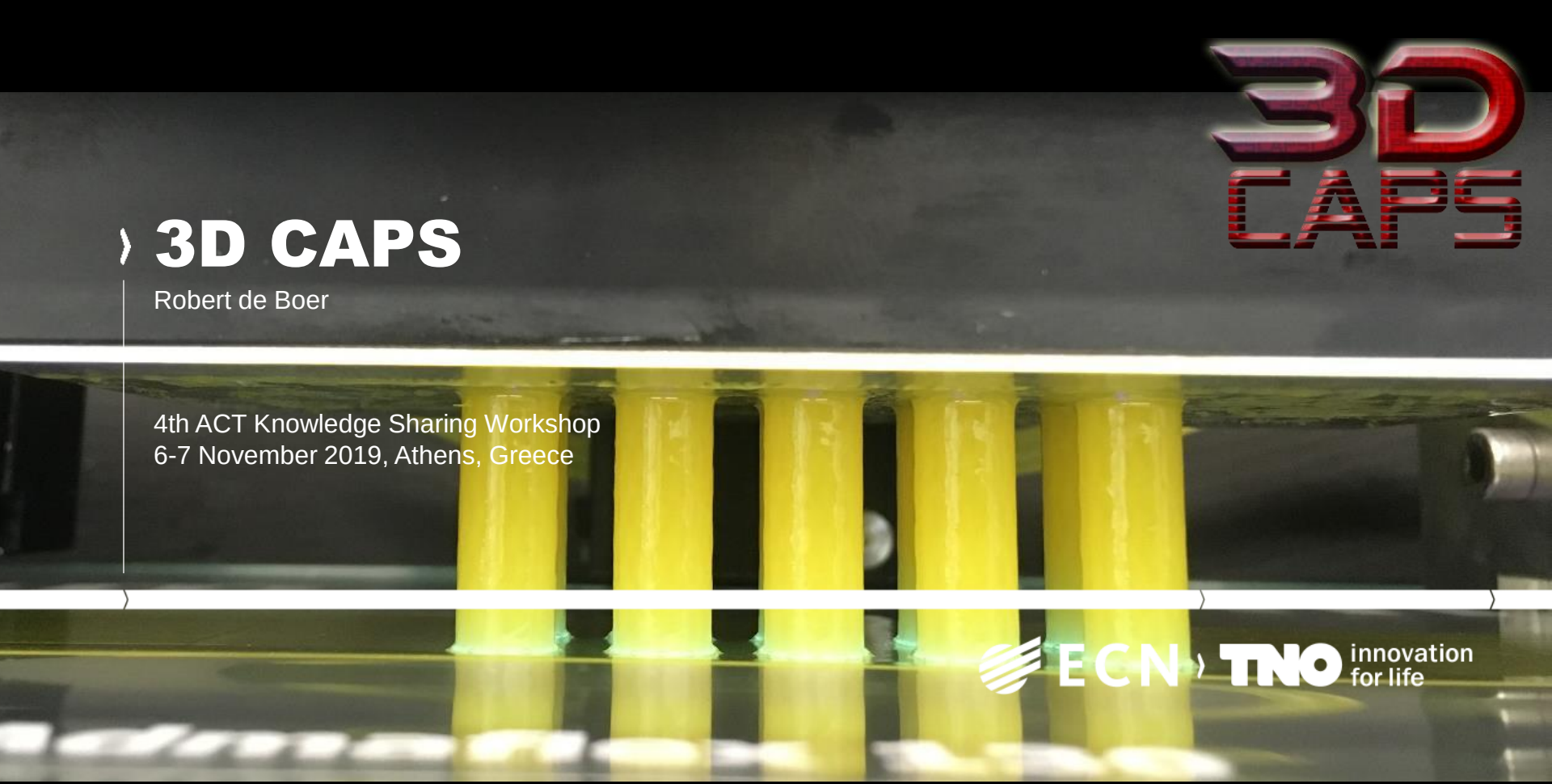

3D CAPS

Robert de Boer

4th ACT Knowledge Sharing Workshop
6-7 November 2019, Athens, Greece

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Three Dimensional Printed Capture Materials for Productivity Step-Change

CONTENT

- Project Background
- Project Overview
- Results
  - 3D Printing of structured sorbents
  - Testing of structured sorbents
  - Modelling: CFD and Process modelling
  - CO_2 capture applications
  - Business Development
  - Knowledge Sharing

EXAMPLES OF CO_2 CAPTURE PLANTS

Carbon Capture and Storage facility at the Scotford Upgrader.

