SINTEF
75 år

WATER PROOF

WaterProof Webinar: From Emissions to Innovation: CO_2-Derived Chemicals

Pioneering Sustainable CO_2 Conversion to C3 Chemicals and High-Value Lipids for Feed and Food Applications

Francesca Di Bartolomeo,
SINTEF Industry

Teknologi for et bedre samfunn

SINTEF
75 år

WATER PROOF

In this presentation:

This is SINTEF, a short intro

CO_2 to value part 1 scaling up C3 chemical production in the PYROCO_2 project

CO_2 to value part 2 Producing feed ingredients from CO_2 and optimization of CO_2 utilization.

SINTEF
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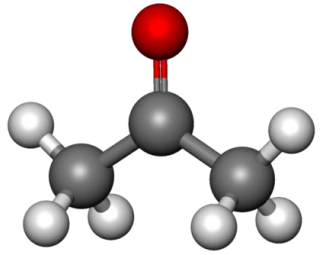

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SINTEF

ONE OF EUROPE'S LARGEST INDEPENDENT RESEARCH ORGANISATIONS

367,5 million
EUR turnover

2200
employees

6400
projects

3300
customers

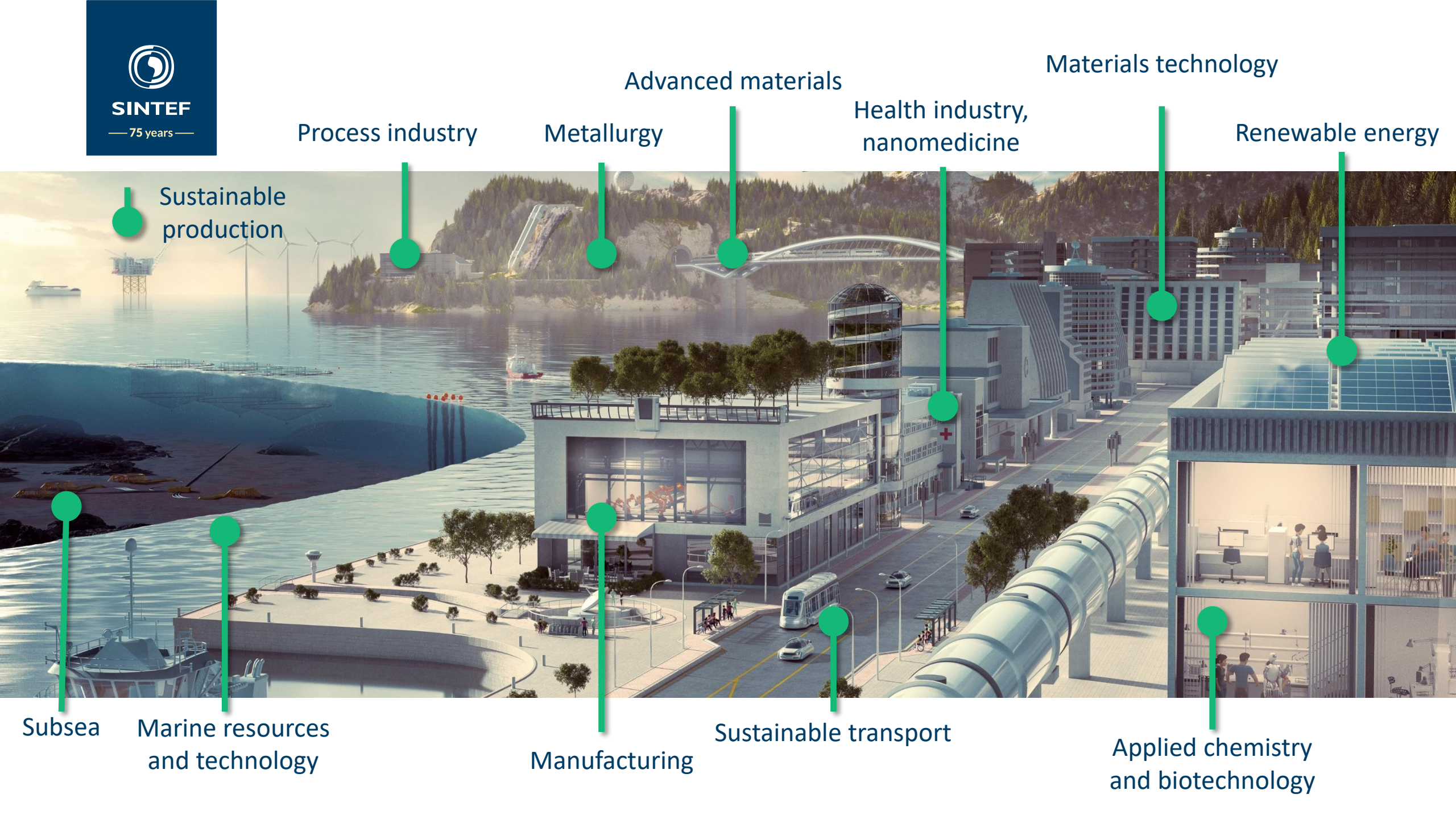
INTERNATIONAL
70,7 million EUR

NATIONALITIES
80

PUBLICATIONS (INCL. DISSEMINATION)
6200

