ACHEMA, FRANKFURT, JUNE 10-14, 2024

e-CODUCT:

Fast-Response electrically heated catalytic reactor technology for CO_2 reDUCTion

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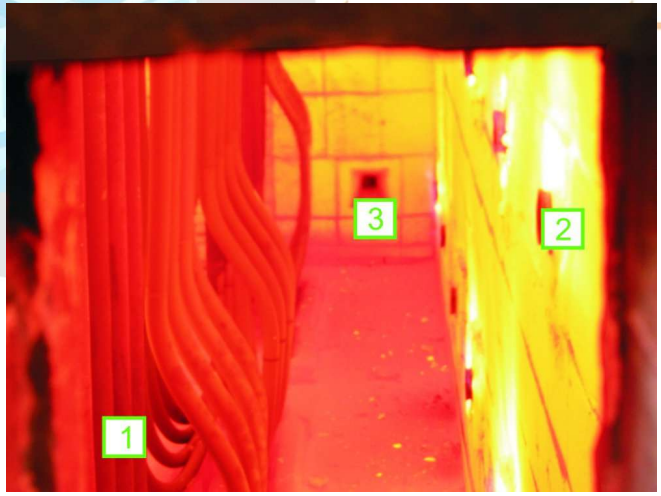
e-CODUCT

heat requirements in chemical reactions

- endothermic reactions
  - thermal cracking
  - dehydrogenation
  - reforming
  - …
- exothermic reactions
  - methanol synthesis
  - Fischer Tropsch
  - oxidation
  - …



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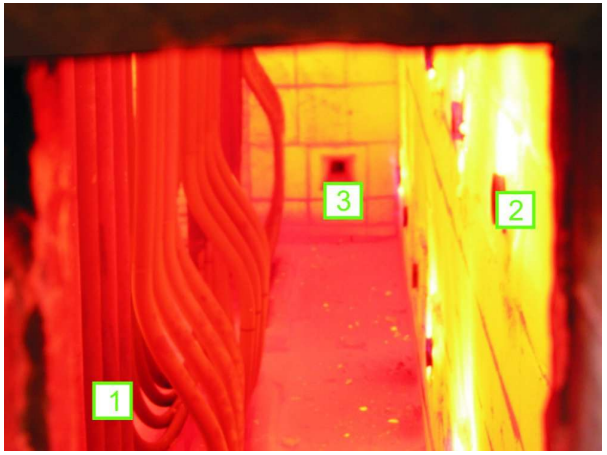
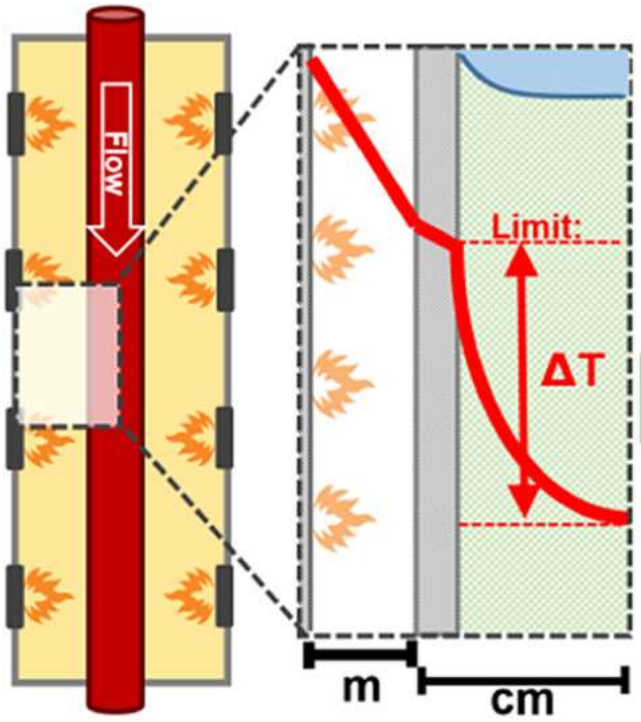
Westerterp, et al. *Chemical Reactor Design and Operation* Wiley (1991)

(strongly) endothermic reactions

- heat transport focused reactor design
  - narrow tubes
  - fired furnace
- pronounced temperature gradients





Wismann, et al. *Ind. Eng. Chem. Res.* 58 (2019) 23380

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challenges/objectives

- enhancing heat transfer efficiency
- faster response to temperature changes

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outline

- introduction
- efficient heating
  - electrification
  - ElectroThermal Fluidized Bed reactor (ETFB)
- e-CODUCT
  - opportunities for simultaneous CO_2 and H_2S abatement
  - powered by renewable energy
- conclusions & perspectives

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how can we enhance heat transfer?

heat containment **electrification**

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how can we do even better?

microwave

induction

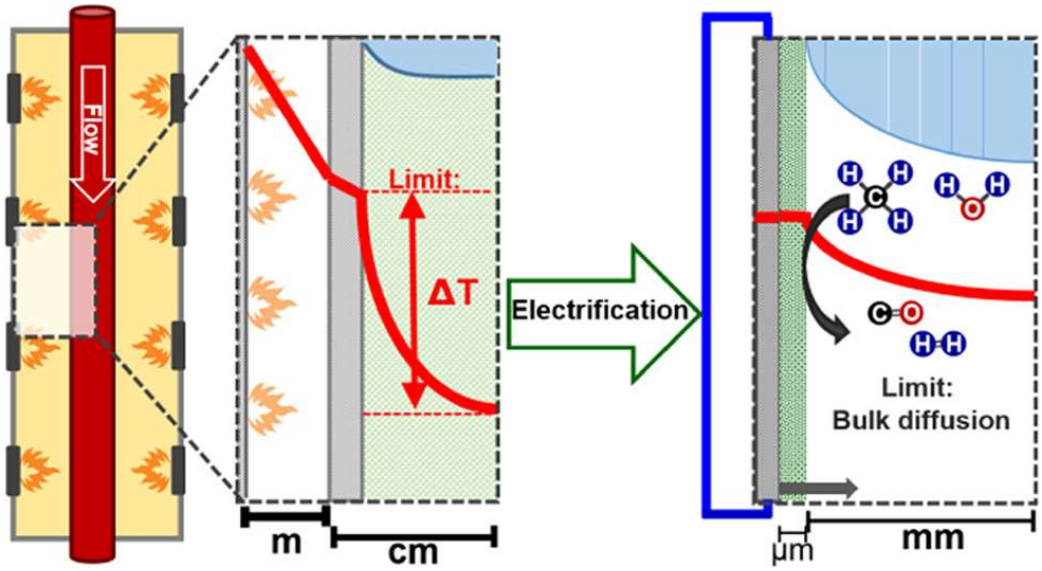
heating from the inside

reactor electrification

electrical heating -> overcoming limitations of combustion

advantageous in terms of:

- energy efficiency
- process control
- safety and maintenance
- rapid heating
- …



Wismann, et al. *Ind. Eng. Chem. Res.* 58 (2019) 23380

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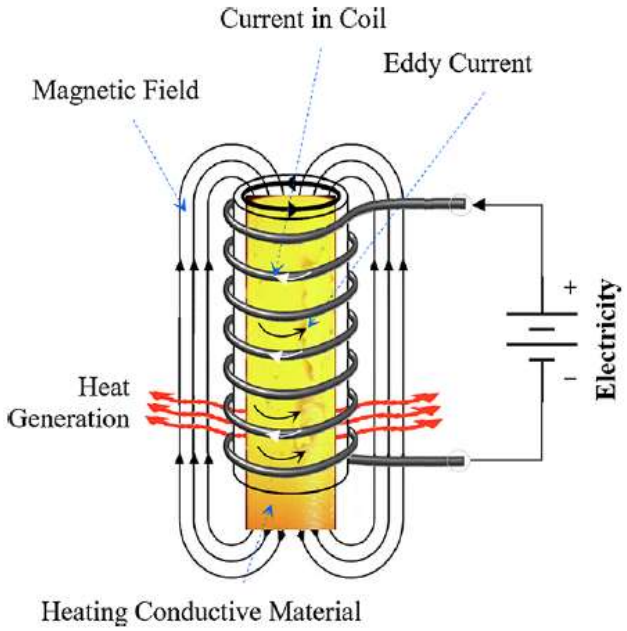
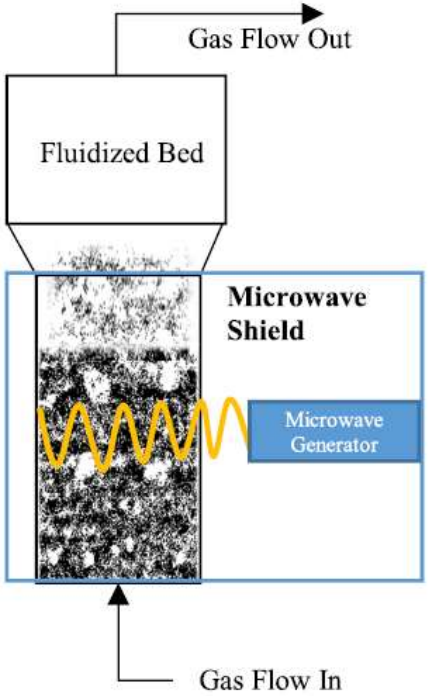
electrical heating

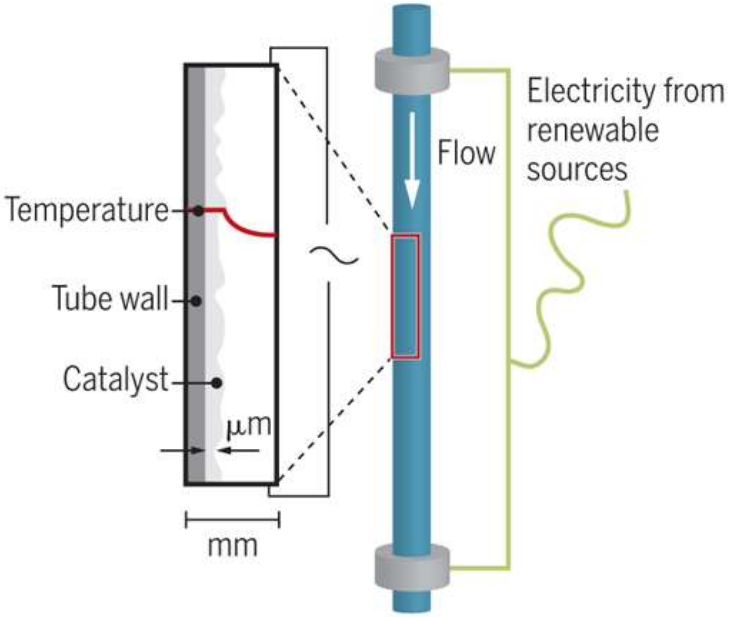
induction



microwave



Joule

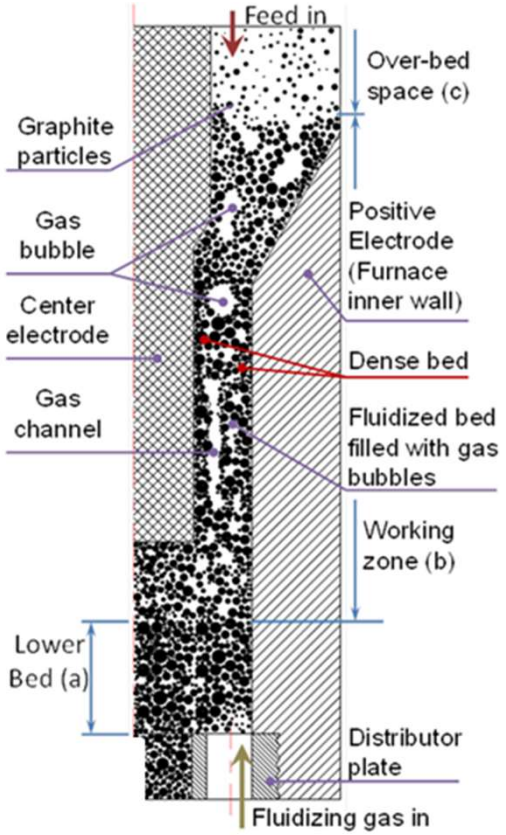


Imtiaz, et al. *Ind. Eng. Chem. Res.* 63 (2024) 4205

sonication
plasma

ElectroThermal Fluidized Bed reactor (ETFB)

- combination:
  - fluidization
  - Joule heating
- compared to conventional fluidized beds
  - better control over bed temperature
  - highly energy efficient
  - rapid and uniform heating



Fedorov *J. Fluids Eng.* 138 (2016) 044502

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e-CODUCT: rationale

fast-response electrically heated catalytic reactor technology for CO_2 reduction

e-CODUCT

why?