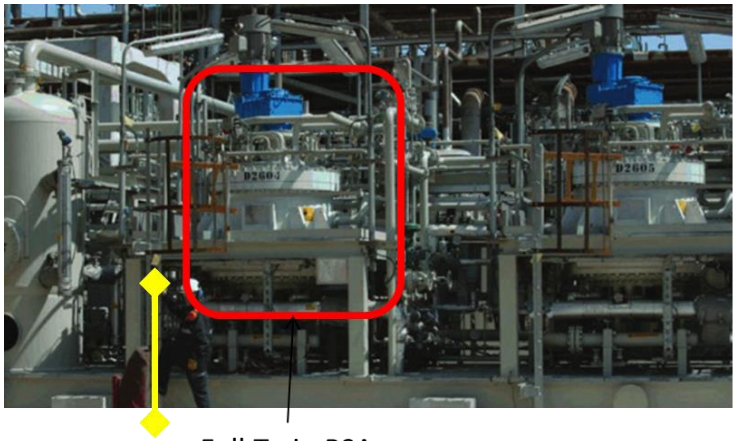
http://www.oilandgasproductnews.com/company/6291/fluor-canada-ltd

Skid Mounted Amine System

https://www.epmag.com/wanted-efficient-gas-treatment-system-fit-tight-fpso-footprint-816471#p=1

MORE COMPACT OPERATION

- Structured sorbents vs. conventional technologies



Full Train PSA

Full Train PSA

Stepwise SEWGS

WHY 3D PRINTING?

- Make structures that cannot be made by other traditional means, improving e.g.:
  - Heat- and mass transfer properties
  - (Re)distribution of gas flows (dispersion)
  - Pressure drop
  - Mixing within the structure
  - Heat supply/removal
  - Volumetric capacity

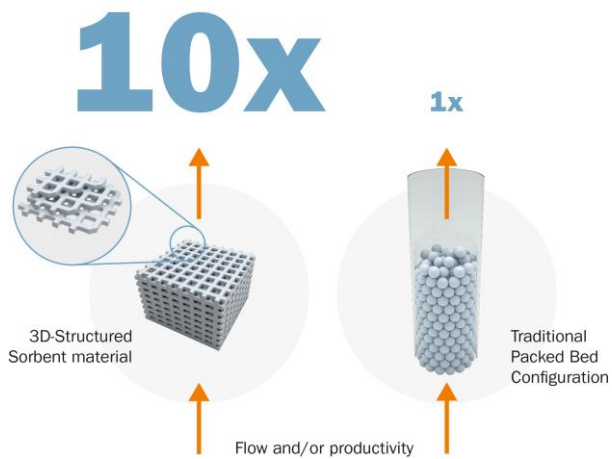
→ Increase productivity!



