Presentations 9 February – Technical session - Capture

- Bjørn Hølaas, Statkraft
- Harald Malerød-Fjeld, CoorsTek
- Mario Ditaranto, SINTEF
- Luca Ansaloni, SINTEF Industry

Bjørn Hølaas

VP/DIRECTOR CCS

CLIMIT SUMMIT

#CLIMITSUMMIT2023
7–9 February

CCS solutions for WtE plants (KAN – Klimakur for avfallsforbrenning i Norge)

Previous role; 24 years within energy utilities.
Trondheim Energy; EVP retail and trading, EVP staff functions, CEO.
Statkraft; SVP district heating, VP leadership support and shared services
Education:
Batchelor communication and risk management.
MBA strategic management

Content

The Research Council of Norway

GASSNOVA

KAN - Klimakur for Avfallsforbrenning (Climate cure for WtE in Norway)

Status and further plans

Bjørn Hølaas, leader of steerco

Supported by;

Content

KAN – Klimakur for Avfallsforbrenning i Norge

(Climate cure for WtE in Norway)

Statkraft Varme, Forus Energigjenvinning, BIR Avfallsenergi, Returkraft og Hafslund Oslo Ceslio are Norwegian WtE plants with CCUS projects and with several common challenges

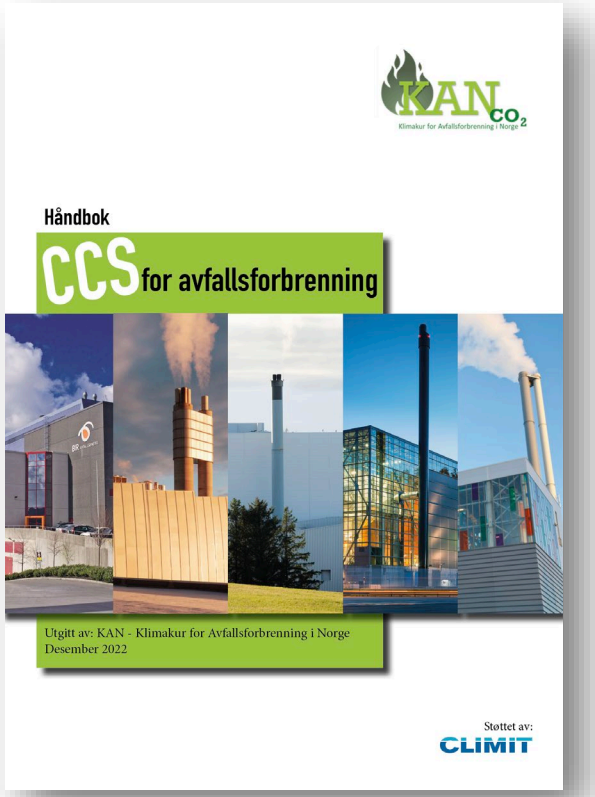
Established an industrial cooperation in 2021

KAN – Klimakur for Avfallsforbrenning i Norge

…to contribute to increased knowledge sharing and better solution for CCUS from WtE, thru increased cooperation.

Statkraft Hafslund Oslo Celsio BIR Forus Energigjenvinning Returkraft

Content



The handbook: CCS for WtE

- Shared knowledge and experience from partners in KAN with input from Norsk Energi and COWI
- Is based on todays knowledge – ongoing development
- Is meant as inspiration, a guide, and not a final recipe.
- Aviable on: www.kanco2.no. (Norwegian)

Content

Developed a reference plant, KAN Referansa, for comparison

Constructed 2010

Waste capacity 100.000 ton/y.

Max CO_2 capture;100.000 ton/y

District heating

Demand: 200 GWh

Waste heat: 175 GWh

Peak load: 25 GWh

Steam production

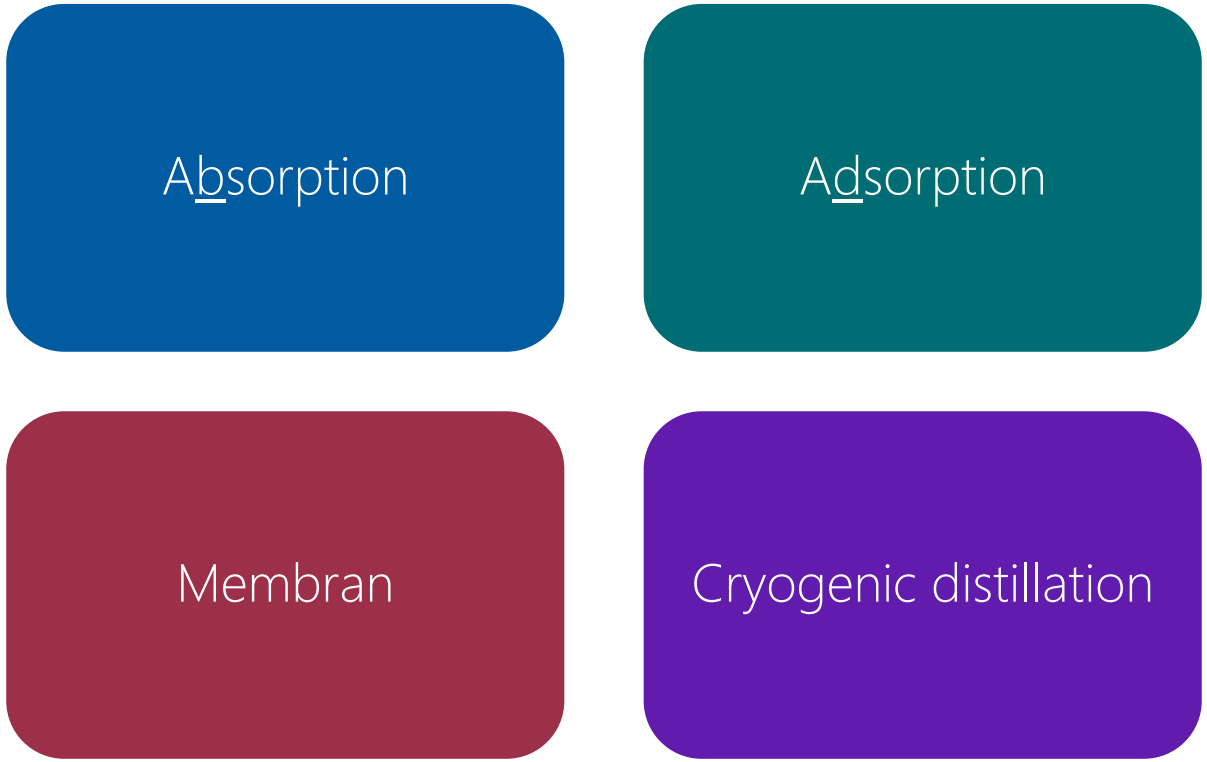
40 bar / 400 °C

Total heat production 280 GWh

Back pressure turbine 50 GWh_{el}

Content

CO_2-capture technologies (post combustion)

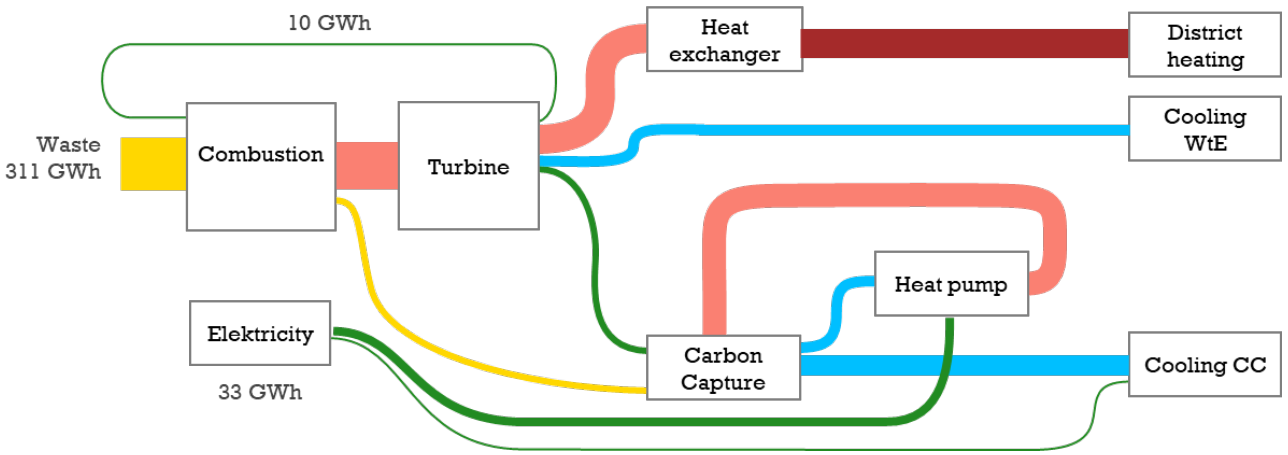


Key takeaways

- Challenges and advantages
  - Energy demand(heat/electricity/cooling)
  - Size/footprint
  - Cost (Capex/Opex)
  - Emission
- Several development projects with different maturity/TRL levels
- Absorption with amine solvent is currently the most mature technology WtE.
- Increased numbers of suppliers with different approach, business models etc

Integration (absorption)

Illustrative with heat recovery



Most important solutions

- Heat supply: with hot water or steam
- Heat recovery towards district heating; with heat pumps

  - cooling the capture process and heat-recovery towards district heating

Key takeaways (with absorption)

- Capture process; large need for thermal energy and considerable amount of cooling

  … but possible to recover and increase the heat delivery to district heating network with heat pumps
- Low return temperature is important for utilization of wase heat from capture process
- «All» electricity generated from the WtE plant will be consumed by the capture process
- Must decide/find the right balance between integration complexity and energy efficiency .

Content

Transport and intermediate storage

Key takeaways

- Early evaluation of method for transport and necessary infrastructure
  - Pipeline, trucks etc
  - Access to quay, utilities etc.
- Potential partners/-cooperation to reduce cost
  - Dimensioning of storage
- CO_2 volume, ship size and frequency important cost elements/drivers.

Distance, truck transport	10 km	20 km	20 km	20 km
Capture capacity	100 000 ton/y	200 000 ton/y	400 000 ton/y	200 000 ton/y
Frequency ship, 7500 m3 Reserve intermediate storage	4 days 1 day	4 days 1 day	4 days 1 day	15 days (full ship) 1 day
OPEX Transport Intermediate storage	 5 MNOK 2,5 MNOK	 20 MNOK 3,7 MNOK	 40 MNOK 7,0 MNOK	 20 MNOK 10,2 MNOK
CAPEX	179 MNOK	208 MNOK	340 MNOK	371 MNOK

Not included; cost for area, civil, utilities, quay

Content

Permanent storage

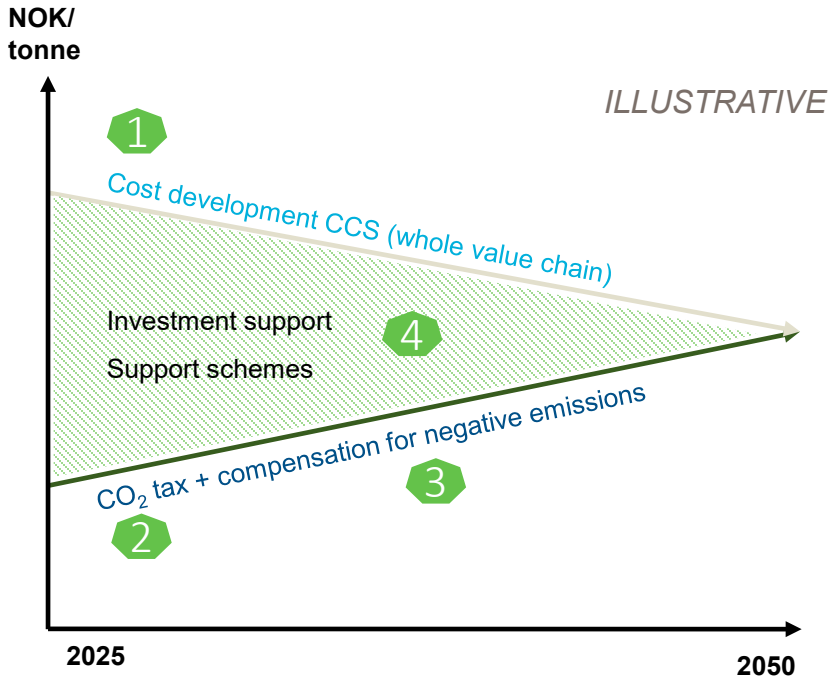
Key takeaways

- Most locations, phase 1, is connected to specific CCS projects - commercial availability in phase 2
- Risk for lack of storage capacity in 2030+, but new locations will be developed
- Important to secure access to permanent storage - before investment decision.

Nr	Navn/Lokasjon	Operative/ Kapasitet	Eiere	Planlagt kapasitet – neste fase	Antatt pris	Kvalitet CO2	Merknad
1	Northern Lights Øygarden	2025 – 1,5 Mta	Equinor Shell Total	2028 – 8 Mta	Ukjent – Ingen kommersielle avtaler utover langskip	Har CO2 spesifikasjon	Har fått støtte til studie for økning i kapasitet.
2	Project Greensand Danmark	2025 –0,5-1,5 Mta	Wintershell Maersk-drilling GEUS	2030 – 5 Mta	Skissert deponiavgift på under 200 Dkk (uten transport)	Ikke kravspec enda, men antatt mindre strenge krav enn NL	Prisantydning ubekreftet, men oppgitt i presentasjon med Thisted kommune
3	Acorn project Skottland	2025 – 0,3 Mta	Storegga, Shell U.K, Harbour energy, NSMP	2027 – 1 Mta 2030 – 5-10 Mta			Bruke eksisterende rør fase 1, St Fergus terminal. St Peterhead port som HUB
4	Northern Endurance Østkyst GB sørlige nordsjø.	2026 – 1,7 mta	BP, Shell, ENI, Equinor, Total, National Grid	2030 – 17 Mta			BP som operatør, Skal serve Net Zero Teeside og Zerocarbon Humber (Grimbsby)
5	Liverpool Bay/ HyNet GB – vestkyst	2025 – 4,5 Mta	Eni UK Progressive E Cadent, CF-Fertilliseres Essars INOVYN	2030 – 10 Mta			Planlagt HUB for industri klynge. Produsere low carbon Hydrogen. Uavklart om mottak fra aktører utenfor klyngen er aktuelt

Content

Regulatory framework and commercial conditions



1 **Cost development**

- Expect decreasing cost, both for capture plants/technology and transport and permanent storage

2 **CO_2 tax for fossil emissions** :

- Target level from Norwegian government; 200 EUR/ton in 2030
- Supports tax on fossil CO_2 emissions, alternative WtE should be included in ETS
- Framework for CO_2 tax should be arranged so that the totality of instruments supports circular economy and makes it possible to realize CO_2 capture

3 **Market for carbon removals:**

- Need viable framework for carbon removals (biogenic CO_2). CO_2 certificates for stored biogenic CO_2 is an important revenue source for WtE.

4 **Investment support/support schemes**:

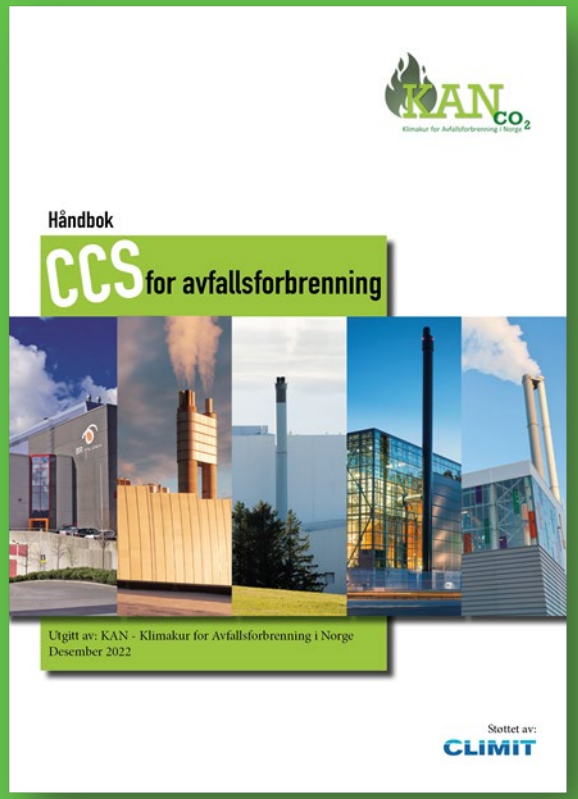
- Need for a time limited support schemes/investment support to realize CCS from WtE .
- Need project financing support for further project development

Content

KAN phase 2- way forward (tentative)

Framework	Commercial	Cooperations
• Structure and arrangement for fossil CO_2 tax • Framework for carbon removals (biogenic CO_2) • Framework for investment support/supports schemes	• Possible market mechanism/ policy instruments - preferred type and level • Market for Carmon removals	• Continue to share knowledge within KAN • Discussion and dialog within other WtE plants • Sharing of knowledge with actors in Sweden and Denmark • Creating social and political acceptance

Content



WWW.KANCO2.NO

Content

Harald Malterød-Fjeld

SENIOR SCIENTIST

CLIMIT SUMMIT

#CLIMITSUMMIT2023
7–9 February

Protonic membrane reformer technology for conversion of natural gas to hydrogen and CO_2

Harald Malerød-Fjeld works as a senior scientist in CoorsTek Membrane Sciences. He has a PhD in materials science and has specialized in high temperature electrochemistry and thermodynamics. In CoorsTek, he works with testing and analysis of multi-cell electrochemical reactors at high temperature and high pressure.

