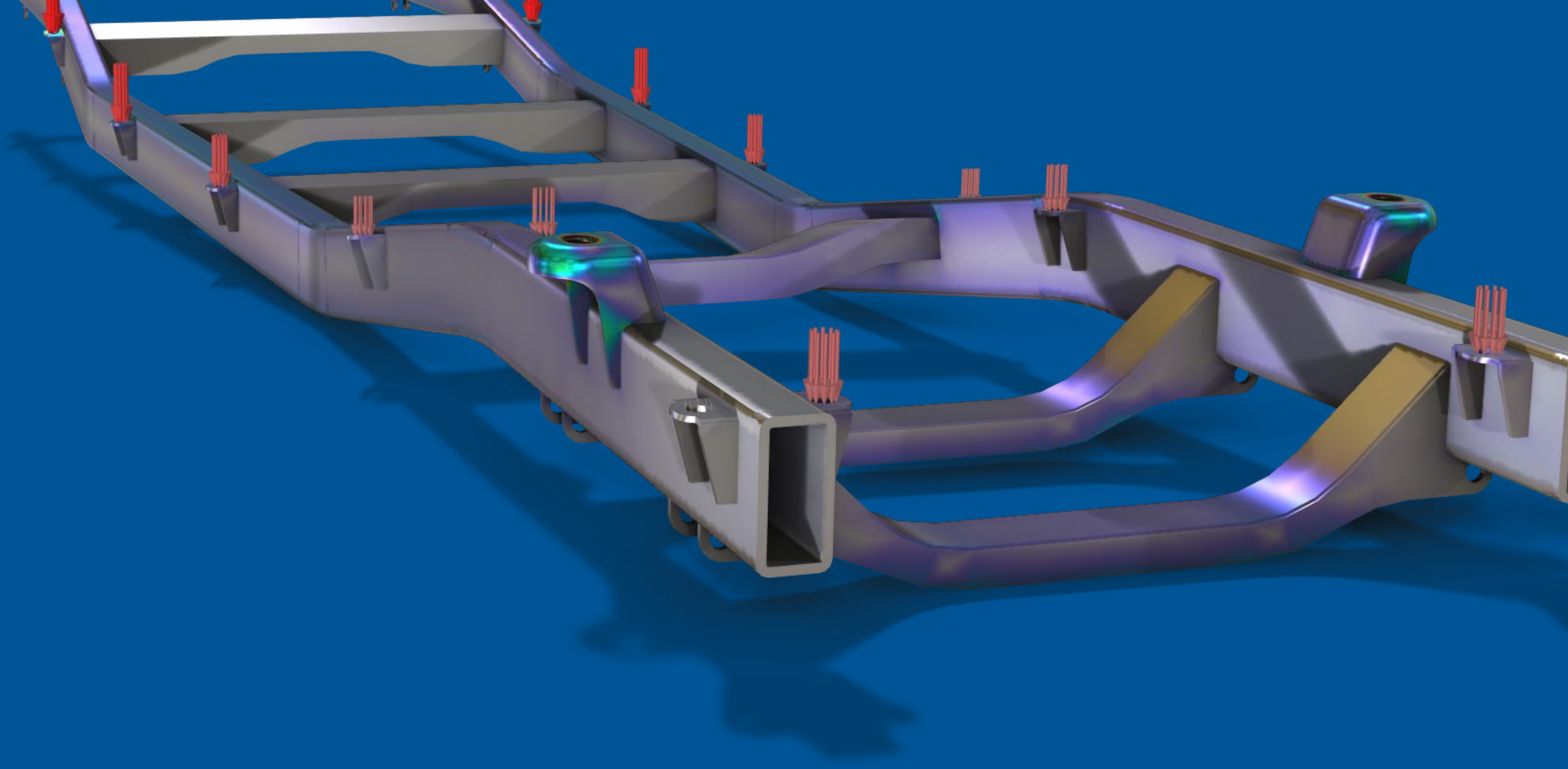
– UCT team

- Installation of cylindrical baffles serving as a surface for biofilm growth
- 360 days experimental setup:
  - Digester with empty headspace
  - Digester with variable headspace
- <u>Surprising result. **Walls were protected, but only up to the height of cylinders. Why? What is the process behind?**</u>





The variable headspace geometry and surprising results: A – Cylinders immersed in the liquid phase protected digester‘s wall, B – Cylinders were suspended 3 cm above the surface and biofilm growth up to 3 cm height.



