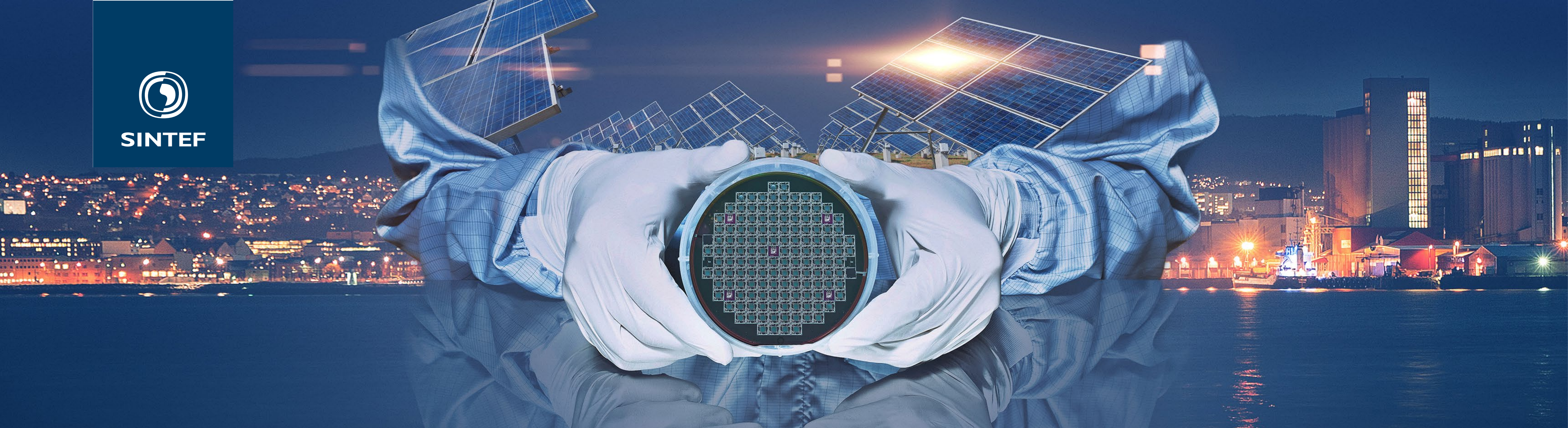
The use of polymer materials in infrastructure to transport CO_2 and hydrogen

Ben Alcock
Research Manager, Polymer & Composites Group
SINTEF Industry



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6400
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3300
customers

INTERNATIONAL
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NATIONALITIES
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PUBLICATIONS (INCL. DISSEMINATION)
6200

CUSTOMER SATISFACTION
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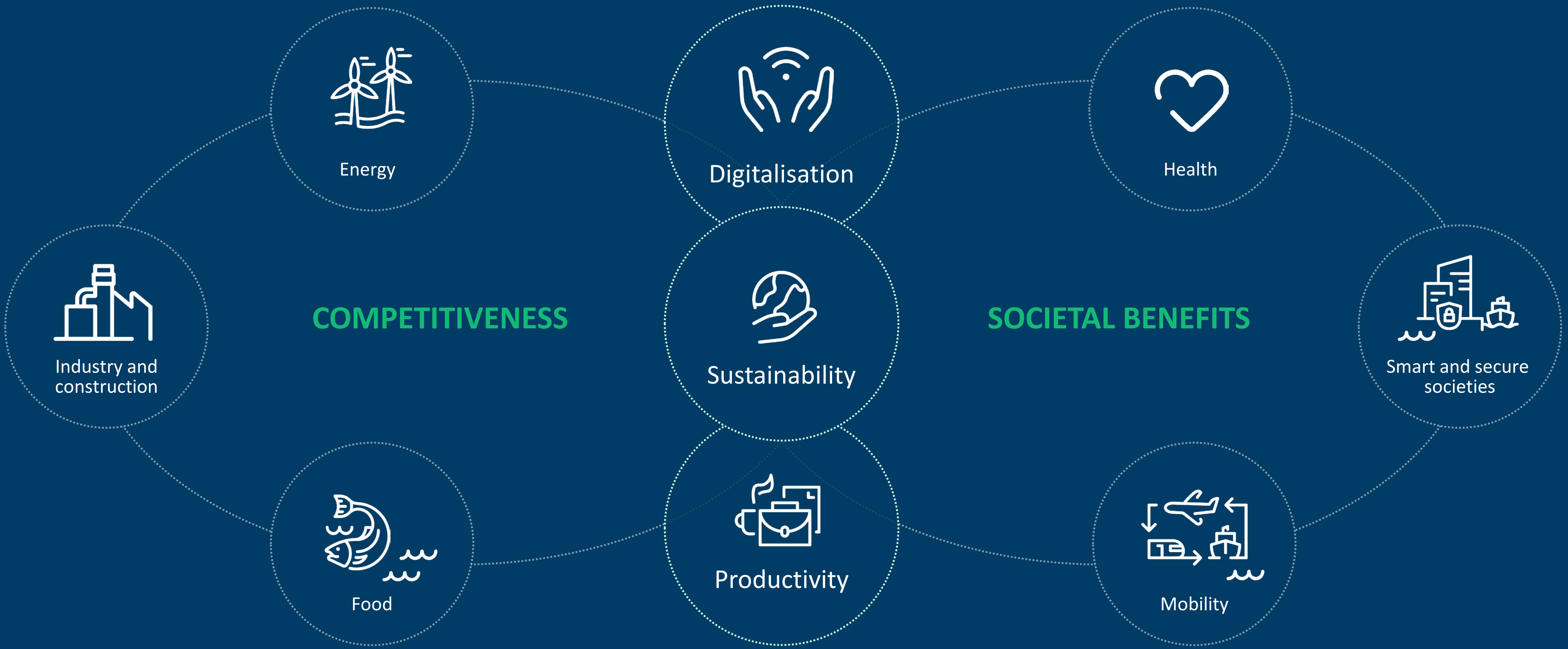
Vision:
Technology for a better society



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CO_2 EPOC

2020-2025

Grant 308765

Funded by
The Research
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Pol(Hy)Mer

2025-2028

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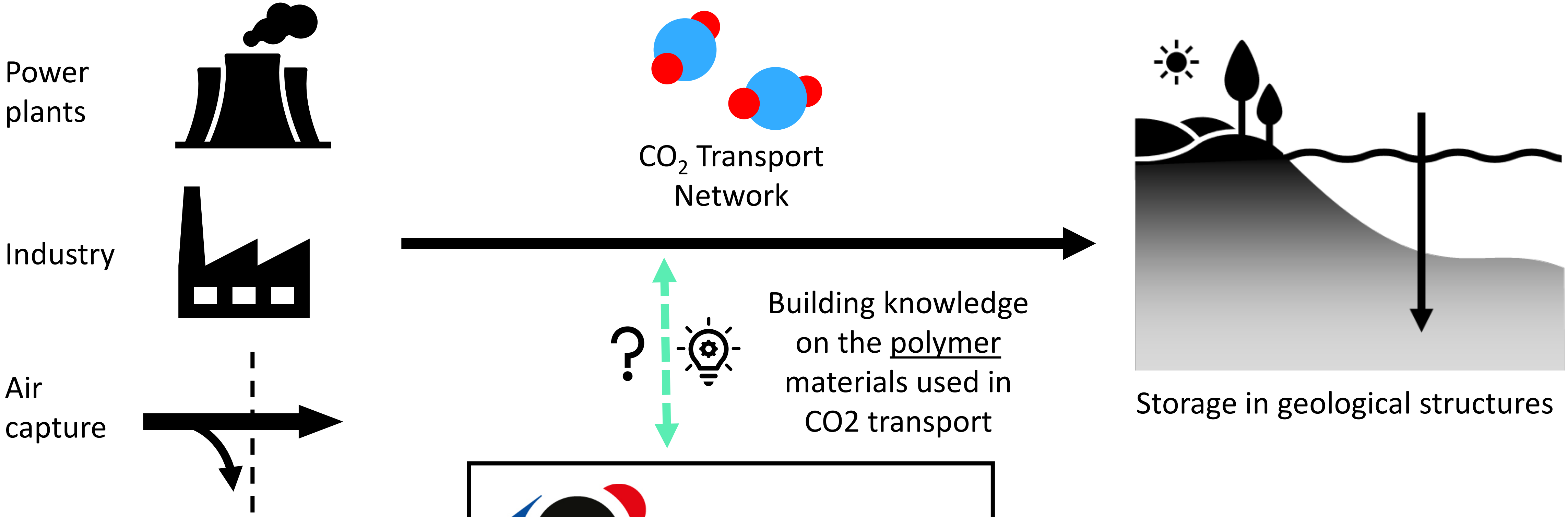
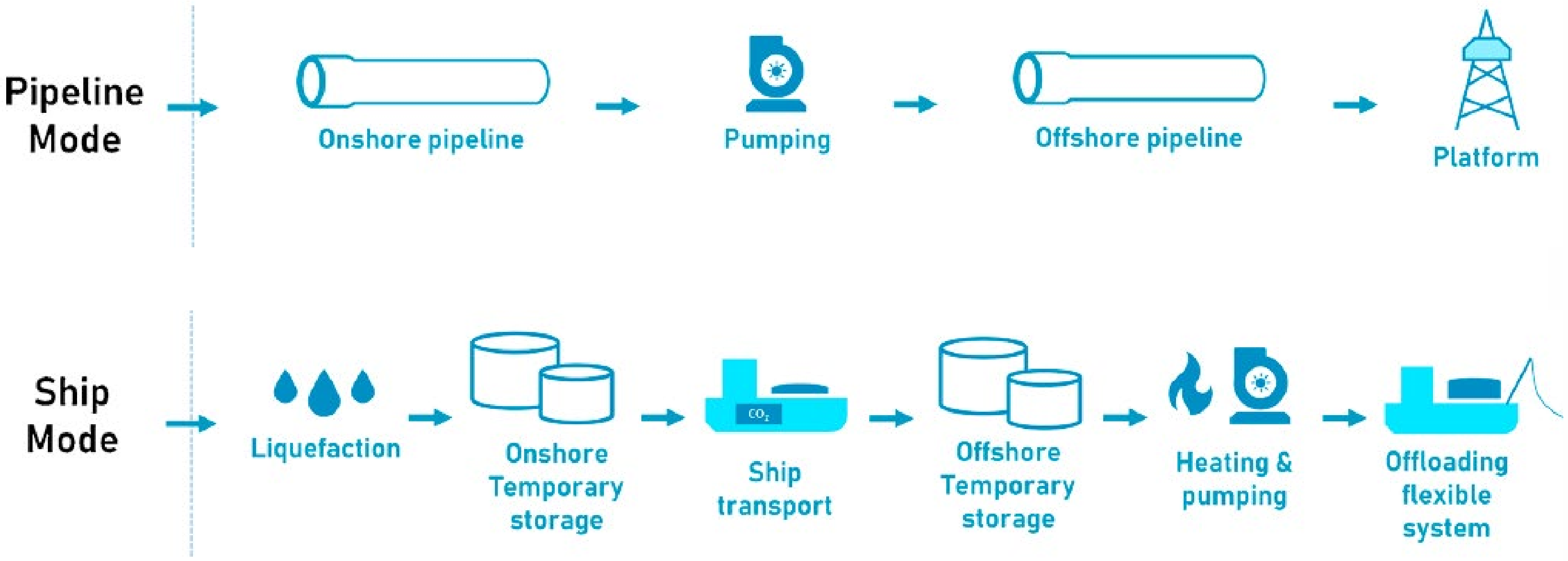
How does CO2 EPOC contribute to carbon storage strategies?