Content

The Research Council of Norway

GASSNOVA

Protonic membrane reformer technology for conversion of natural gas to hydrogen and CO_2

Harald Malerød-Fjeld
Senior Scientist, CoorsTek Membrane Sciences

CLIMIT SUMMIT, Larvik, 9 February 2023

CoorsTek Amazing Solutions®

CoorsTek MEMBRANE SCIENCES

Content

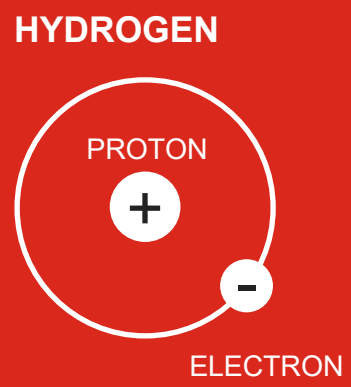
About us

COORSTEK MEMBRANE SCIENCES:

- Technology development company located in Norway with ~25 employees / contractors
- Leading position in the development of solid-state proton conductors, the most efficient of all hydrogen technologies
- Global network of R&D collaborations, regular publications in top scientific journals (Nature/Science branded)
- Business focus on collaboration agreements with major energy companies for joint technology development

COORSTEK:

- Global advanced materials company with 6 000+ employees and leading position in technical ceramics
- Headquarter in Colorado, USA, with operations world-wide



PROTON CERAMIC MEMBRANES operate at elevated temperatures between 400°C and 800°C by breaking hydrogen into its sub-atomic particles (PROTONS and ELECTRONS) and then transporting protons across a solid dense ceramic electrolyte

PROTON CERAMIC MEMBRANES offer unique opportunities for more efficient hydrogen production

Content

CoorsTek Worldwide

50 MANUFACTURING SITES
10,000 CUSTOMERS IN 70 COUNTRIES
CONNECT & COLLABORATE WORLDWIDE

Content

History of Innovation Within Protonic Membranes

CLIMIT Demo: PROTONIC I — PROTONIC II

2015
CTMS is formed on the basis of 15 years of R&D at CoorsTek and the acquisition of Protia

2016
Science
Article on conversion of gas to chemicals using protonic membranes

2017
nature energy
Article published on hydrogen from natural gas with minimal energy loss

2017
First development projects funded by industry leading partners

2019
Collaboration agreement signed, with funding from six major energy companies and Norwegian grants

2020
Completion of prototype manufacturing line for membrane reactors in Oslo, Norway

2021
First kW-scale hydrogen generator demonstrated

2022
Science
Article is published on the scaling of cells to stacks

Single-step hydrogen production from NH_3, CH_4, and biogas in stacked proton ceramic reactors

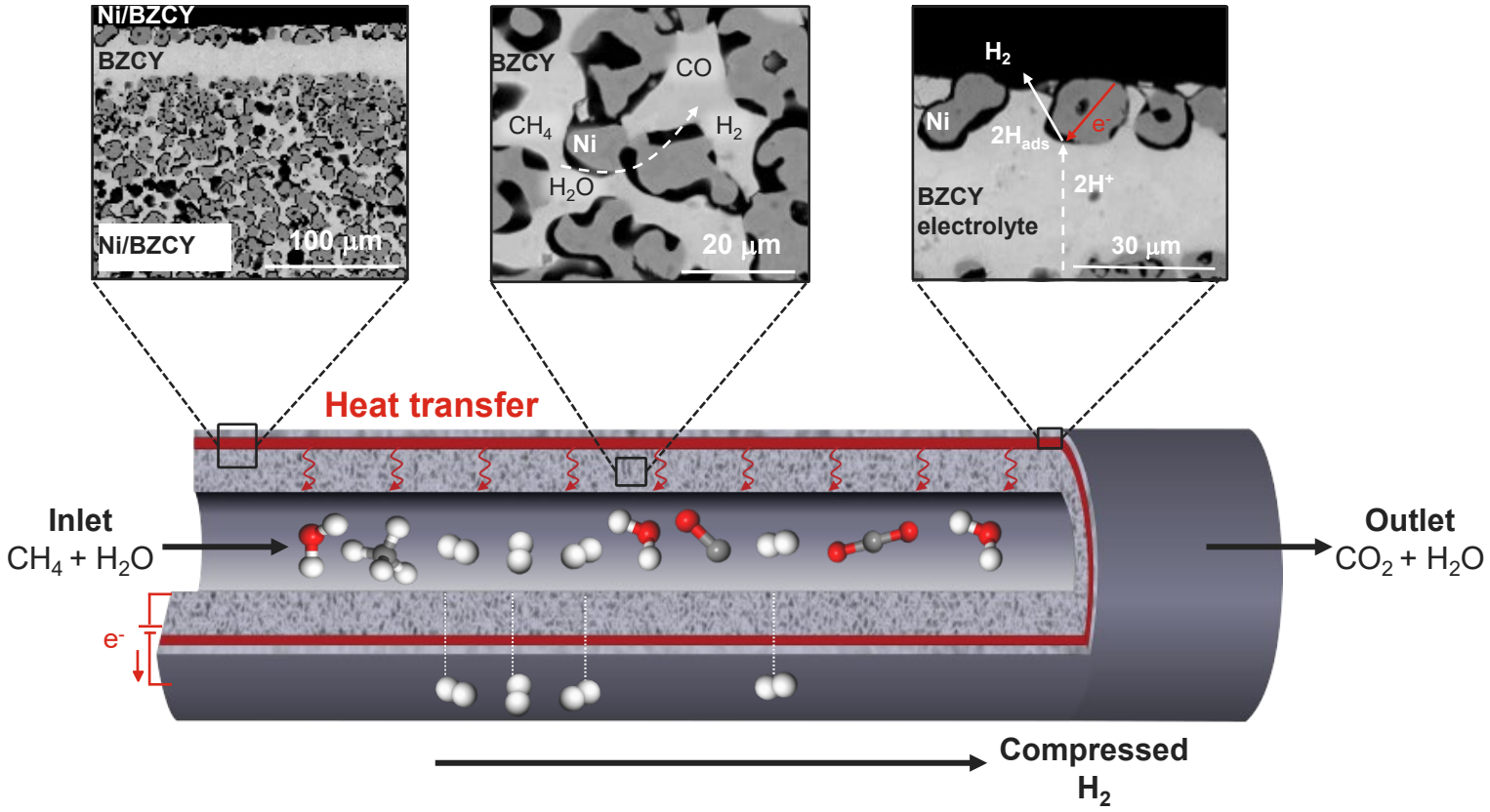
2015 2016 2017 2018 2019 2020 2021 2022

- Publications in leading academic journals
- History of collaboration and development with leading industry players
- Multiple prototypes deployed, with TRL6 achieved

Content

Protonic Ceramic Electrochemical Reactor

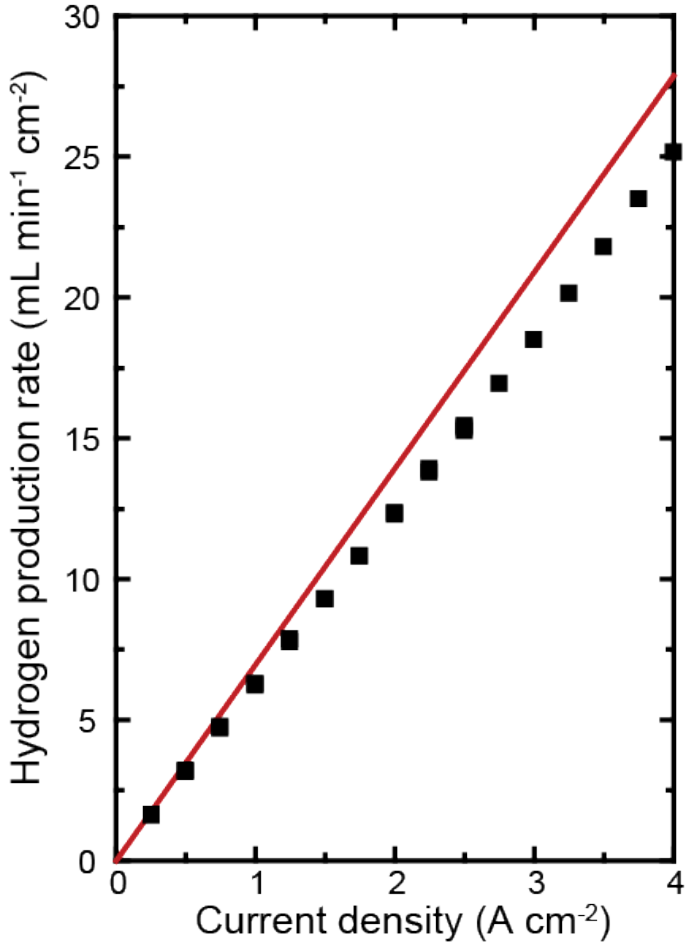
Selective extraction of hydrogen through dense ceramic layer



nature energy ARTICLES
https://doi.org/10.1038/s41560-017-0029-4

Thermo-electrochemical production of compressed hydrogen from methane with near-zero energy loss

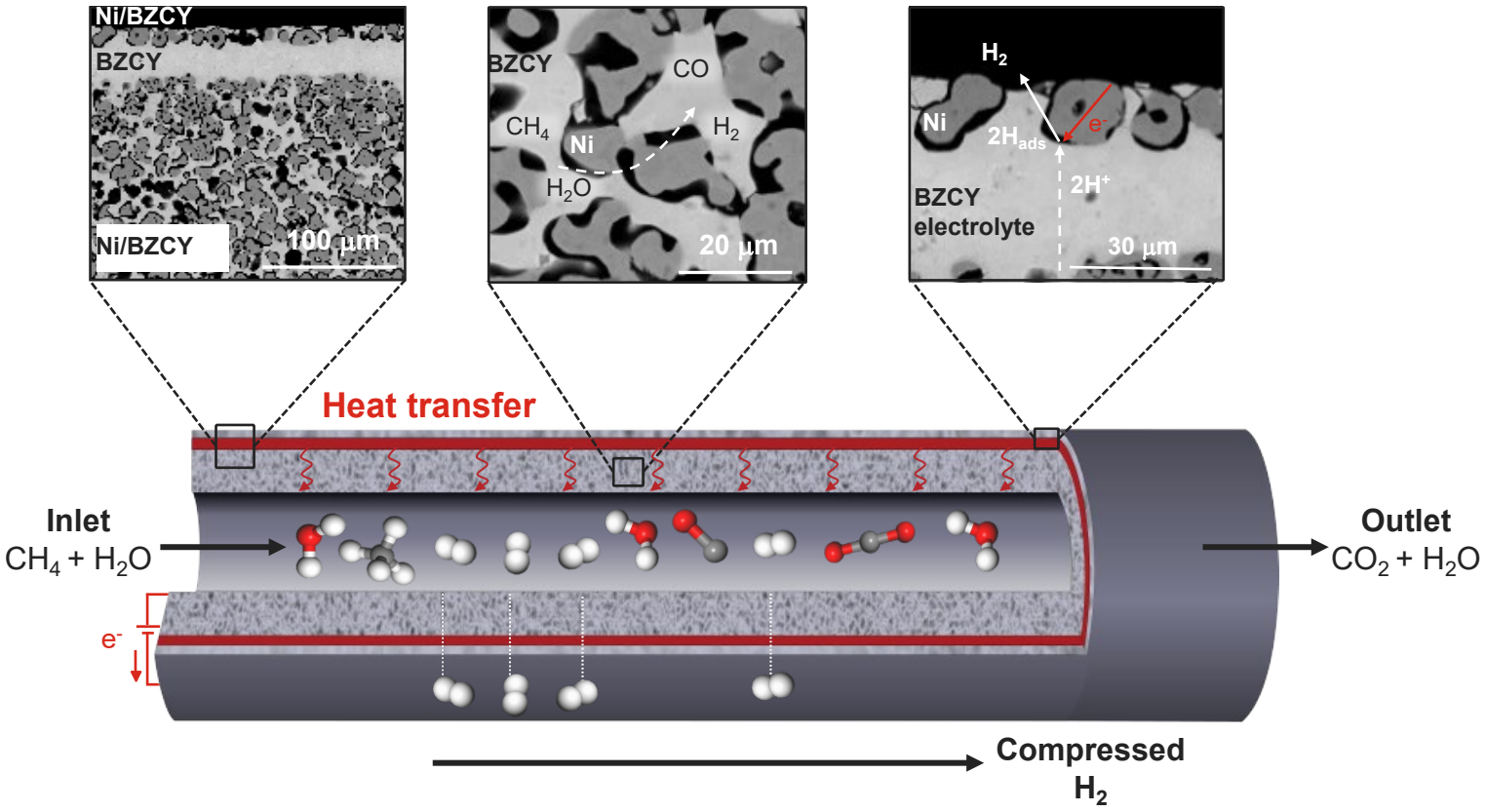
Harald Malerød-Fjeld[1], Daniel Clark[1,2], Irene Yuste-Tirados[1], Raquel Zanón[3], David Catalán-Martinez[3], Dustin Beeaff[1], Selene H. Morejudo[1], Per K. Vestre[1], Truls Norby[2], Reidar Haugsrud[2], José M. Serra[3*] and Christian Kjølseth[1*]