- current CO_2 reduction technologies require highly pure streams
- no existing technologies for simultaneous CO_2 and H_2S reduction
- making more feedstock sources available

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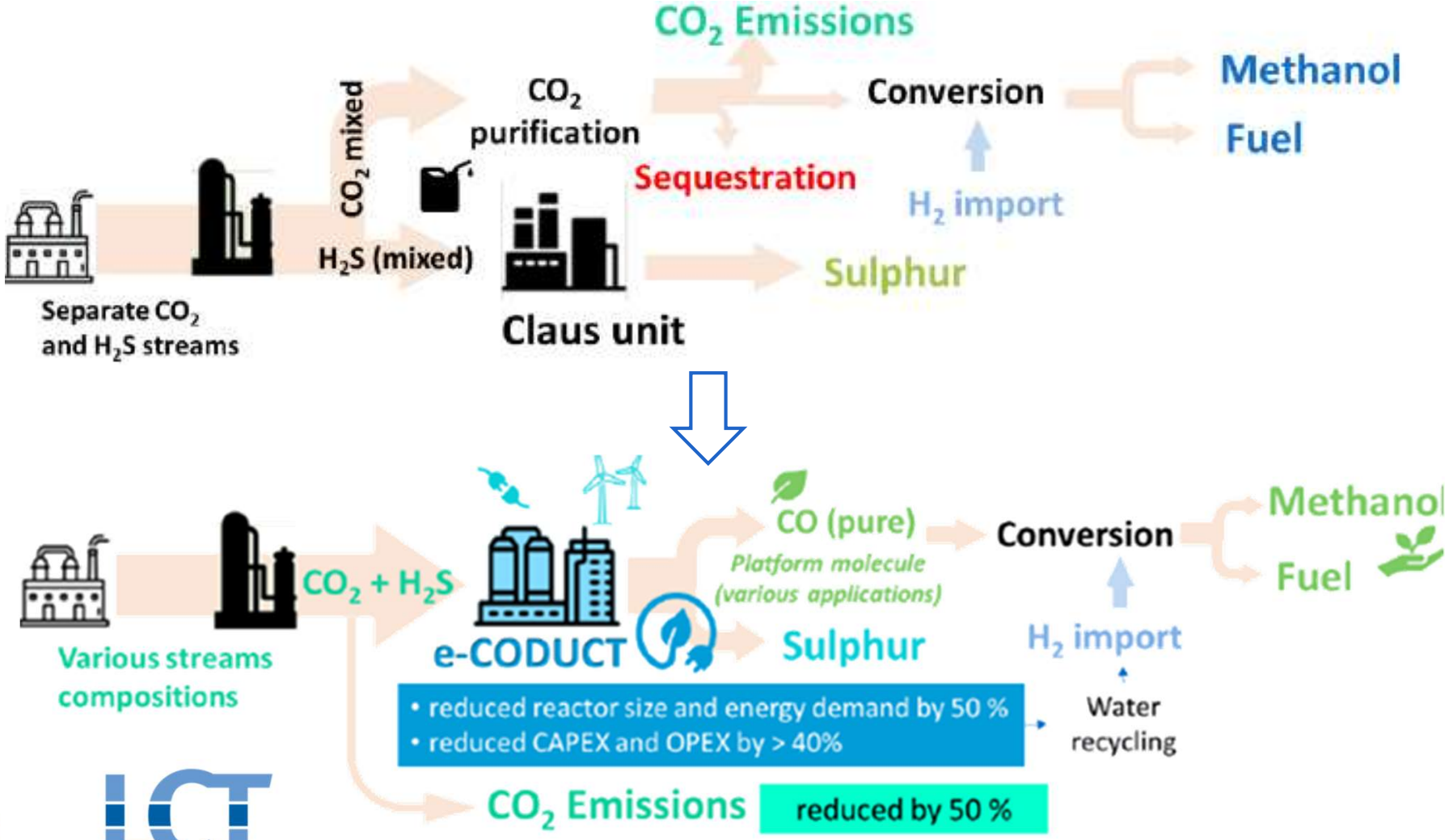
e-CODUCT: positioning



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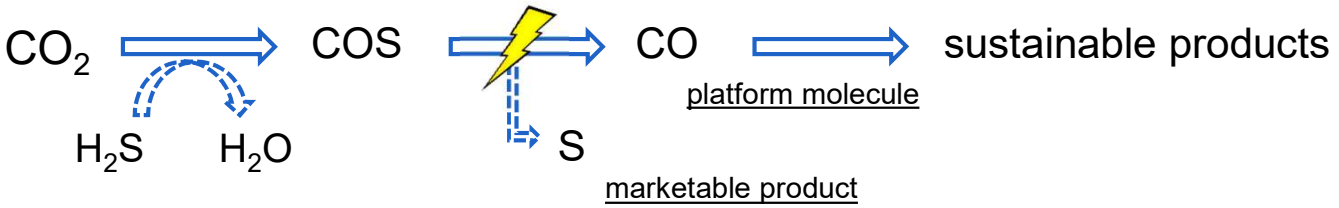
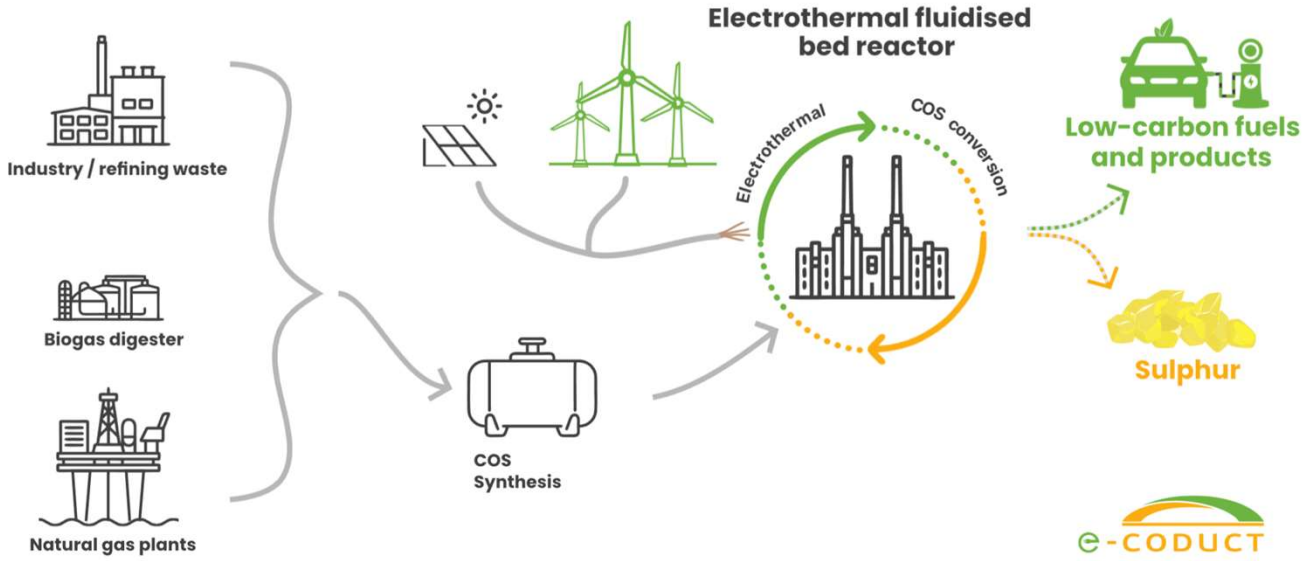
e-CODUCT: process lay-out





