



Renewable **Fuels** and **Chemicals** for Switzerland*

The reFuel.ch Toolbox for Optimizing Green Methanol Synthesis

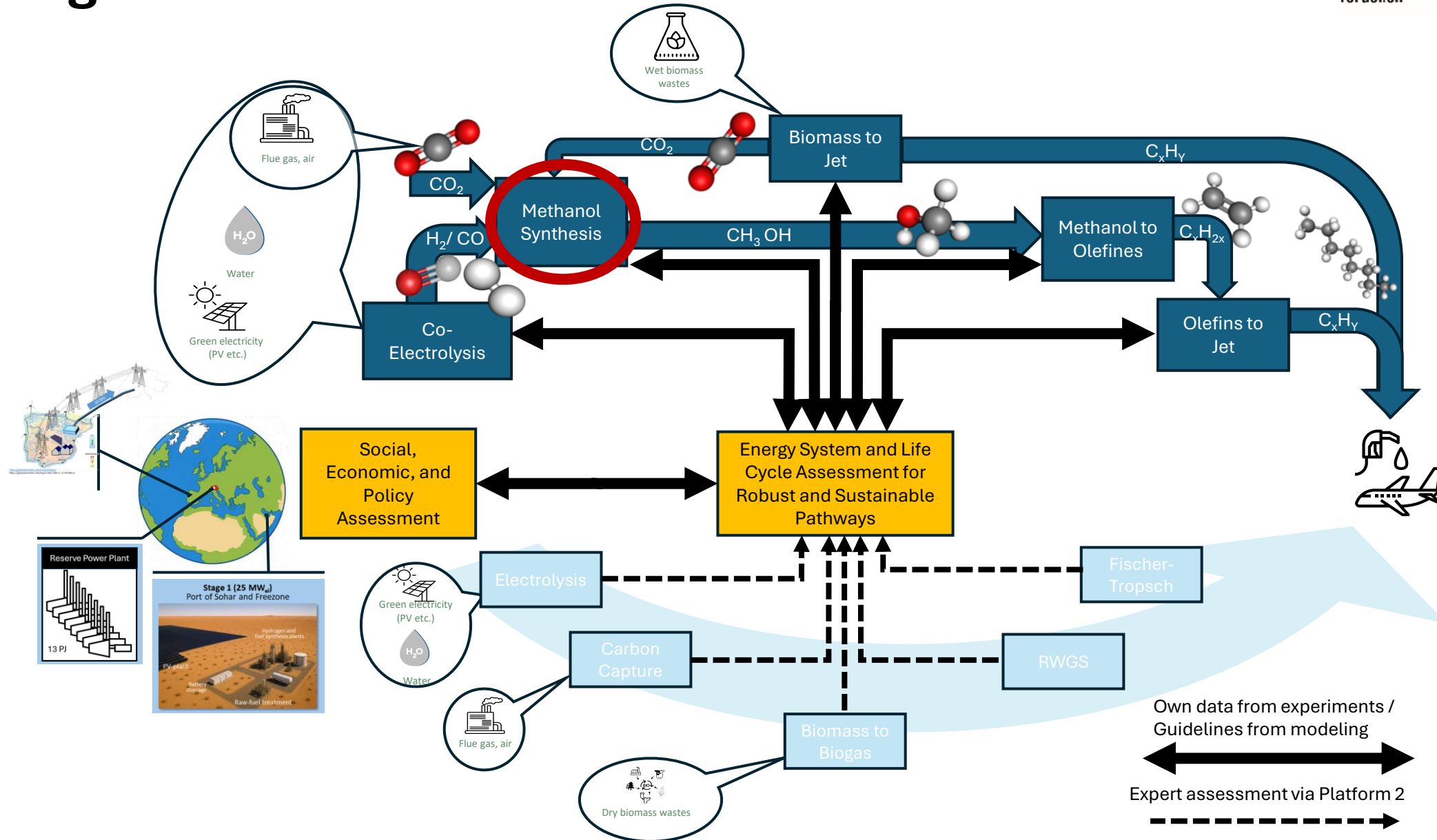
Presenter: Riccardo Puragliesi



*reFuel.ch is a consortium sponsored by the Swiss Federal Office of Energy's SWEET programme and coordinated by Empa.



