e-CODUCT: Coupling COS Conversion with Methanol Production via Electrified Processes

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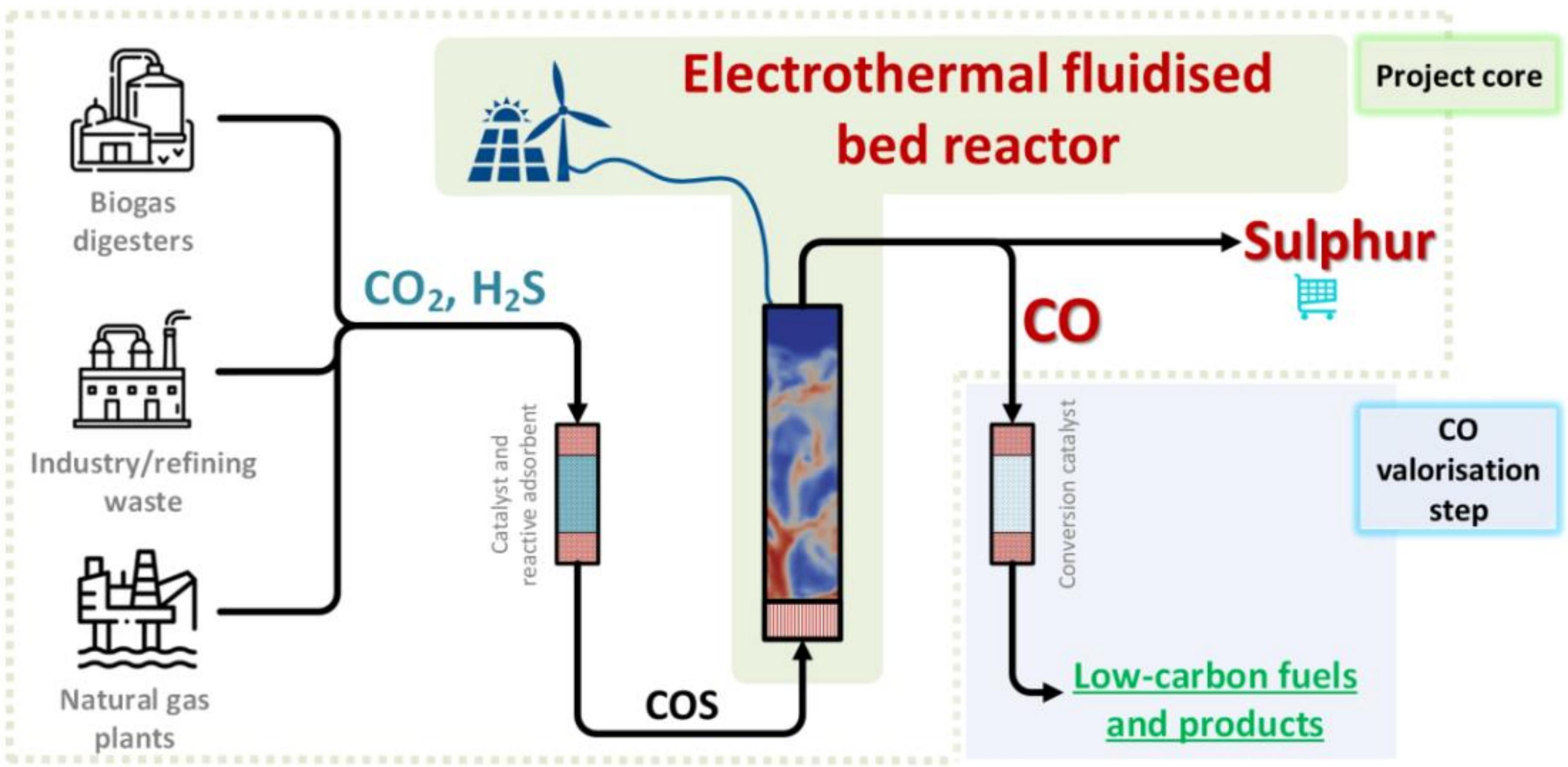
Introduction