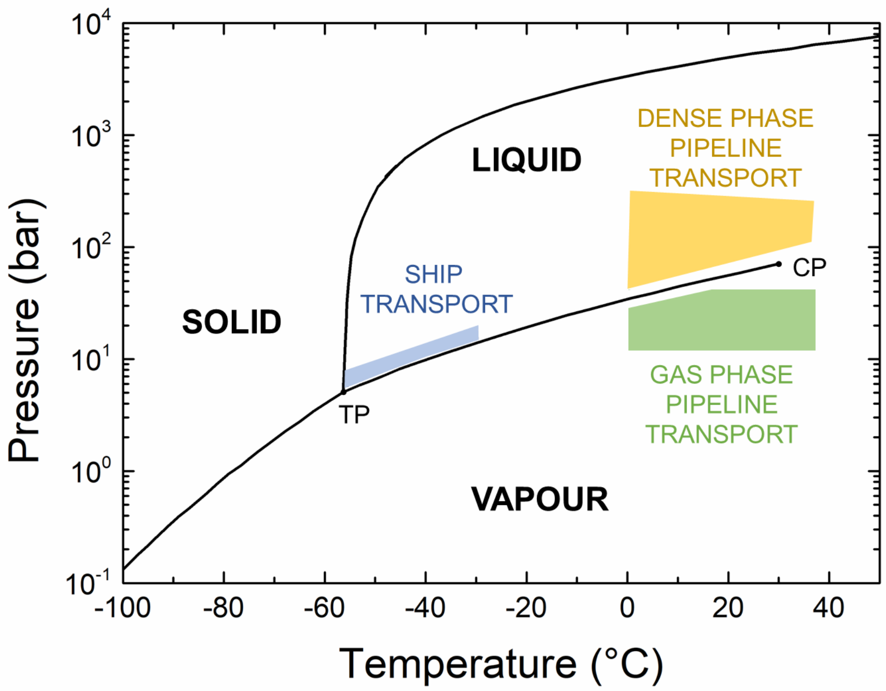
Carbon capture and storage is an essential part of the strategy to reduce global emissions



CO2 EPOC

How can we transport CO_2 from capture to storage?





- State of CO_2 depends on temperature and pressure
- Transport is usually more economical when density is higher
- Any leakage during transport undermines the efforts of CO_2 capture

https://doi.org/10.1016/j.ijggc.2019.102930

Examples of uses of polymers in gas/liquid transport infrastructure?

Elastomers

- O-rings, Seals
- Gaskets

Thermoplastics

- Thermoplastic liners for metallic pipes, storage vessels
- Pump coatings
- Valve seat components

Thermosets

- Epoxy liners for metallic pipes
- Matrices for fibre reinforced composites (e.g. pipes, pressure vessels)

Advantageous to use polymer materials which are already used in other applications (e.g. oil and gas)

↓

Enables reuse of existing infrastructure and value chains

Example: elastomers used in seals in the CO_2 transport

- A simple o-ring, used as a primary barrier to leakage
- A small but essential component to prevent leakage (both around and through the elastomer)
- May be exposed to static and cyclic pressurizations, temperature variations, chemical exposure

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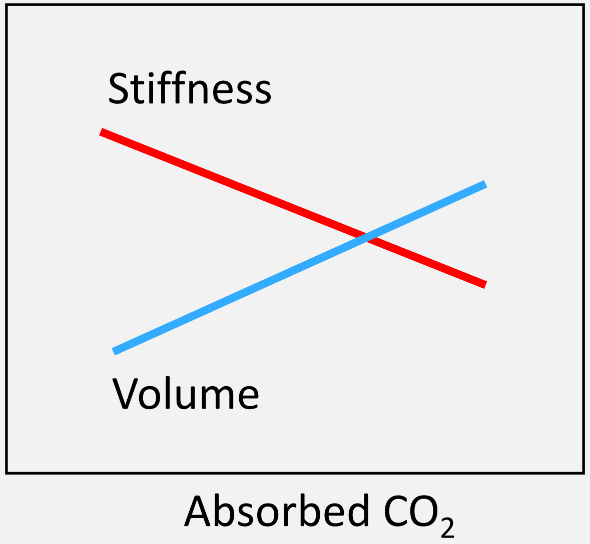
CO2 EPOC

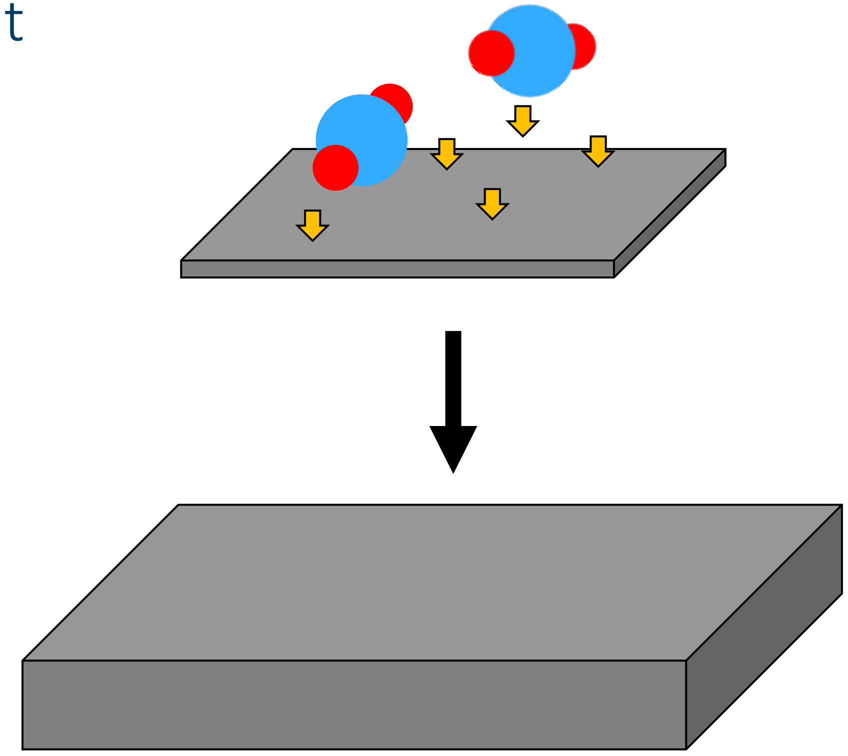
Swelling of elastomers

- CO_2 is soluble in many polymers and can cause significant swelling
  - Volumetric expansion
  - Reduction in stiffness