CUSTOMER SATISFACTION
4,6 / 5

Vision:
Technology for a better society


SINTEF
75 years
Sustainable production
Process industry
Metallurgy
Advanced materials
Health industry, nanomedicine
Materials technology
Renewable energy
Subsea
Marine resources and technology
Manufacturing
Sustainable transport
Applied chemistry and biotechnology

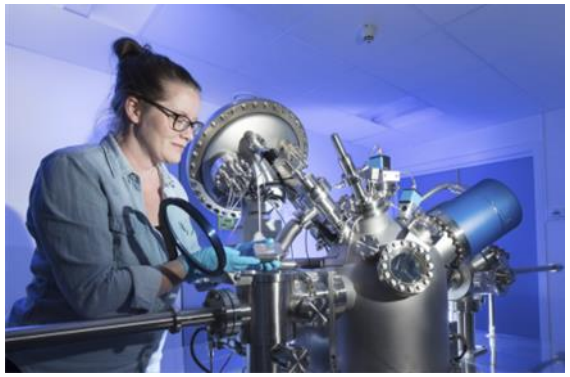
Laboratories

CO_2-laboratory, Tiller

Formation Physics

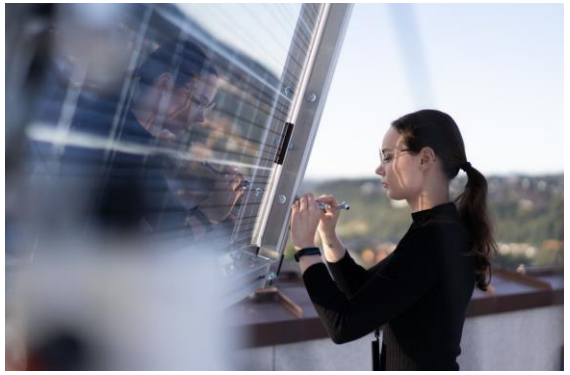
Multiphase Flow, Tiller

Mass spectrometry



Materials characterisation

Nanotechnology



Solar cells

Metal production

Advanced membranes

Material technology

Biotechnology

Biotechnology and Nanomedicine

Our expertise:

- Bioprocess development
- Microbial molecular biology
- Advanced research-based analyses
- Nanomedicine, polymer particles and surface chemistry

Applied within:

- pharmaceutics, vaccines, biomaterials, enzymes, food, feed, chemicals and energy

Process Technology

Our expertise:

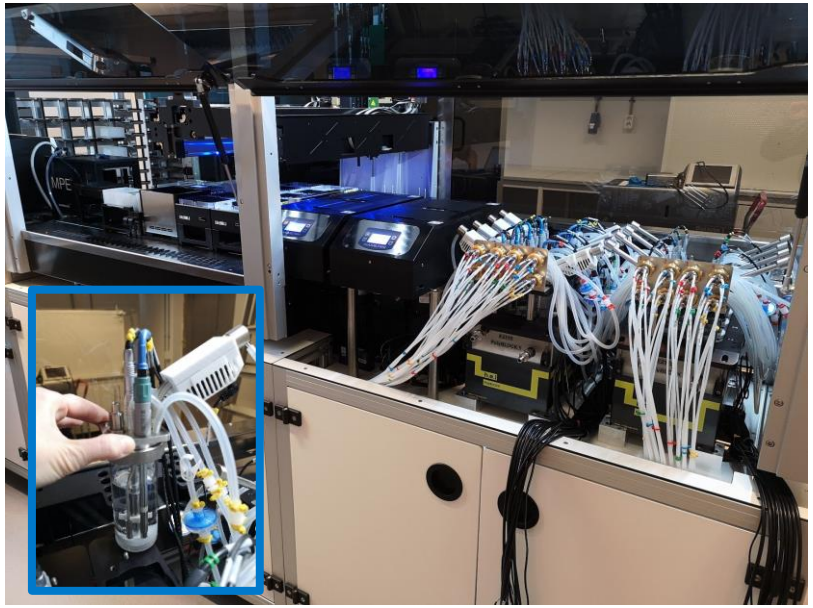
- Computational Fluid Dynamics (CFD) and Multiphase flow
- Catalysis and Kinetics
- Porous and functional materials, separation
- Powder Technology
- High Throughput Technology
- Process Analytical Technology (PAT)
- CO_2 Capture and Separation (CCS)
- Process design and Techno-Economics
- Large scale experimental testing and validation

SINTEF's Capacity and Infrastructure

From lab to industry-scale bioprocess optimization and CO_2 capture

SINTEF's state-of-the-art facilities support both **gas fermentation and CO_2 capture**, offering **end-to-end capacity** from lab-scale trials to industrial-scale applications—making SINTEF an ideal partner for both development and scaling

>30 years of experience and leading laboratory for development of microbial and cell-based production processes with advanced research-based analyses.



Lab scale fermentors (54)

- **16** x 0.2-L fully automated
- **32** x 1-3-L fermentors
- **8** x 0.2-L gas fermentors
- **5** x high pressure gas
- fermentors