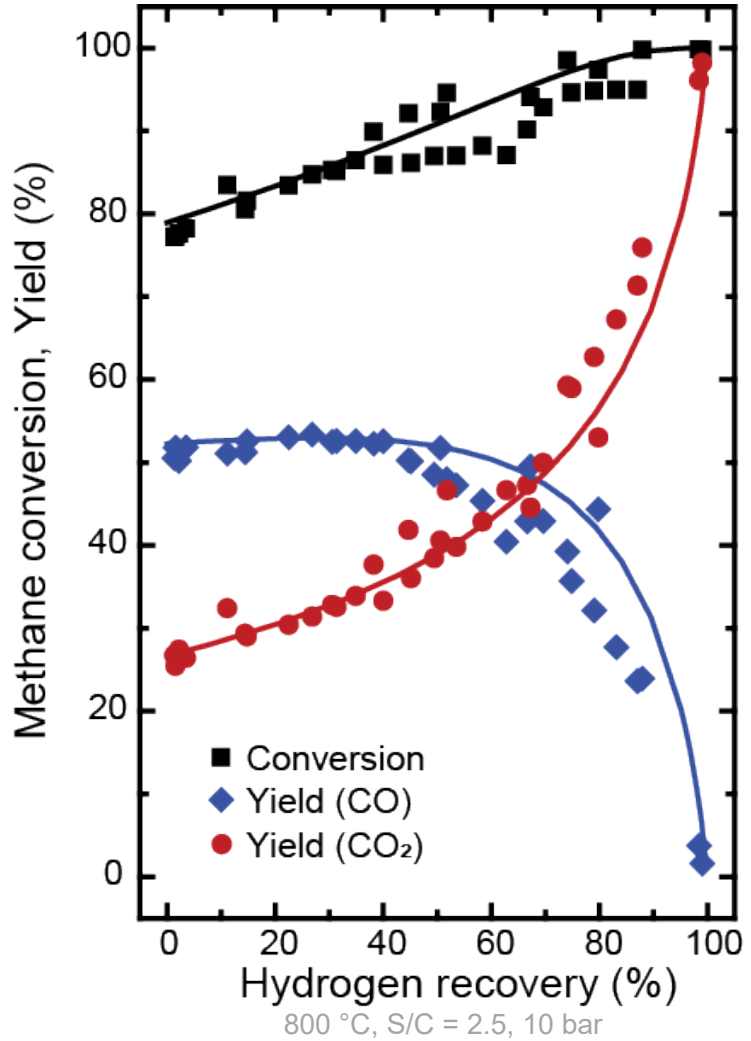


Content

Protonic Ceramic Electrochemical Reactor

Selective extraction of hydrogen





$$CH_4 + H_2O = 3\,H_2 + CO$$

$$CO + H_2O = H_2 + CO_2$$

H. M-Fjeld et al., Nature Energy **2** 923-931 (2017).

Content

PCER stack for electrochemical H_2 production

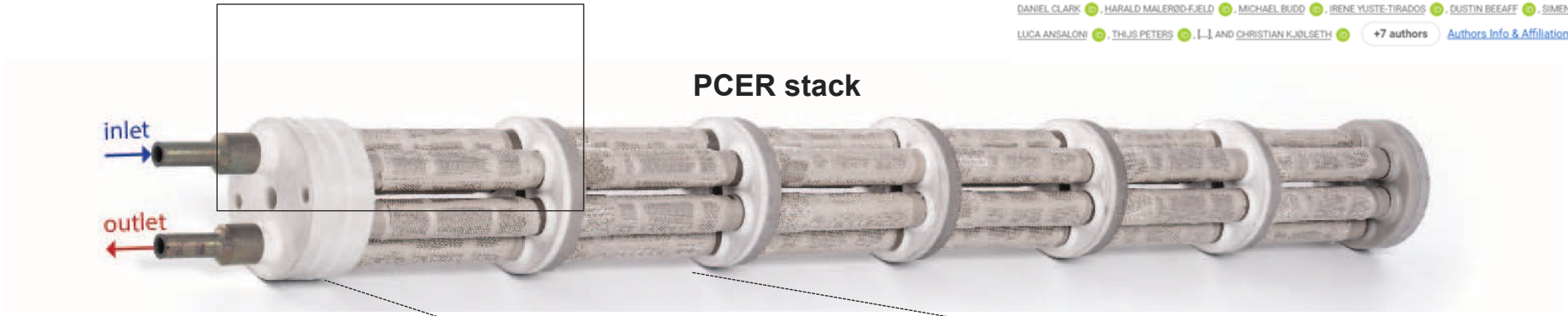
Content

Stack for electrochemical H_2 production

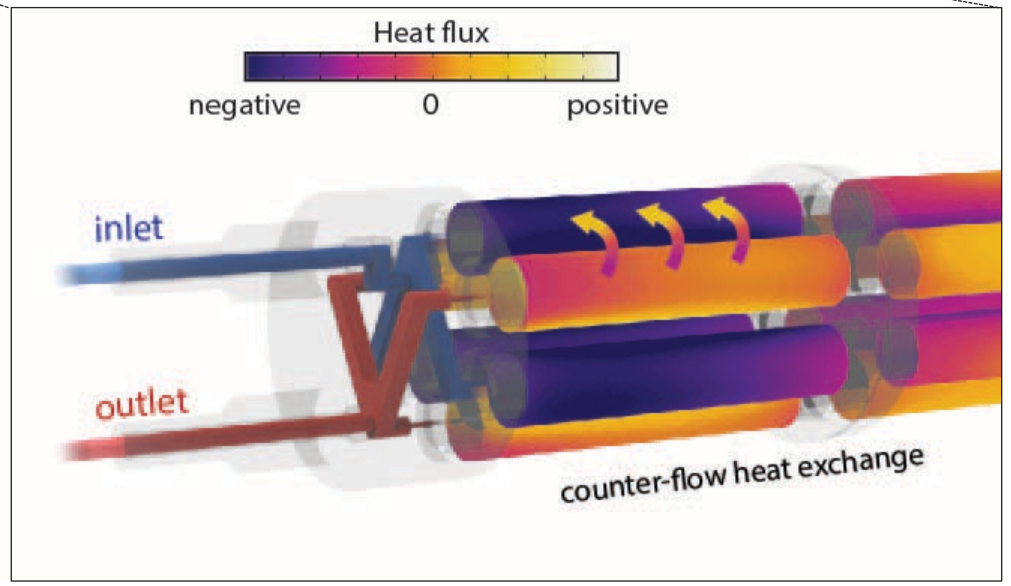
Science
REPORT | CATALYSIS

Single-step hydrogen production from NH_3, CH_4, and biogas in stacked proton ceramic reactors

DANIEL CLARK, HARALD MALERØD-FJELD, MICHAEL BUDD, IRENE YUSTE-TIRADOS, DUSTIN BEEAFF, SIMEN AAMODT, KEVIN NGUYEN, LUCA ANSALONI, THIJS PETERS, [...], AND CHRISTIAN KJØLSETH +7 authors Authors Info & Affiliations



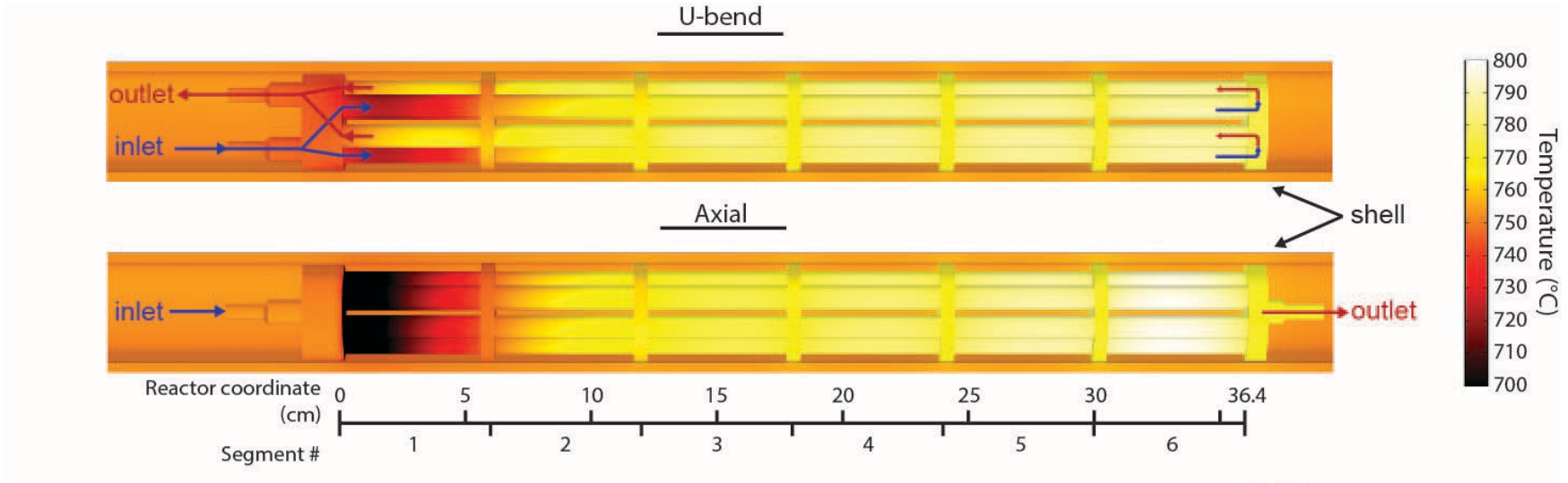
- Series of six barrels (six single cells per barrel)
- U-bend type of gas flow
- Electrically connected in parallel
- Ni-based glass-ceramic composite ICs
- **Microthermal heat integration**



Content

PCER stack for electrochemical H_2 production

- **CFD multiphysics modelling**
- **Gas flows - heat transfer - current distribution - reaction kinetics**



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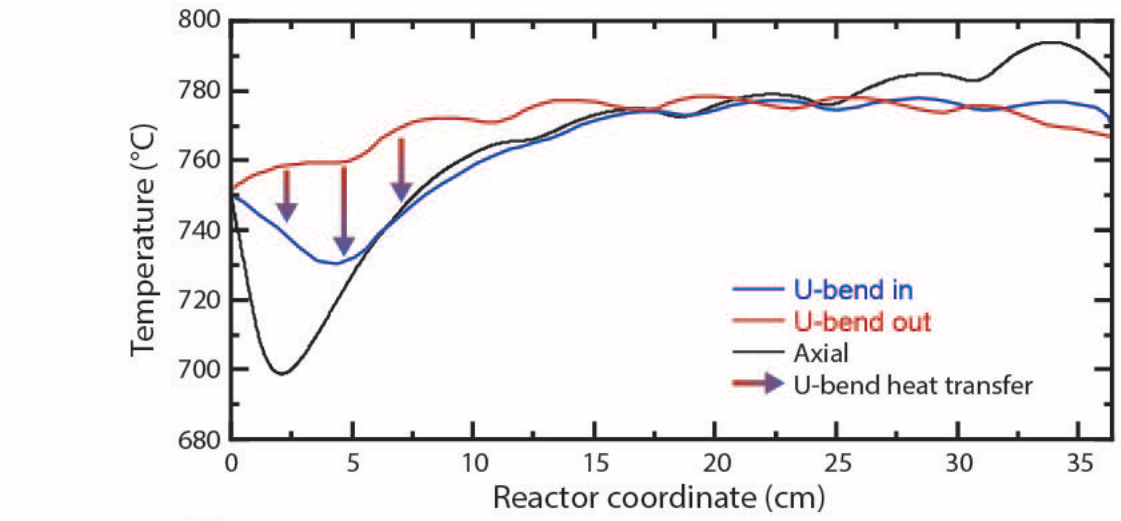
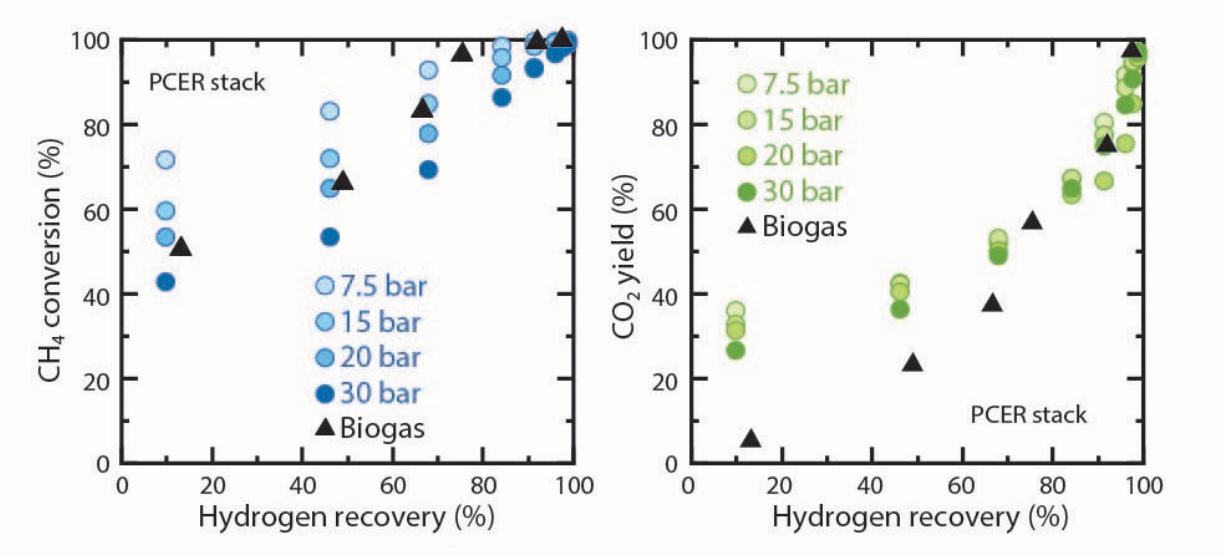


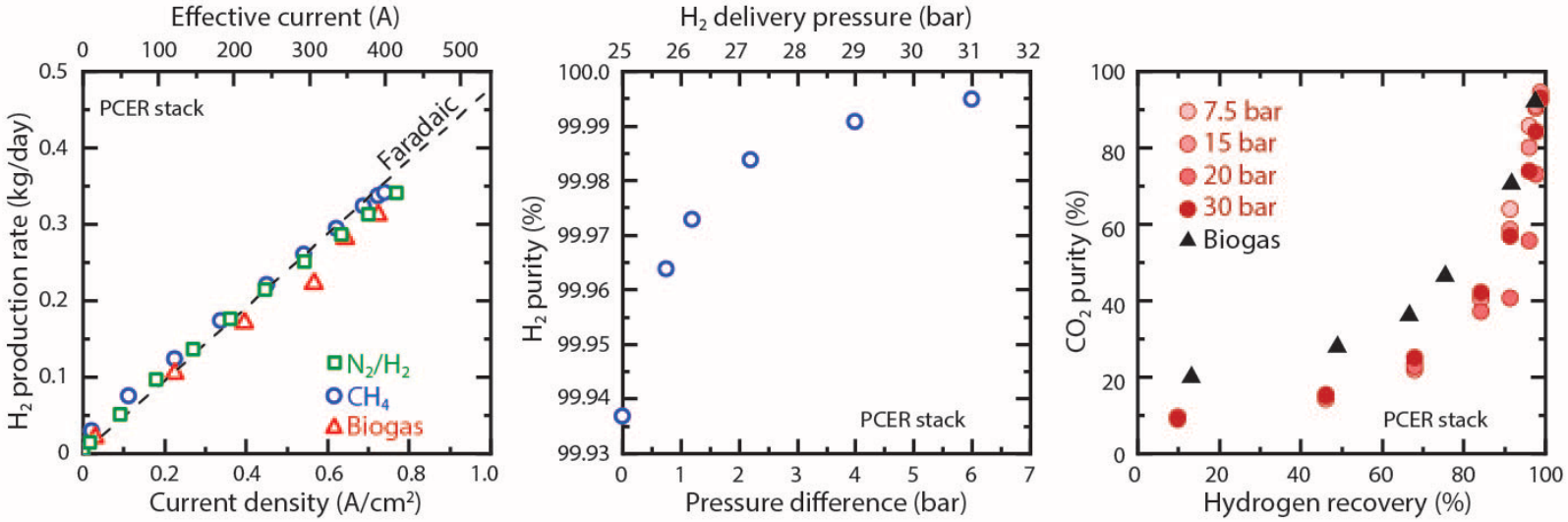
Content

D Clark et al., Science **376** 390-393 (2022).

PCER stack performance

- ✓ H_2 recovery >99%
- ✓ High pressure operation enabled
- ✓ Faradaic operation
- ✓ High purity hydrogen production
- ✓ Capture ready CO_2 stream



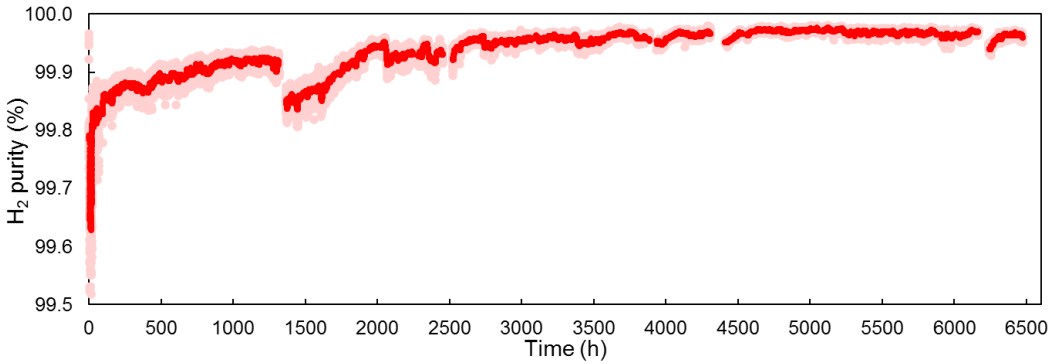


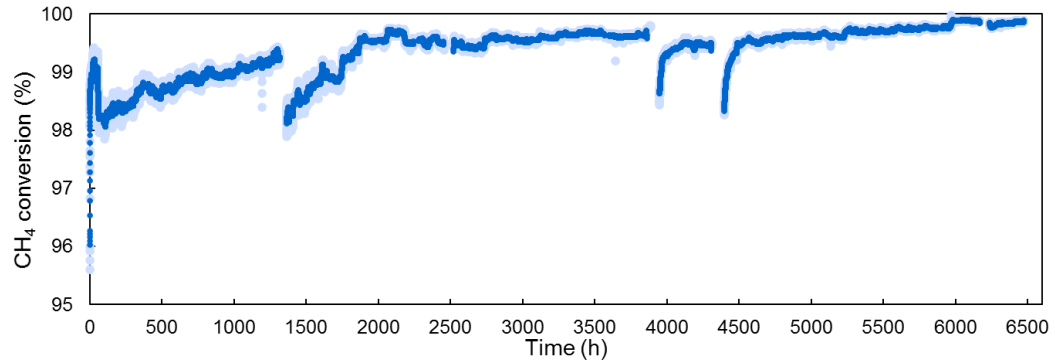
D Clark et al., Science **376** 390-393 (2022).