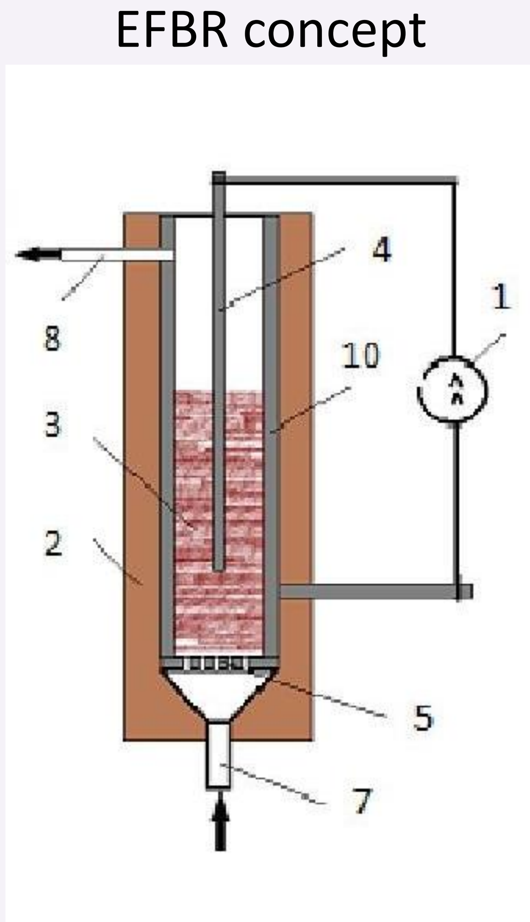
Currently, vast amounts of CO_2 from heating and industrial activities are released into the atmosphere, while natural sequestration captures only about 2 Gt per year and technical carbon capture and storage (CCS) remains limited by high costs[1]. Only a small share of CO_2 is valorized, as existing technologies fall short of enabling a true circular economy or substantially cutting emissions. Refineries and petrochemical plants alone emit around 1.24 Gt of CO_2 annually and handle more than 3.6 Mt of H_2S, a major component of acid gas[2]. Conventional treatments such as the Claus process are inefficient for dilute H_2S streams and require highly purified CO_2 for reduction or storage. The e-CODUCT concept addresses these challenges by electrifying the joint conversion of CO_2 and H_2S into COS and marketable sulfur products. The process first transforms CO_2 and H_2S into COS in a fixed-bed reactor, followed by conversion of COS into CO and S_x in an electrothermal fluidized-bed reactor. With the potential to convert over 4.7 Gt of CO_2 annually, e-CODUCT could substantially lower the carbon footprint of refineries and biogas upgrading. Importantly, the CO produced serves as a critical intermediate for methanol synthesis, providing a sustainable route to one of the most versatile platform chemicals in the chemical and energy industries.