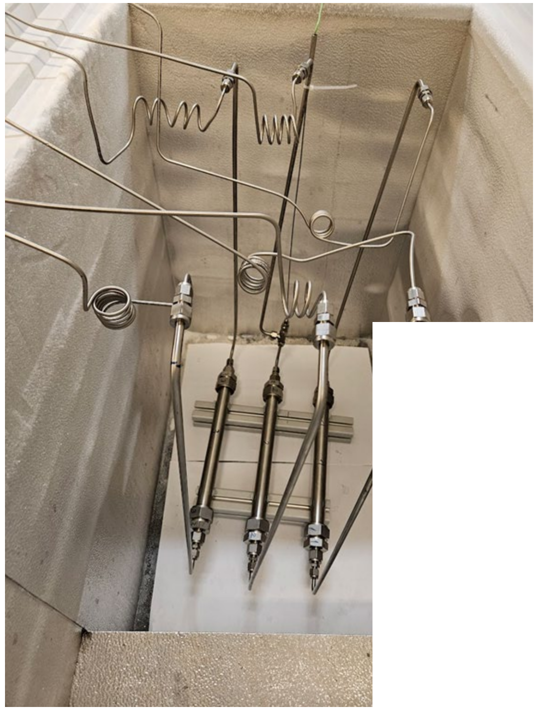
CO2 EPOC

Understanding the effects of CO_2 on mechanical and physical properties



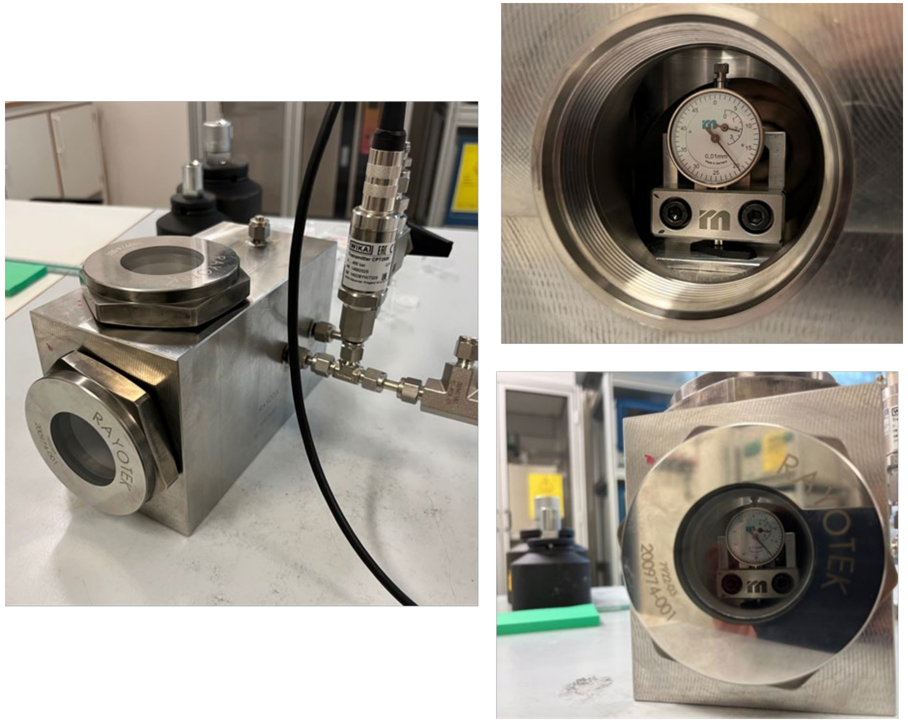


Infrastructure



Autoclave – ship scenario

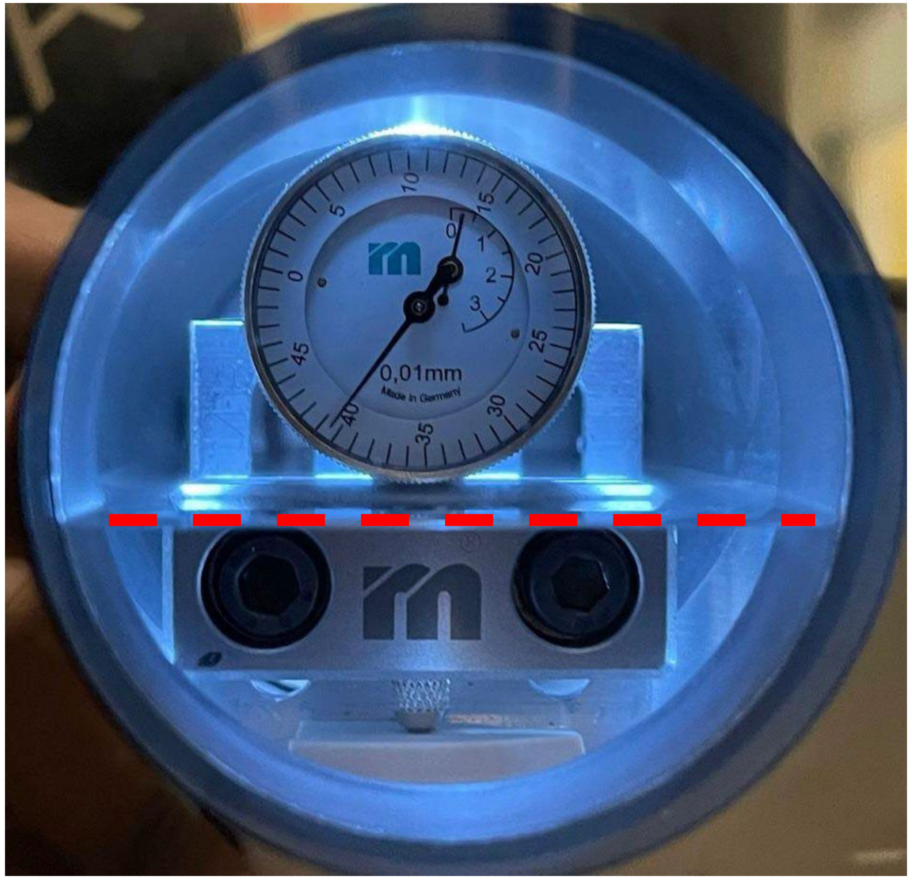
LCO_2 (down to -50 C, up to 50 bar)

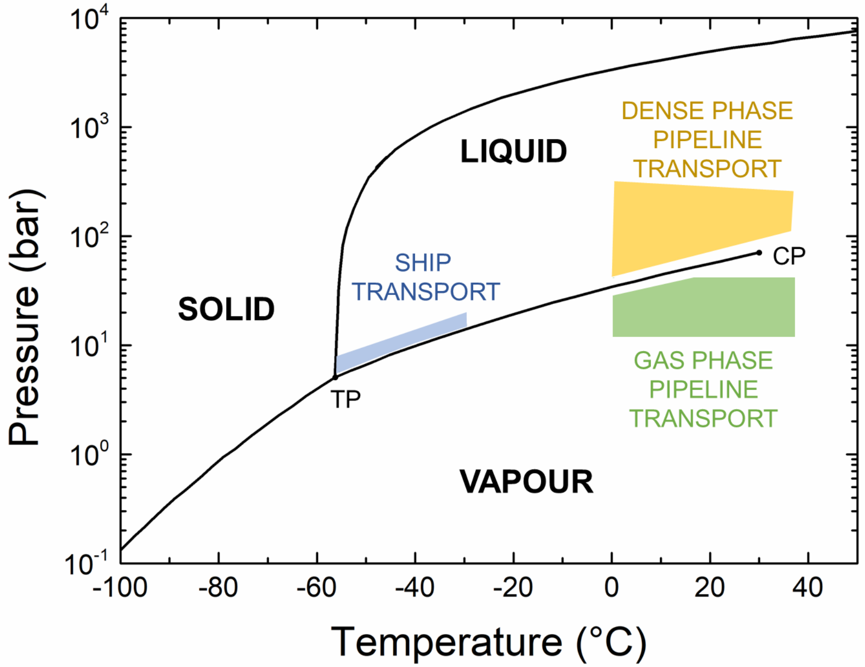


Autoclave – pipeline scenario

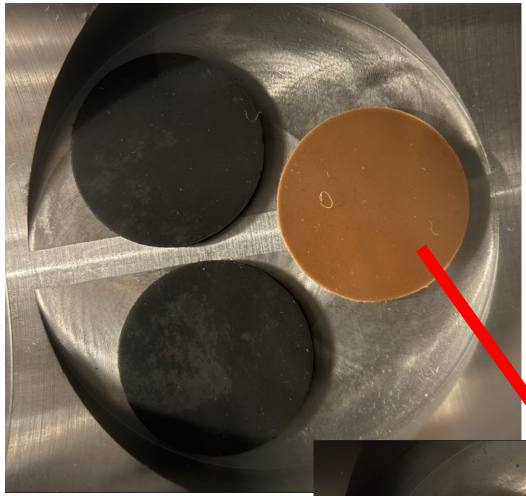
sCO_2 (RT, up to 200 bar)