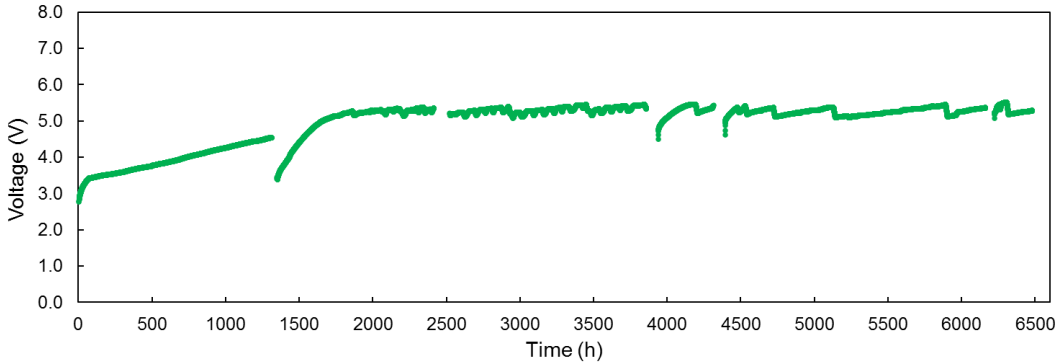
Content

Proton membrane reformers: Strong lifetime performance

- High H_2 purity, CH_4 conversion and CO_2 yield
  - Materials employed in the core of the PMR technology, including materials used for sealing, are stable under relevant industrial conditions
  - Recovery of performance after process shutdowns and unstable test rig conditions
- SEU (36 cell stack) testing over 6500 hours (and running):
  - Stable catalytic activity for SMR and WGS reactions
  - No degradation of membrane's ability to transport hydrogen







Initial conditions: 750 °C, 20 bar, S/C = 2.6

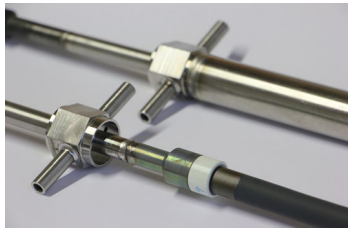
Content

Technology status @ CTMS

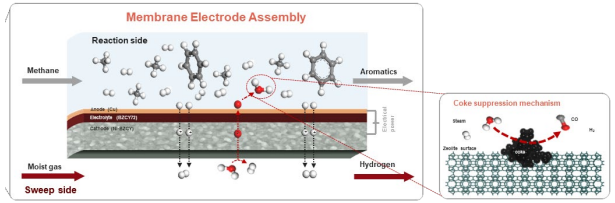
- Pilot line for fabrication of membranes
- Semi-automated stack fabrication procedure developed
- Focus on protonic membrane reformer for hydrogen generation

  >70 stacks fabricated (36 cells per stack)
- Laboratory and pilot testing > 40 bar confirms
  - Hydrogen production ~2 kg H_2 per day on multistack panels
  - CO_2 concentration > 95%
- Developed membrane system can be used for adjacent technologies

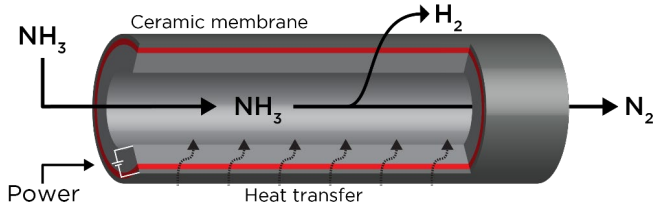
HT-STEAM ELECTROLYSIS



HYDROCARBON UPGRADING



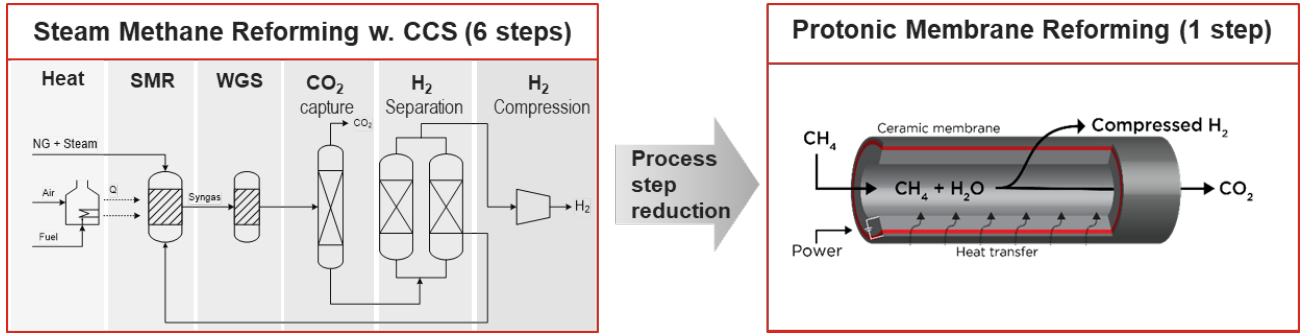
ENABLING NH_3 AS ENERGY CARRIER



Content

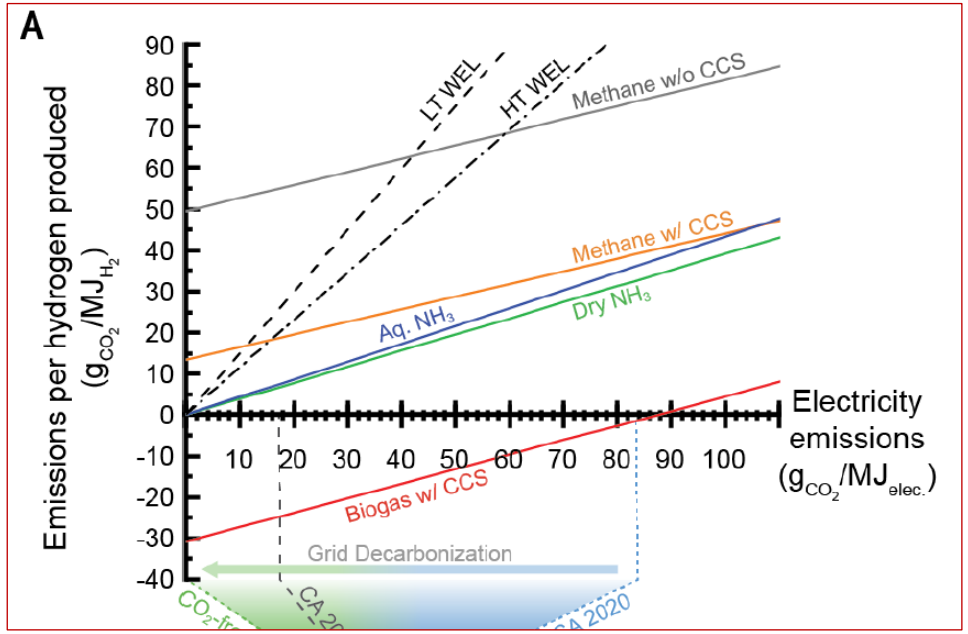
Why this technology can become a winner in the future

- **High system level energy efficiency**
  - Process intensification
  - High hydrogen recovery rate
  - Microthermal heat integration



- **Electrification**
  - No use of NG for heating and in the carbon capture process

- **Efficient carbon capture**
  - 99+% carbon capture rate feasible on system level
  - High CO_2 concentration in stream for liquefaction



Content

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Mario Ditaranto

CHIEF SCIENTIST

CLIMIT SUMMIT

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7–9 February

Enabling carbon capture with oxy-fuel combustion technology for the Waste-to-Energy sector (CAPEWASTE)

Mario Ditaranto is Chief Scientist at SINTEF Energi and has more than 20 years of professional experience in the field of combustion science and technologies covering combustion systems for power and industrial processes. He currently leads research projects in oxy-fuel combustion for the Waste-to-Energy and Cement sectors, and in the use of hydrogen and ammonia for gas turbines and furnaces.

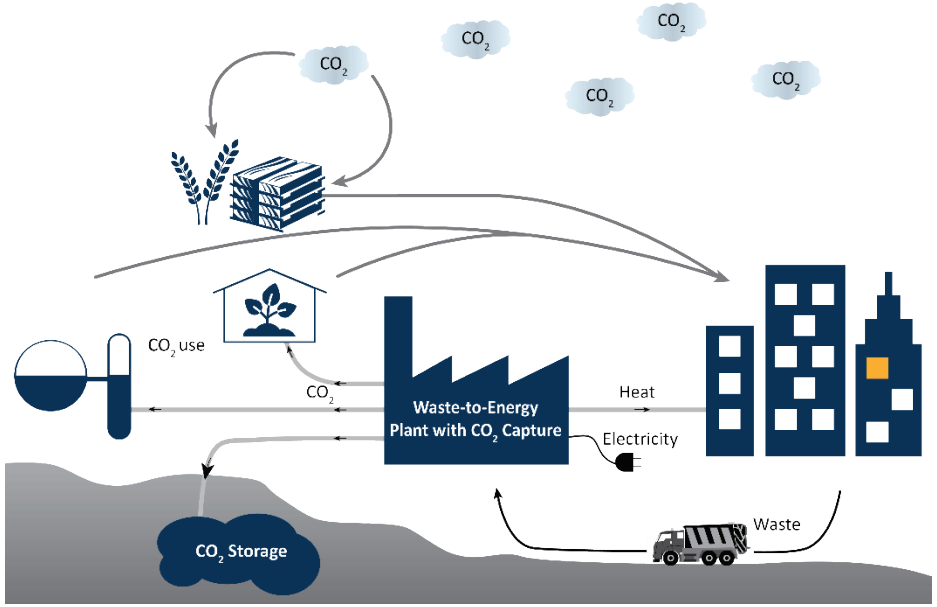
Content

The Research Council of Norway

GASSNOVA

CAPEWASTE project

Enabling carbon capture with **oxy-fuel combustion** technology for the **Waste-to-Energy sector**



Mario Ditaranto, Michael Becidan, Chao Fu, Mette Bugge (SINTEF Energi)

Johnny Stuen (ex-City of Oslo REG)

Oslo
Renovasjons- og gjenvinningsetaten

Linde

CLIMIT

NORWEGIAN ENVIRONMENT AGENCY

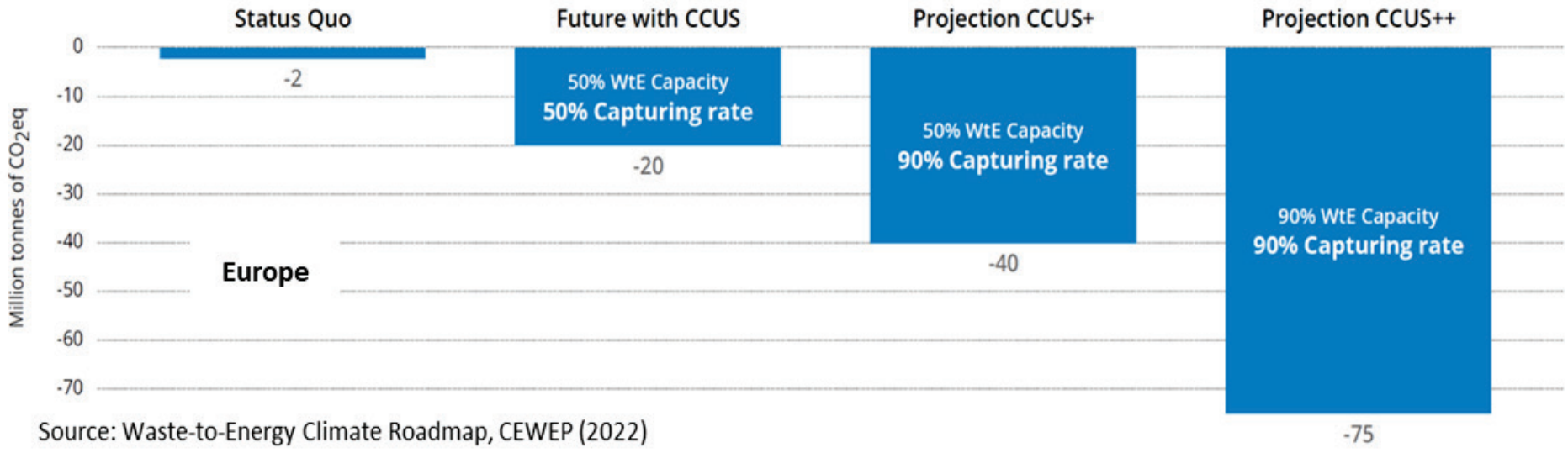
SINTEF

NEWEST-CCUS

SINTEF

Waste-to-Energy: a growing industrial sector and an opportunity for **CCS**

- **Worldwide** : 2,100 Mt MSW are generated annually
- **China**: 190 Mt/yr of waste produced
- **Europe**: 160 Mt/yr of waste produced



Source: Waste-to-Energy Climate Roadmap, CEWEP (2022)

SINTEF

Waste-to-Energy with CCS – **which capture technology?**

160 Mt/yr of waste produced i Europe

- ca. 100 Mt/yr MSW treated in ca. 500 plants: **Retrofit CCS** potential
- ca. 60 Mt/yr MSW landfilled: **Greenfield CCS** potential

oxy-fuel combustion capture?

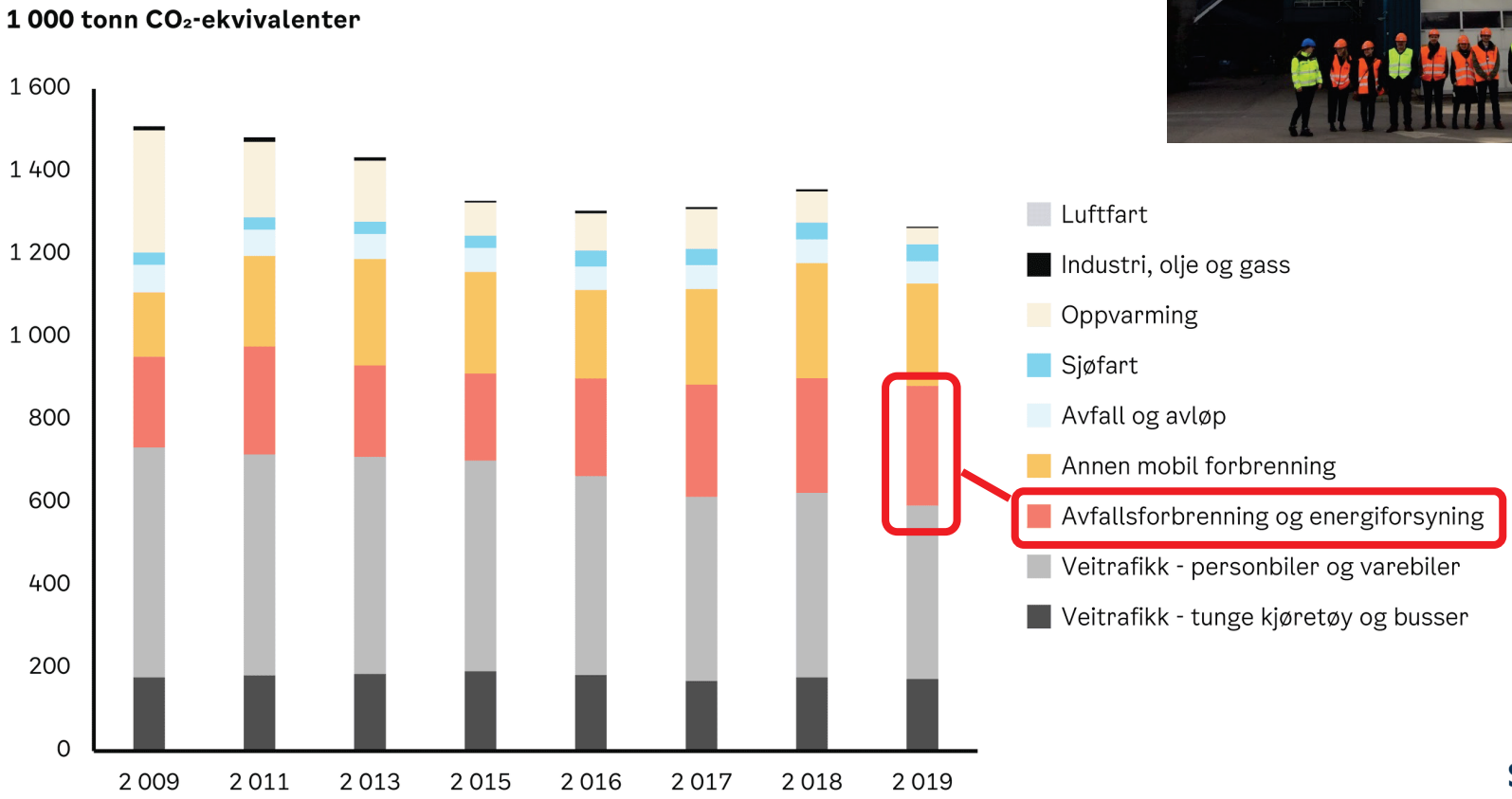
Norwegian Context

Oslo 2030

MÅLSETNING

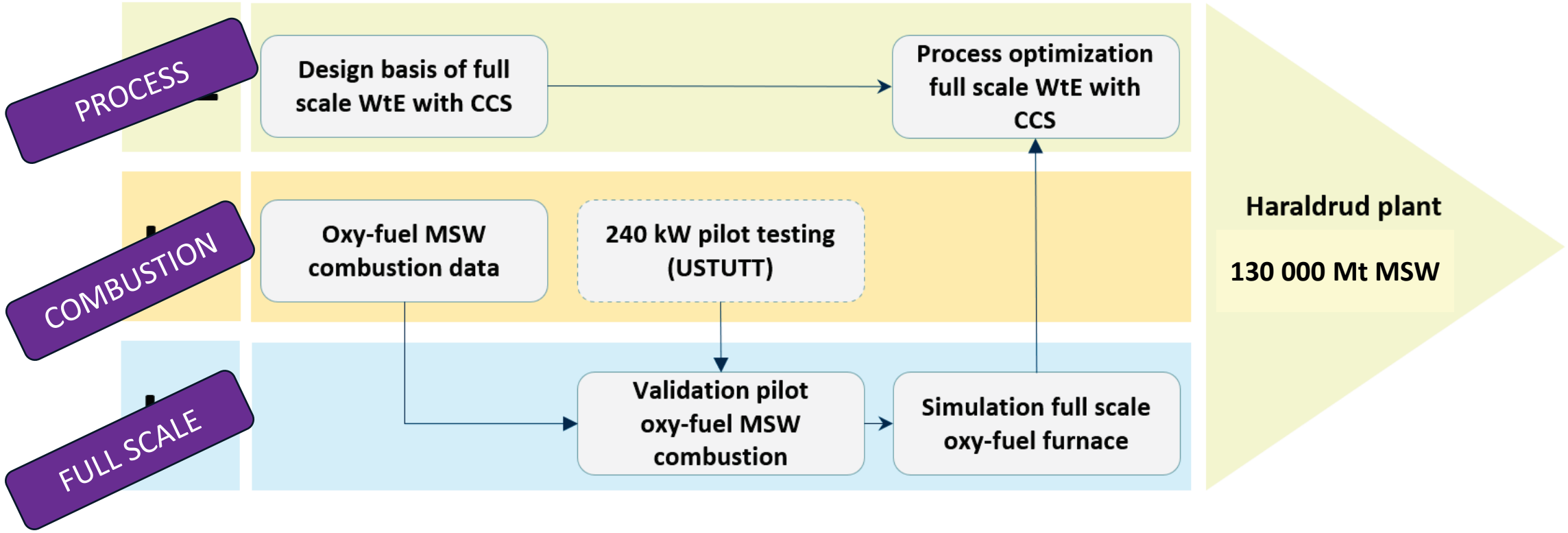
- Å BLI KLIMAROBUST OG TILNÆRMET UTSLIPPSFRI