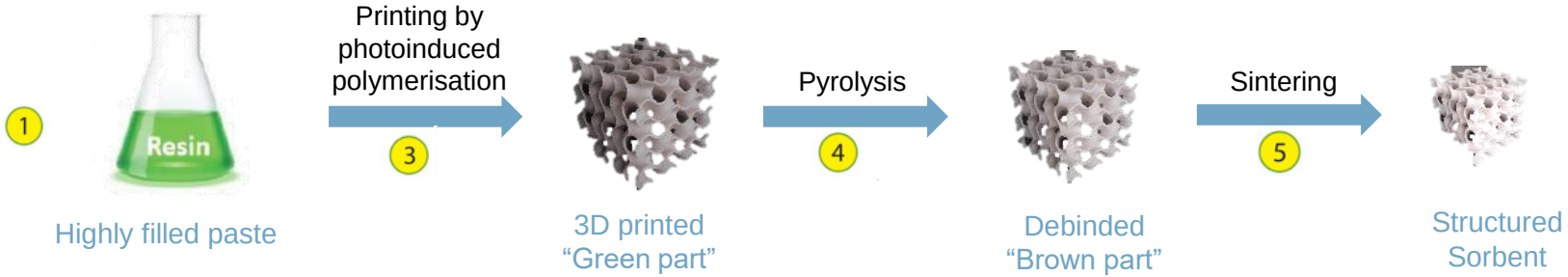

Zocca, *et al.*, *J. Am. Ceram. Soc.*, **2015**, 98, 1983–2001

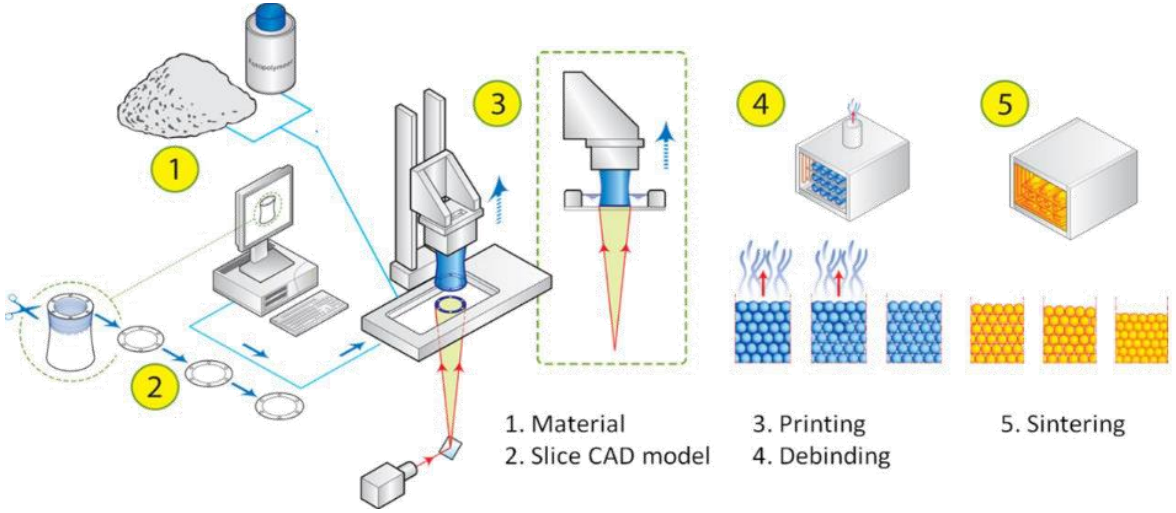
PROJECT OVERVIEW

- Overall objective:
  - Productivity (kg CO_2/m^3hr) increase by factor 10 of sorbent based capture technologies
- Means:
  - Additive manufacturing, 3D-printing
- Materials:
  - Hydrotalcite
  - Amine Functionalised Silica
- Modelling: CFD and process models
- Applications:
  - *Post-combustion* capture NGCC power plants
  - *Pre-combustion* capture for H_2 production



DIGITAL LIGHT PROCESSING, DLP 3D PRINTING





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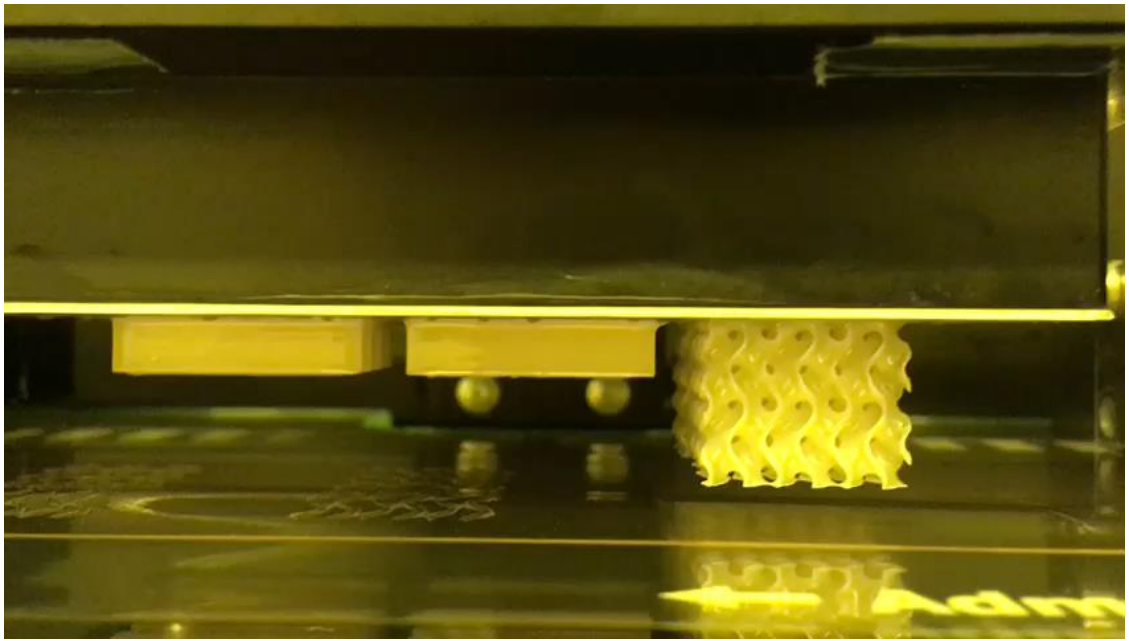
PRINTING AMORPHOUS SILICA