Swelling of elastomers in CO_2

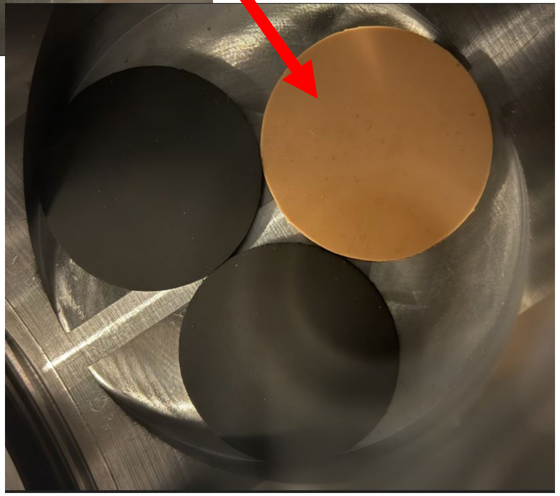


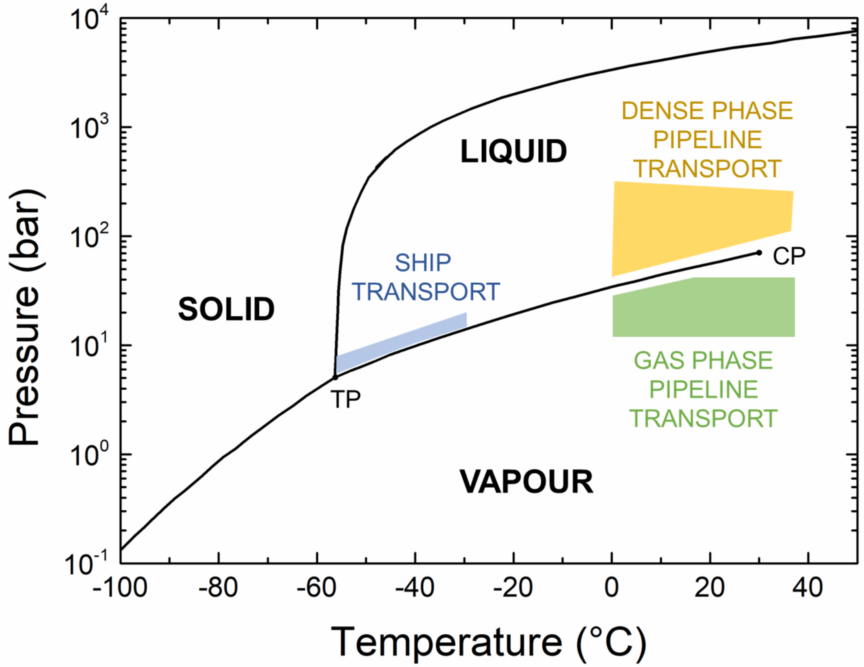


Swelling of elastomers in CO_2



Swelling of polymer due to CO_2 absorption

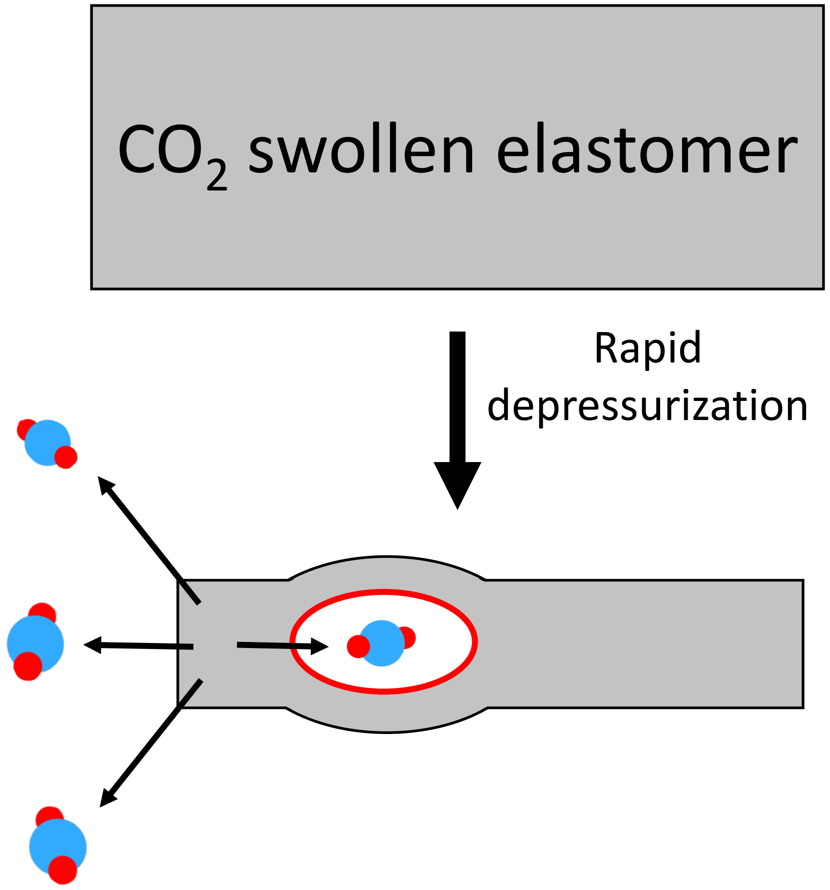




Rapid gas decompression damage

- Dissolved CO_2 can lead to rapid decompression damage
  - Blister, tear formation
  - Catastrophic seal failure

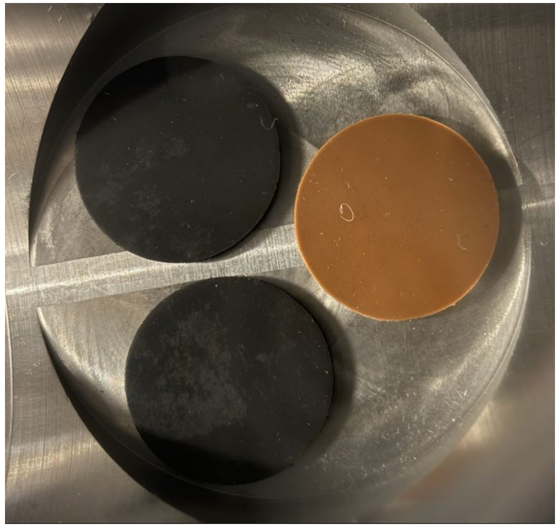
How does RGD damage evolve after exposure to CO_2? → Understanding the effect of material formulation on CO_2 RGD resistance



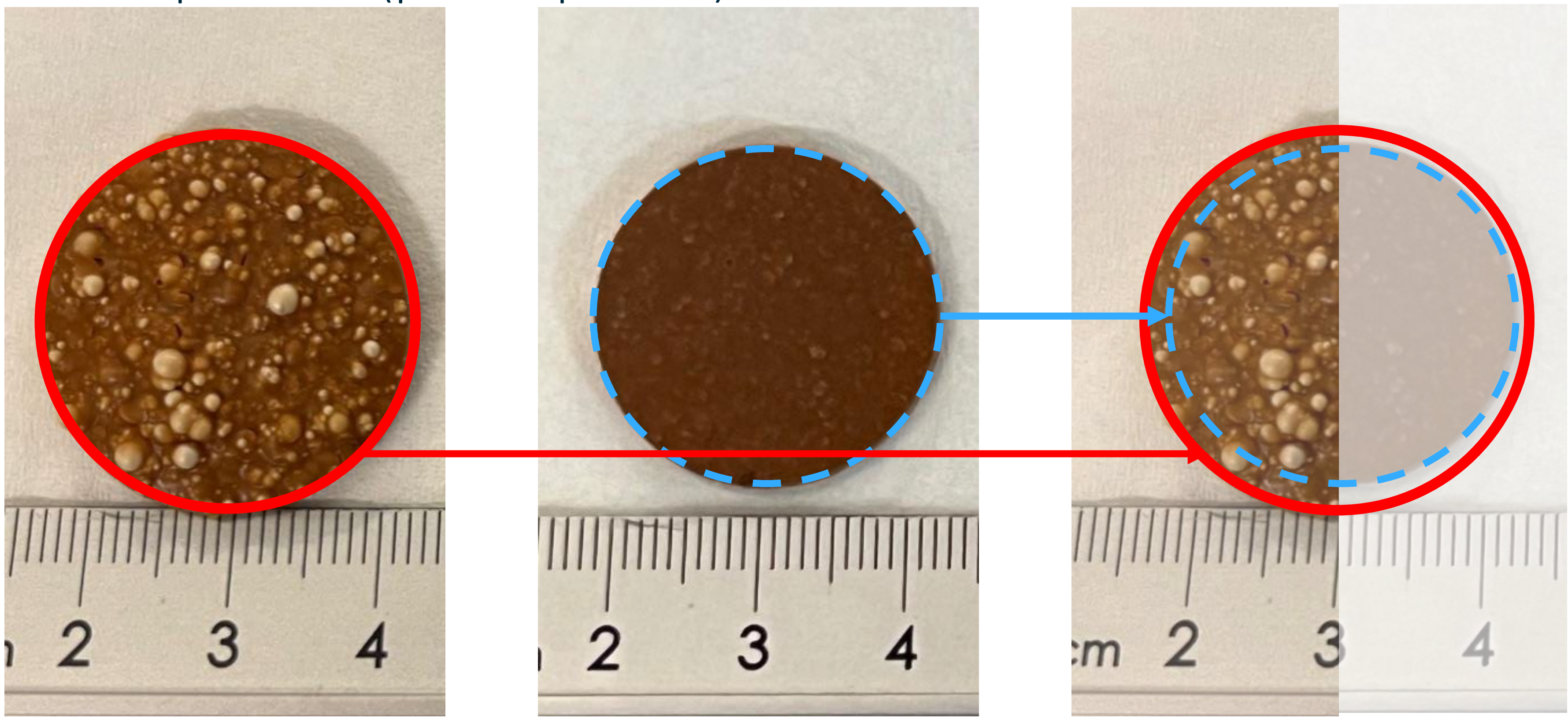
Effects of absorbed CO_2 on elastomers

- Blistering and swelling is transient, but RGD damage is permanent

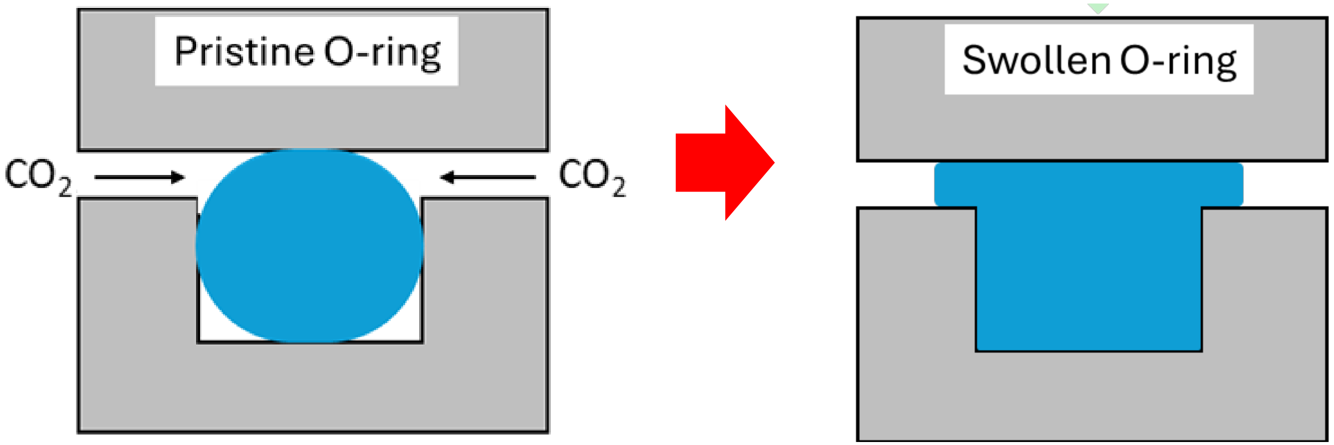
Pre-exposure



Decompression (post exposure)



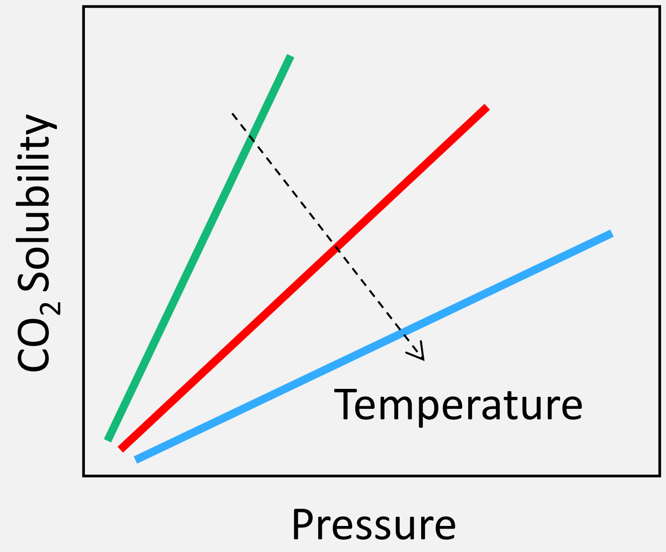
Swelling in CO_2 in a Semi-constrained State