Time for COMSOL Multiphysics®

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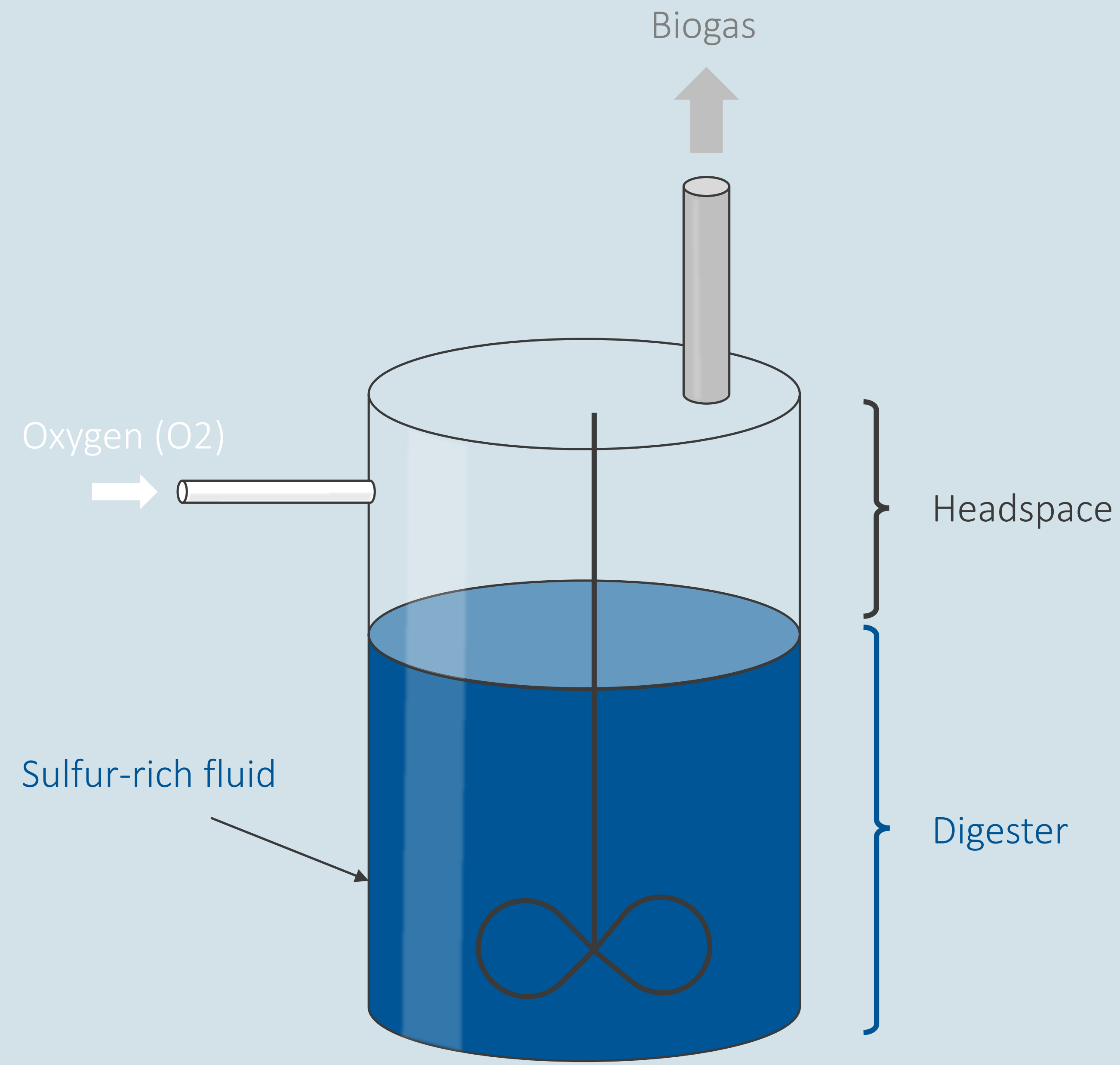
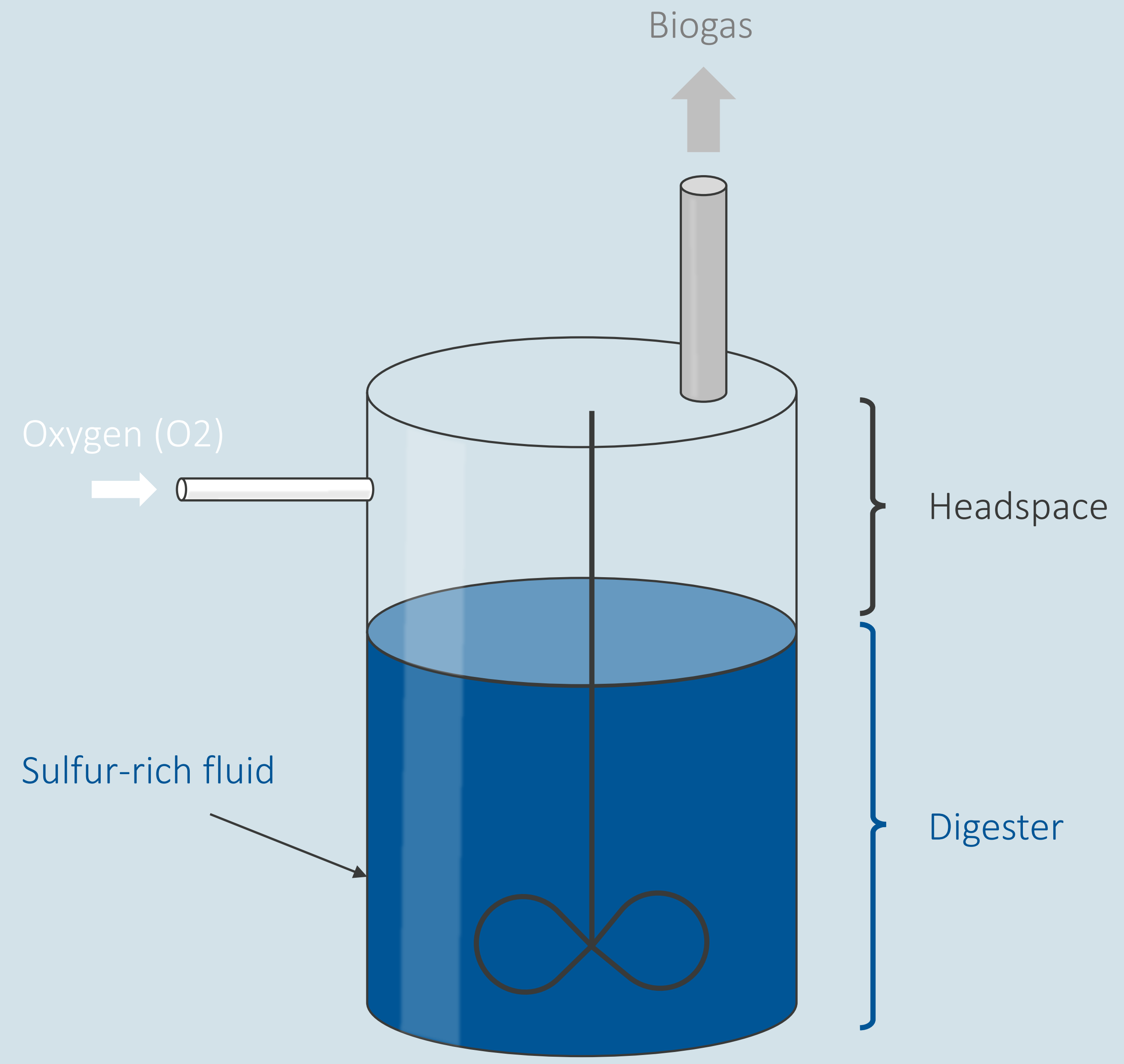
CFD simulation on demand for the university team