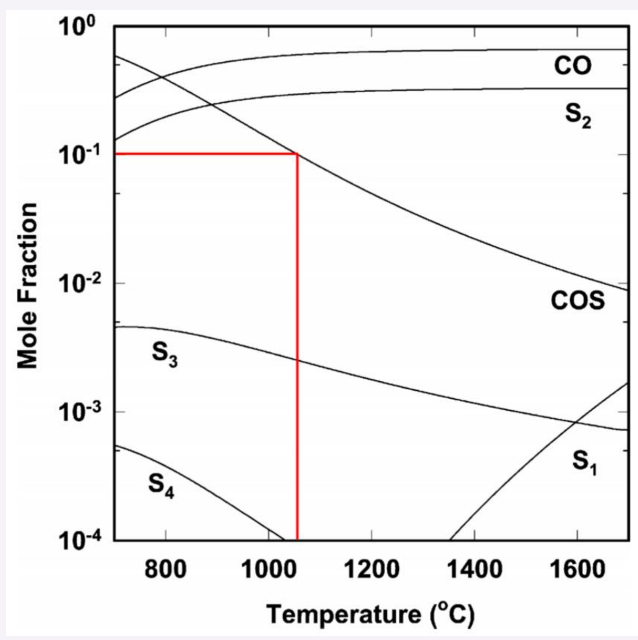
eCODUCT Process



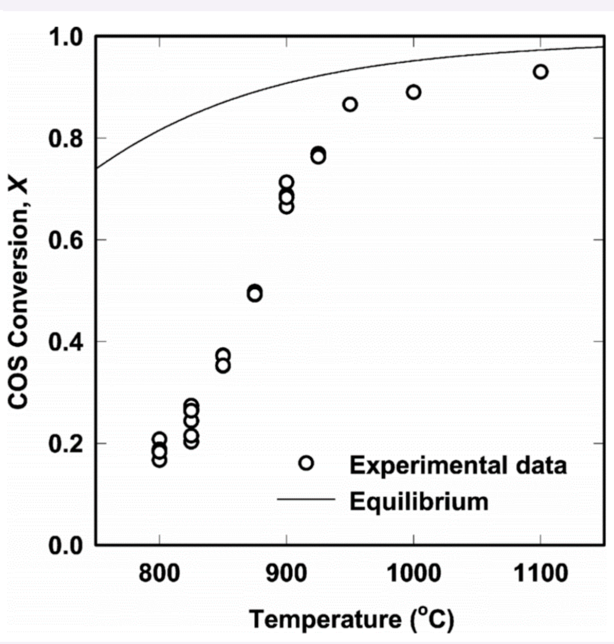
COS Decomposition

EFBR concept





Equilibrium distribution of chemical species with pure COS as the feed. P = 101.3 kPa. 90% conversion at app. 1070 °C[3]



Experimental COS conversion as a function of temperature. 16 m reactor, 2.33 mol.% COS in feed. Residence time: 1.2 – 1.5 s[1]

CO to MeOH Conversion in Fixed-bed Reactor

$$CO + 2H_2 \rightleftharpoons CH_3OH$$

Reaction rates

$$r_j^{ads} = k_j^{ads} \cdot P_j \cdot \theta_{VS} \qquad r_j^{des} = k_j^{des} \cdot \theta_j$$

$$r_i^{surf} = k_i^{surf} \cdot \theta_m \cdot \theta_n$$

$$k_i^{surf}(T) = k_i^{surf}(T_{ref}) \cdot \exp\left(\frac{Ea_i^{surf}}{R} \cdot \left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right)$$