High-level introduction & link to consortium



How can we achieve efficient, load-flexible conversion of CO₂ to methanol?

High-level goals of WP5:

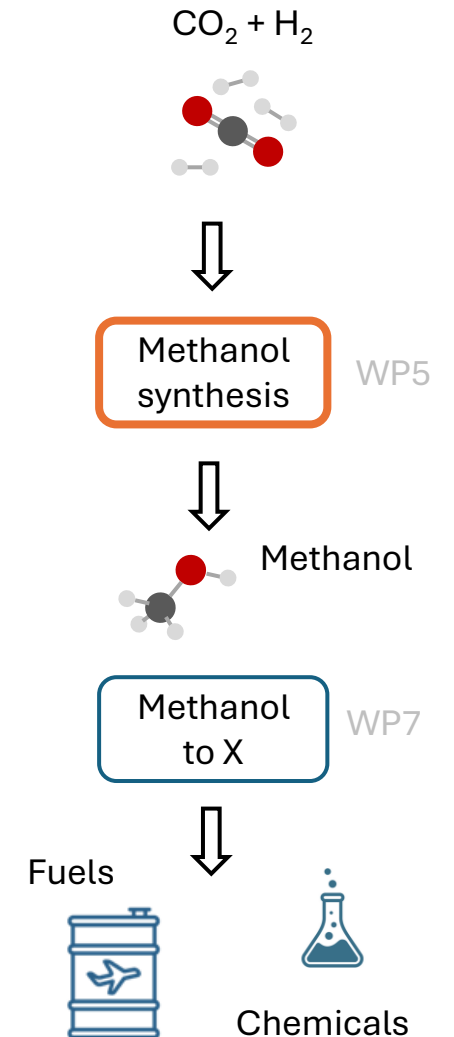
- Direct CO₂ conversion to methanol → carbon-neutral product
- Optimize process by increasing conversion → increase energy efficiency
- Increase load flexibility → couple with fluctuating renewable energy supply

Approach:

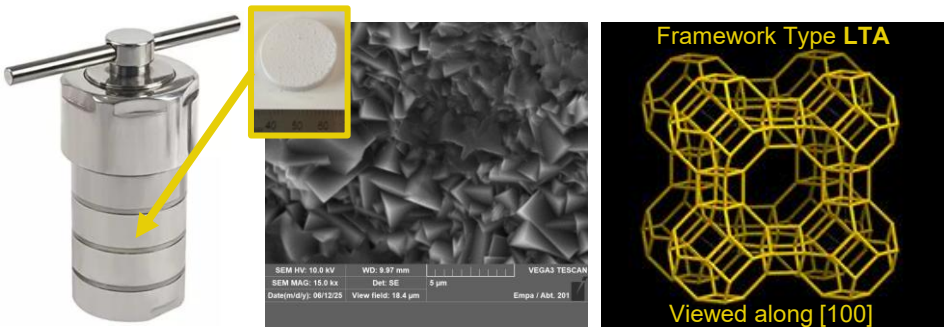
- Selective separation of (by-)products increases conversion
- In-situ water removal increases feed flexibility
- New operation strategies increase load flexibility

Link to consortium objectives:

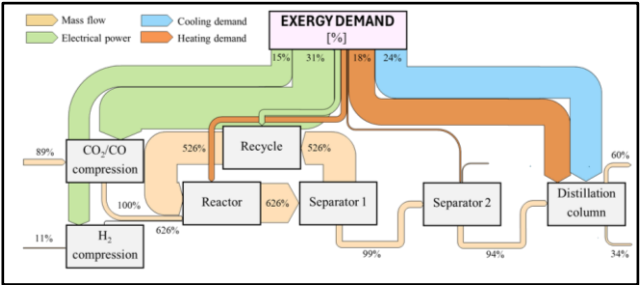
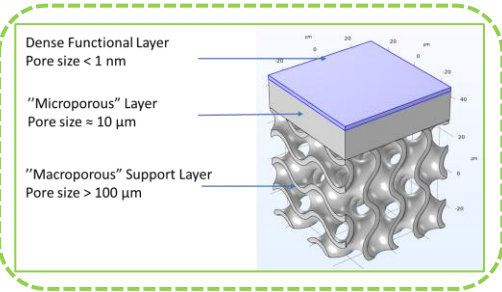
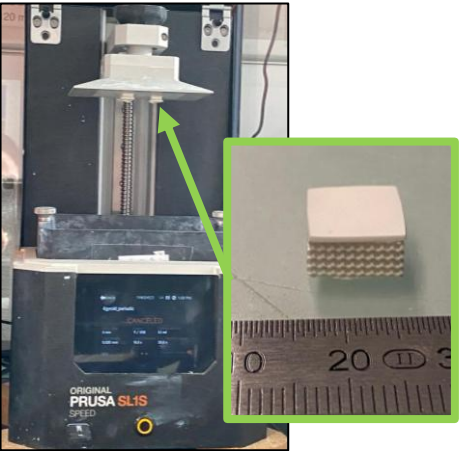
- Flexible CO₂-based platform chemical and energy carrier
- Integration into future energy system
- Easy to store, transport, and convert to a large palette of products (fuels, chemicals, goods)



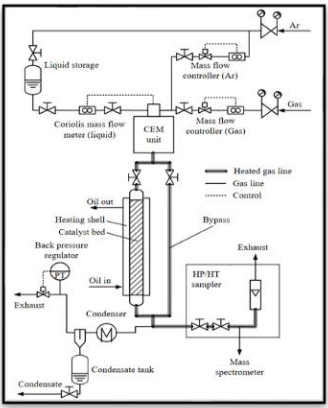
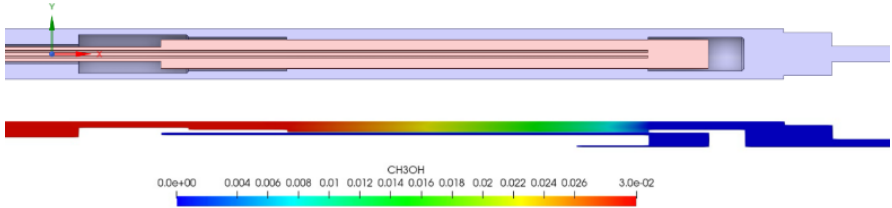
The Toolbox for Optimizing Green Methanol Synthesis