- Physics Interface
  - Mixture Model, Laminar Flow (continuous phase biogas, dispersed phase oxygen)
- Modelling challenges:
  - Stirring of the sulfur-rich fluid (60 RPM)
  - Three geometry scenarios



Modelling Challenges: Simulation of Stirring

Important simplification: Computational domain made only from digestor's headspace



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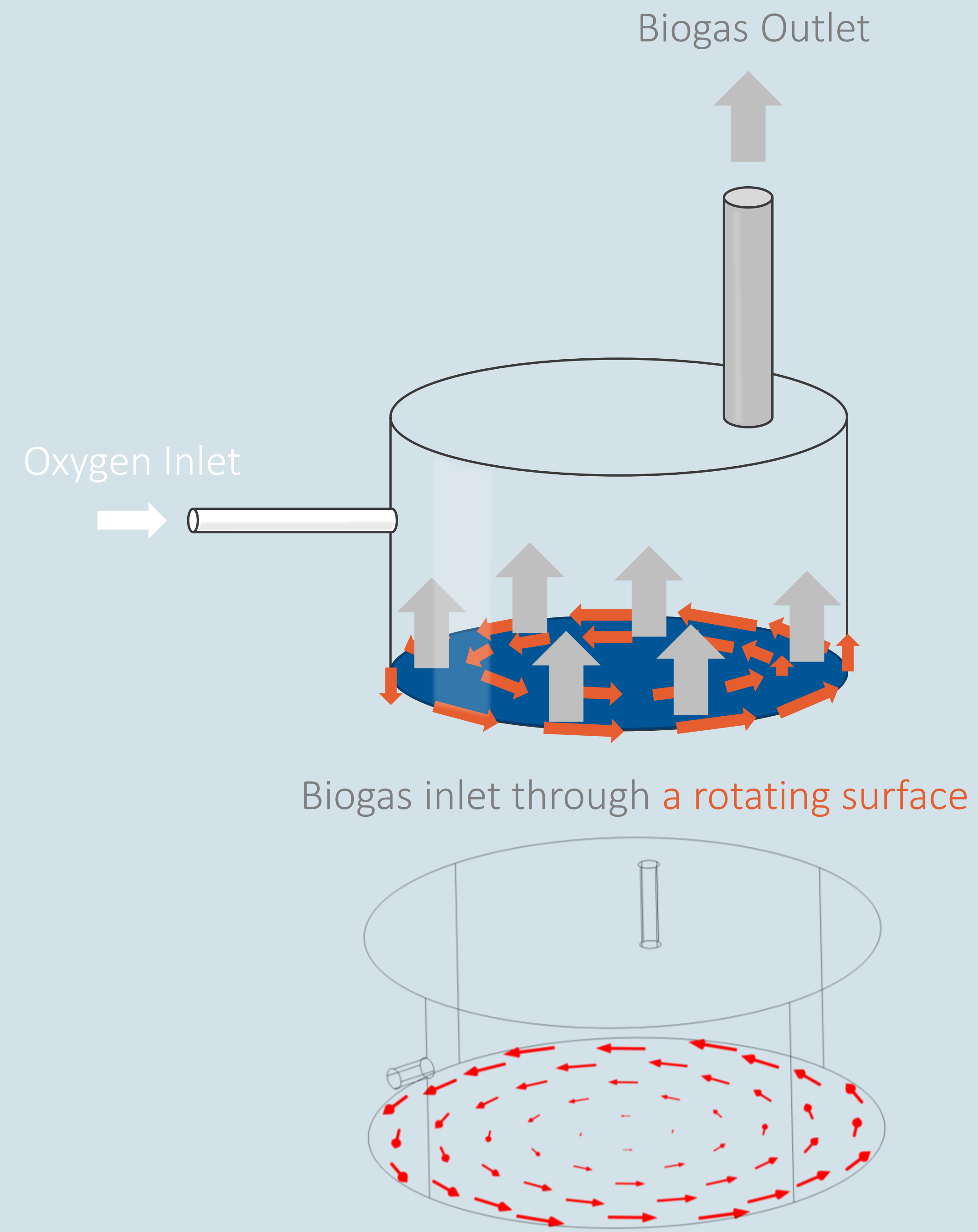
Modelling Challenges: Simulation of Stirring

Important simplification: Computational domain made only from digestor's headspace

- Assumption 1: Biogas uniformly inflows through rotated fluid surface
- Assumption 2: Fluid surface rotates with the same RPM as the stirrer
- Assumption 3: We neglected shape of rotated fluid surface – paraboloid (we computed with planar boundary instead)