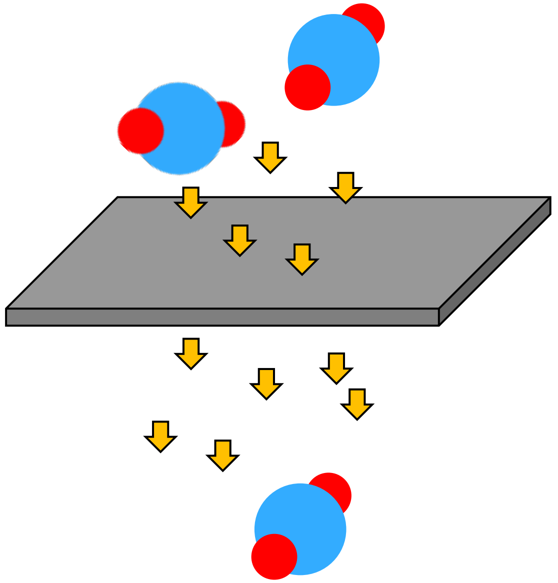


Permeability of elastomers

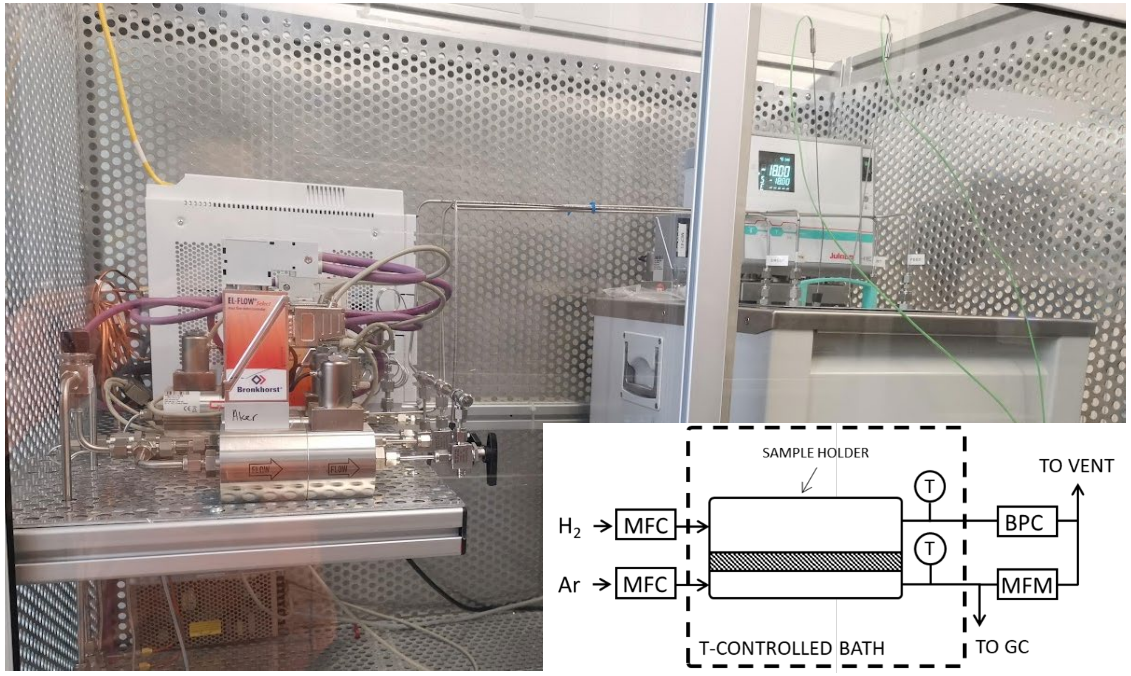
- CO_2 will diffuse through polymers
  - Elastomers are not perfect barriers
  - Barrier properties are temperature and pressure dependent

Measuring transport properties of CO_2 in polymers





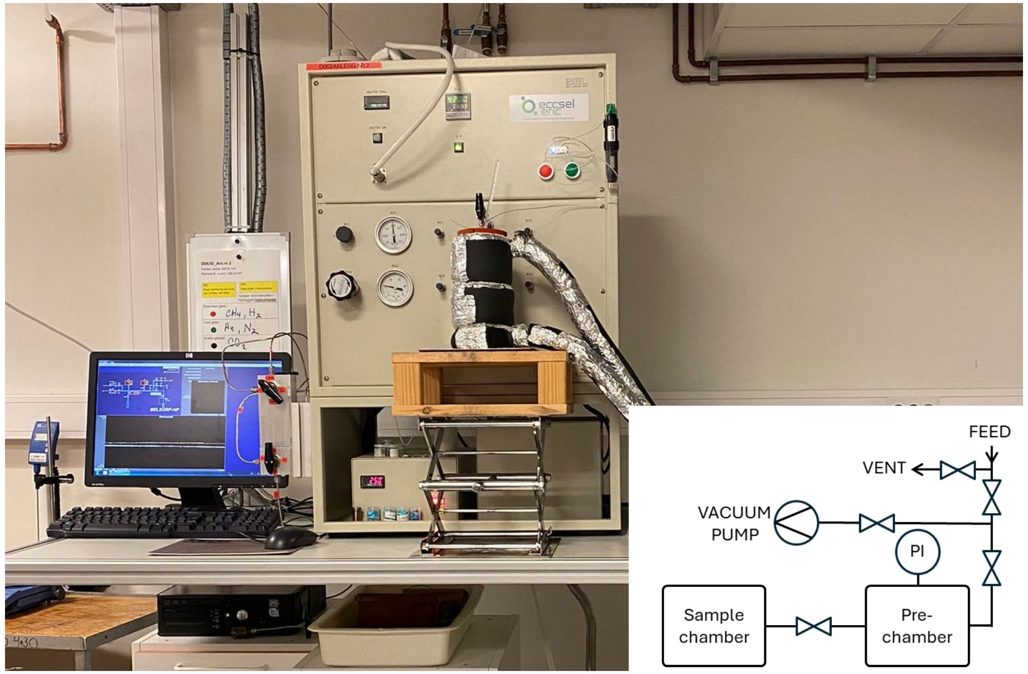
Infrastructure



CO_2 Permeation unit

LCO2 (-30 to -50 C, up to 25 bar)

sCO2 (5 – 45 C, up to 180 bar)



CO_2 sorption unit

gCO2 (-30 to 45 C, up to 50 bar)

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Predictive models

- Thermodynamic models have been developed to describe polymer + penetrant mixtures, suitable to polymer melts, solutions or rubbers (equilibrium systems)
- Can describe
  - Solubility
  - Diffusivity
  - Permeability

ELSEVIER

Chemical Engineering Journal

Available online 22 March 2025, 161826

In Press, Journal Pre-proof What's this?

Cryo-compressed CO_2 sorption and diffusion in elastomers for the CO_2 transport chain: Examples of FKM, EPDM and HNBR

E. Ghiara [a, 1], G. Lazzari [a], V. Signorini [a], L. Ansaloni [b], B. Alcock [b], M. Minelli [a]

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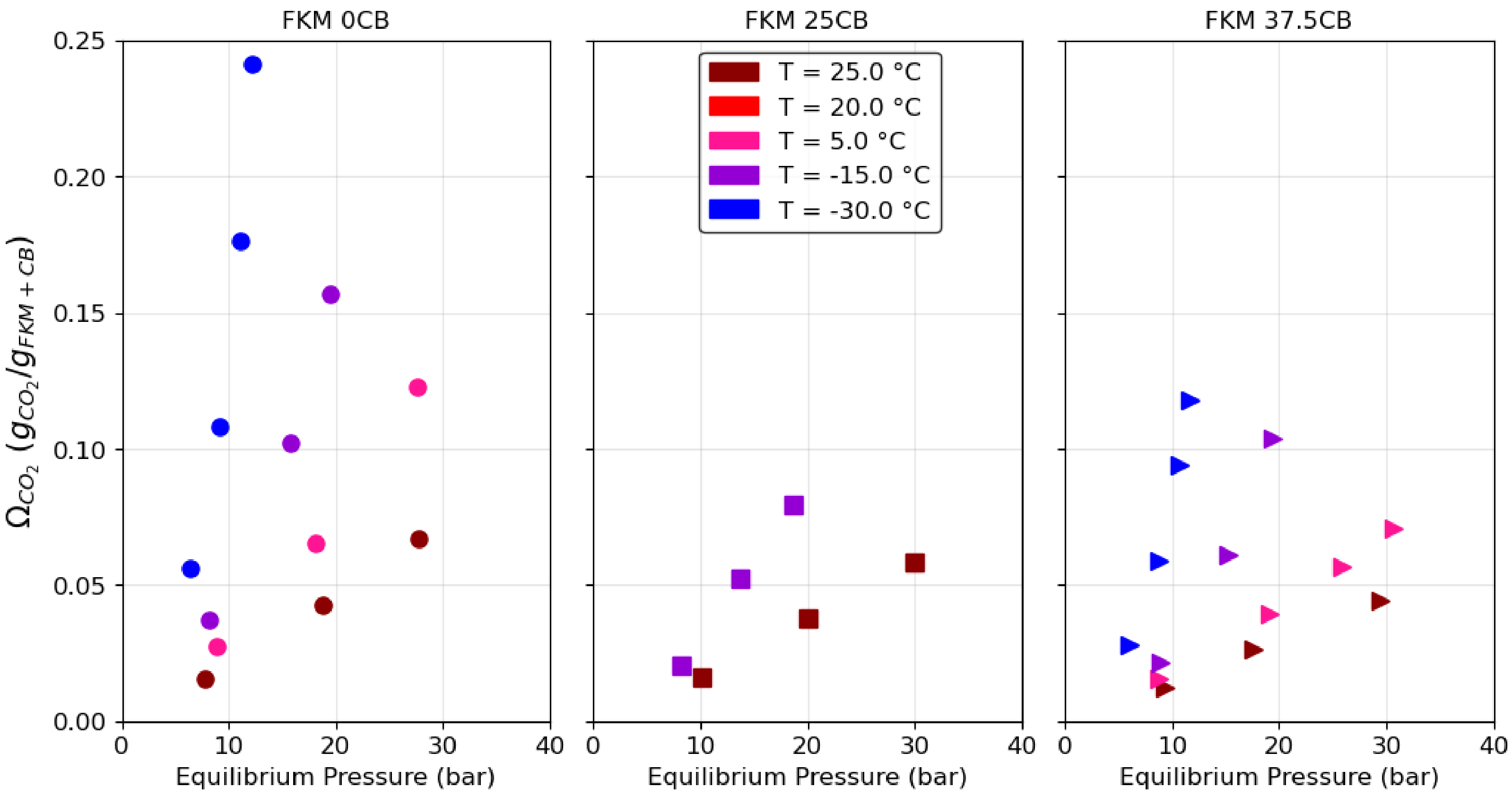
Highlights

- CO_2 solubility and diffusivity in elastomers is inspected in wide ranges of temperature and pressure.
- The suitability of representative FKM, HNBR and EPDM for CO_2 transport applications is assessed.
- Prediction of key parameters is obtained through thermodynamic and transport models.