Material synthesis tools



Computational tools



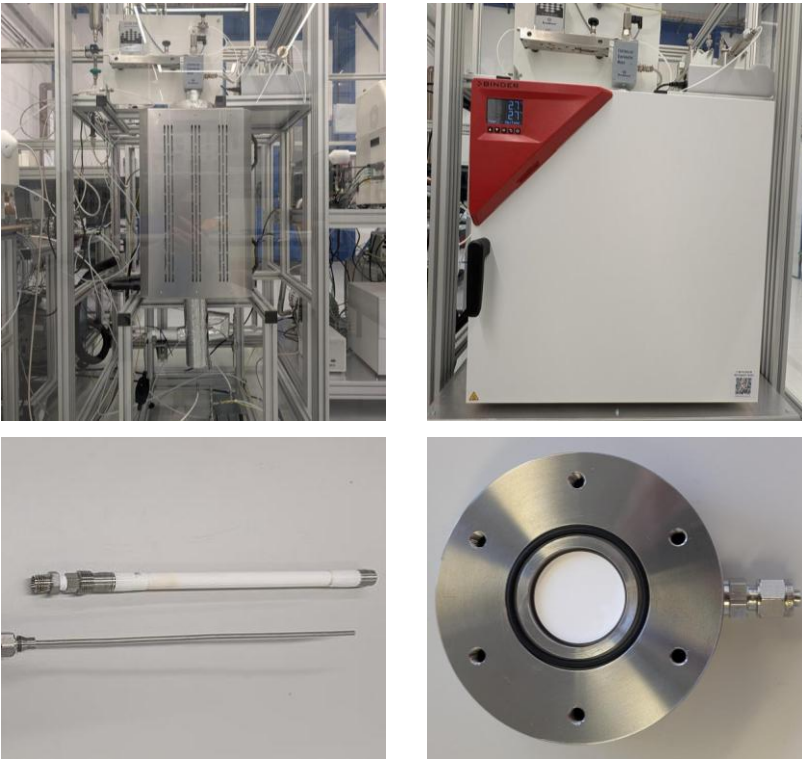
Experimental tools



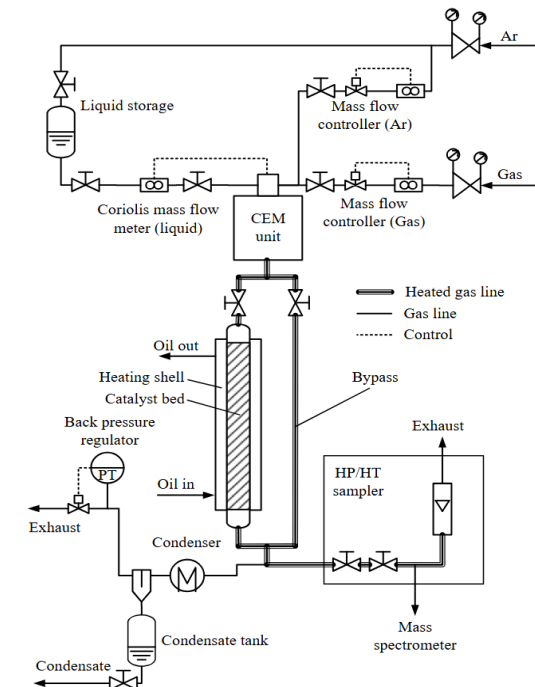
Experimental infrastructure

- Up to 50 bar characterization of catalysts, sorbents, and membranes under process conditions
- Full process cycle boundary conditions simulation enables rapid transfer from TRL2 to TRL4