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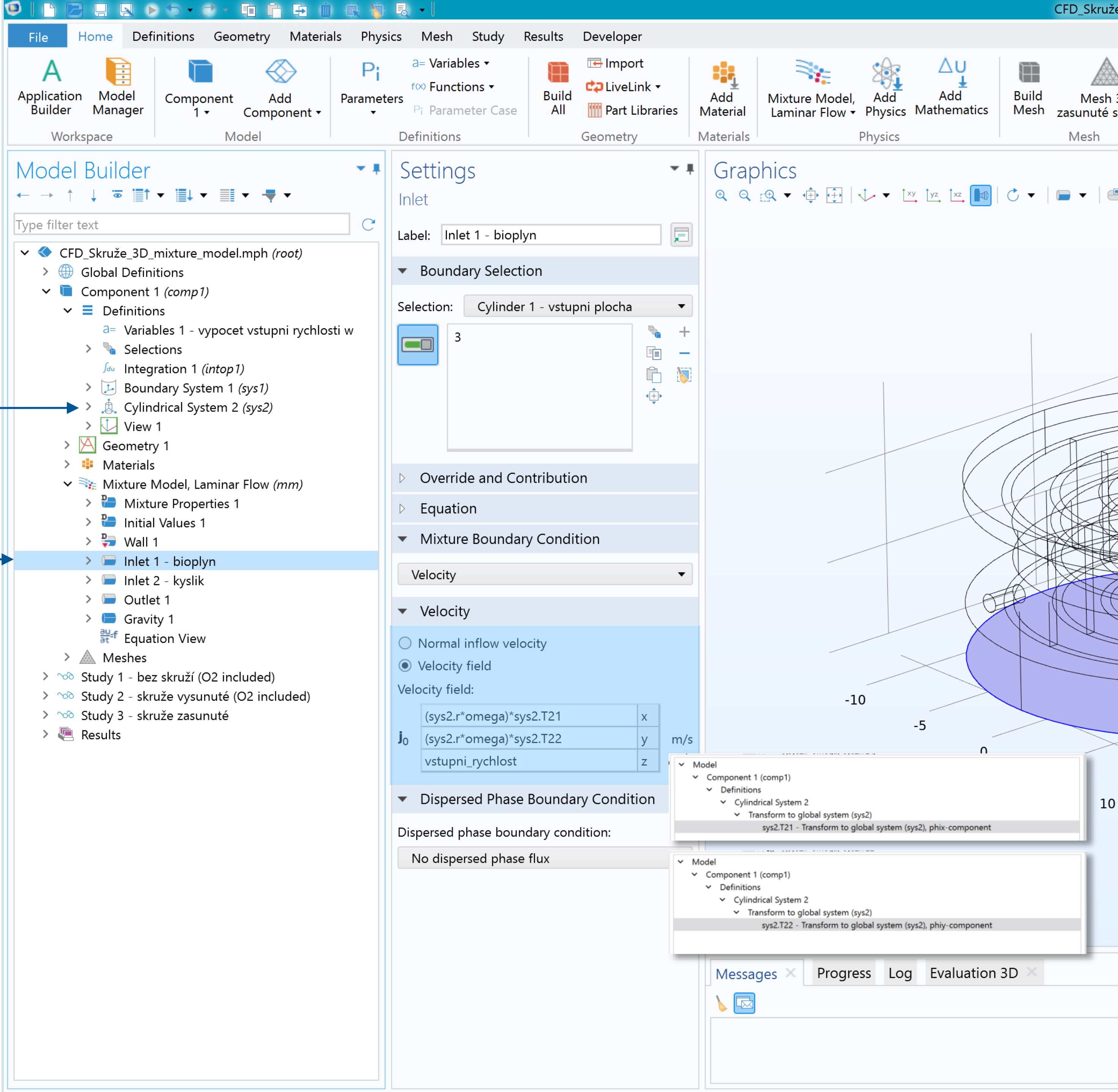
Modelling Challenges: Simulation of Stirring

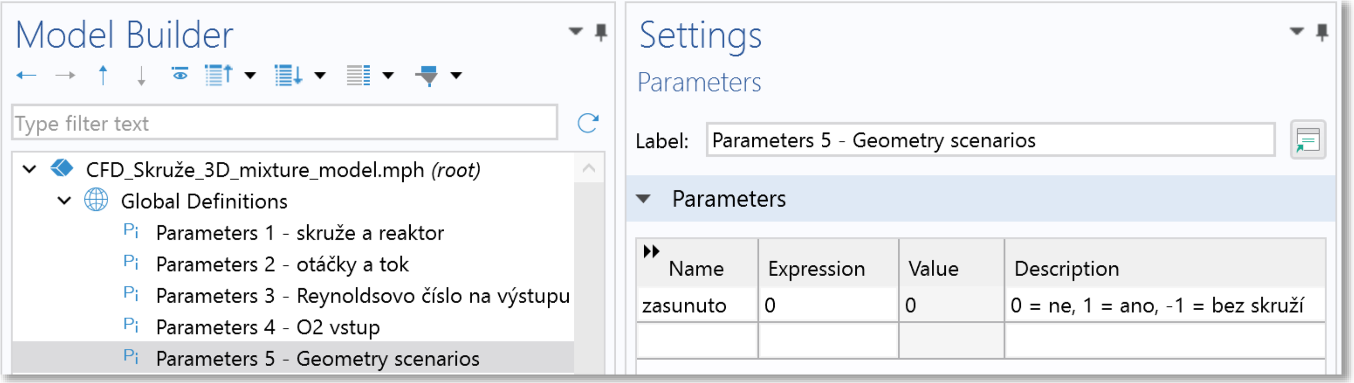
Important simplification: Computational domain made only from digestor's headspace

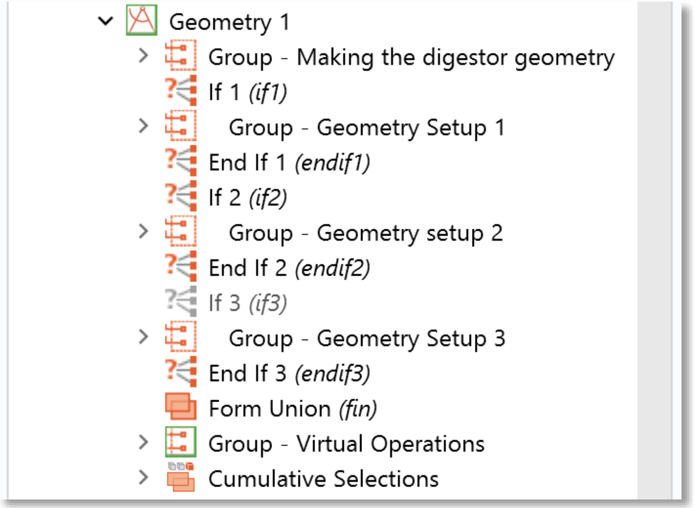
- Model Settings:
  - Cylindrical Coordinate System defined
  - Biogas laminar inlet with user-defined velocity field (transformation between Cartesian system 1 and cylindrical 2 used)
  - Oxygen normal inflow velocity
  - Biogas constant pressure outlet
  - Gravity included