3D-PRINTING STATUS AND RESULTS

- **HTC:**
  - Paste development and printing ✗
    - Varying results → poorly reproducible
  - Design and printing different structures ✓
  - Characterisation of pressure drop, strength, sorption properties — ongoing
- **Silica:**
  - Paste development and printing ✓
  - Structure design updates ✓
  - Optimise grafting / impregnation of amines ✓

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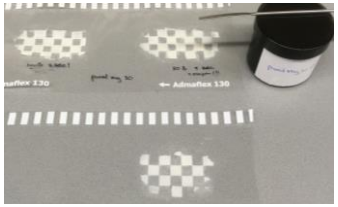
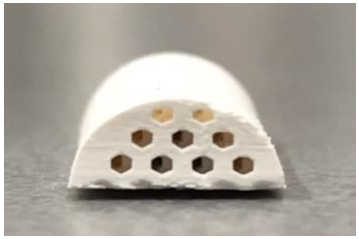
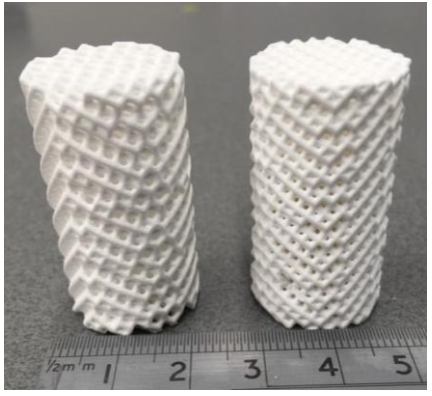






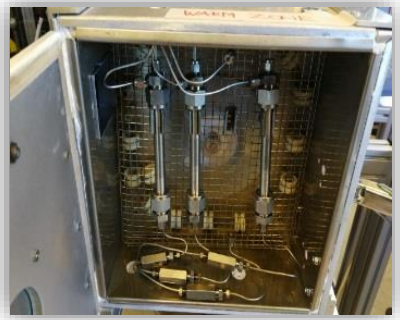
TESTING 3D PRINTED SORBENTS

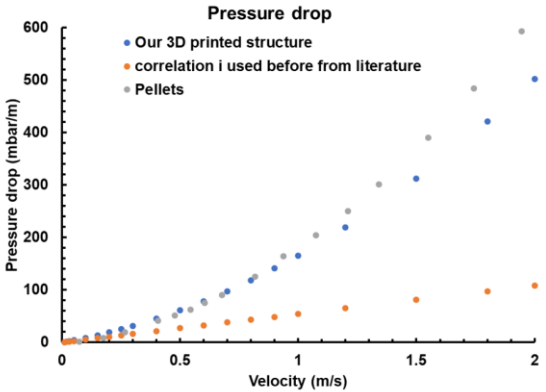
Functionalised Silica

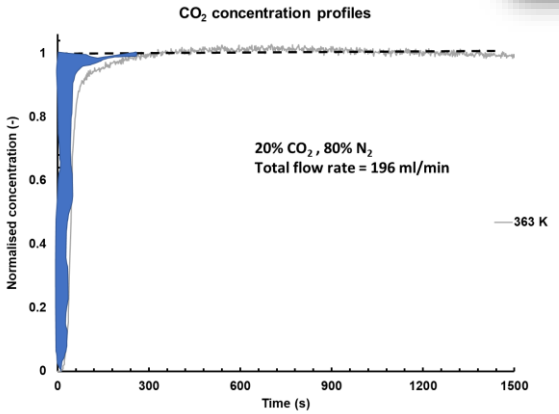
8.3 mm in height,18 mm diameter
2 structures weighing 2.3 g packed in the column
A step input in concentration provided followed by purge with Nitrogen

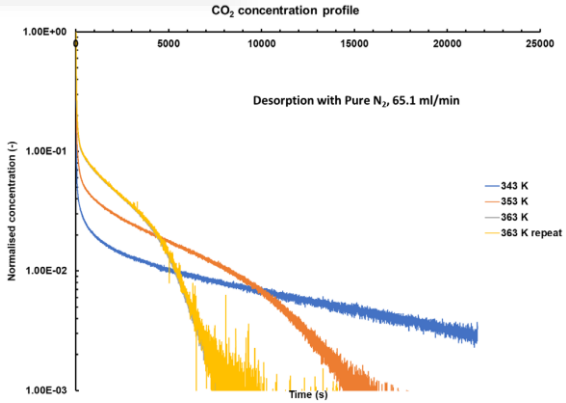
TESTING OF 3D-PRINTED SORBENTS

- Pressure drop ongoing
- Sorption capacity and sorption isotherms ongoing
- Breakthrough curves → Kinetic data ongoing