Example of CO_2 Sorption tests

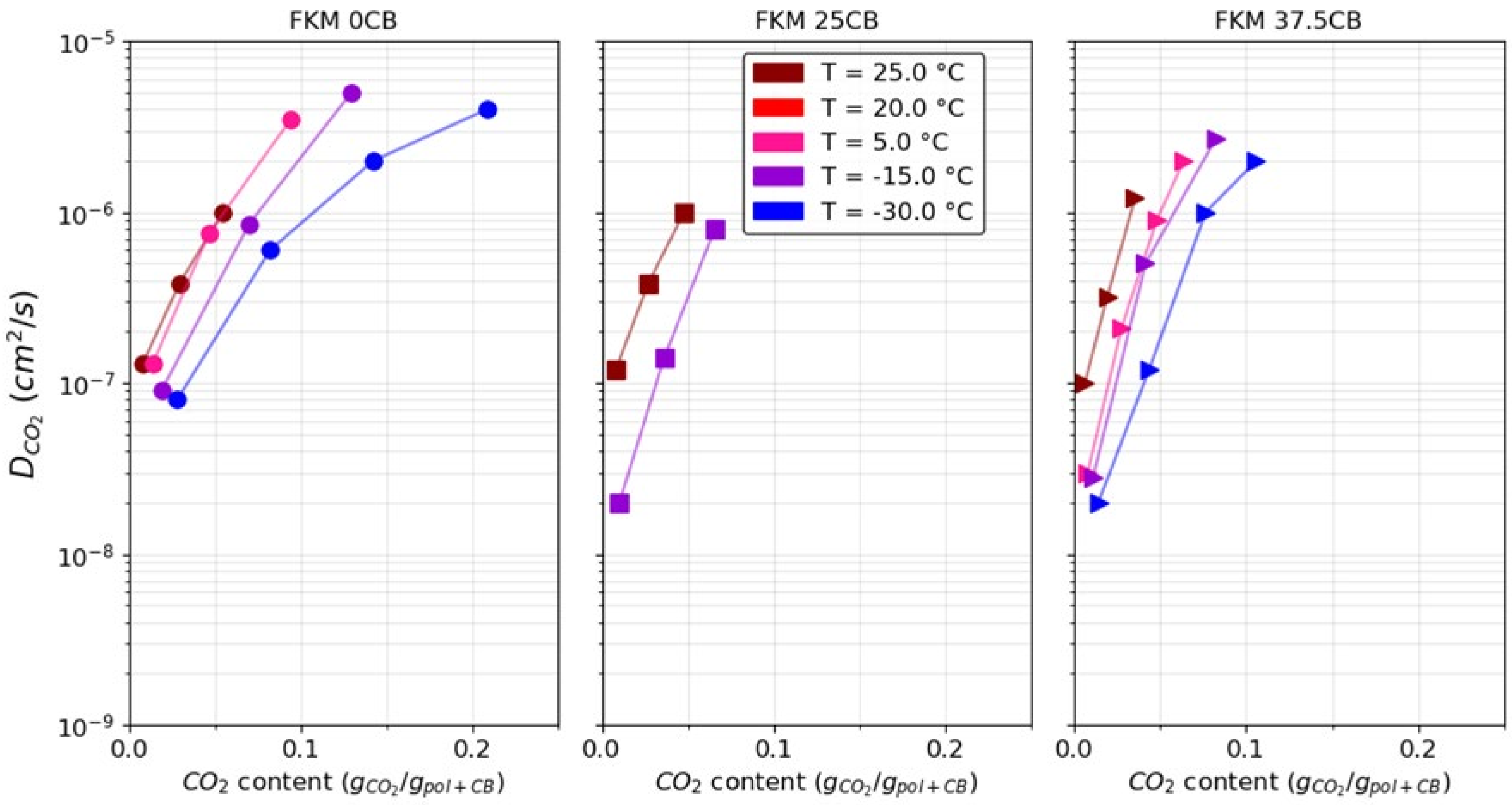
- Effect of carbon black (CB) content in FKM on CO_2 solubility



Ghiara E. et al., Chemical Engineering Journal, 2025

Example of CO_2 Sorption tests

- Effect of carbon black (CB) content in FKM on CO_2 diffusivity

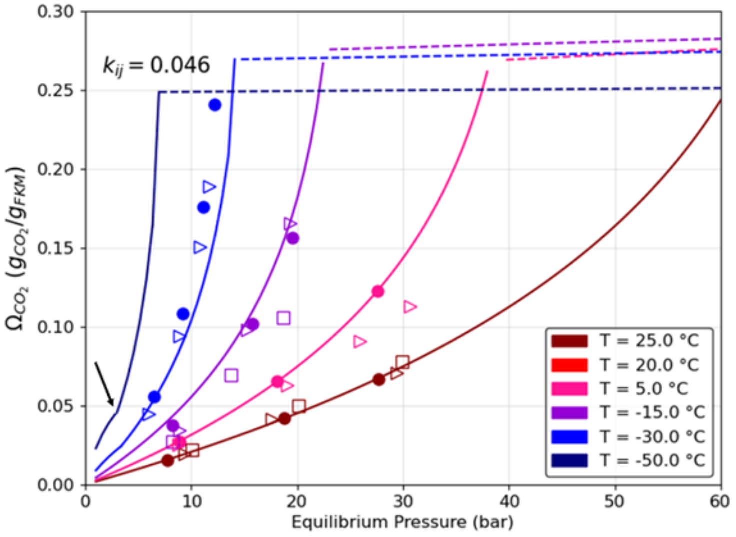


Ghiara E. et al., Chemical Engineering Journal, 2025

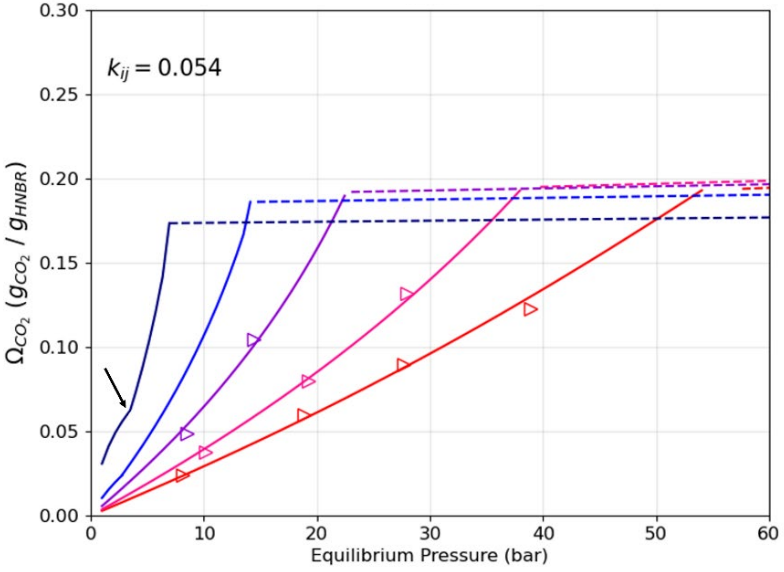
Examples of CO_2 Sorption tests

- CO_2 sorption in different elastomers (lines represent model predictions)