7 Oslo skal ha en forsvarlig, kretsløpsbasert avfall- og avløpshåndtering uten utslipp av klimagasser der avfall og restkomponenter utnyttes som ressurser



SINTEF

CAPEWASTE methodology



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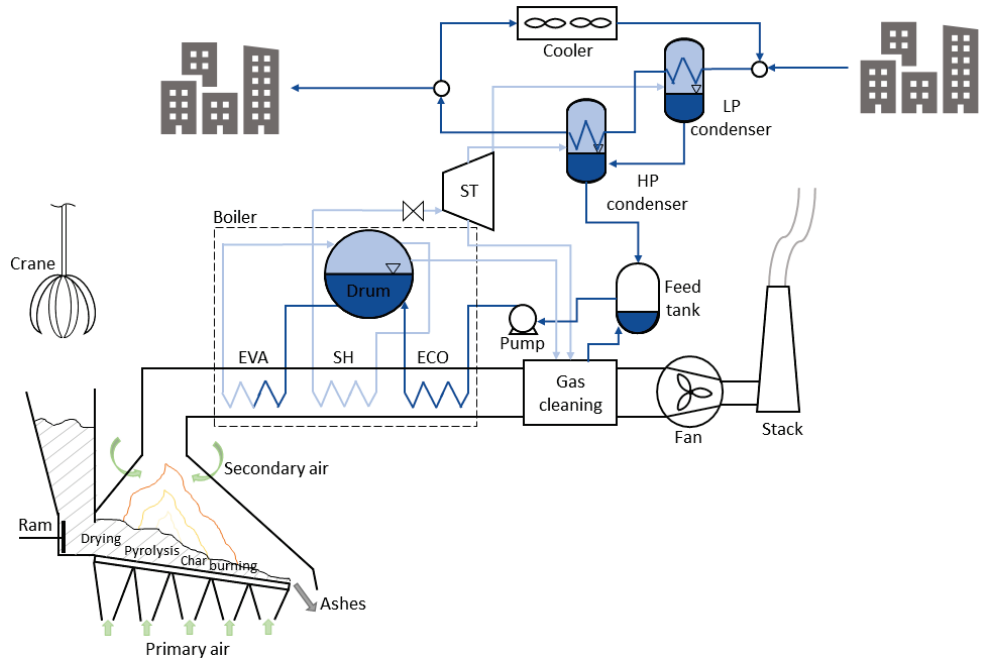
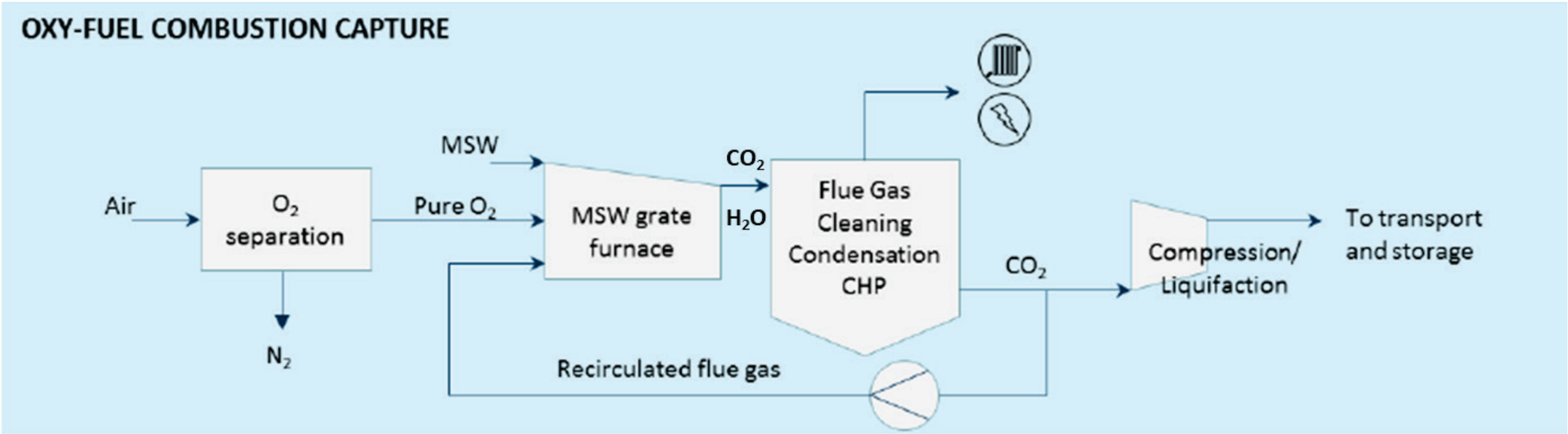
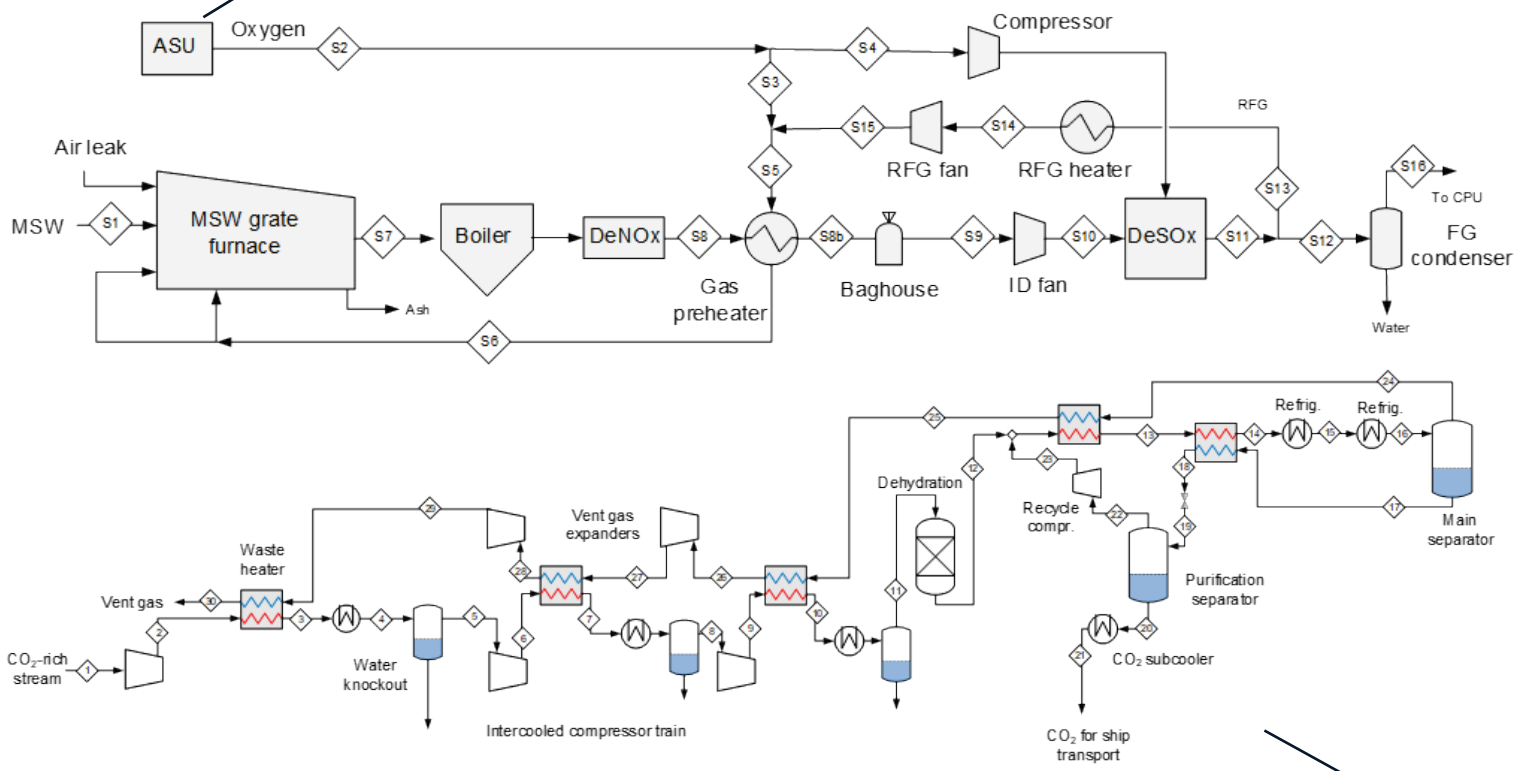
Waste-to-Energy plant





Oxy-fuel WtE Process

53 % power consumption



42 % power consumption

510 kg CO_2/t_MSW

of negative emission

at Haraldrud plant

Assumptions:

- MSW supply: 130 000 t/yr
- Air leakage: 2.5%
- Oxygen content at furnace outlet: 4%
- Oxygen purity: 95 mole%
- FGR: 75.7 %

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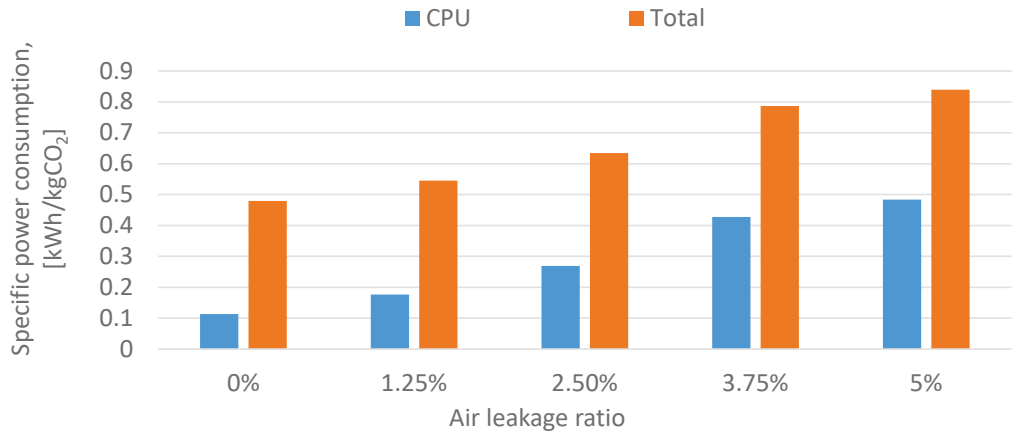
Oxy-fuel WtE Process

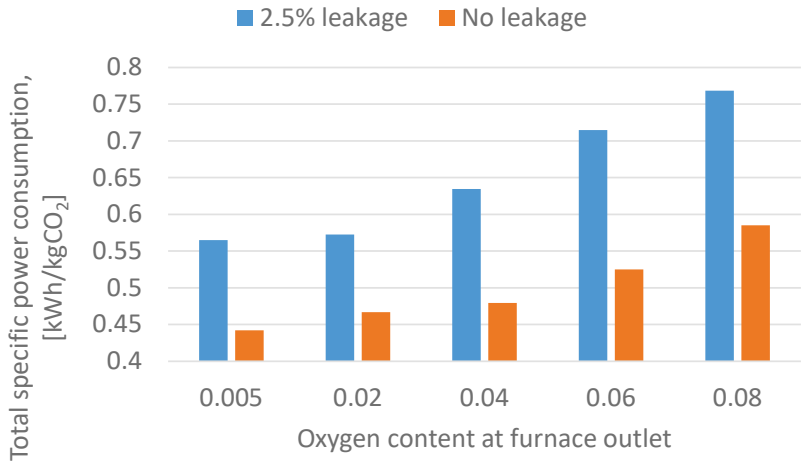
Optimization of power consumption in order of priority:

1) minimize furnace air leakage

2) minimize furnace oxygen excess

3) increase oxygen purity





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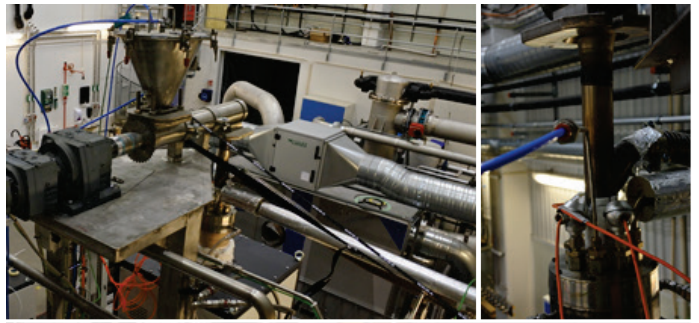
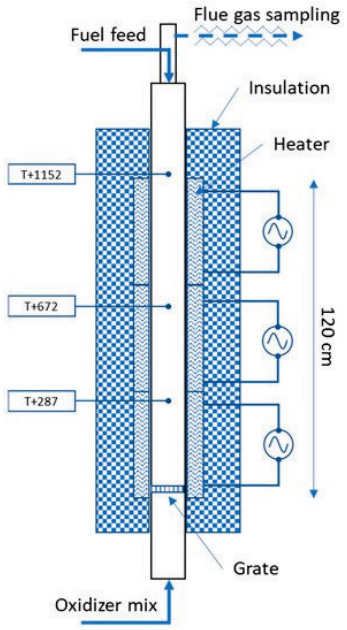
Oxy-fuel Combustion

- Burning of MSW in oxy-fuel atmosphere is feasible with no apparent showstopper

- Stable limits under low O_2 mapped
  -> Flue Gas Recirculation control

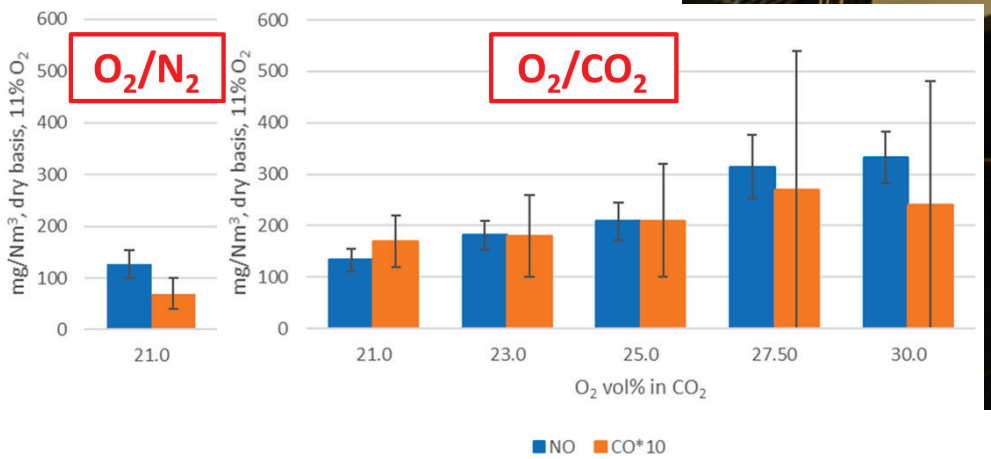
- Propensity to NOx similar to air
  -> existing cleaning units adequate





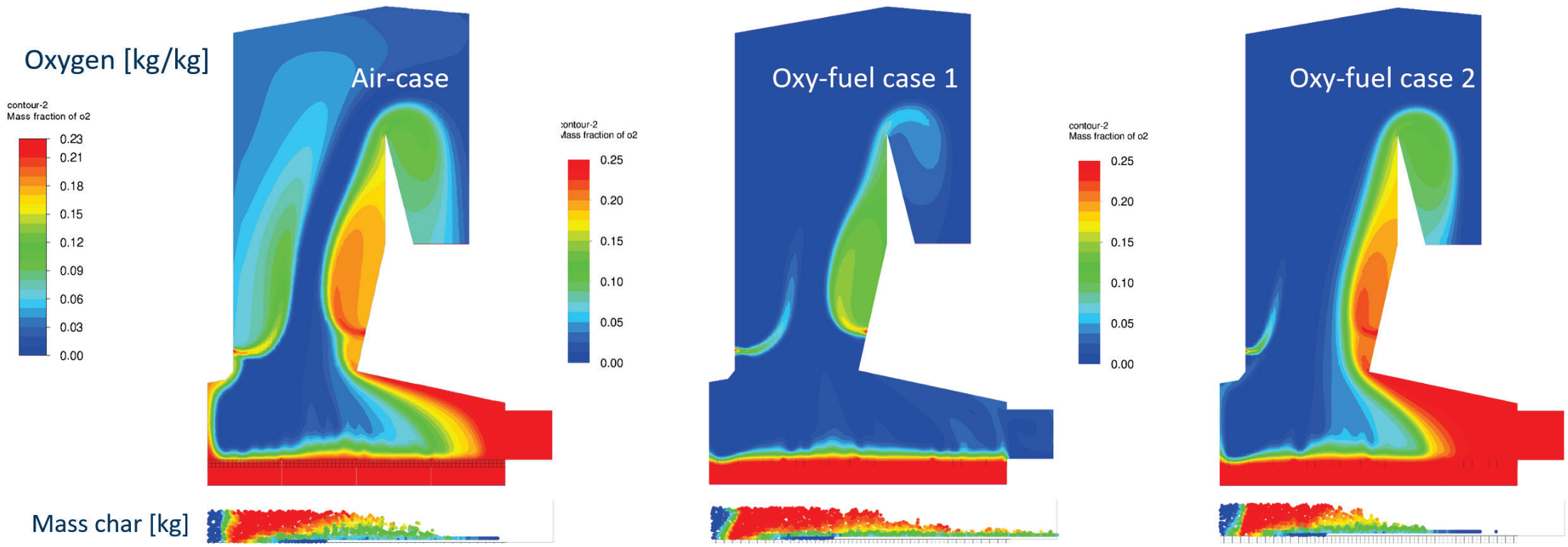
Fuel	MC	VM	FC	Ash
	%wt as			
Spruce	1.1	80.5	17.7	0.7
Paper	4.3	76.9	-	20.20
Cardboard	3.7	82.9	-	9.08
Plastic	0.6	>95	-	<0.1
Mixture 1**	3.0	78.9	7.1	11.3
Mixture 2**	2.6	80.8	7.1	9.3

**calculated



Energies **2021**, *14*(17), 5297

Full scale plant CFD model



Effect of oxygen distribution on conversion and burn-out and compared to air

SINTEF

Conclusions

- An oxy-fuel plant at Haraldrud can remove ca. 510 kg_{CO2}/t_{MWS} from the atmosphere
- Oxy-fuel combustion of MSW is feasible
- The critical parameters for optimizing plant efficiency are highlighted
- Simulation tools are ready for oxy-fuel combustion of complex MSW fuels
- **What's next?**

Oxy-fuel technology demonstration in Årdal?...