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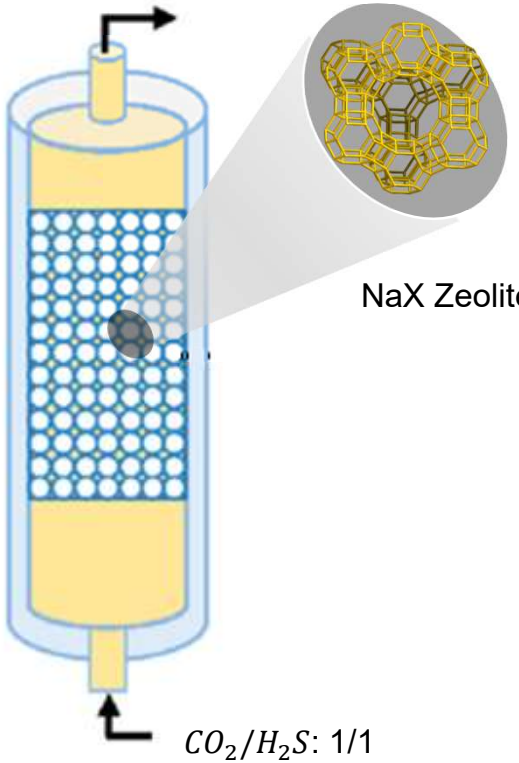
http://www.ecoduct.eu 2022-2025 GA 101058100

COS synthesis: experimental

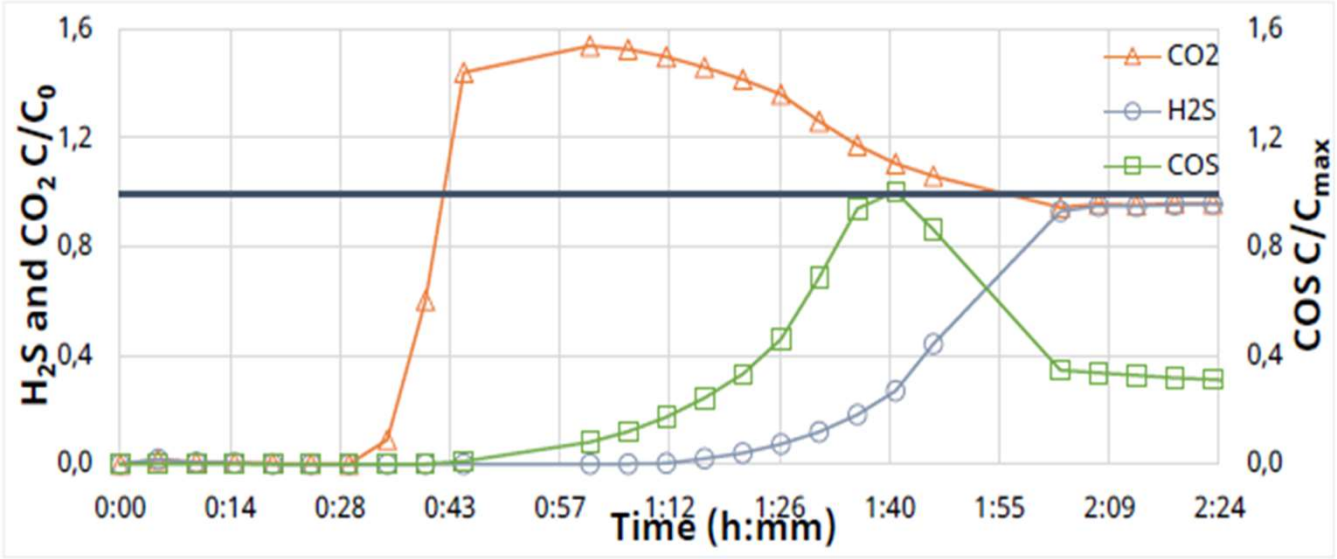


NaX Zeolite

CO_2/H_2S: 1/1

$$CO_2 + H_2S \leftrightarrows COS + H_2O$$

Feed mixture of H_2S:CO_2=1:1 on 13X at 45°C. Thick line at C/C_0 = 1.



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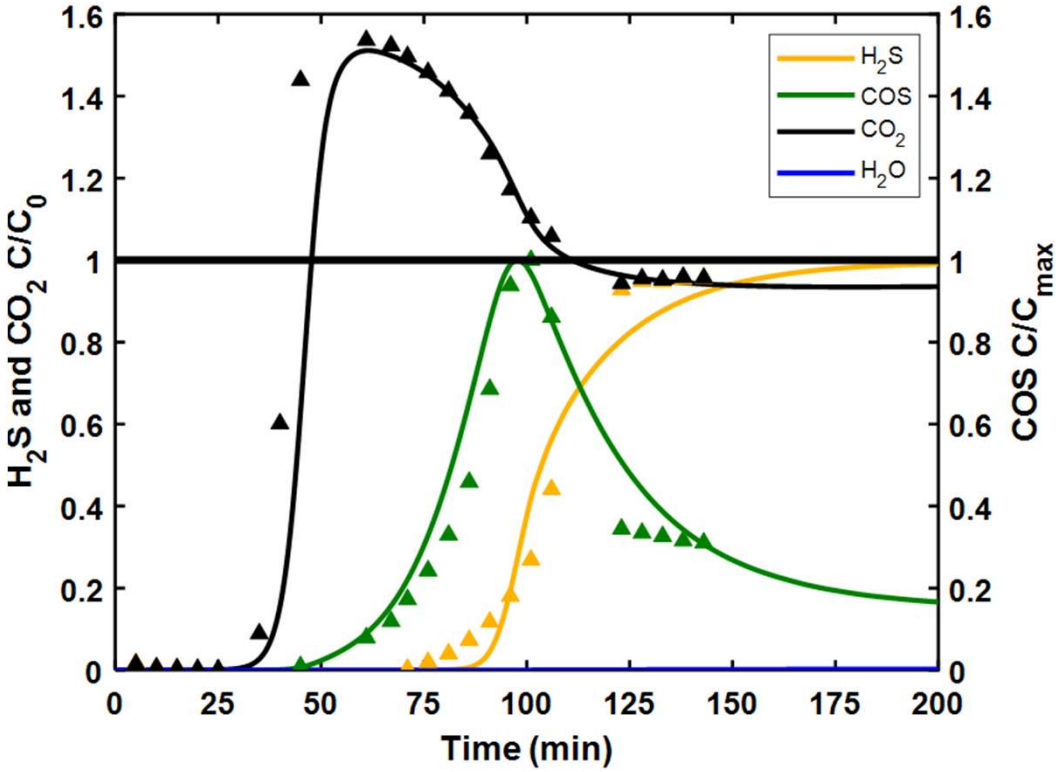
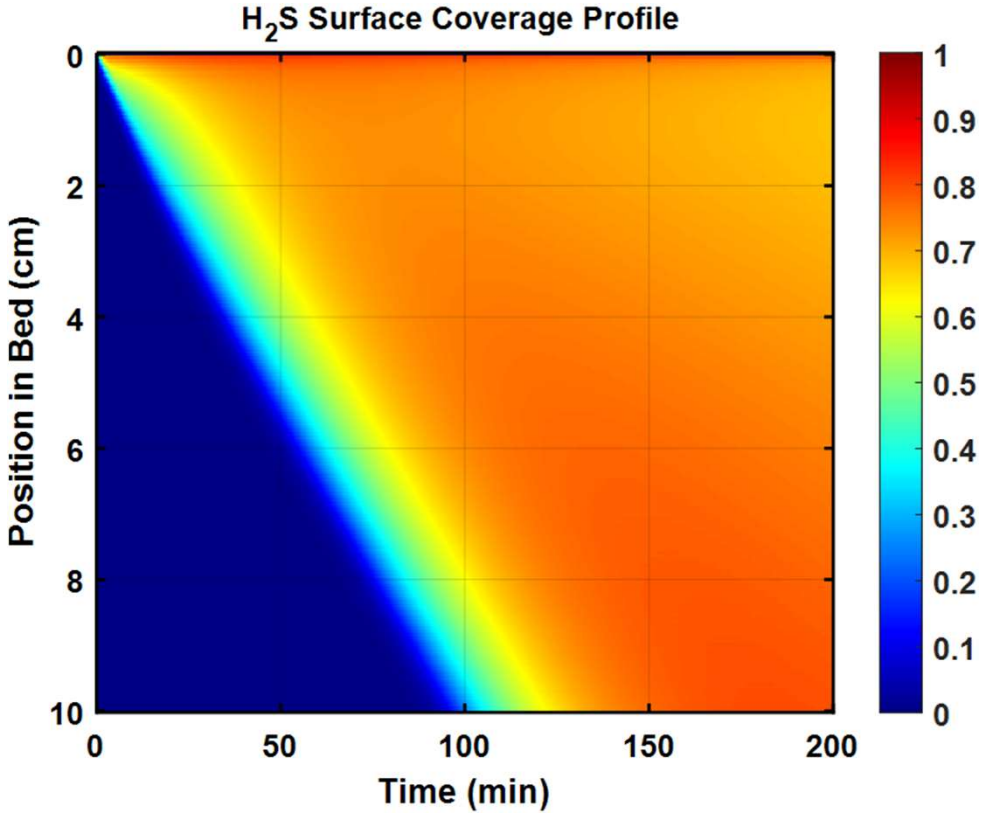
COS synthesis: modeling