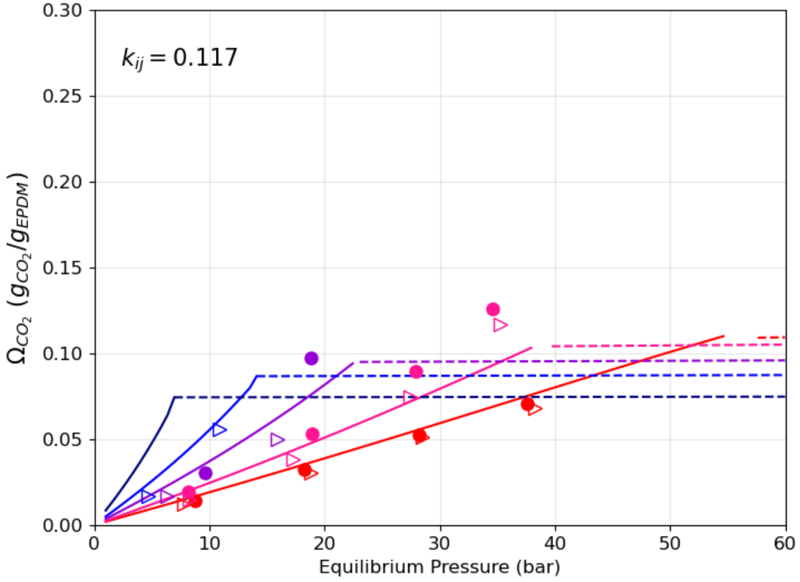
FKM 37.5% CB



HNBR 35% CB



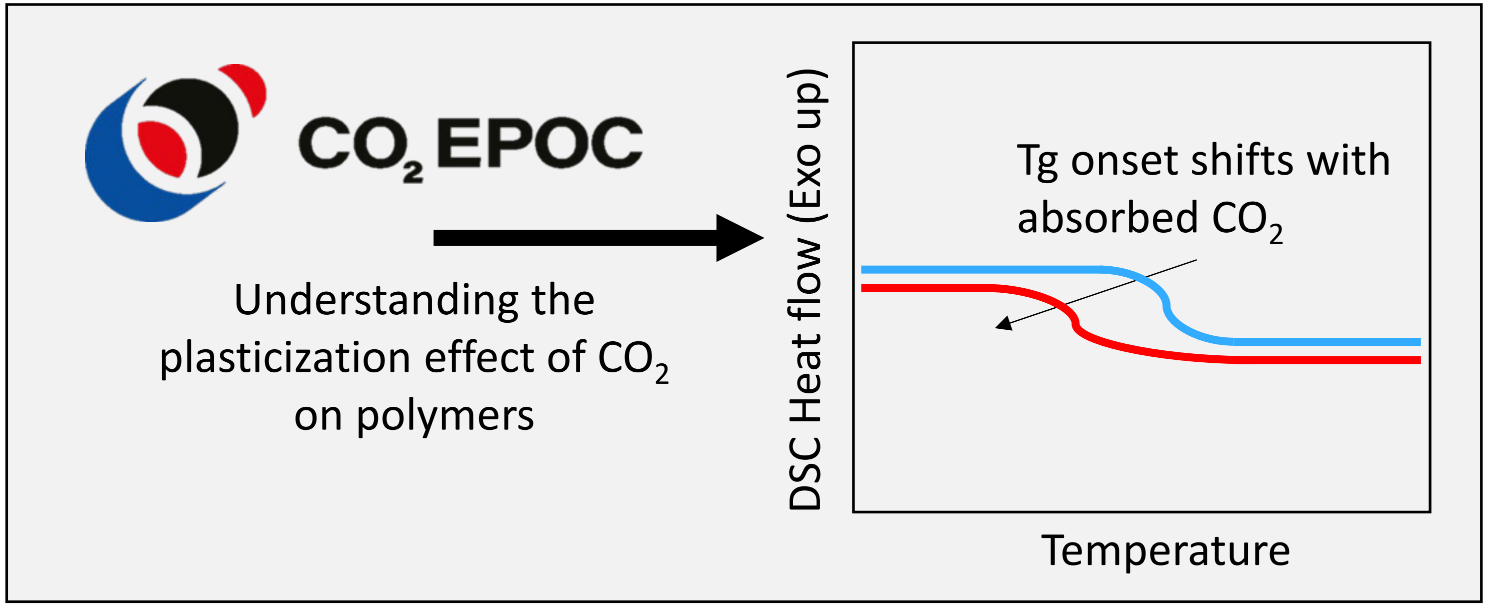
EPDM 37.5% CB

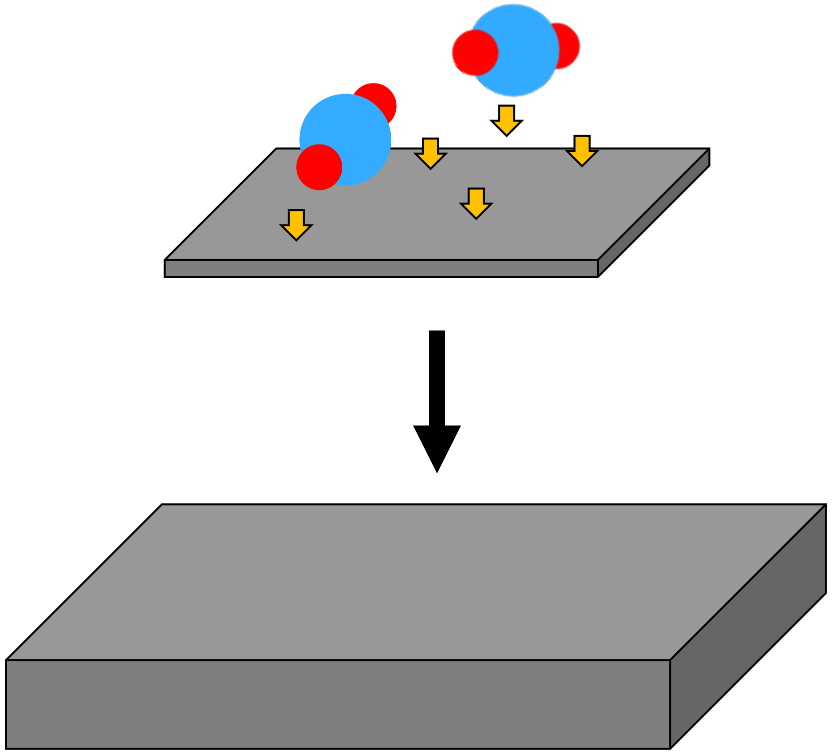


Ghiara E. et al., Chemical Engineering Journal, 2025

Plasticization by CO2

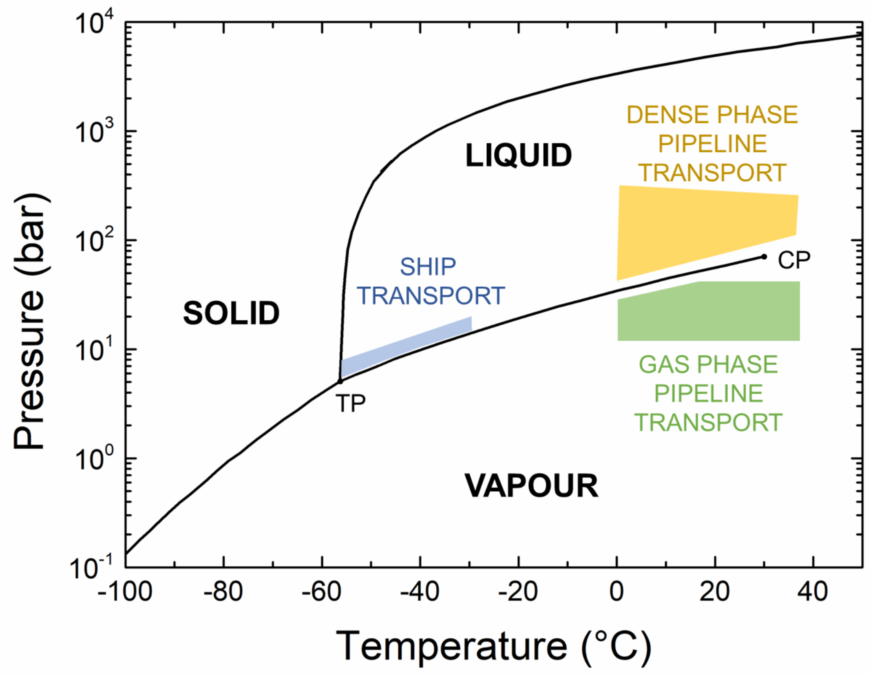
- Polymers can be significantly plasticized by CO_2
  - Reduction in onset of glass transtion temperature





Combined effects at low temperatures

- Ship transport of CO_2 involves low temperatures
- Combined effects are complex (especially on decompression events)
  - Stiffness increase due to low temperatures – but what about plasticization due to CO_2 sorption?
  - Sorption increases with decreasing temperature
  - Diffusivity increases with temperature
  - Joule-Thompson cooling effect on decompression



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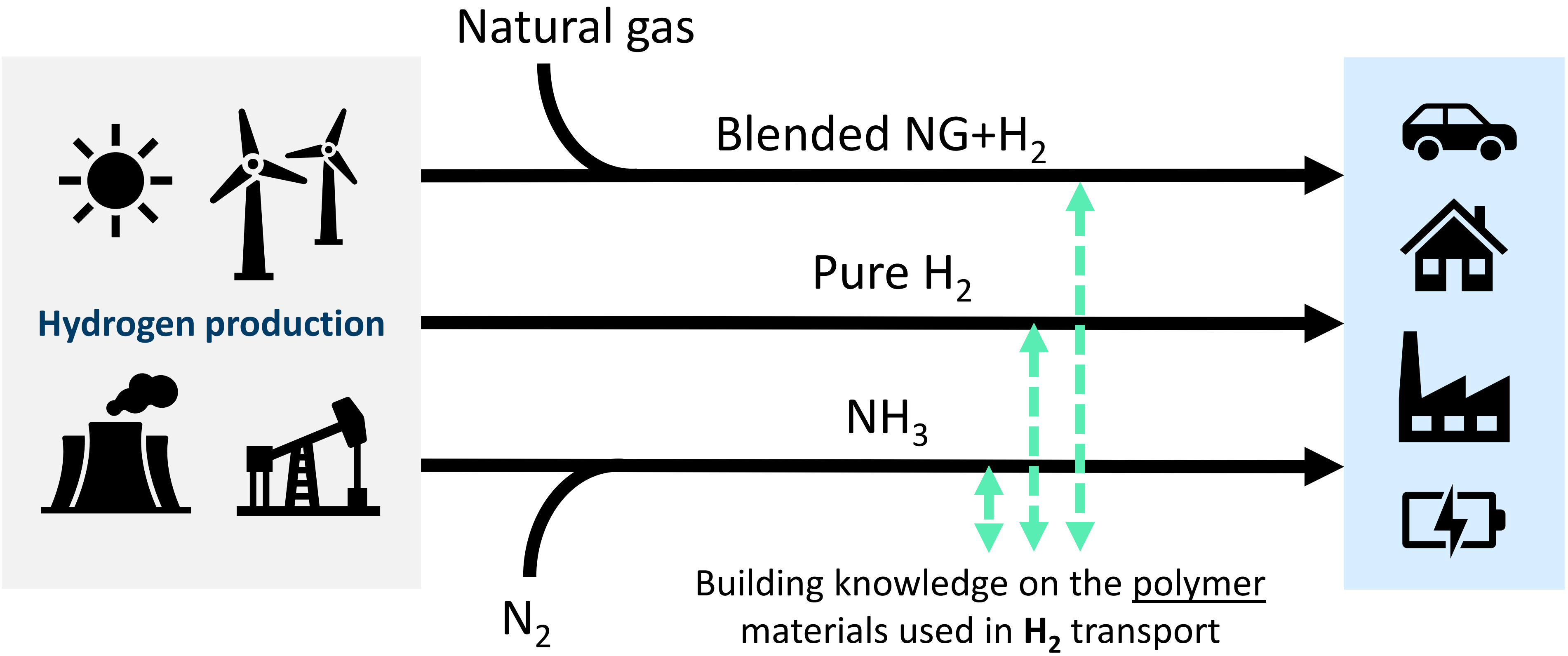
How does Pol(Hy)Mer contribute to decarbonisation of the energy network?