CO_2 CAPTURE MODELLING

- Computational Fluid Dynamics (CFD) modelling
  - Optimization of 3D-printed configurations
- Multi Cycle modelling
  - Performance analysis and optimisation of sorption cycle process with 3D-Sorbents
- Flowsheeting
  - Sorption system integration and TE-evaluation

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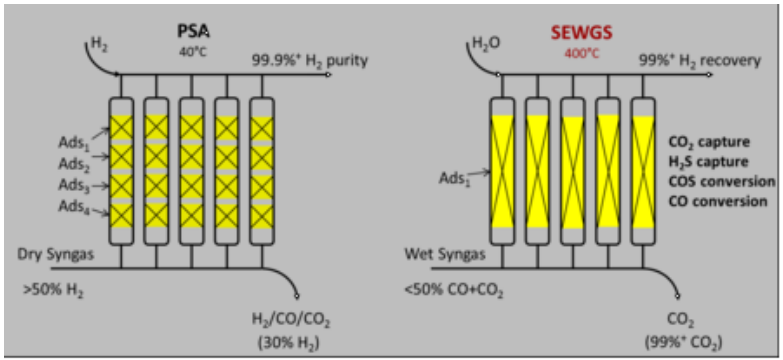
CFD Analysis

Kelvin cell structures

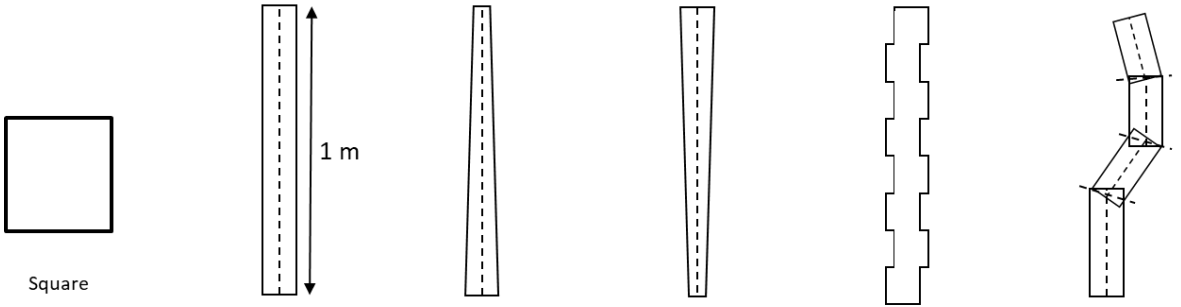
Chemical Engineering Journal

Volume 264, 15 March 2015, Pages 514-521

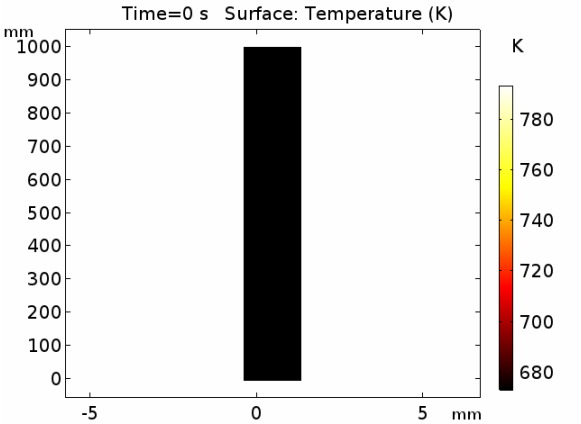


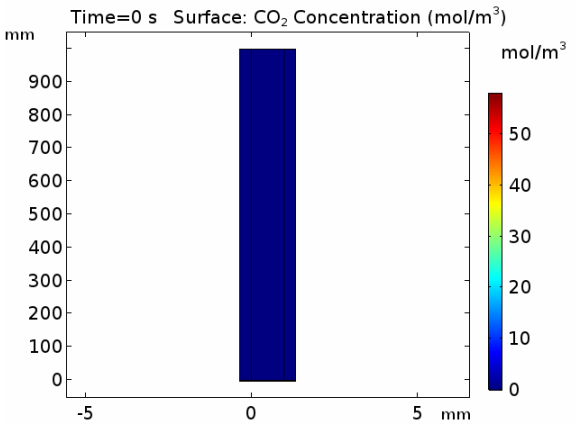
CFD MODELLING OF STRUCTURED SORBENTS

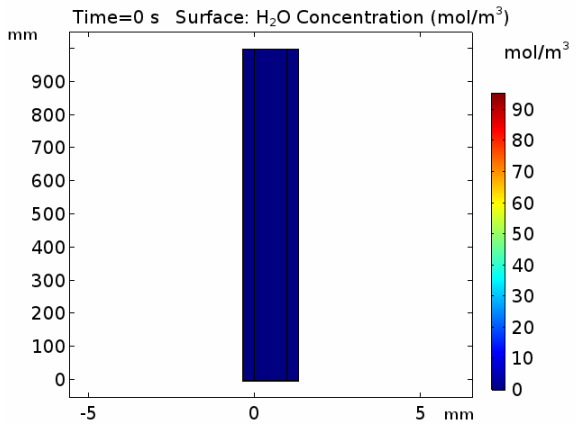
- Five 2D channel geometries, square cross section 1 mm^2 – 1 m length