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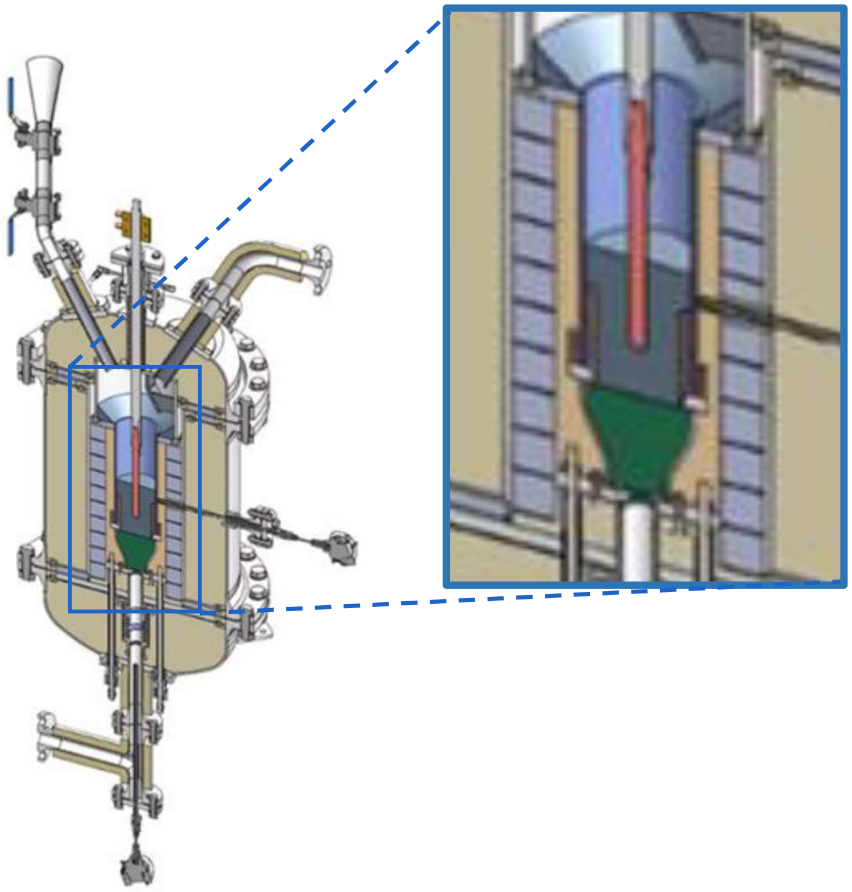
COS decomposition



- COS decomposition to CO and sulphur
- temperatures up to 800-1200 °C
- in situ heat generation by joule heating