Membrane reactors



Reactive breakthrough setup



Develop a selective, stable, and economic catalyst system

Demonstrate the sorption-enhanced reactor system on laboratory scale



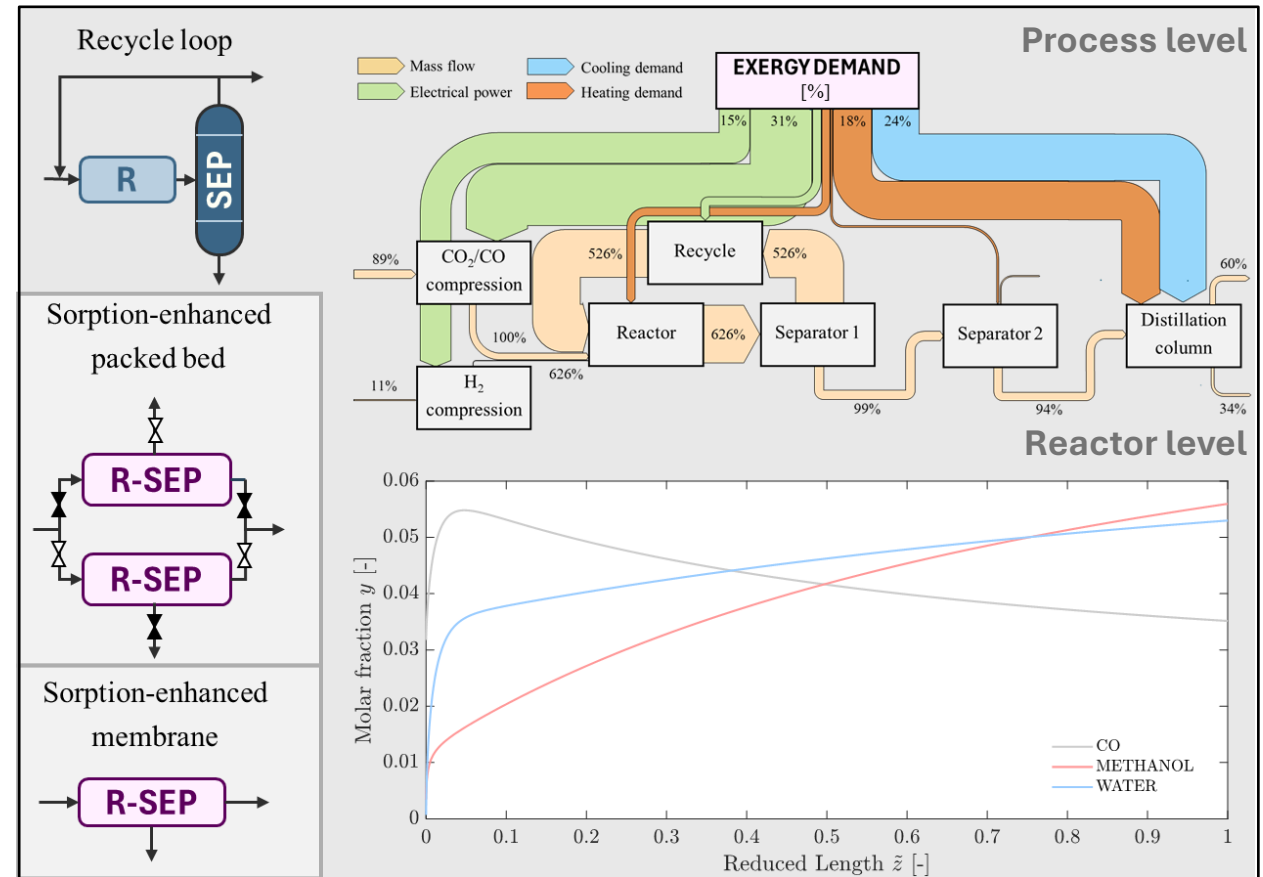
Model Infrastructure – Process Level

Efficient model framework:

1. Steady-state models for conventional and membrane reactors
2. Transient model for sorption-enhanced reactor
3. Flowsheet simulation
4. Aspen Plus integration for distillation modeling

- High flexibility in reactor concepts
- High accuracy in energy-demanding unit operations
- Benchmarking and KPI calculation
- Techno-economic assessment