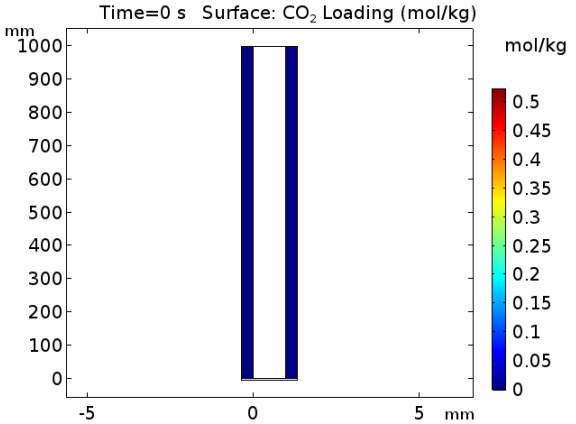
Evolution of time-dependent model

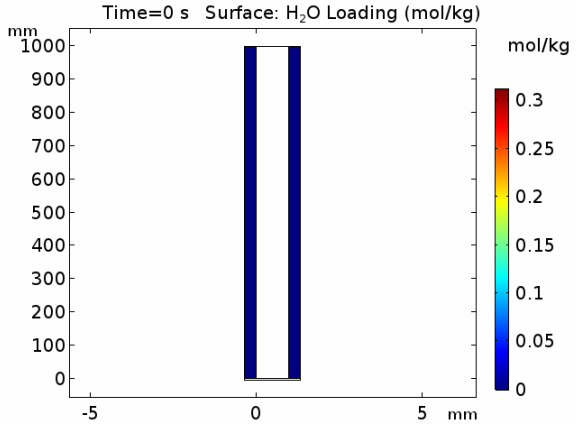






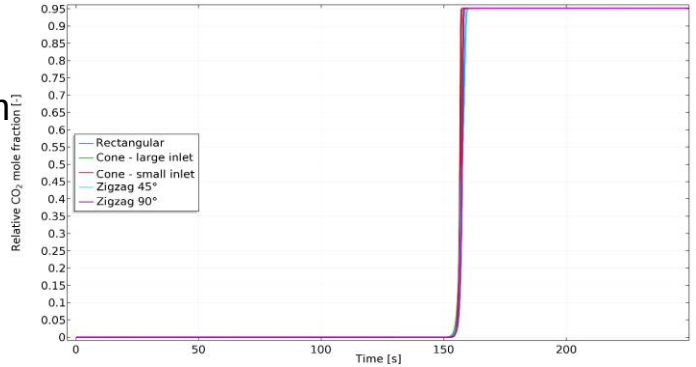
- Interconnected phenomena
- Strong impact of heat transfer
- Competitive nature of adsorption

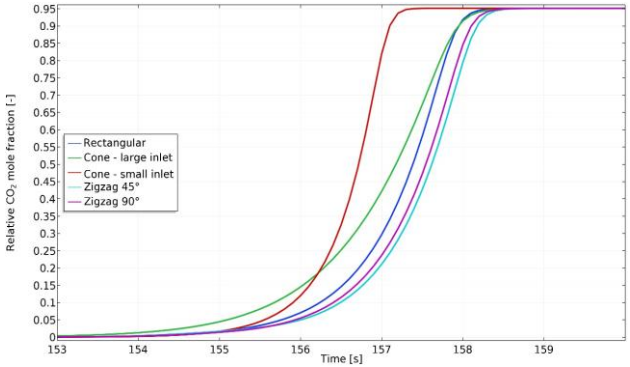




RESULTS AND NEXT STEPS

- Breakthrough curves
- Standard flow rate, 20 lpm
- 400°C / 25 bar



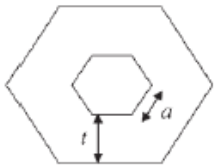


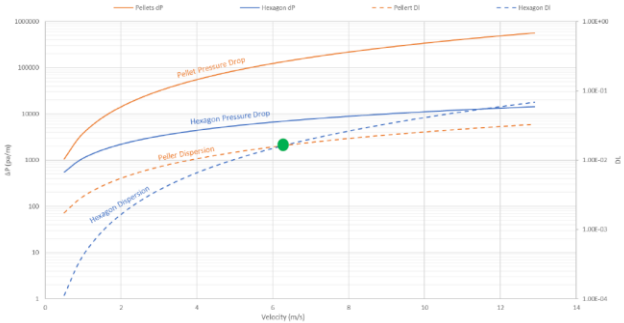
- NEXT STEPS
  - Flow rate sensitivity analysis
  - Validation of CFD model
    - Direct –structured bed data
    - Indirect – packed bed
  - Transition from 2D → 3D time constraints!