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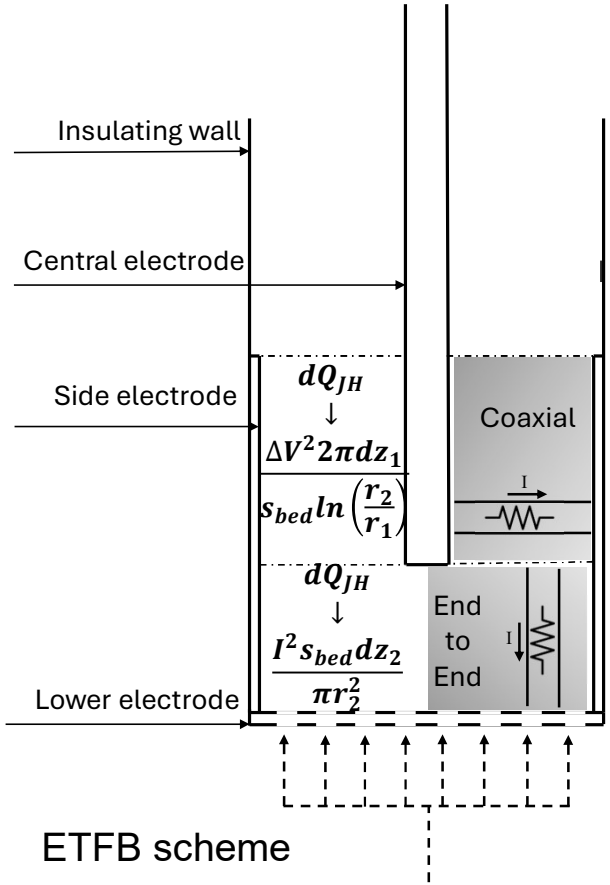
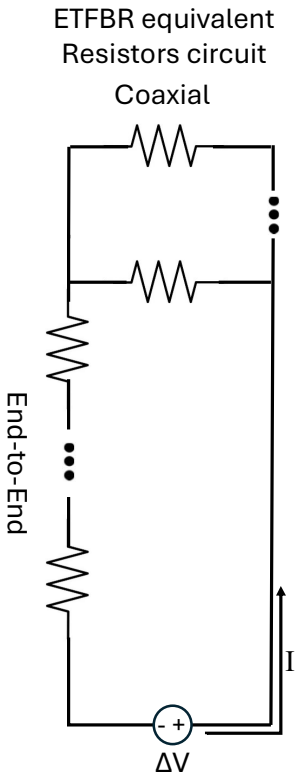
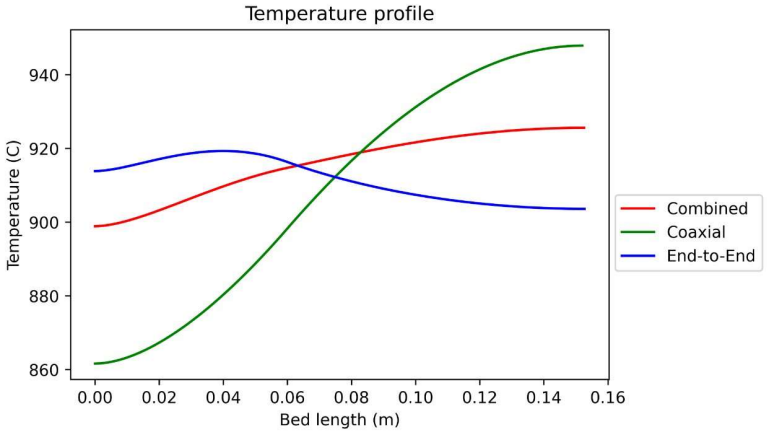
e-CODUCT – ETFB modelling

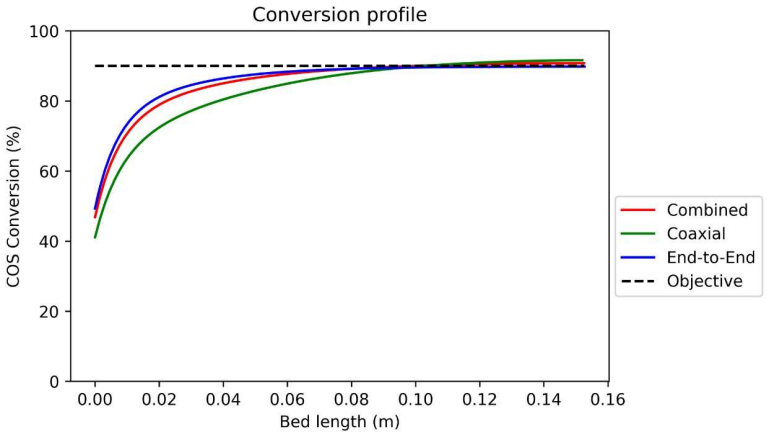


ETFB scheme



Resistor configuration





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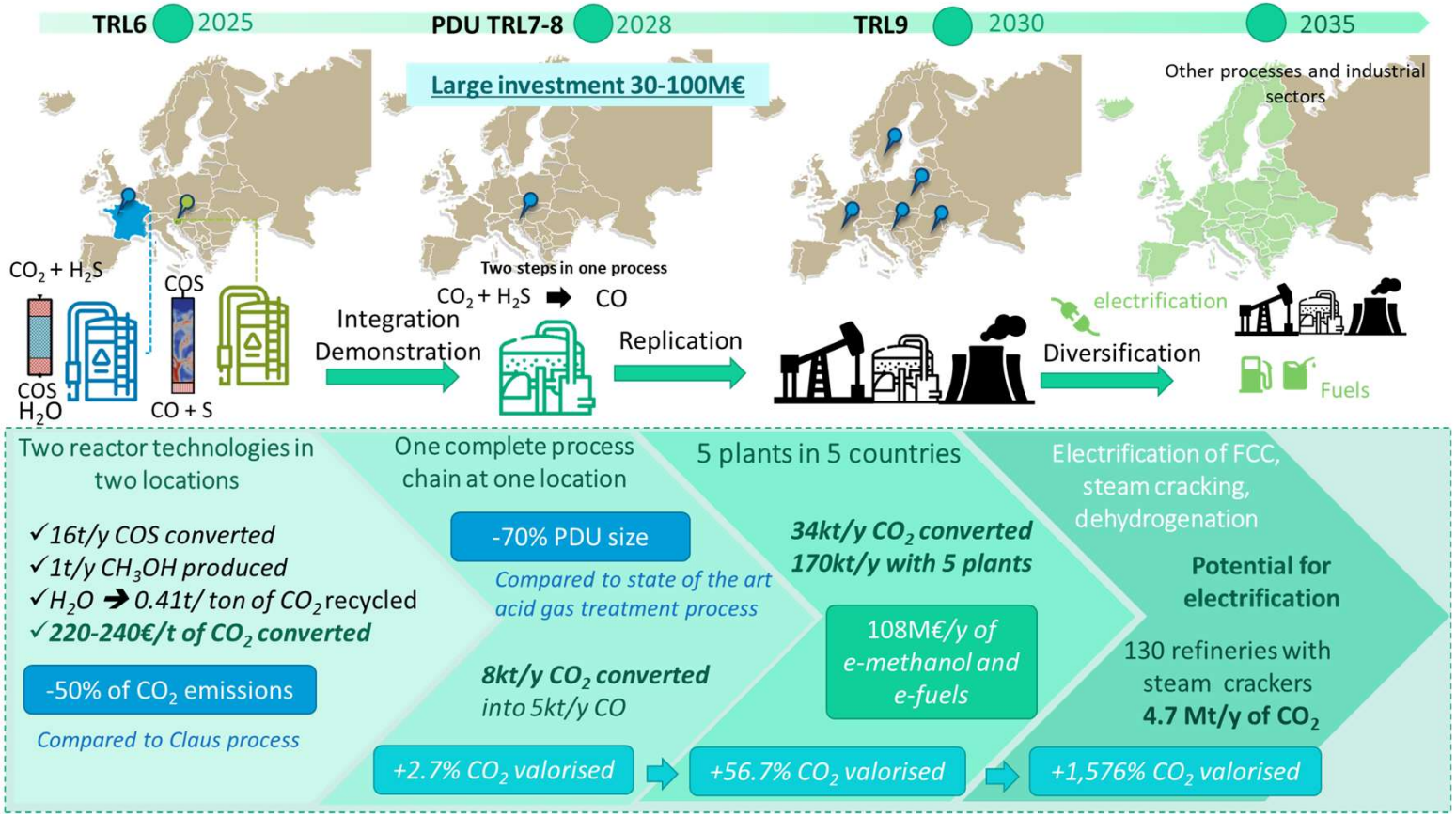
e-CODUCT valorization roadmap