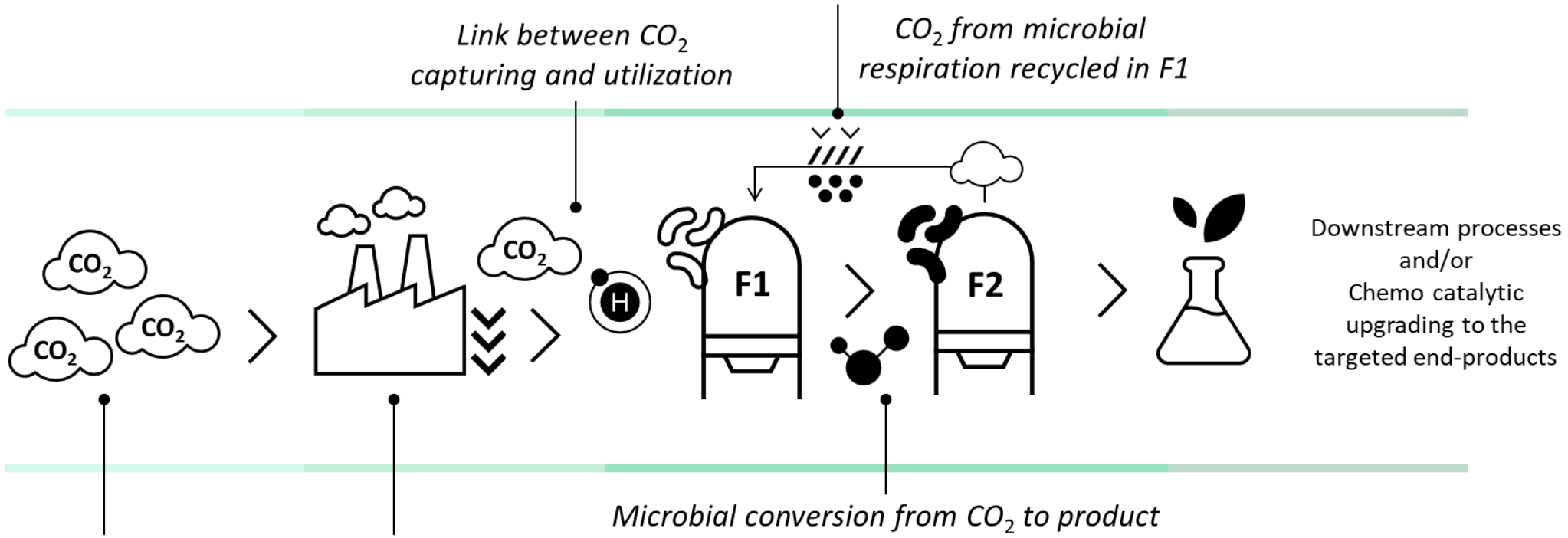
Pilot unit and BioLectors …

Tiller CO_2 capture pilot plant

Converting CO_2 emission into products

Putting CO2 in good use through integrated value chains that combine CO2 sourcing and capturing – biotechnological conversion – chemo catalytic product diversification

We can target a vast array of end-products From chemicals to materials – from efuels to feed



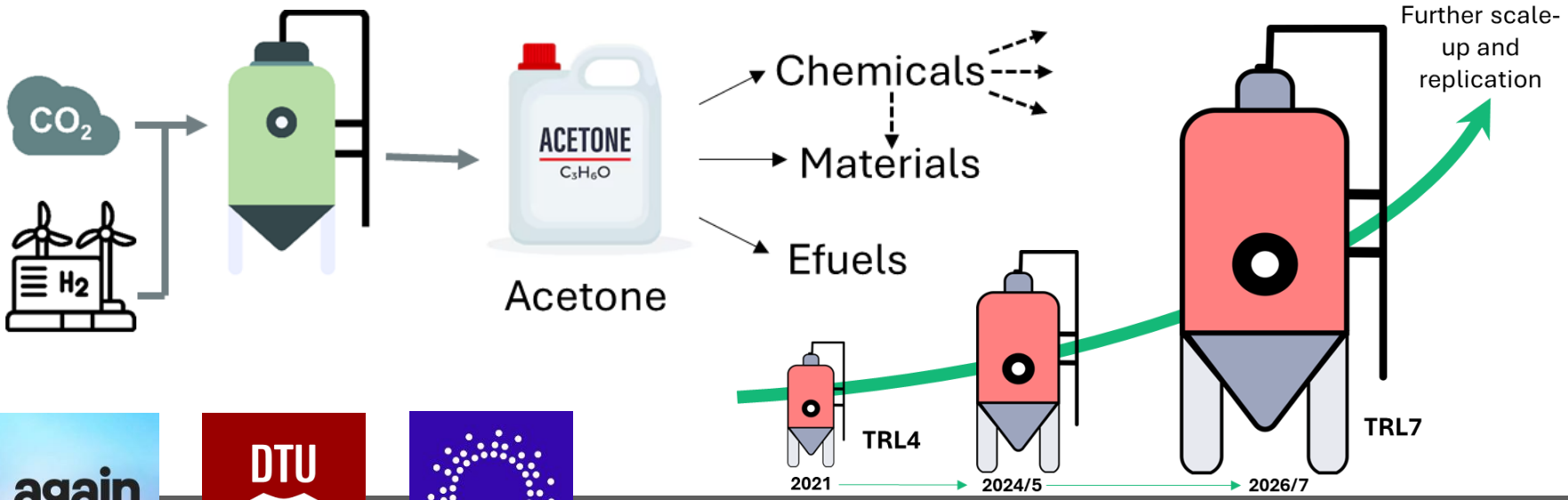
CO2 to value part 1
scaling up C3 chemical production in the PYROCO2 project

CO2 to value part 2
Producing feed ingredients from CO2 and optimization of CO2 utilization.