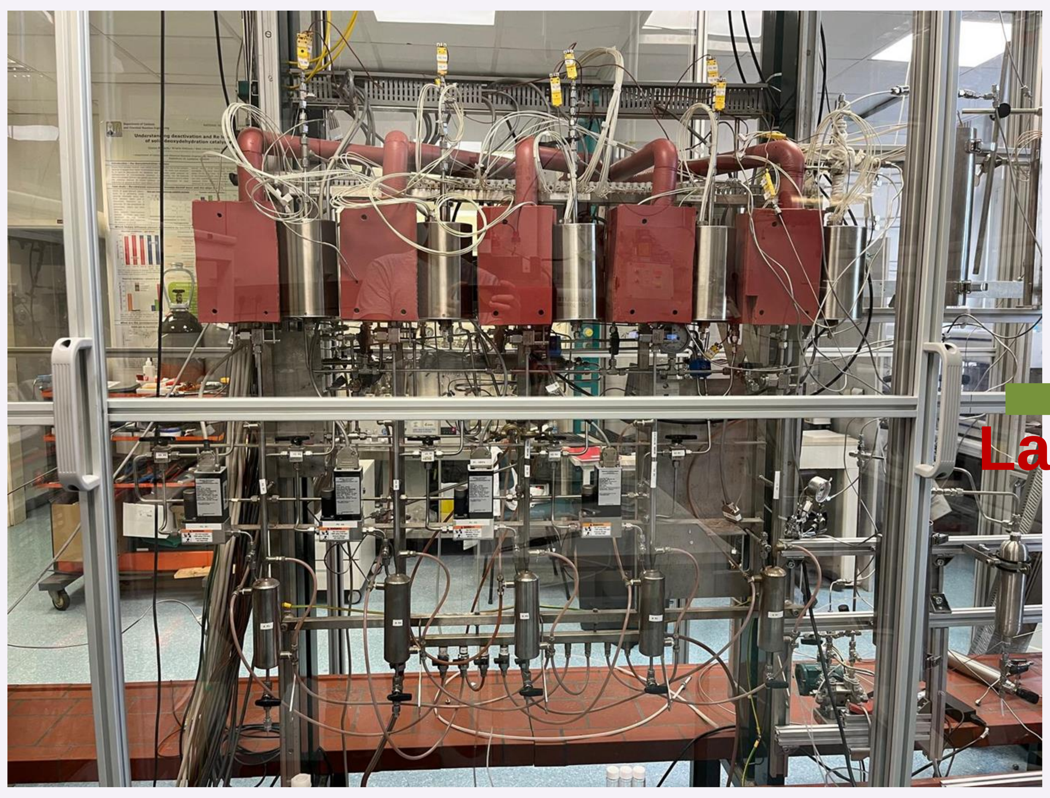
Mass balances

$$\frac{\partial P_j}{\partial t} = -\frac{\partial}{\partial z}\left[v_z \cdot P_j - D_j^e \cdot \frac{\partial P_j}{\partial z}\right] + \left(-r_j^{ads} + r_j^{des}\right) \cdot \frac{R \cdot T \cdot n_{TS}}{V^G}$$

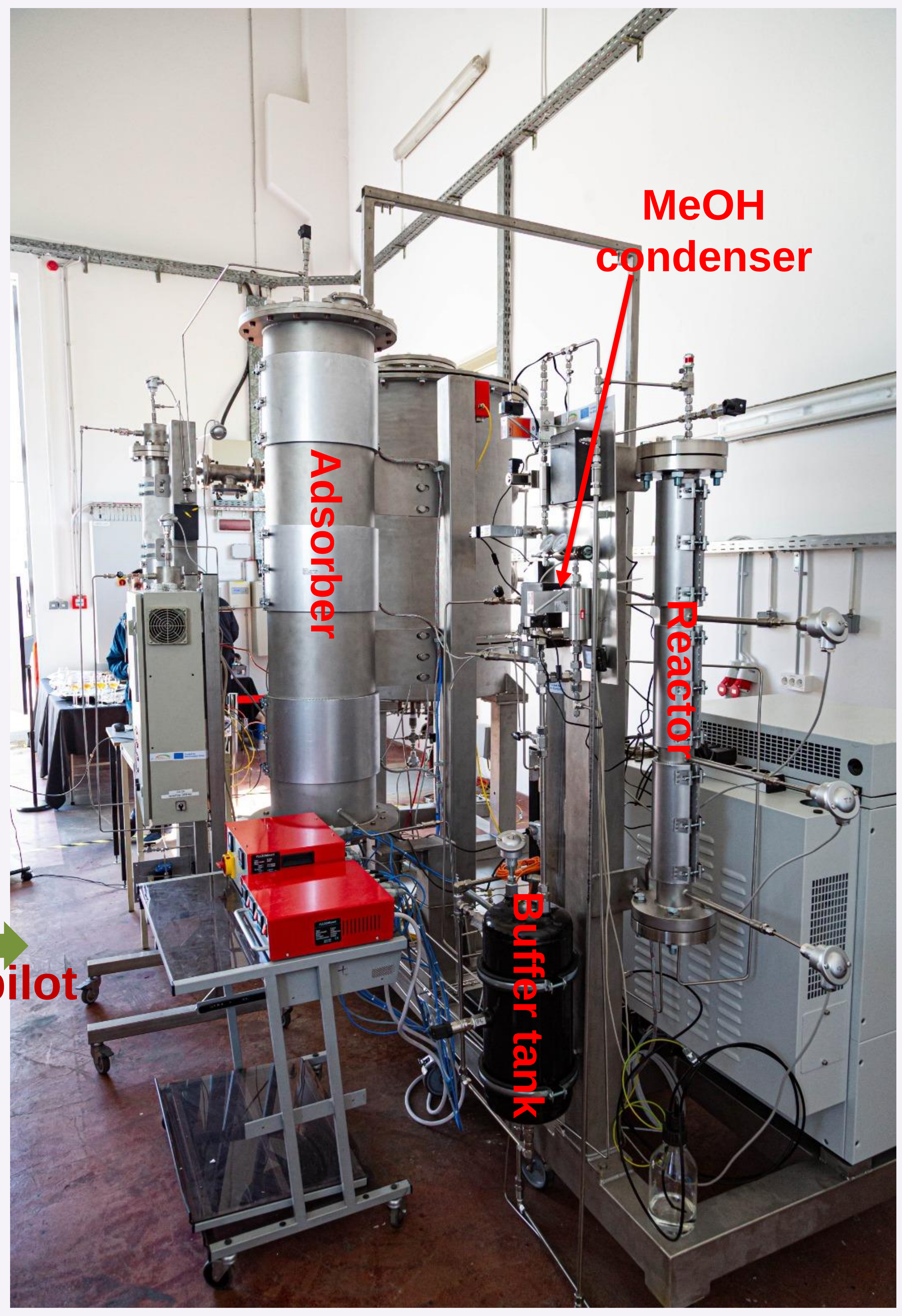
$$\frac{\partial \theta_j}{\partial t} = r_j^{ads} - r_j^{des} \sum_i^I \pm r_i^{surf}$$