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conclusions, opportunities and perspectives

- chemical reactor electrification
  - more than connecting an electric heater to the grid
  - reasoning from the inside
  - CO_2 emission reduction
  - integration in a process
  - …
- challenges
  - few large-scale vs many small-scale applications
  - electricity availability
  - impact on the chemistry
  - …

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acknowledgments

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acknowledgements (2)

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Anoop Chakkingal

Bert Biesemans

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Carlos Alvarado Camacho

César Pernalete

Kevin De Ras

Klaus Jacobs

Laura Pirro

Loïc Eloi

Lucas Ivan Garbarino

Maria Herrero Manzano

Marie-Elisabeth Lissens

Nebojsa Korica

Noor Aljammal

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Raman Ghassemi

Reza Monjezi

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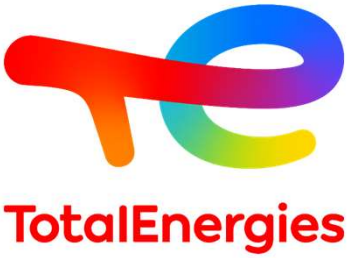
acknowledgements (3)



European Research Council

12th International Symposium on Catalysis in Multiphase Reactors
&
11th International Symposium on Multifunctional Reactors

CONFERENCE THEME

Multiscale modeling and experimentation

- Reactor design
- Process development
- Low carbon technology
- Renewable chemicals
- Polymer design
- Catalysis and kinetics

8-11 SEPTEMBER 2024

Ghent, Belgium

early bird registration
deadline: June 30th

MORE INFO

www.camure.ugent.be

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Chairman of the symposium

prof. dr. ir. Joris THYBAUT

Co-chairmen of the symposium

prof. dr. ir. Kevin VAN GEEM
prof. dr. ir. Mark SAEYS

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e-CODUCT: Want to know more?!

Website: https://e-coduct.eu/

LinkedIn: @e-coduct project
https://www.linkedin.com/in/ecoduct/

Twitter: @eCODUCT2022
https://twitter.com/eCODUCT2022

YouTube: @ecoduct2022
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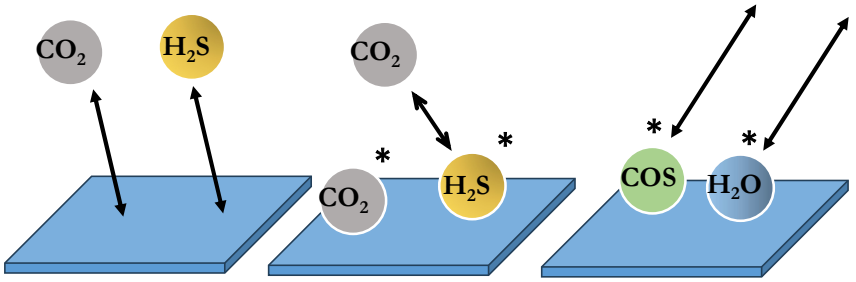
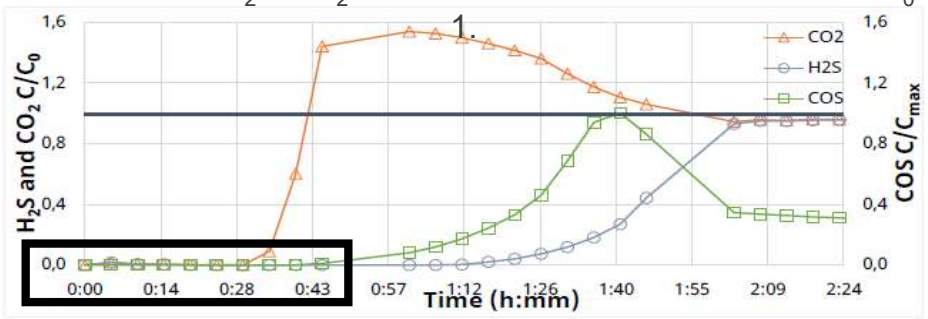
Modified ER Mechanism

Eley-Rideal with CO_2 & COS adsorption

$H_2S + * \leftrightarrows H_2S*$	$r_1 = k_1^+ C_{H_2S}\theta_* - k_1^- \theta_{H_2S}$
$H_2S* + CO_2 \leftrightarrows COS + H_2O*$	$r_2 = k_2^+ C_{CO_2}\theta_{H_2S}\theta_* - k_2^- \theta_{H_2O}\,\theta_{*COS}$
$H_2O * \leftrightarrows H_2O + *$	$r_3 = k_3^+ \theta_{H_2O} - k_3^- C_{H_2O}\theta_*$
$COS + * \leftrightarrows COS *$	$r_4 = k_4^+ \theta_{COS} - k_4^- C_{COS}\,\theta_*$
$CO_2 + * \leftrightarrows CO_2*$	$r_5 = k_5^+ C_{CO_2}\theta_* - k_5^- \theta_{CO_2}$



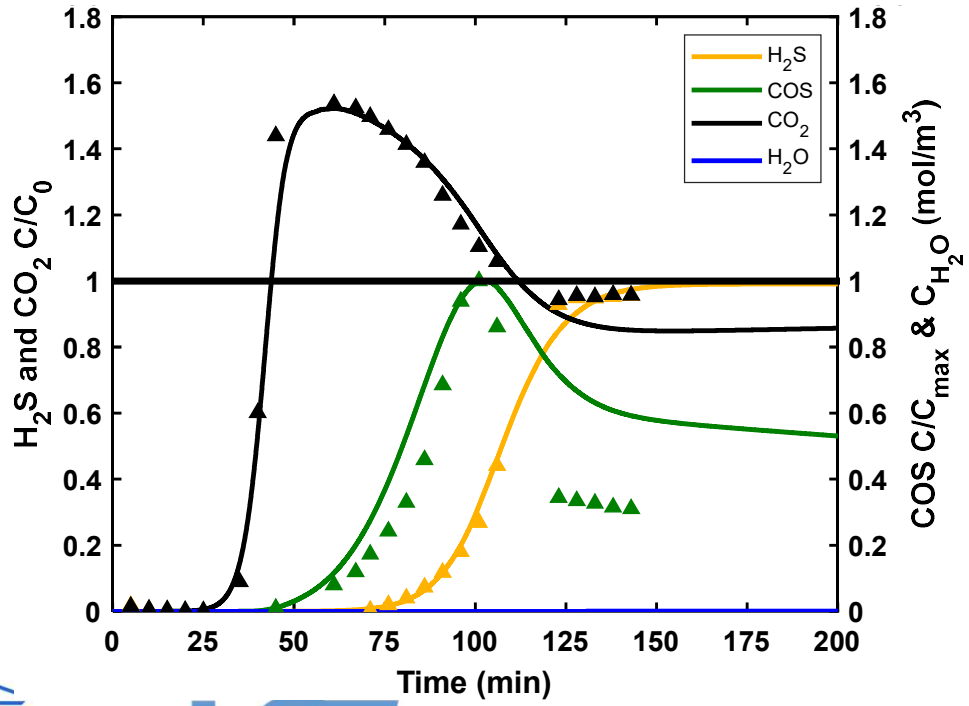
Feed mixture of H_2S:CO_2=1:1 on 13X at 45°C. Thick line at C/C_0 = 1.