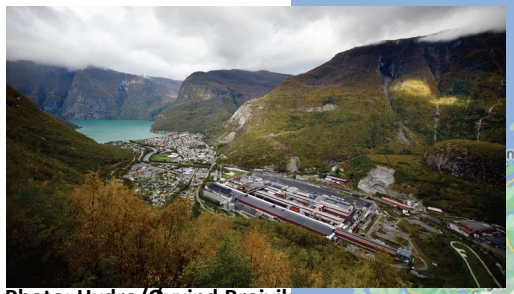
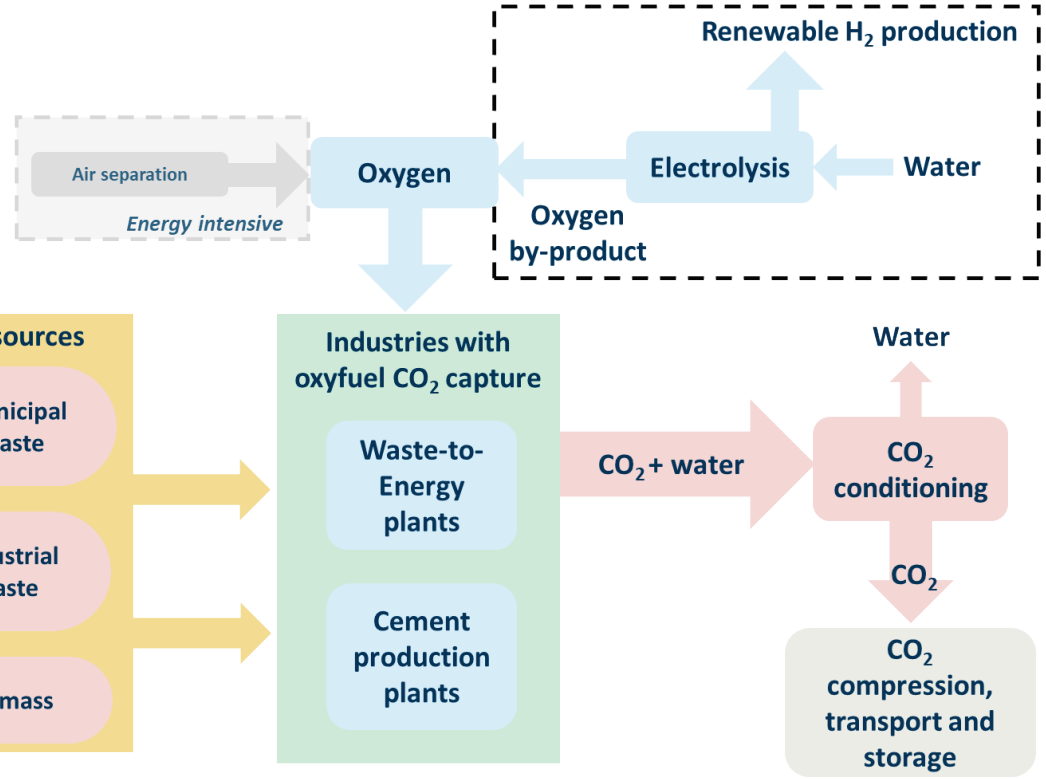


Photo: Hydro/Øyvind Breivik

Photo: REG Oslo Kommune

CETPartnership EUROPEAN PARTNERSHIP

NETOX Proposal to 2nd round



Acknowledgements

Supported by the Research Council of Norway under the CLIMT program grant nr. 629364 (CapeWaste)

and by the ERA-NET Accelerating CCS Technologies initiative grant nr. 299683 (NEWEST-CCUS)

Luca Ansaloni

RESEARCH SCIENTIST

CLIMIT SUMMIT

#CLIMITSUMMIT2023
7–9 February

Membranes with Aligned nanostructures for CO_2 separation

Luca Ansaloni is a research scientist in the Sustainable Energy department of SINTEF Industry (part of SINTEF AS). He obtained his PhD in 2014 from the University of Bologna with a thesis on transport properties of gases in membranes for CO_2 capture. After the PhD, he served as postdoc in the Chemical Engineering department at NTNU (2015 – 2018) and joined SINTEF Industry in 2018

Content

The Research Council of Norway

GASSNOVA

MEMBRALIGN - Membranes with Aligned nanostructures for CO_2 separation

Luca Ansaloni – SINTEF AS

Larvik, 7-9 February 2023

CLIMIT SUMMIT

Content

Teknologi for et bedre samfunn

MEMBRALIGN project

The MembrAlign project was financed by the CLIMIT program of NFR

Project details:

- Type: **IPN** (Innovation Project for the Industrial Sector)
- Running period: **2018 – 2022**
- Budget: **11.5 MNOK**, of which 7.7 MNOK from NFR
- Partners:

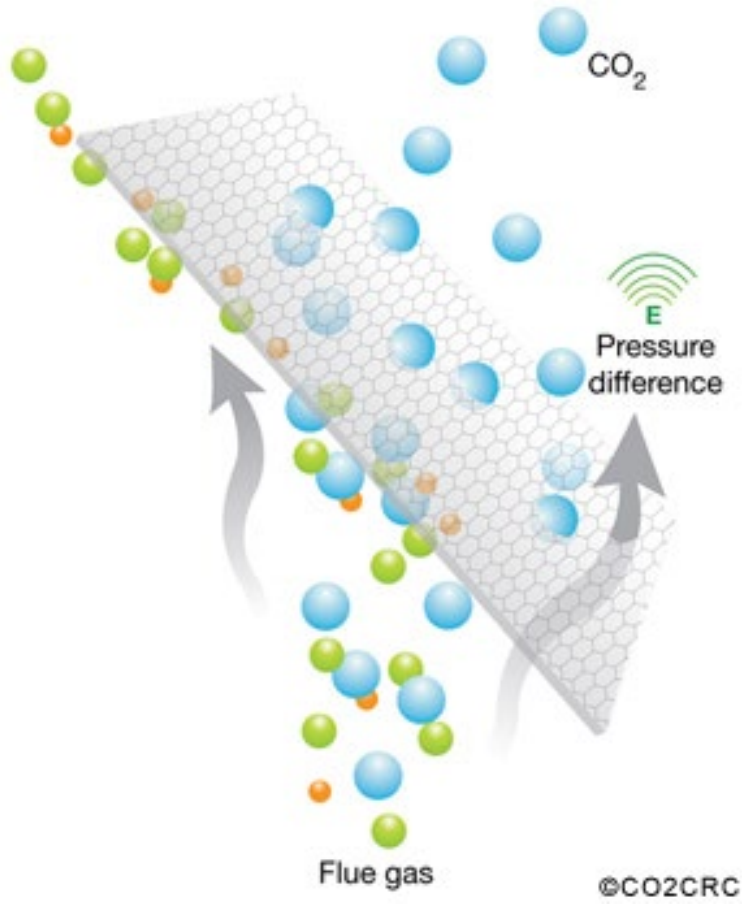
CondAlign coordinator

SINTEF

NTNU Norwegian University of Science and Technology

Polymeric membranes for CO_2 capture

- A membrane is a barrier layers that allows the selective permeation of one components (CO_2) while blocking the other gases to pass
- Polymer membrane represents an attractive technology to capture CO_2 from flue gas
  - Modularity
  - No use of harmful chemicals
  - Low energy consumption (hybrid processes)
  - Polymer membrane represents an attractive technology to capture CO_2 from flue gas



Polymeric membranes for CO_2 capture

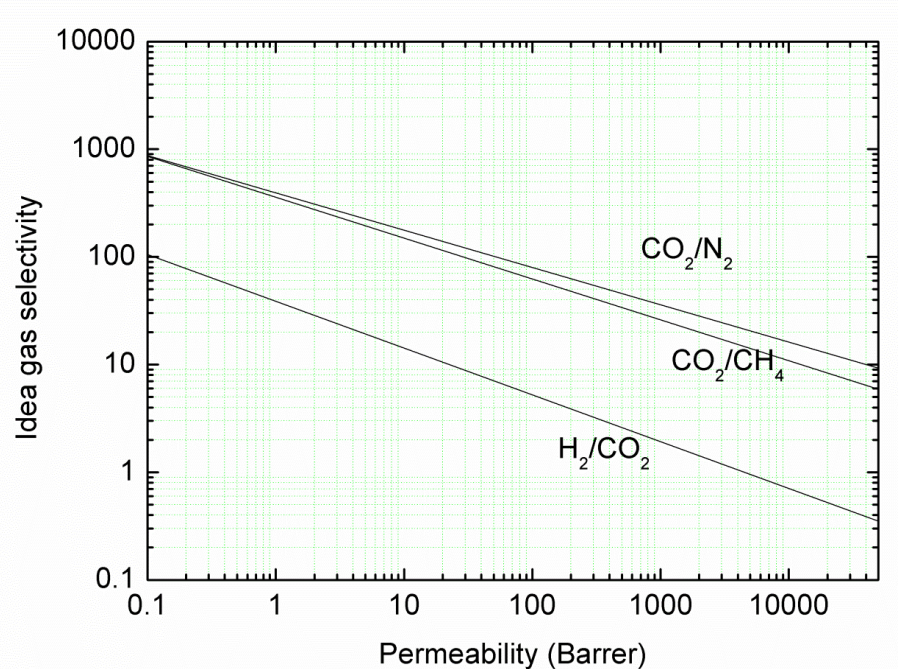
PERFORMANCE PARAMETERS

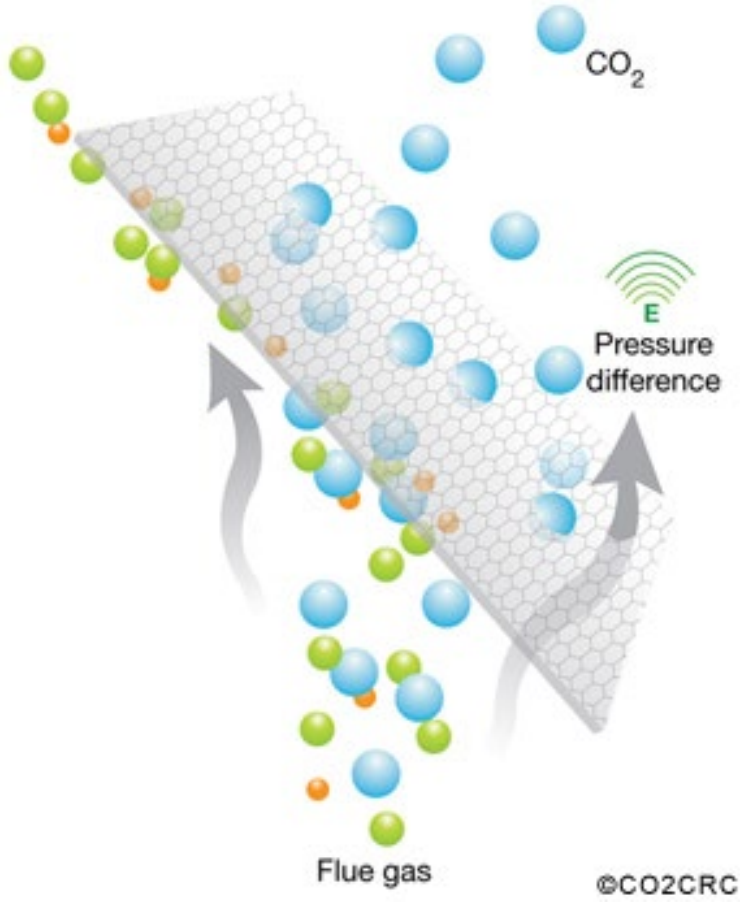
Permeability

$$P = \frac{flux \cdot thickness}{driving\ force} = \frac{J \cdot \ell}{\Delta p}$$

Selectivity

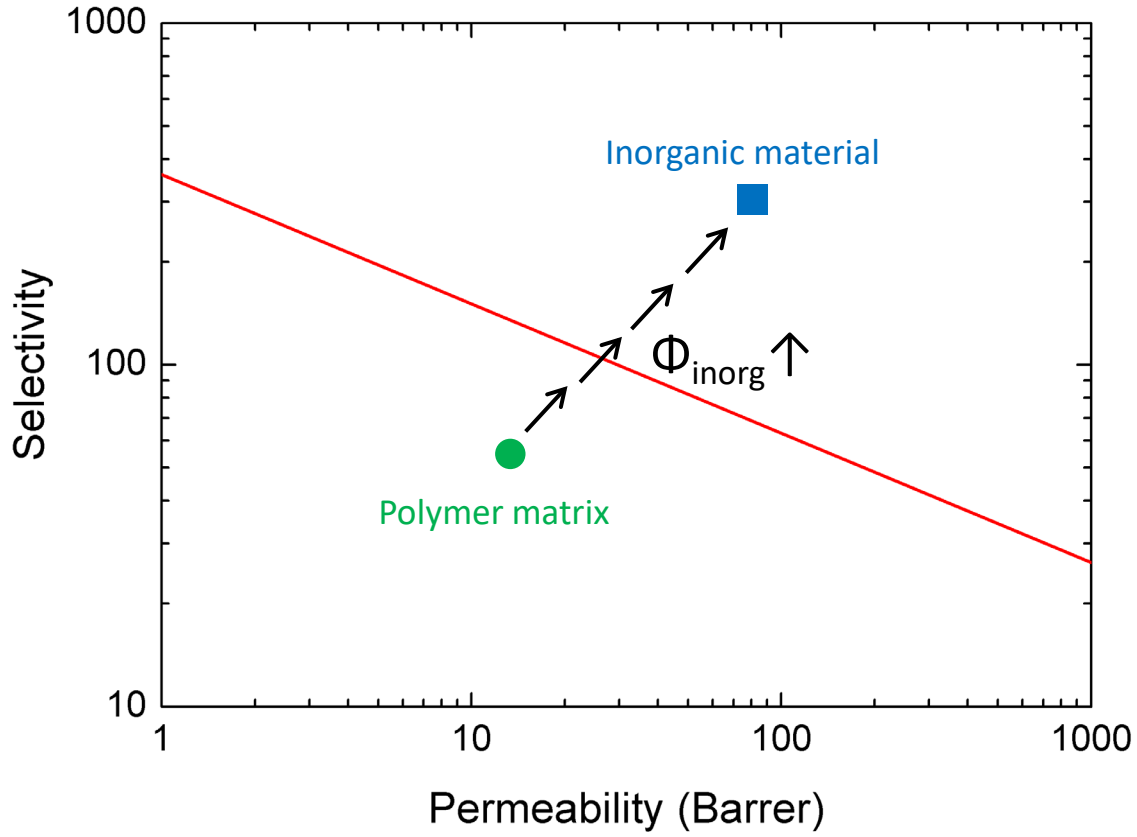
$$\alpha = \frac{\left(y_{co_2}/y_{N_2}\right)_{perm}}{\left(y_{co_2}/y_{N_2}\right)_{feed}}$$