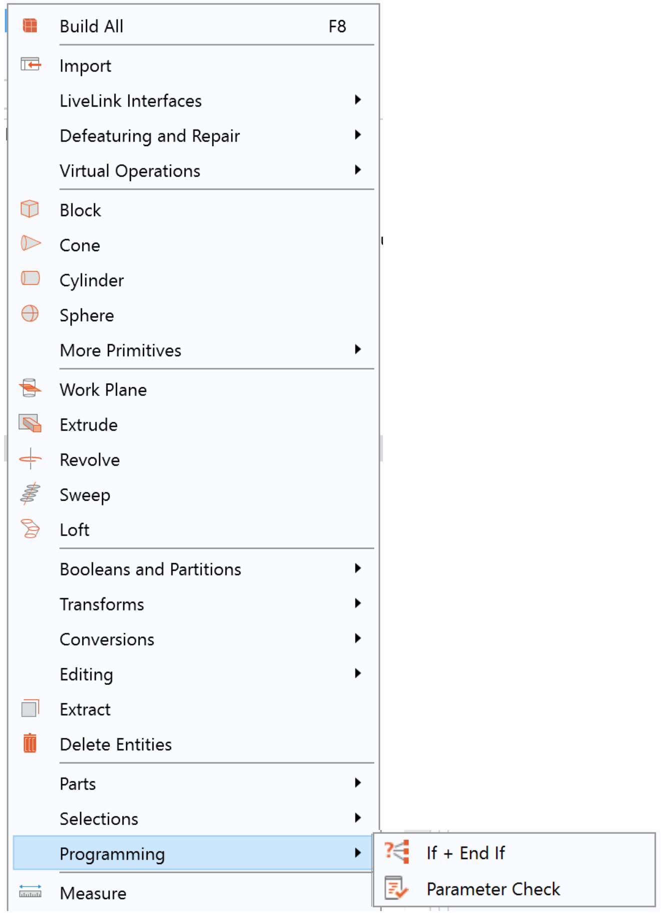


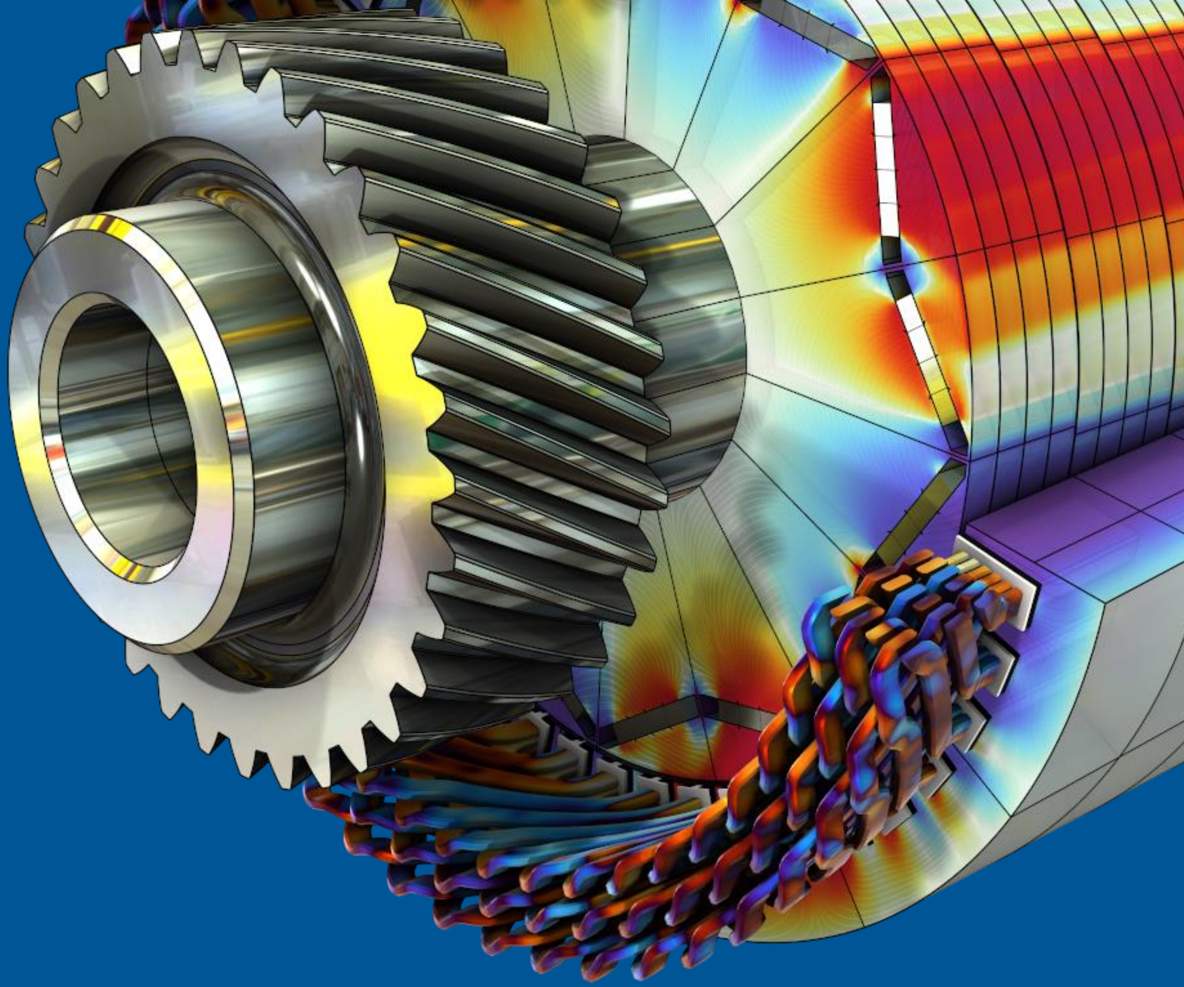
Modelling Challenges: 3 Geometry Scenarios

- Scenarios have different topology
- User changes a global parameter value:
  - 0 = cylindrical baffles 3 cm above
  - 1 = cylindrical baffles immersed in fluid
  - -1 = without baffles
- Less known functionality of programming the geometry reads parameter and changes geometry setup accordingly.
- Another possible solution would be making three different components.