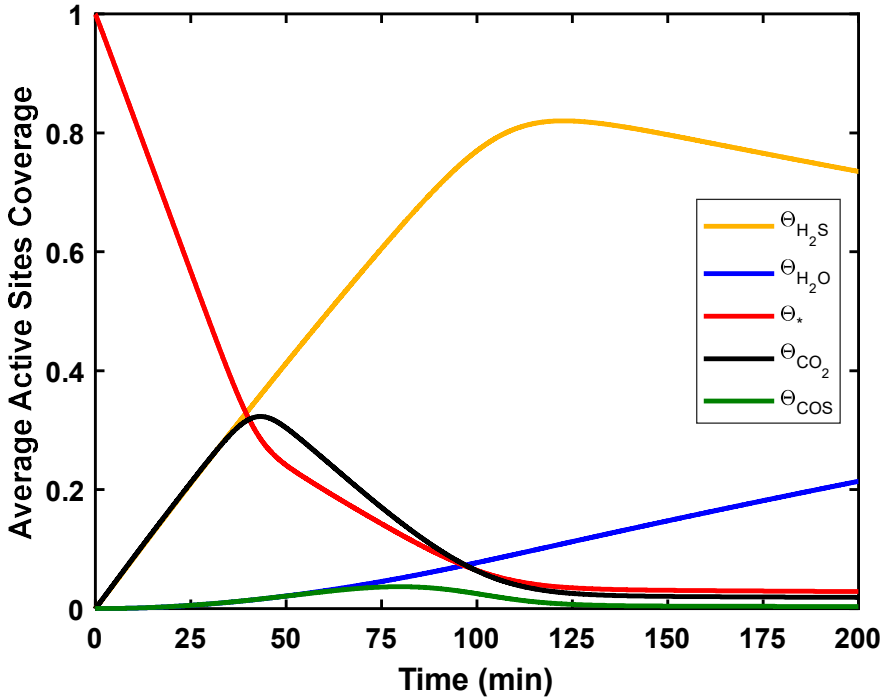


CO_2 and COS retention is accounted

Modified ER Mechanism: Results

Feed mixture of H_2S:CO_2=1:1 on 13X at 45°C. Thick line at C/C_0 = 1.

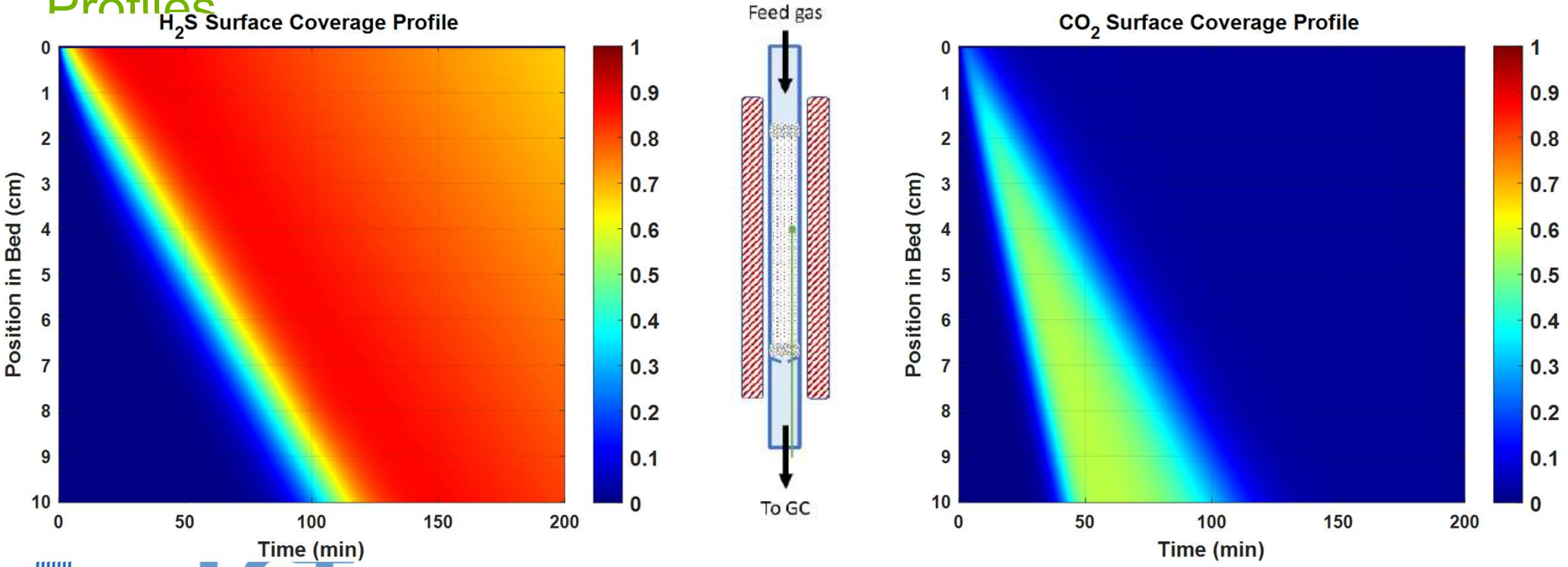




$k^{ads}_{H_2S}$	$k^{des}_{H_2S}$	k^{f}_{r}	k^{r}_{r}	$k^{des}_{H_2O}$	$k^{ads}_{H_2O}$	$k^{ads}_{CO_2}$	$k^{des}_{CO_2}$	k^{des}_{COS}	k^{ads}_{COS}
1E-3	1.8E-4	5.5E-6	1E-7	1E-4	1	6E-4	4E-3	3E-3	1E-3

Modified ER Mechanism: Results – Reactant Profiles

Feed mixture of H_2S:CO_2=1:1 on 13X at 45°C. Thick line at C/C_0 = 1.



Modified ER Mechanism: Results – Product Profiles

Feed mixture of H_2S:CO_2=1:1 on 13X at 45°C. Thick line at C/C_0 = 1.