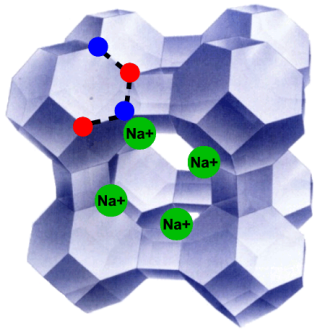




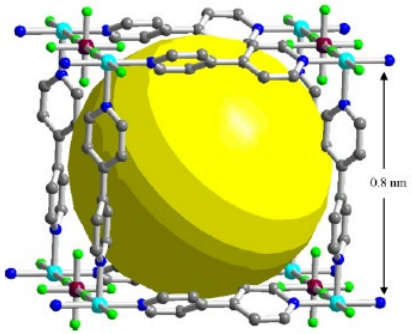
Content

Mixed matrix membranes

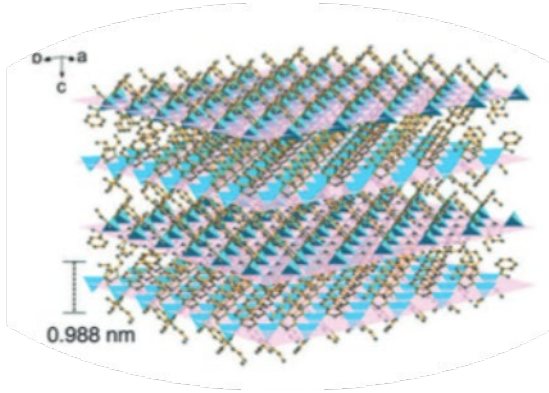




Zeolite



MOFs

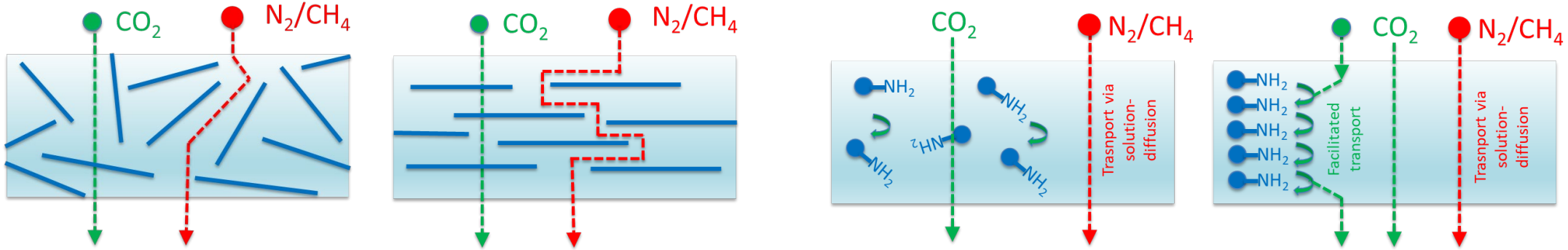


2D porous nanomaterials

Content

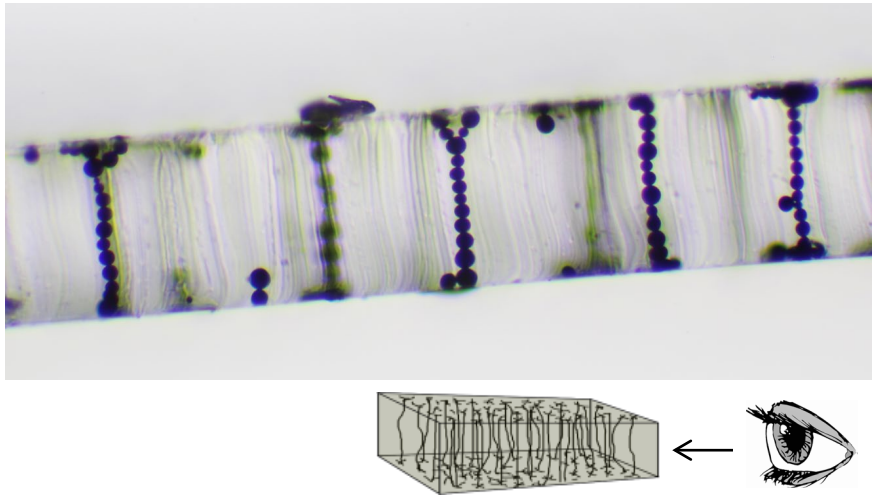
The MEMBRALIGN approach

- The MembrAlign project employed manipulation at the nanostructural level to improve the performance of hybrid membranes for CO_2 capture



CONDALIGN technology

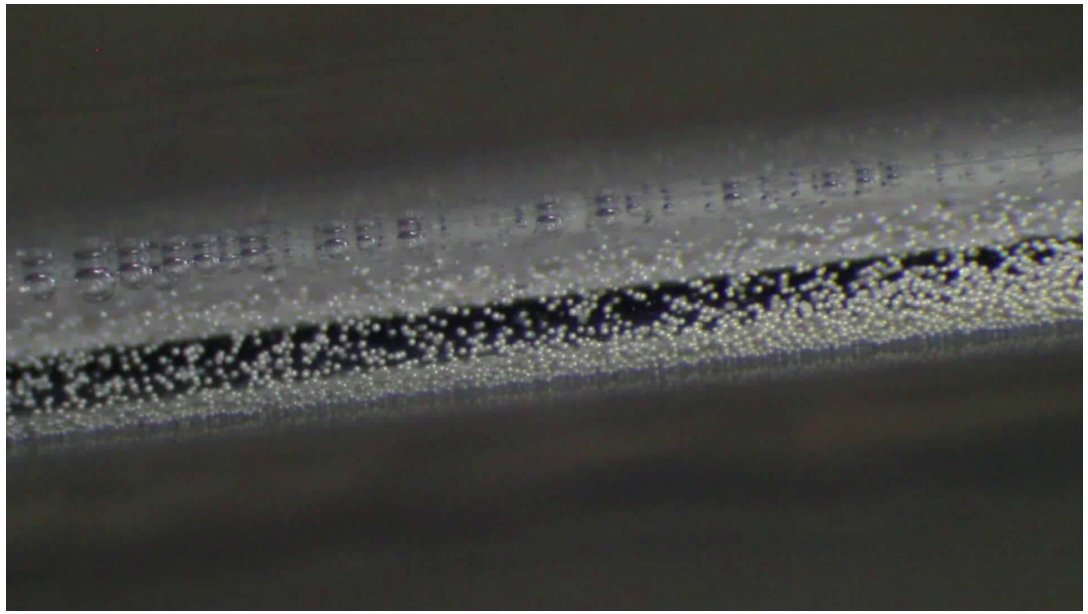
- CondAlign has developed a proprietary technology to align particles in polymeric films through the use of electric field (via di-electrophoresis)

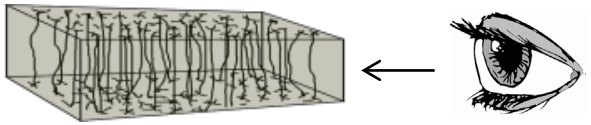


CONDALIGN technology

Key advantages of CA technology:

- **Material and particles' size independent**, so any type of polymer/particles combination can be used
- **Short alignment time is required**, therefore it can be easily upscaled in R-2-R fabrication



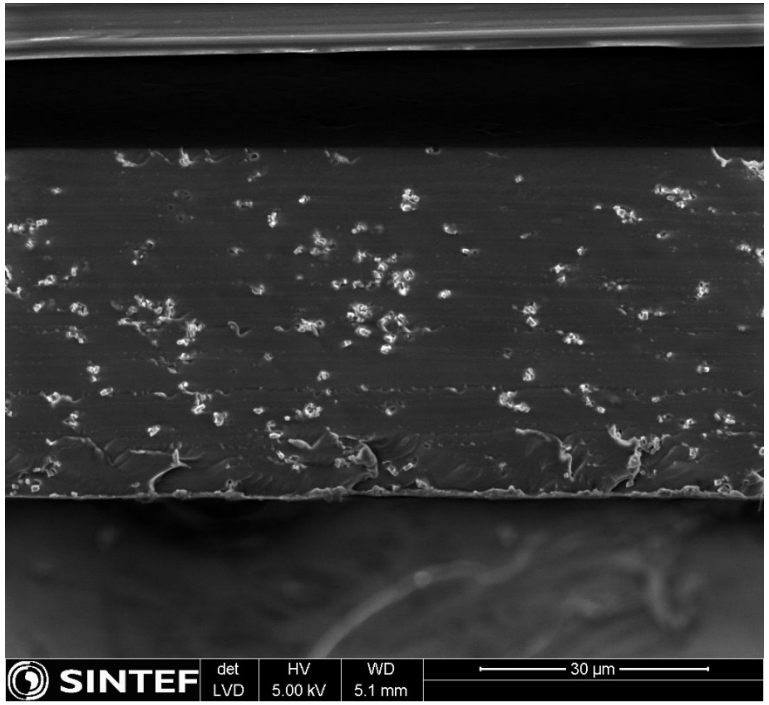


Polyurethane film (approx. 400µm thickness)
w/Silver coated glass particles (approx. 25µm)

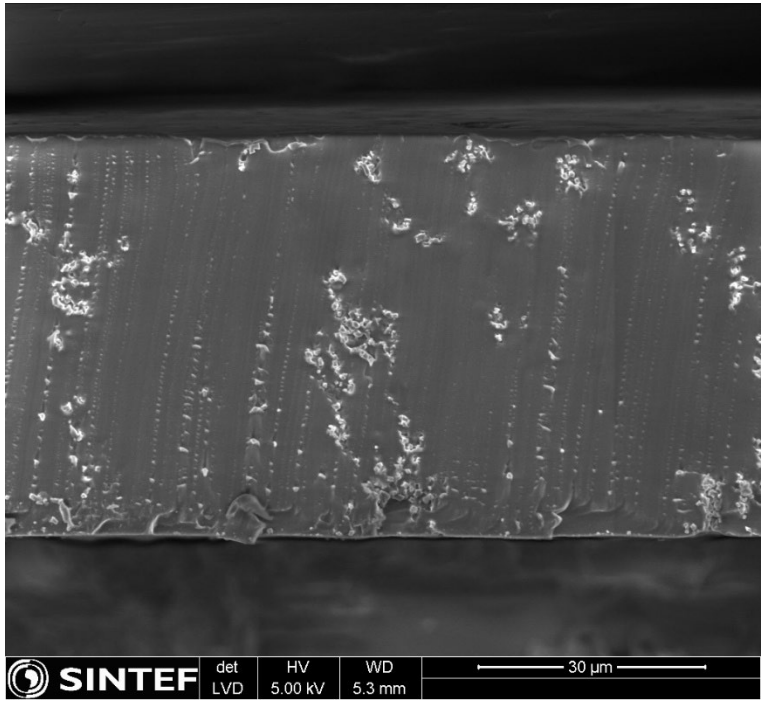
In-plane alignment

- Example of through plane alignment using Pebax 2533 as polymer phase and a µm-size MOF (NH_2-MIL53) for CO_2 capture application

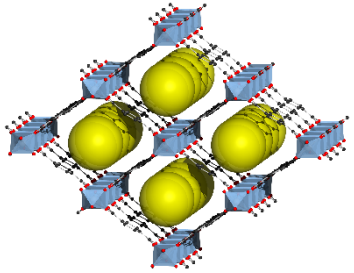
Not Aligned



Through Plane Aligned

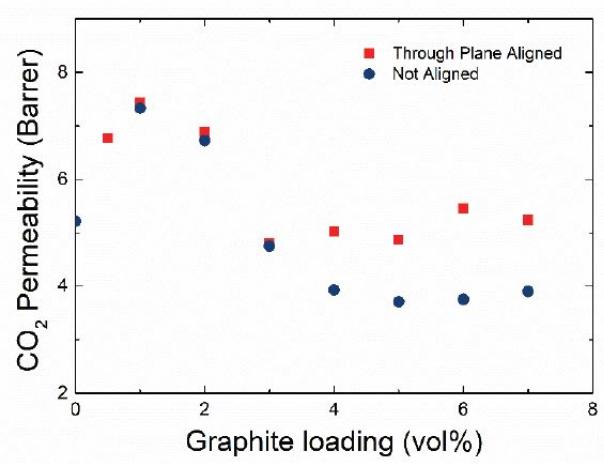


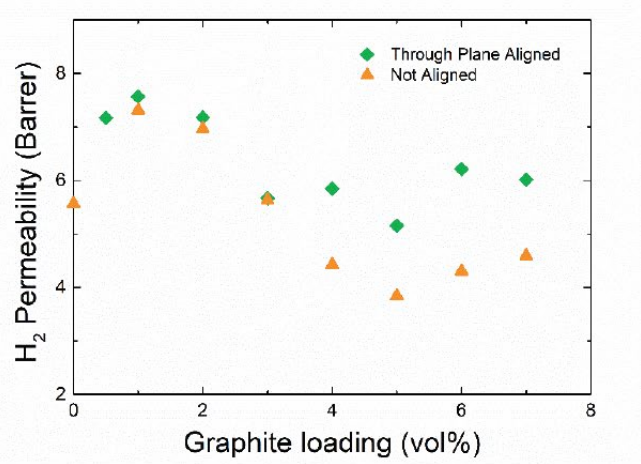
NH_2-MIL53

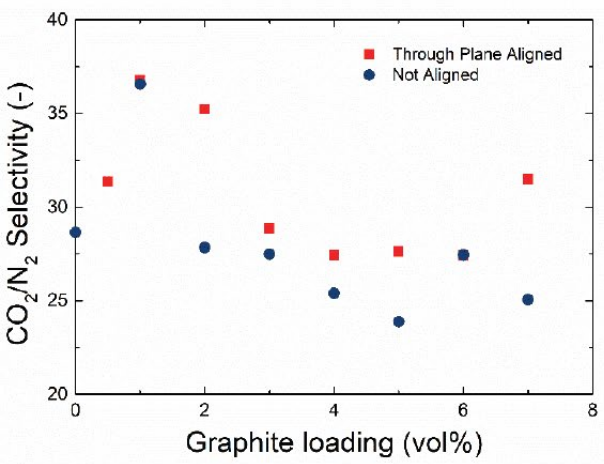


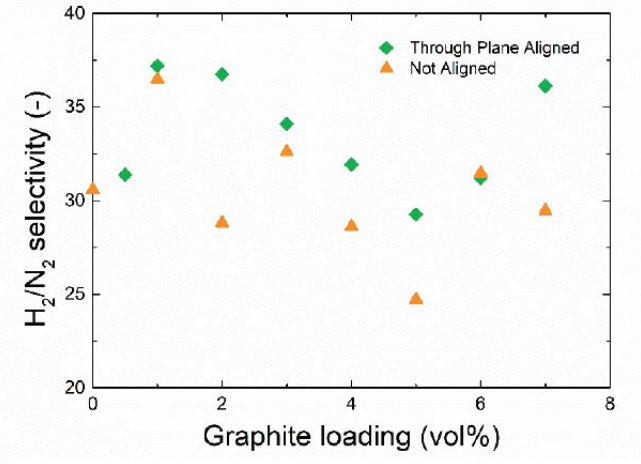
Effect of CA technology on membrane

- The positive effect of CA technology on a PU membrane loaded with Graphite particles was demonstrated
- The effect of CA technology is particulary evident at high particles loadings, where the CO_2 permeability is enhanced
- Minor positive effects are observed on the selectivity