C3 chemicals from CO_2

PYROCO2 Project: Converting CO_2 to high-value acetone

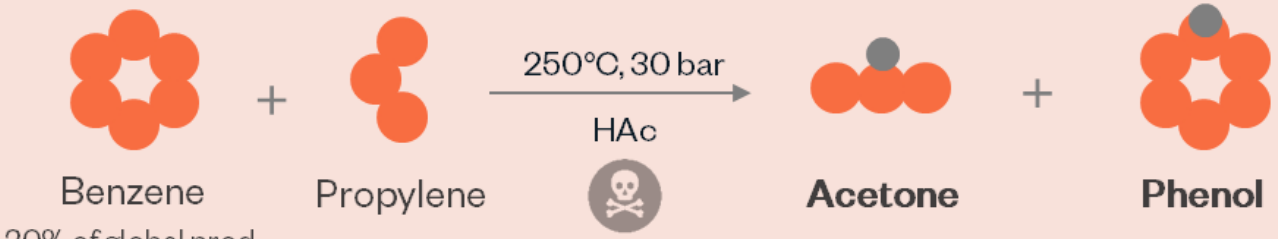
The PYROCO2 project addresses the challenge of producing **C3 chemicals from CO_2** by focusing on acetone, a building block less accessible than C2 molecules. Using thermophilic microbial fermentation, we convert CO_2 and green hydrogen into sustainable acetone. Scaled up to 10-50 m^3, this process is well projected towards industrial applications, providing a versatile petrochemical alternative with uses in **plastics, specialty materials, and fuels -** demonstrating the potential of circular carbon solutions.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037009.

3-Carbon molecules are currently attainable through petrochemical processes

Cumene process



Carbon Oxygen

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037009.

CCU facilitates the reuse of captured carbon into materials society is built upon

Current CCU approaches predominantly result in 1 or 2-carbon chemicals

All are valuable in different products


Pharmaceuticals


Cosmetics


Plastics


Appliances


Electronics


SAFs


Methanol

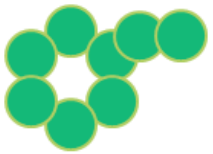

Ethanol


Ethylene


Acetic acid

...

Which can be condensed into C_{2X} compounds


Styrene


Poly Vinyl Chloride (PVC)


Vinyl Acetate (VAM)

...

Carbon Oxygen Chloride

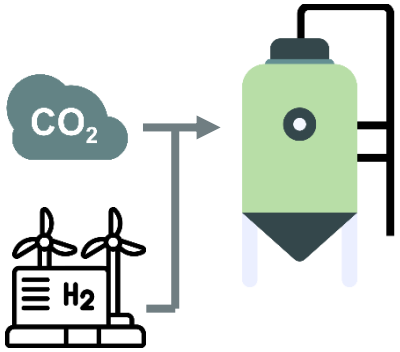
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037009.

PYROCO$_2$
Accessing the C3-derived chemical space with CCU

Biology

Flexibility of biology

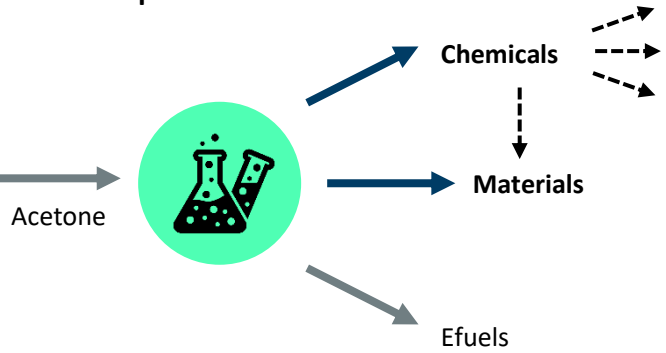
- Efficient two-step fermentative conversion of CO_2 & H_2 into acetone