Simulation Results

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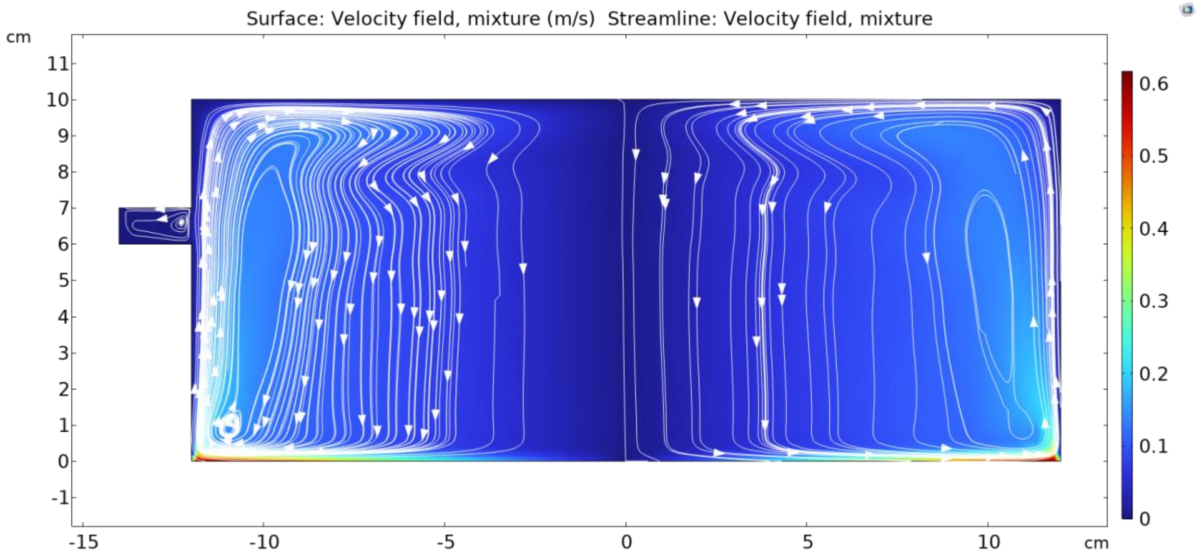
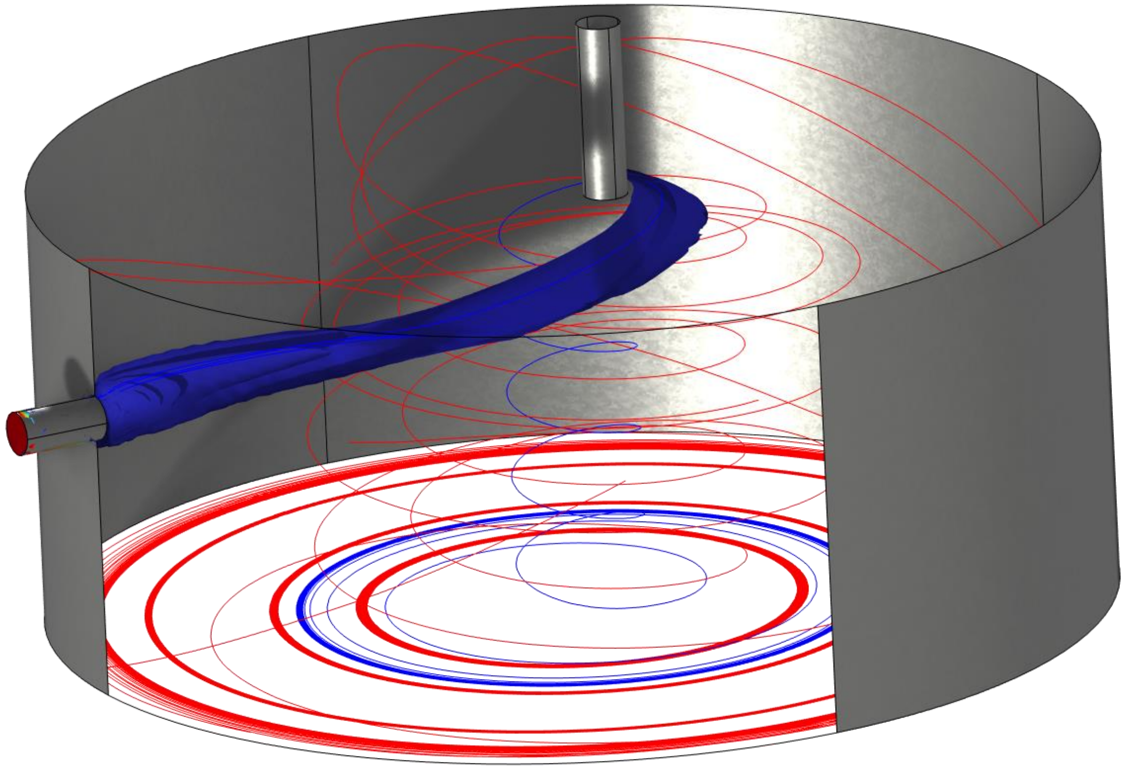
Without the Cylindrical Baffles

- Mesh consists of 133410 elements
- Results are independent on the mesh
- Red Streamlines: continuous phase
- Blue Streamlines: dispersed phase
- Isosurface: Dispersed phase volume fraction
- Conclusion:

„In the experiment with empty headspace, the biogas coming from the liquid was carried to the walls by centrifugal force together with oxygen. The gas mixture was evenly distributed throughout the headspace.“