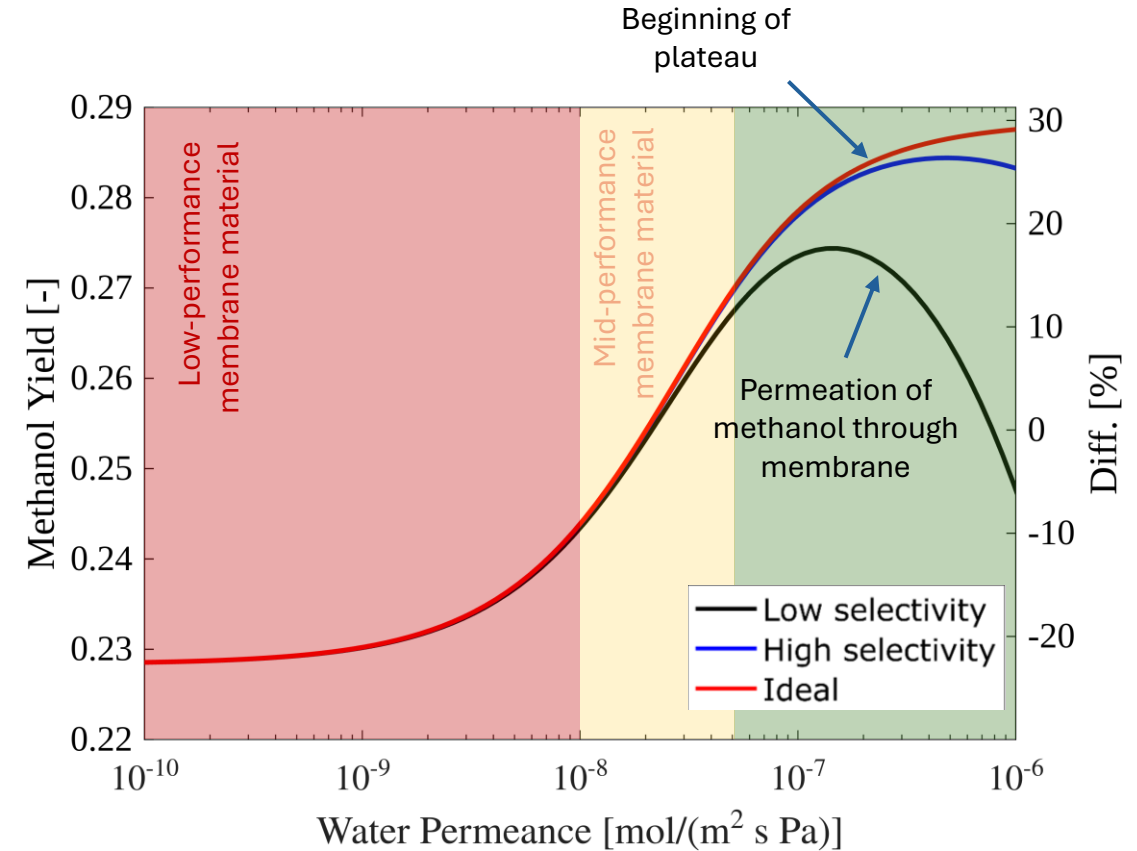
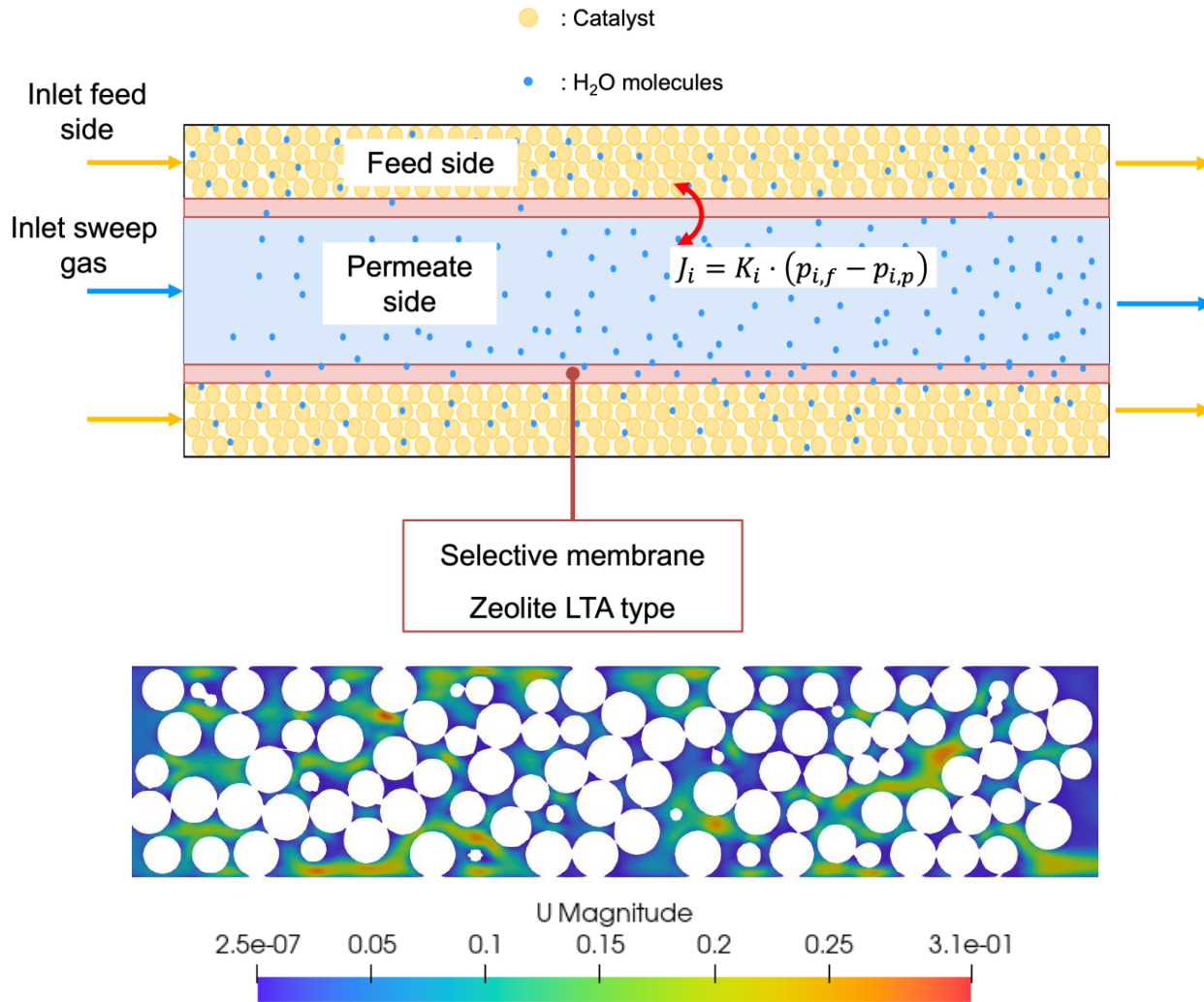
Come and see the poster!