CO_2 SORPTION CYCLE MODELLING
SEWGS-POST COMBUSTION CASE

- Evaluate increase in productivity of structured sorbents in comparison to packed bed design.

- Parameter study on the impact of channel geometry on:
  - Mass transfer rate, K_{ldf}
  - Pressure drop
  - Axial dispersion





- Obtain a sorbent geometry and gas velocity that maximizes productivity
- From packed bed (pellets) to structured sorbent bed → **volume reduction factor of 8** ✔

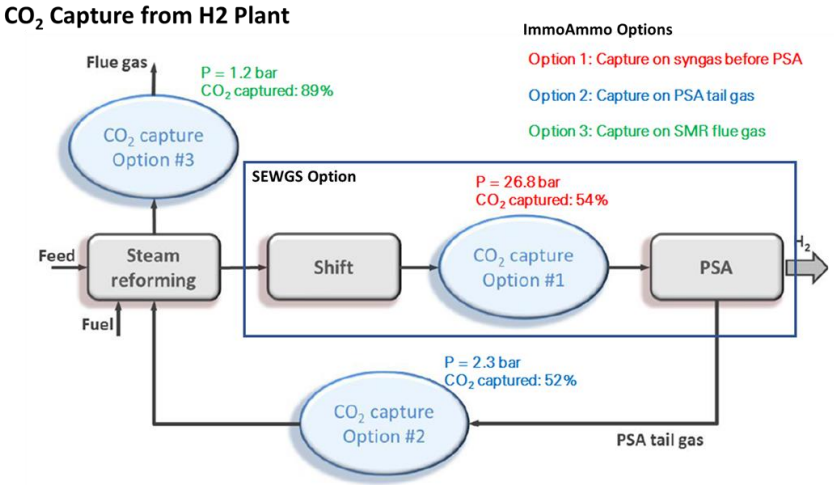
- NEXT STEPS: Modify multicycle simulation to update for new micro and macro geometries and process conditions

CO_2 CAPTURE APPLICATIONS

TECHNO-ECONOMIC ANALYSIS

- **ImmoAmmo (SiO_2)**
  1. *Post-combustion* capture for NGCC plants
  2. *Pre-combustion* capture for H_2 production
- **SEWGS (Hydrotalcite)**
  3. *Pre-combustion* capture for **H_2 production**
  4. ~~*Pre-combustion* capture for NGCC plants~~

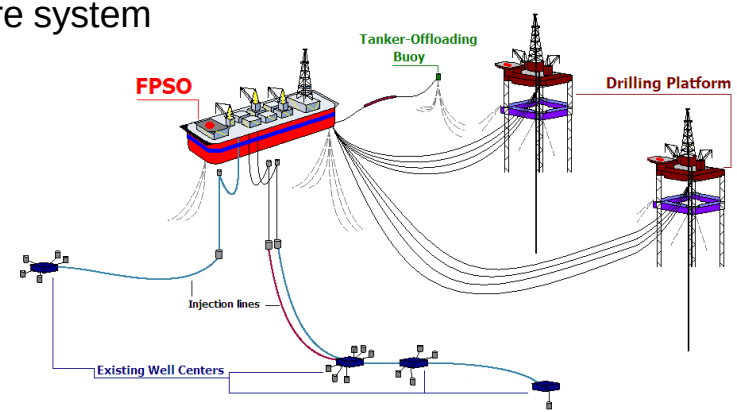
- Quantify costs and performances of:
  - Reference plants (without CO_2 capture)
  - Base cases (CO_2 capture using existing technology, IEAGHG-2017)
  - 3D-CAPS technologies



BUSINESS DEVELOPMENT

ACCELERATING CAPTURE TECHNOLOGY

- Identify and quantify use cases such as:
  - Offshore CO_2 capture from natural gas production
  - CO_2 capture from residual steel gases;
  - H_2S capture from natural gas production on FPSO's improving safety;
- Preparing for next development step: Containerized 3D-capture system