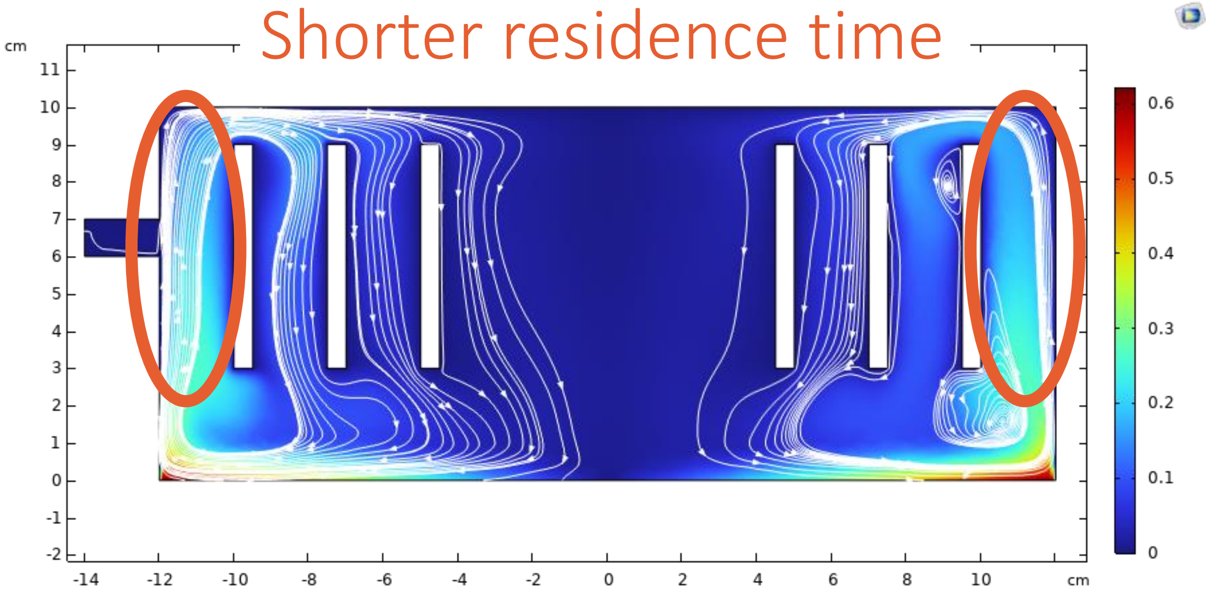


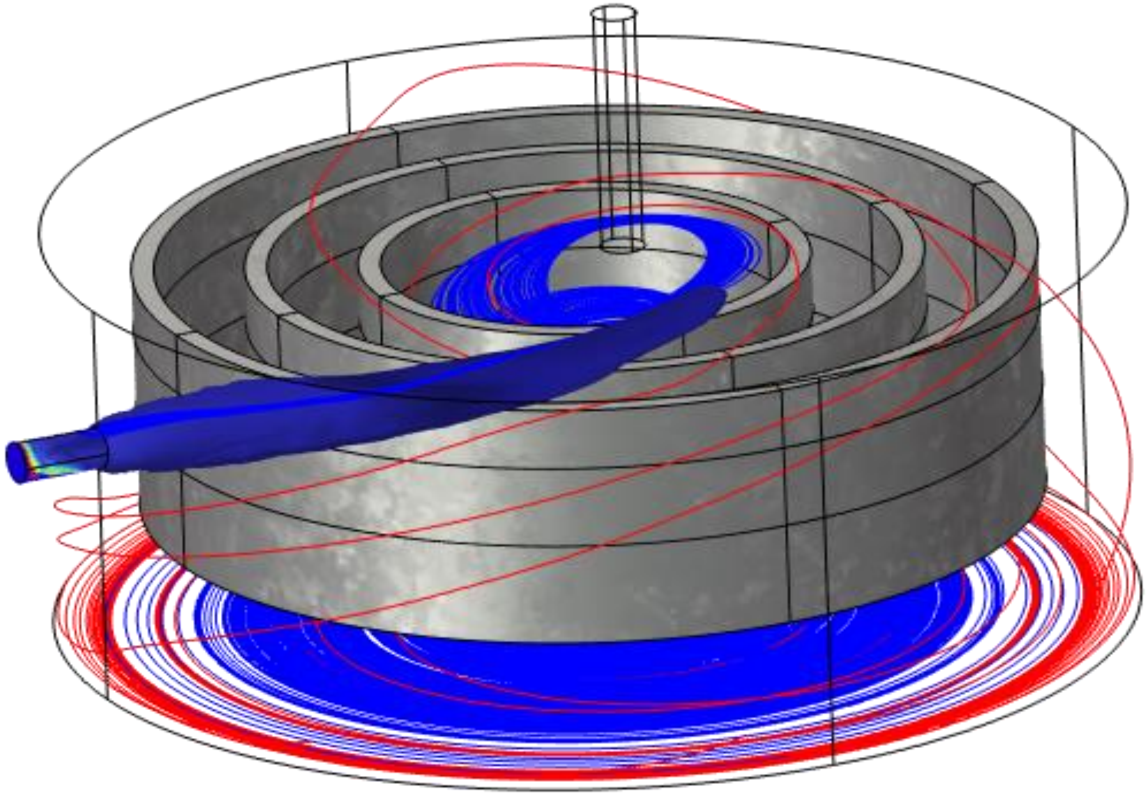


Cylindrical Baffles Up

- Mesh consists of 1290048 elements
- Results are independent on the mesh
- Red Streamlines: continuous phase
- Blue Streamlines: dispersed phase
- Isosurface: Dispersed phase volume fraction
- Conclusion:

„The biogas coming from the liquid was carried to the walls by centrifugal force together with oxygen. However, the velocity between the last cylinder and the wall is much higher because of a cross-section reduction. It leads to shorter residence time in the area.“