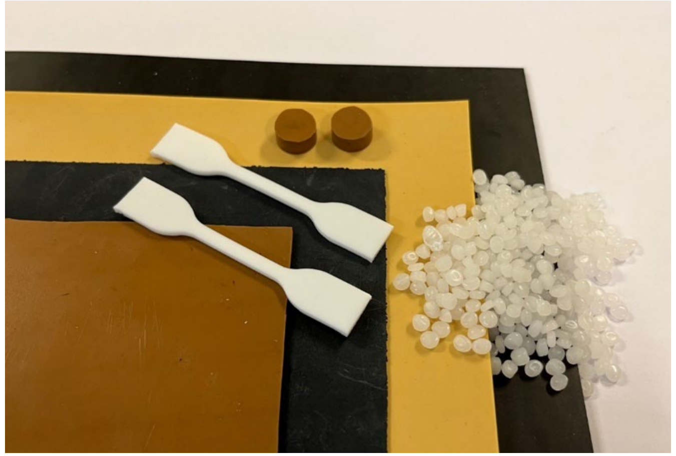
Pol(Hy)Mer

Technology for a better society

Understanding effect of H_2 on different polymer types

Elastomers, Thermoplastics, Composites

Seals, o-rings, membranes, liners, pipes

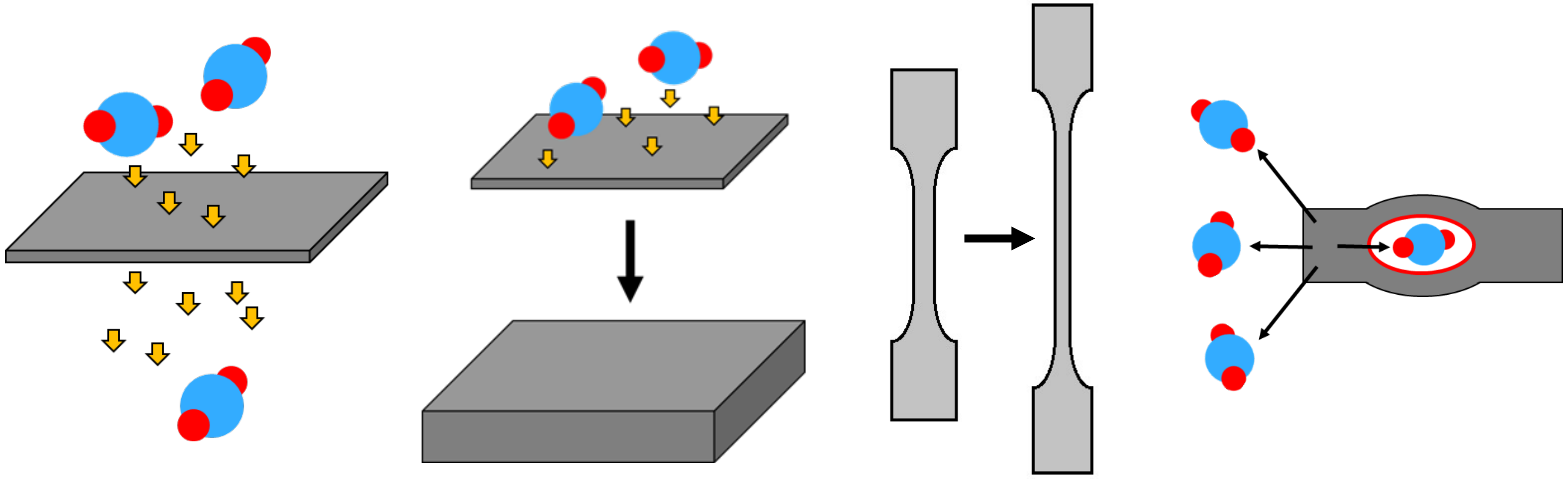


Solubility / Permeability

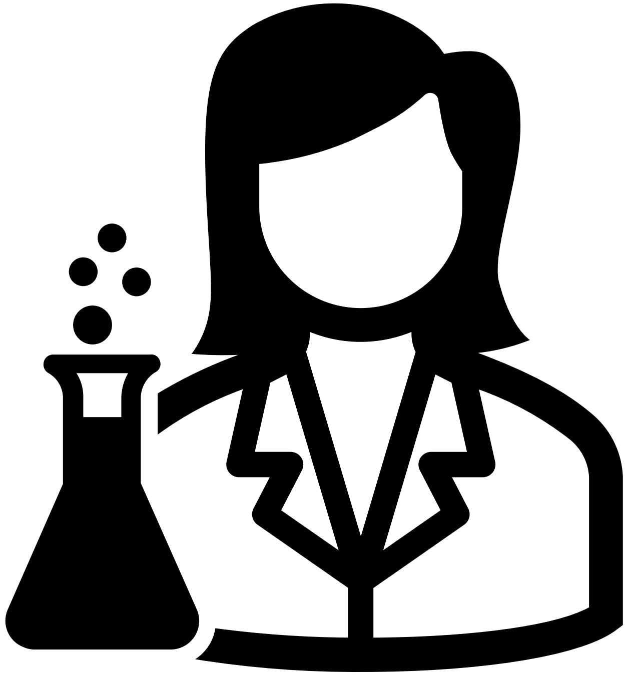
Volumetric Swelling

Mechanical Properties

Rapid Gas Decompression Damage



Pol(Hy)Mer Project – PhD Recruitment

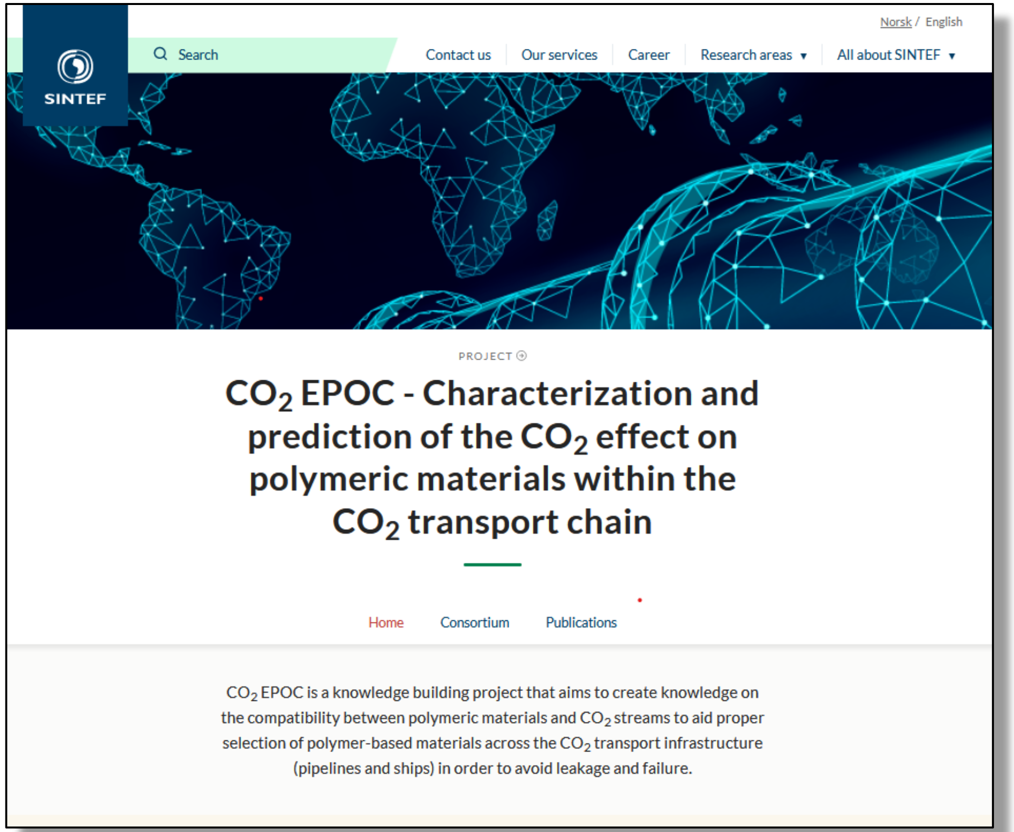


- Vacancy opening for a PhD candidate to start in 2025 in the Pol(Hy)Mer project
  - Based at NTNU in Gjøvik, Norway
  - Will be advertised soon

Summary

- CO2 EPOC Project (Carbon Dioxide)
  - CO_2 transport creates some challenging conditions for polymer materials
  - Reuse of existing O&G infrastructure for CO_2 transport may have economic advantages
  - Combinations of low temperatures and absorbed gases create complex conditions for polymer materials
  - Experimental work has enabled the development of models to predict how polymers will perform in the CO2 transport chain

- Pol(Hy)Mer Project (Hydrogen)
  - Characterization of polymers in the operational windows required by different hydrogen transport scenarios
  - Development of models to give a fundamental description of material performance in the operating conditions used in current industry practice
  - Prediction of the short- and long-term effects of H2, blended H2 and ammonia as a H2 carrier chemical on polymer based materials used in the hydrogen value chain



https://www.sintef.no/en/projects/2020/co2-epoc/

CO2 EPOC Research Team

SINTEF

- Dr. Ben Alcock (Project Manager)
- Dr. Luca Ansaloni
- Dr. Thijs Peters
- Vilde Andreassen

University of Oslo

- Anu Muthukamatchi (PhD candidate)
- Prof. Reidar Lund

University of Bologna

- Emma Ghiara
- Gaia Lazzari
- Roberta Di Carlo
- Dr. Virginia Signorini
- Prof. Matteo Minelli
- Prof. Marco Giacinti Baschetti

SINTEF

CO_2 EPOC

Ben.Alcock@SINTEF.no

CO2 EPOC Project Webinars

01/04/25

1200 - 1215 Dr Ben Alcock, SINTEF, Norway - *Introduction to the CO2 EPOC Project*
1215 - 1235 Roberta Di Carlo, University of Bologna, Italy - *Cryo-compressed CO2 permeation through elastomers for CO2 ship transport*
1235 - 1255 Dr Jon Huse, DNV, Norway - *Qualifying non-metallic materials for CO2 pipelines – Next steps*
1255 - 1315 Vilde Andreassen, SINTEF, Norway - *An initial study of the impurities effect on the mechanical and gas barrier properties of non-metallics in the CO2 transport chain*

https://events.teams.microsoft.com/event/34193be2-53ec-4550-ae65-7d625961a810@e1f00f39-6041-45b0-b309-e0210d8b32af

08/04/25

1200 - 1225 Prof Matteo Minelli, University of Bologna, Italy - *Development of a model for permeation and swelling prediction of non-metallic materials in contact with CO2*
1225 - 1250 Dr Luca Ansaloni, SINTEF, Norway - *Sorption, diffusion and swelling induced by CO2 in different elastomers*
1250 - 1315 Prof Sylvie Neyertz and Prof David Brown, Université Savoie Mont Blanc, France - *Molecular modelling of gas permeation in polymer membranes for separation and barrier applications*
1315 - 1340 Dr Simon Gant / Dr Adam Bannister, HSE UK - *Title tbc*

https://events.teams.microsoft.com/event/bb221b94-f325-477e-8933-c375614c4f01@e1f00f39-6041-45b0-b309-e0210d8b32af

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