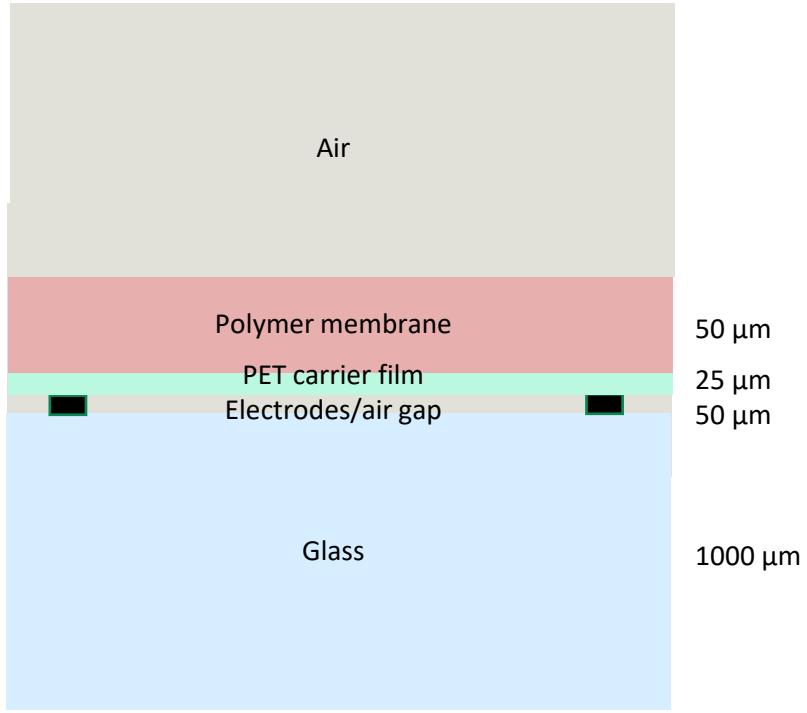


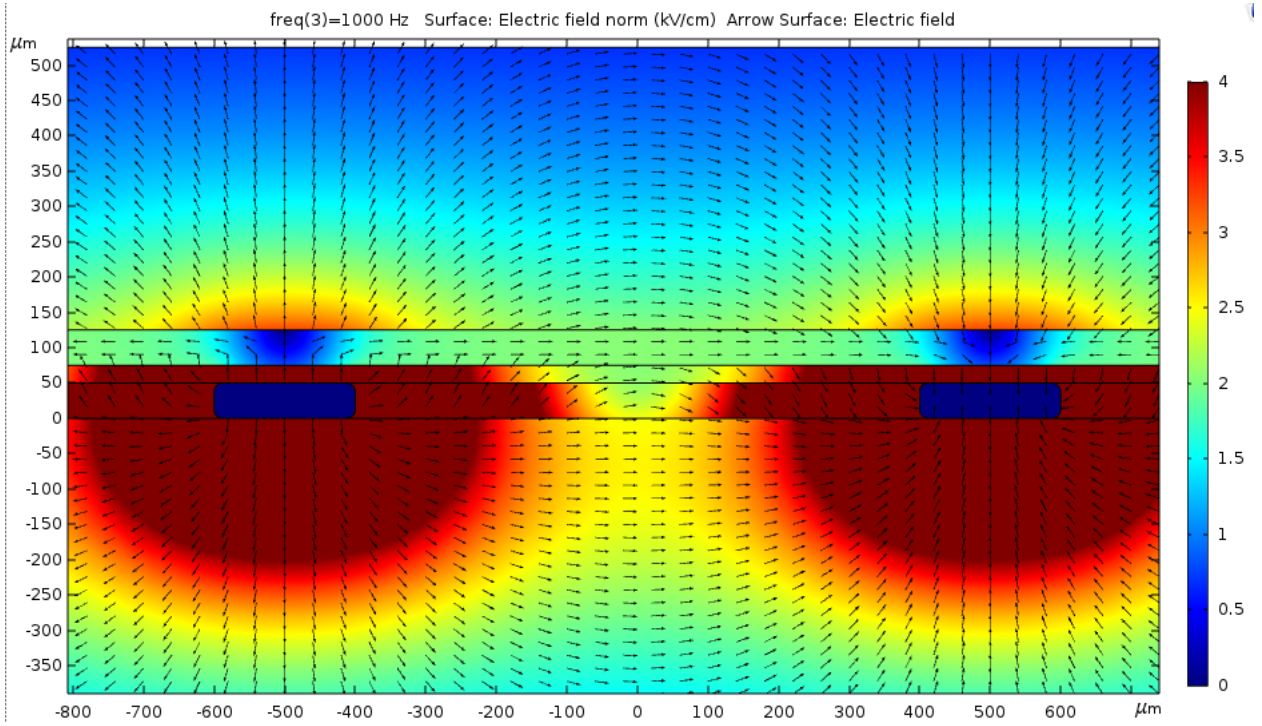




In-plane alignment

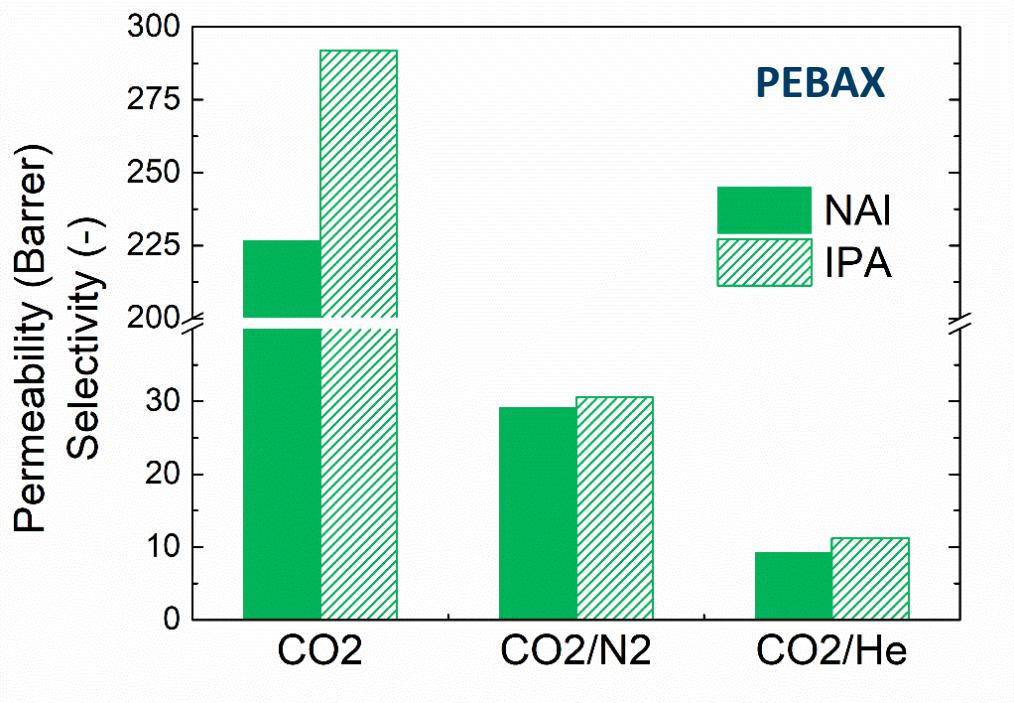
- CondAlign has developed a proprietary technology to align particles in polymeric films through the use of electric field (via di-electrophoresis)

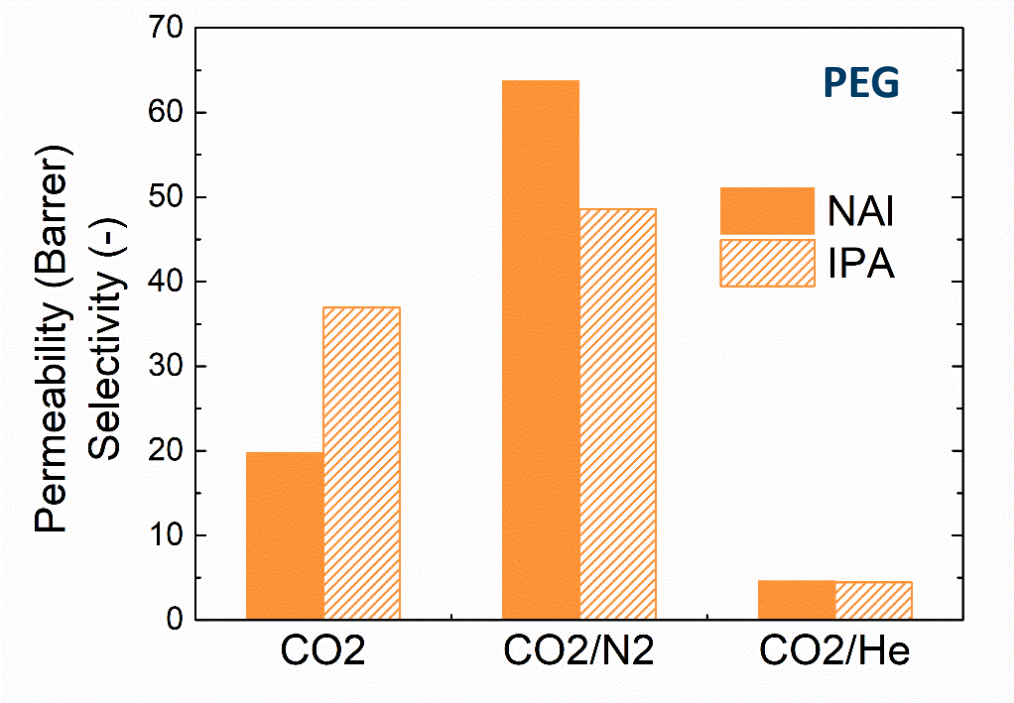




Effect on pure polymers

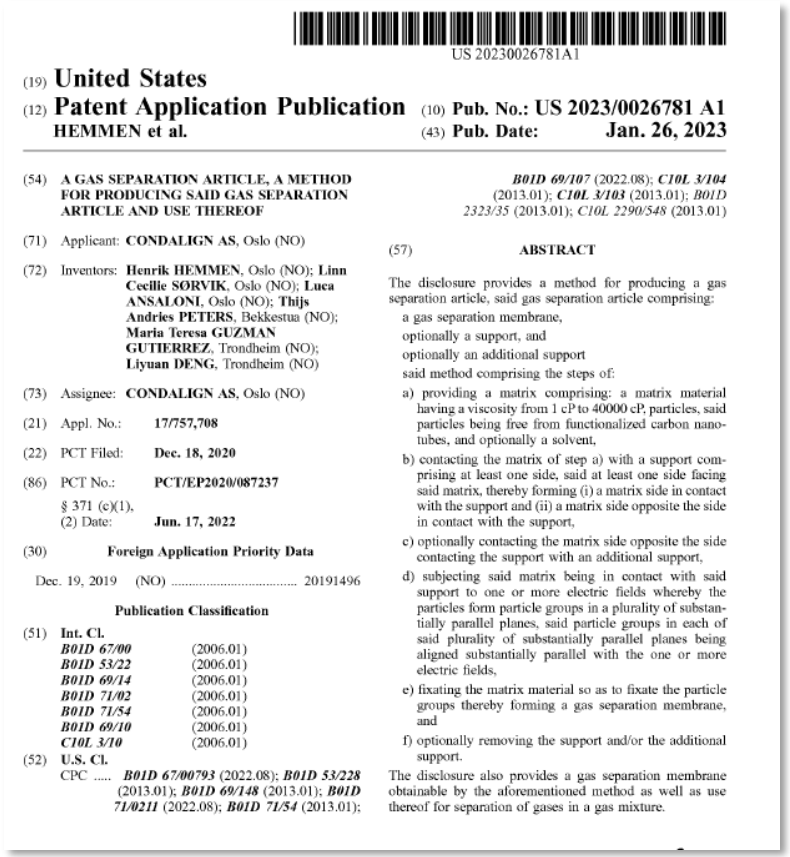
- During the project it was found that the alignment technique has also a positive impact on the pure polymer performance





Patents

- 2 Patents were submitted and approved at the end of the project



US 20230026781A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2023/0026781 A1**

HEMMEN et al. (43) **Pub. Date: Jan. 26, 2023**

(54) **A GAS SEPARATION ARTICLE, A METHOD FOR PRODUCING SAID GAS SEPARATION ARTICLE AND USE THEREOF**

(71) Applicant: **CONDALIGN AS**, Oslo (NO)

(72) Inventors: **Henrik HEMMEN**, Oslo (NO); **Linn Cecilie SØRVIK**, Oslo (NO); **Luca ANSALONI**, Oslo (NO); **Thijs Andries PETERS**, Bekkestua (NO); **Maria Teresa GUZMAN GUTIERREZ**, Trondheim (NO); **Liyuan DENG**, Trondheim (NO)

(73) Assignee: **CONDALIGN AS**, Oslo (NO)

(21) Appl. No.: **17/757,708**

(22) PCT Filed: **Dec. 18, 2020**

(86) PCT No.: **PCT/EP2020/087237**

§ 371 (c)(1),
(2) Date: **Jun. 17, 2022**

(30) **Foreign Application Priority Data**

Dec. 19, 2019 (NO) 20191496

Publication Classification

(51) **Int. Cl.**

B01D 67/00	(2006.01)
B01D 53/22	(2006.01)
B01D 69/14	(2006.01)
B01D 71/02	(2006.01)
B01D 71/54	(2006.01)
B01D 69/10	(2006.01)
C10L 3/10	(2006.01)

(52) **U.S. Cl.**

CPC ***B01D 67/00793*** (2022.08); ***B01D 53/228*** (2013.01); ***B01D 69/148*** (2013.01); ***B01D 71/0211*** (2022.08); ***B01D 71/54*** (2013.01); ***B01D 69/107*** (2022.08); ***C10L 3/104*** (2013.01); ***C10L 3/103*** (2013.01); *B01D 2323/35* (2013.01); *C10L 2290/548* (2013.01)

(57) **ABSTRACT**

The disclosure provides a method for producing a gas separation article, said gas separation article comprising:

a gas separation membrane,

optionally a support, and

optionally an additional support

said method comprising the steps of:

a) providing a matrix comprising: a matrix material having a viscosity from 1 cP to 40000 cP, particles, said particles being free from functionalized carbon nanotubes, and optionally a solvent,

b) contacting the matrix of step a) with a support comprising at least one side, said at least one side facing said matrix, thereby forming (i) a matrix side in contact with the support and (ii) a matrix side opposite the side in contact with the support,

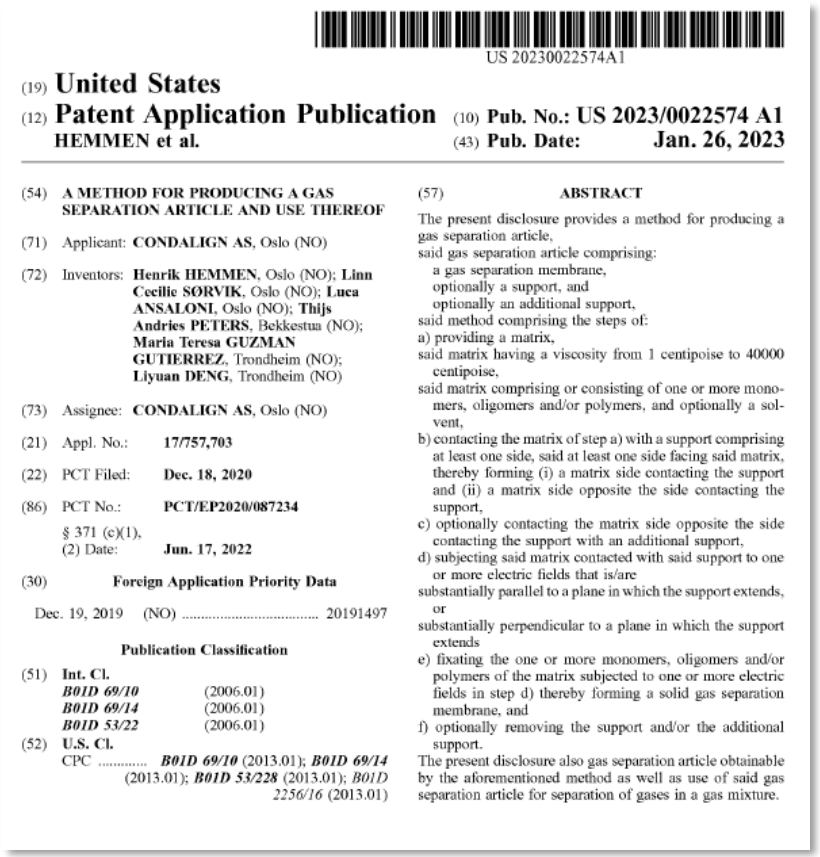
c) optionally contacting the matrix side opposite the side contacting the support with an additional support,

d) subjecting said matrix being in contact with said support to one or more electric fields whereby the particles form particle groups in a plurality of substantially parallel planes, said particle groups in each of said plurality of substantially parallel planes being aligned substantially parallel with the one or more electric fields,

e) fixating the matrix material so as to fixate the particle groups thereby forming a gas separation membrane, and

f) optionally removing the support and/or the additional support.

The disclosure also provides a gas separation membrane obtainable by the aforementioned method as well as use thereof for separation of gases in a gas mixture.



US 20230022574A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2023/0022574 A1**

HEMMEN et al. (43) **Pub. Date: Jan. 26, 2023**

(54) **A METHOD FOR PRODUCING A GAS SEPARATION ARTICLE AND USE THEREOF**

(71) Applicant: **CONDALIGN AS**, Oslo (NO)

(72) Inventors: **Henrik HEMMEN**, Oslo (NO); **Linn Cecilie SØRVIK**, Oslo (NO); **Luca ANSALONI**, Oslo (NO); **Thijs Andries PETERS**, Bekkestua (NO); **Maria Teresa GUZMAN GUTIERREZ**, Trondheim (NO); **Liyuan DENG**, Trondheim (NO)

(73) Assignee: **CONDALIGN AS**, Oslo (NO)

(21) Appl. No.: **17/757,703**

(22) PCT Filed: **Dec. 18, 2020**

(86) PCT No.: **PCT/EP2020/087234**

§ 371 (c)(1),
(2) Date: **Jun. 17, 2022**

(30) **Foreign Application Priority Data**

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Publication Classification

(51) **Int. Cl.**

B01D 69/10	(2006.01)
B01D 69/14	(2006.01)
B01D 53/22	(2006.01)

(52) **U.S. Cl.**

CPC ***B01D 69/10*** (2013.01); ***B01D 69/14*** (2013.01); ***B01D 53/228*** (2013.01); *B01D 2256/16* (2013.01)

(57) **ABSTRACT**

The present disclosure provides a method for producing a gas separation article,
said gas separation article comprising:
a gas separation membrane,
optionally a support, and
optionally an additional support,
said method comprising the steps of:
a) providing a matrix,
said matrix having a viscosity from 1 centipoise to 40000 centipoise,
said matrix comprising or consisting of one or more monomers, oligomers and/or polymers, and optionally a solvent,
b) contacting the matrix of step a) with a support comprising at least one side, said at least one side facing said matrix, thereby forming (i) a matrix side contacting the support and (ii) a matrix side opposite the side contacting the support,
c) optionally contacting the matrix side opposite the side contacting the support with an additional support,
d) subjecting said matrix contacted with said support to one or more electric fields that is/are
substantially parallel to a plane in which the support extends, or
substantially perpendicular to a plane in which the support extends
e) fixating the one or more monomers, oligomers and/or polymers of the matrix subjected to one or more electric fields in step d) thereby forming a solid gas separation membrane, and
f) optionally removing the support and/or the additional support.
The present disclosure also gas separation article obtainable by the aforementioned method as well as use of said gas separation article for separation of gases in a gas mixture.

Conclusion and outlook

Achievements:

- Demonstrated the feasibility to apply CondAlign technology for the fabrication of membranes for CO_2 capture (thin film composite membranes)
- Extented CA technology to the case of in-plane alignment
- 2 patents

Outlook:

- Establishment of CondAlign Capture AS https://www.condalign.no/about/condalign-capture/
- Looking for possible partners in the membrane manifacturing field

Teknologi for et bedre samfunn

Content