Chemistry

Maturity of catalytic chemistry

- Benefit from pre-existing processes & infrastructure coupled to novel catalyst development



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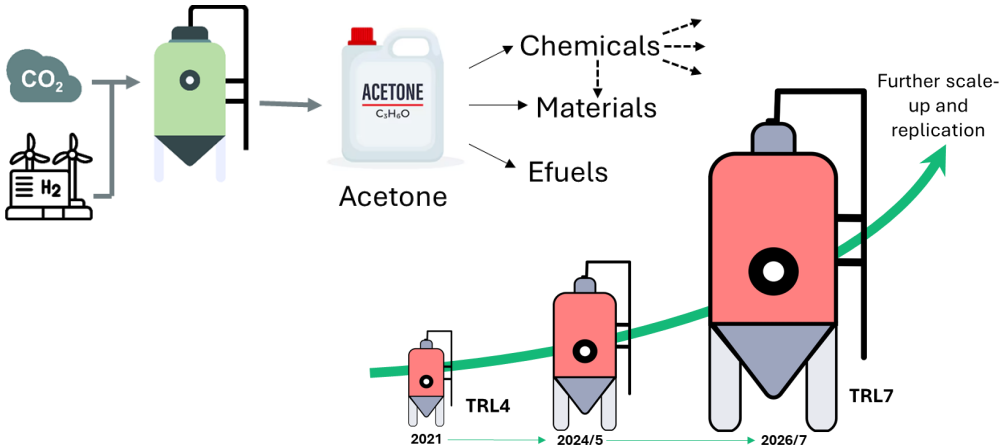
From Laboratory to Demo

2-5 L

200ml



150 L

1000 L … and beyond

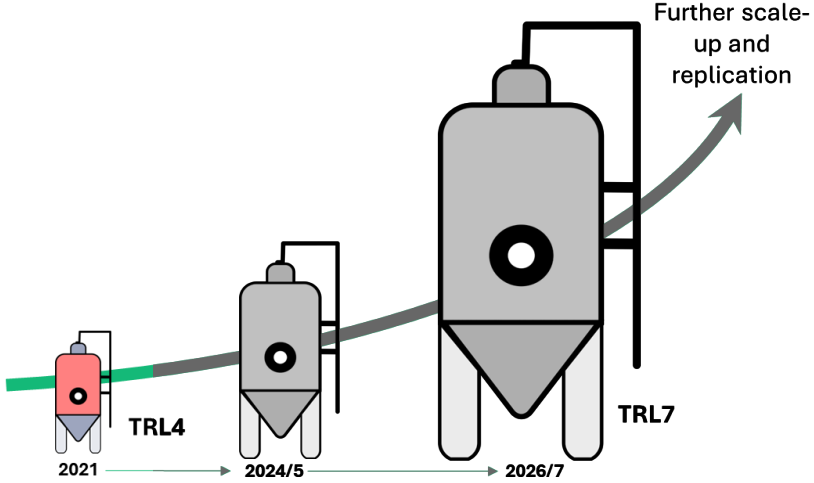
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037009.