Identify the best sorption-enhanced catalytic approaches for efficient methanol synthesis from CO₂



Model Infrastructure – Reactor Level

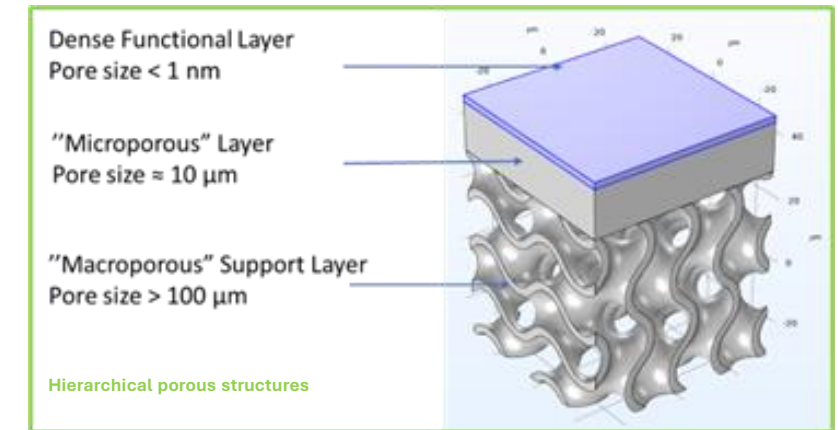
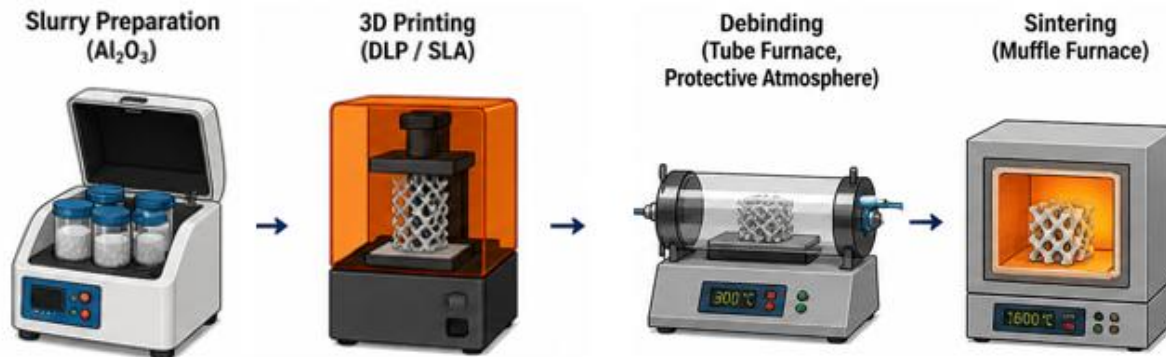