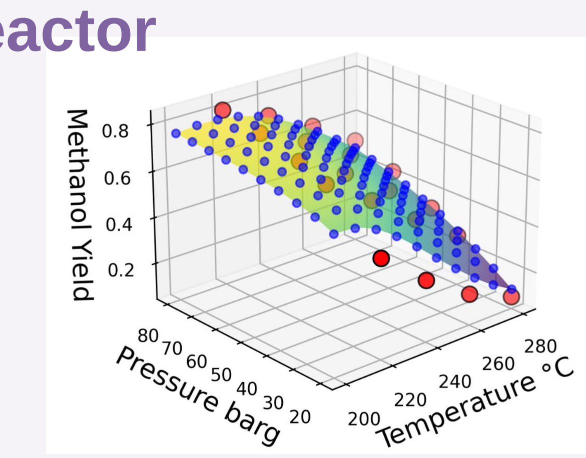
Matlab 2025a**: ode15s** and **fminsearch**

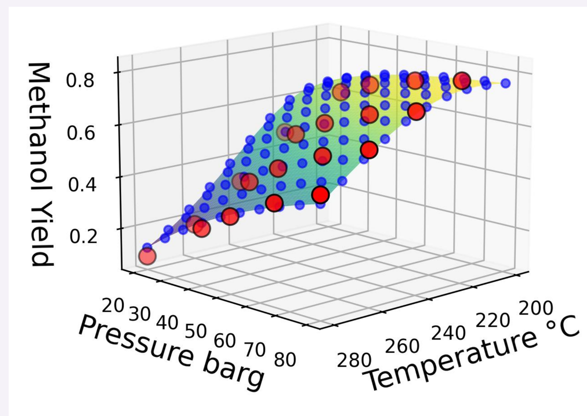
$$f\left(k_j^{ads}, k_i^{surf}, k_j^{des}\right) = \sum_j^I \left(P_j^{measured} - P_j^{calculated}\left(k_j^{ads}, k_i^{surf}, k_j^{des}\right)\right)^2$$