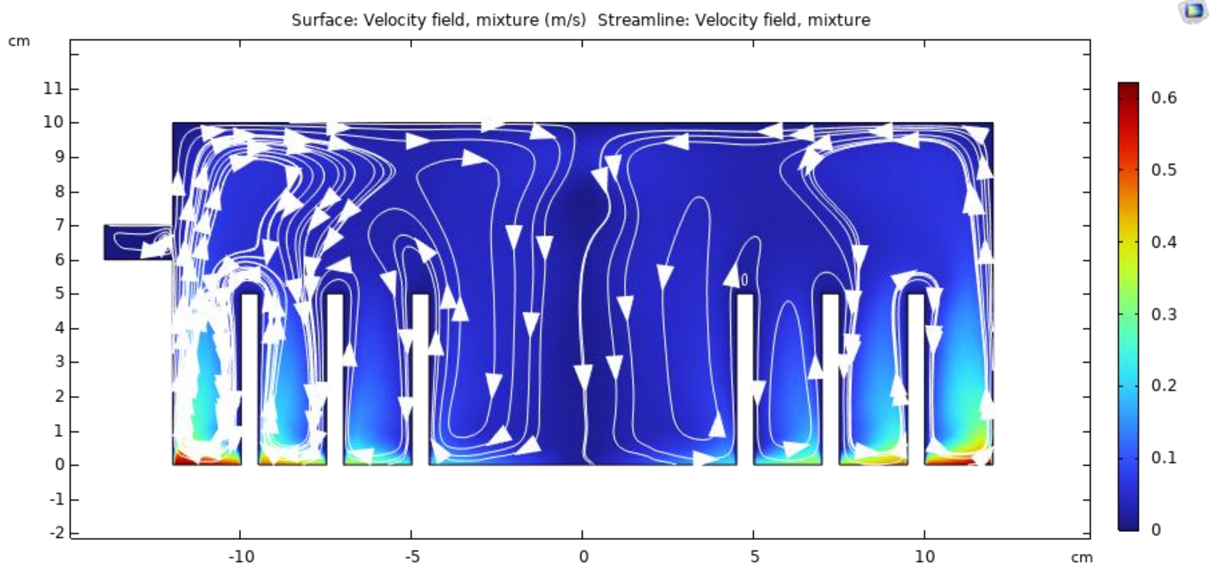


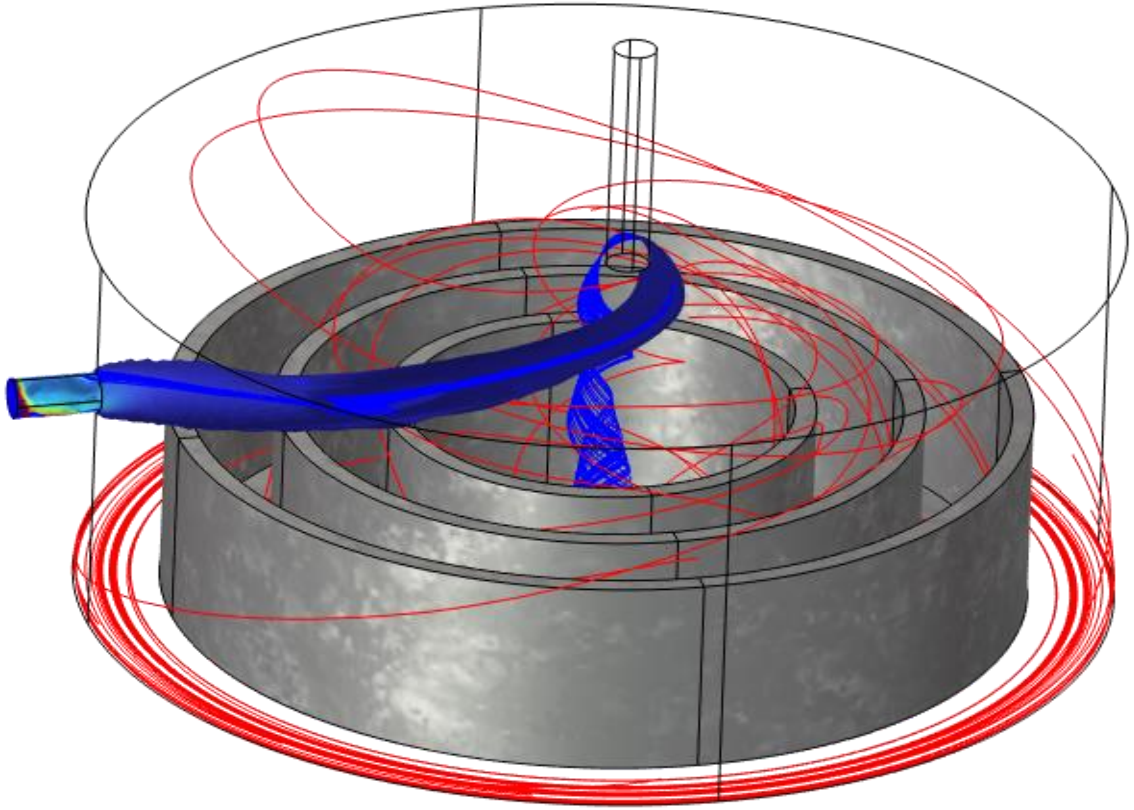


Cylindrical Baffles Immersed

- Mesh consists of 1168122 elements
- Results are independent on the mesh
- Red Streamlines: continuous phase
- Blue Streamlines: dispersed phase
- Isosurface: Dispersed phase volume fraction
- Conclusion:

„The gas mixture could not be directly pushed to the walls since the cylinders interrupted the flow. The mixture flows from the center from one gap to another. The residence time of the mixture between the cylinders could have caused all oxygen was entirely consumed.“





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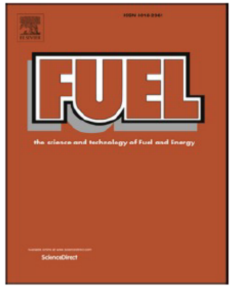

Full Length Article

Importance of digester's headspace geometry for the efficient H_2S removal through microaeration; experimental and simulation study

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A R T I C L E I N F O

Keywords:
Anaerobic digestion

A B S T R A C T

Microaeration for biogas desulfurization occurs mainly in the headspace of anaerobic digesters where the biofilm growth is mainly reported; however, no study has been focused on the effect of headspace geometry on

There is a Space for Improvements

There is a Space for Improvements

- The model explained the experimental results, but…
- Boundary condition **Internal Wall** for the baffles would spare plenty of DOFs
- **Particle Tracing** would help to visualize and compute the Residence Time Factor
- The **Optimization Module** could find the optimal design of cylindrical baffles

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