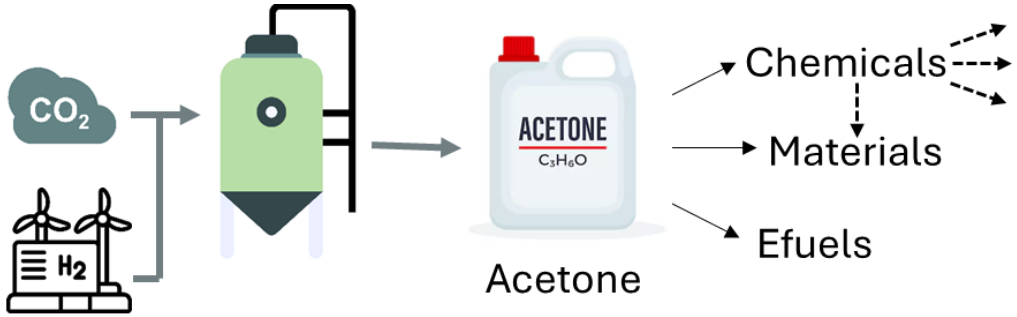
From Laboratory to Demo

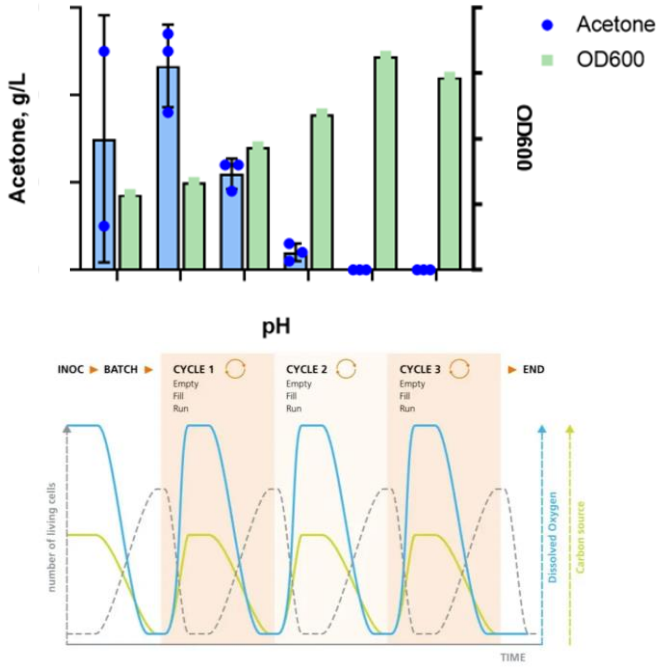
We still focus on the strain engineering and optimization processes!

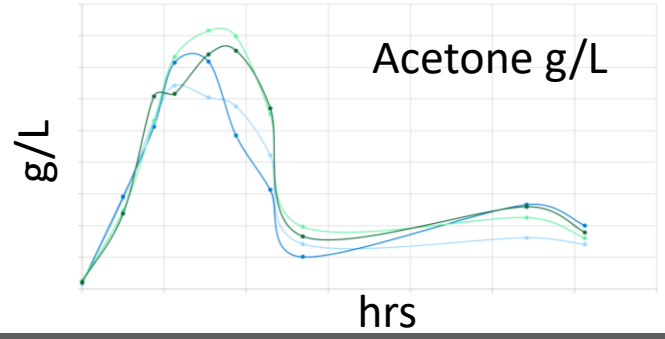
2-5 L

200ml









Millgaard et al. An improved integrative GFP-based vector for genetic engineering of *Parageobacillus thermoglucosidasius* facilitates the identification of a key sporulation regulator. *AMB Express* (2023) 13, p. 44