Lab to pilot







Aspen equilibrium data and prediction by the kinetic model

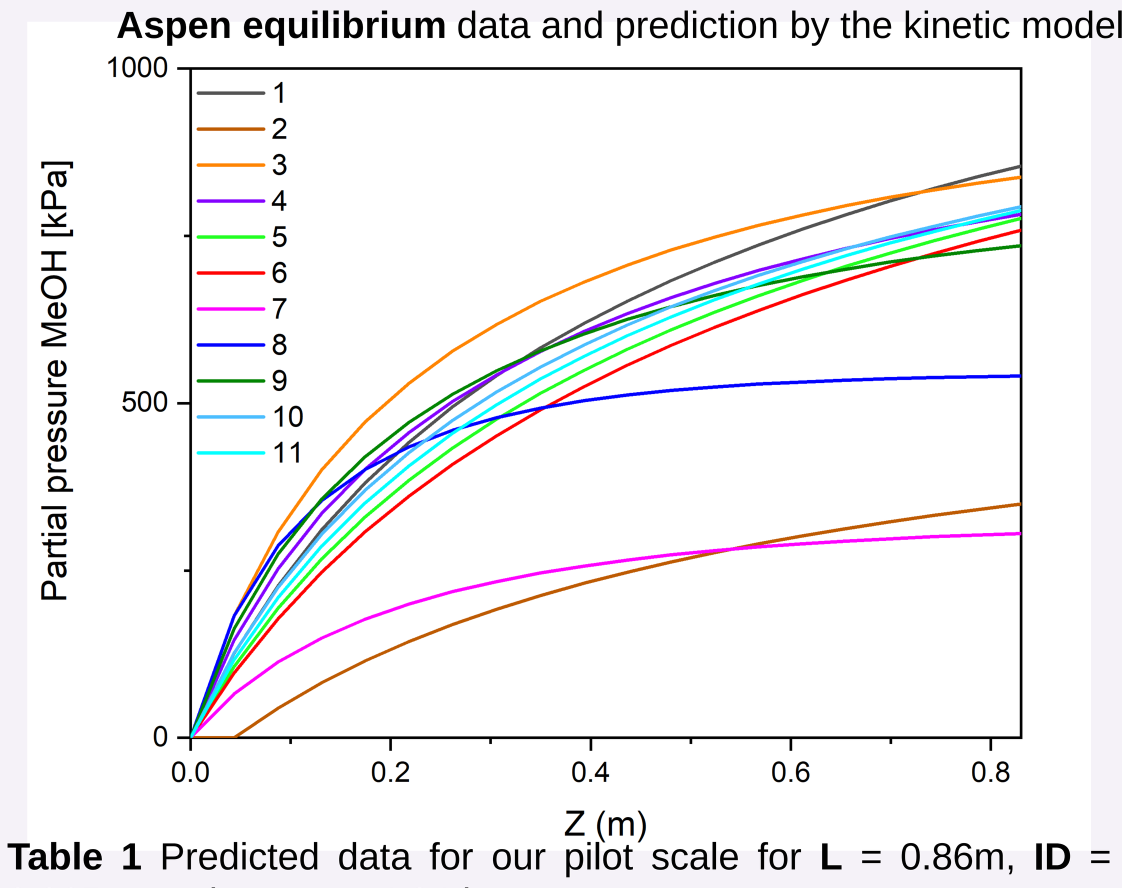


Table 1 Predicted data for our pilot scale for **L** = 0.86m, **ID** = 0.065 m and $\mathbf{m}_{catalyst}$=4.24 kg

#	Temperature °C	Pressure tot barg	Flow rate L/min	Productivity kg/h
1	225	50	36	0.7158
2	225	25	36	0.5107
3	250	50	36	0.6925
4	250	50	50	0.8757
5	230	50	50	0.8699
6	225	50	50	0.8447
7	250	25	36	0.4213
8	280	50	50	0.5464
9	260	50	50	0.8053
10	240	50	50	0.8946
11	235	50	50	0.887

References

[1]Estimation based on announcements of relevant projects by CRI, Shell, Syneco, Vattenfall, Ineratec, Engie, EDL, Sunfire, Repsol

[2]The latter is estimated based on existing data on sulfur production in EU (Non-critical raw material factsheet, doi: 10.2873/587825) and CO2 emissions from refining sector (EU, Bloomberg and IFPEN data, Overview of the refining industry in the European Union Emissions Trading System (EU ETS))

[3]Karan, K., Mehrota, A. K., & Behie, L. A. (2005). Thermal decomposition of carbonyl sulphide at temperatures encountered in the front end of modified claus plants. Chem. Eng. Comm., 192(3), 370-385

Acknowledgments

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www. e-coduct. eu