- Public Questionnaire *via* https://3d-caps.eu/

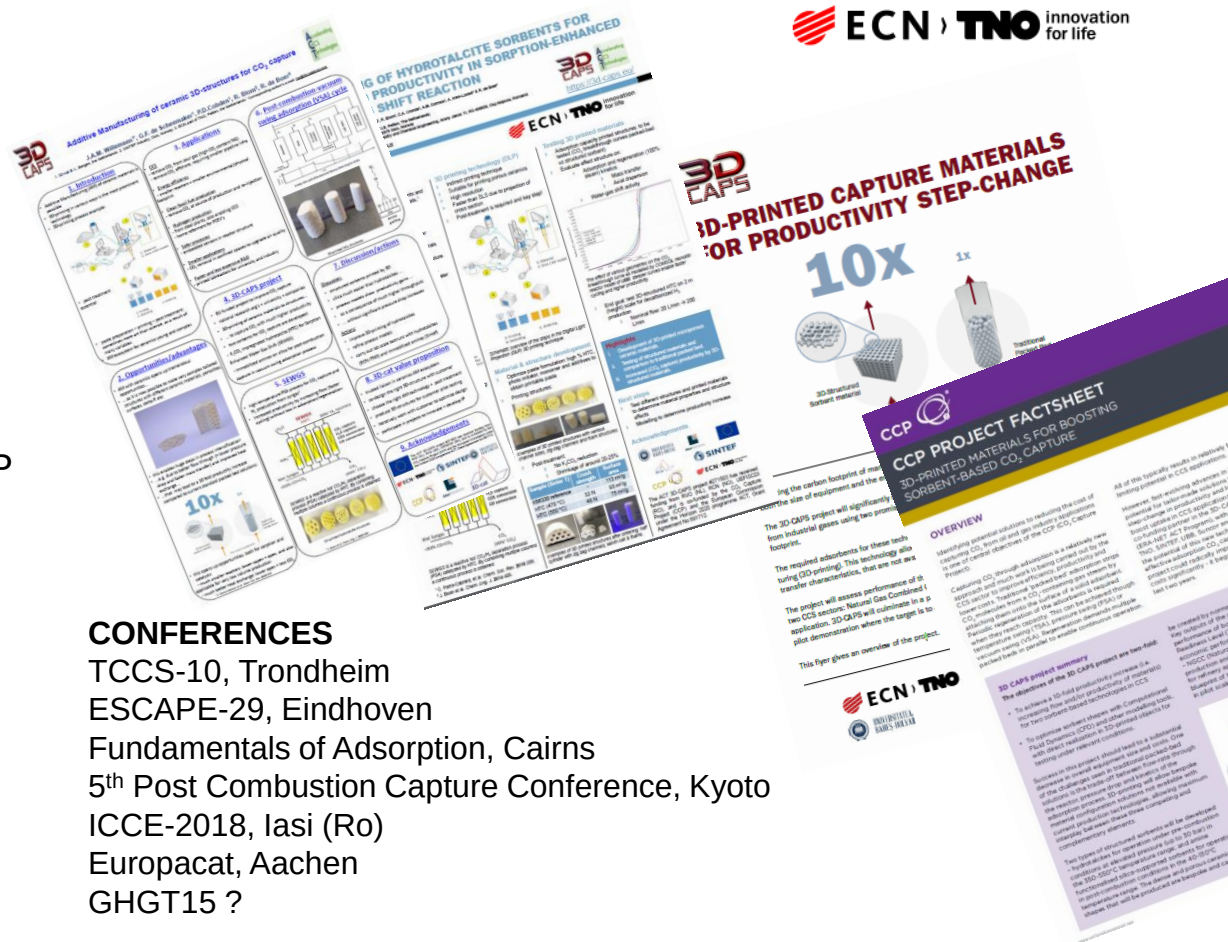
KNOWLEDGE SHARING

- Accelerating CO2 Capture technology
  - 3D CAT: start-up company involved for business development,
  - Discussions with CCP partners (end-users), EPC contractor.

- Collaboration/communication
  - F2F progress meetings 6Months
  - Telco Progress: 3Months
  - Frequent WP-meetings / telco
  - Staff exchange

DISSEMINATION

- Website
- Questionnaire
- Project Flyer
- CCP Project FactSheet
- News items through TNO and CCP
- Position Paper
- Conference presentations/posters
- Journal paper
- Book chapter CCP
- Banner



CONFERENCES
TCCS-10, Trondheim
ESCAPE-29, Eindhoven
Fundamentals of Adsorption, Cairns
5th Post Combustion Capture Conference, Kyoto
ICCE-2018, Iasi (Ro)
Europacat, Aachen
GHGT15 ?

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Acknowledgements

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