High-fidelity reactor simulation for optimized reactor geometries and operation conditions

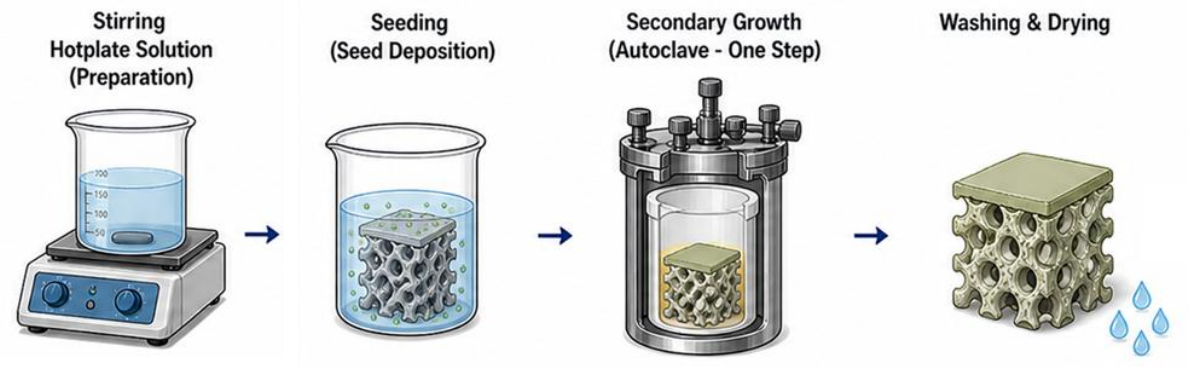


Materials Synthesis

3D printing of ceramic supports



Zeolite membrane synthesis



High-performance membranes

- Mechanical stability $\rightarrow$ robust supports for CO_2 to methanol membrane reactor conditions
- Controlled shape $\rightarrow$ complex geometries, optimized flow & scalability
- Performance enhancement $\rightarrow$ improved permeability, selectivity & catalytic efficiency
- Hierarchical porosity $\rightarrow$ better mass transport & reduced diffusion limitations



Develop a selective, stable, and economic catalyst-membrane system

Conclusions

What are the applications of the toolbox?

Materials development will emphasize process and material optimization, ongoing performance testing under operational conditions, and developing suitable sealing materials.



Materials property database for membrane and sorbent materials

Optimization of transport processes in membrane systems and fixed-bed sorption-enhanced reactors, pursued through a joint effort involving materials development, modeling, experimental testing, and process design.



Relevant material properties and limitations

Rigorous assessment of novel developments, from materials to process-system level



Ensure that the WP remains focused on relevant and impactful topics

Acknowledgement

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reFuel.ch - Renewable Fuels and Chemicals for Switzerland

reFuel.ch is a consortium sponsored by the Swiss Federal Office of Energy's SWEET programme and is hosted by Empa.

The authors bear sole responsibility for the conclusions and the results presented.