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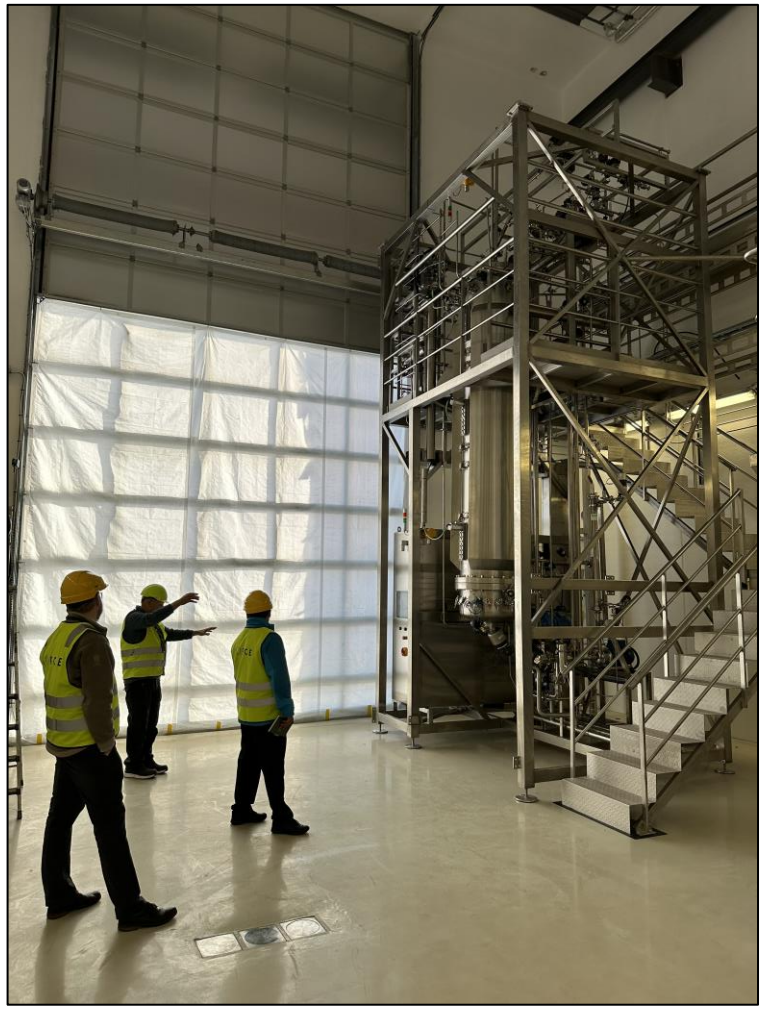
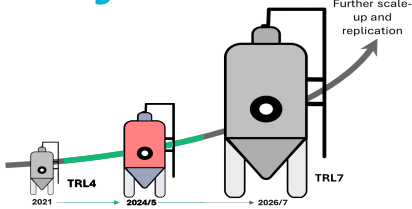
The importance of intermediate-scale fermentation system





BIOPROCESS TECHNOLOGY

NORCE

again DTU

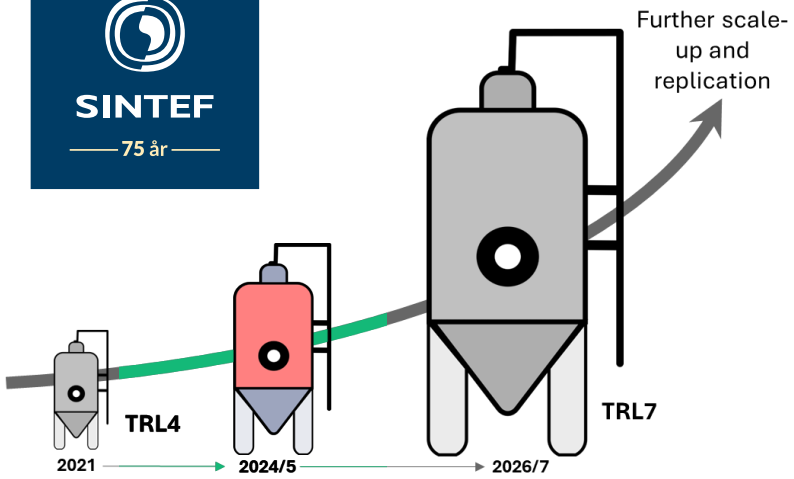
SINTEF

150L and 1m^3 gas bioreactors at NORCE, Risavika

Strain engineering (sporulation, robustness, productivity)
CFD and kinetic modelling
Acetone recovery and purification
Bioprocess integration & optimisation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037009.

The importance of intermediate-scale fermentation system



- Integrating the 2 fermentation steps
- Identifying potential challenges with scaling up
- Providing chemical cat. with enough acetone
- Work flow and design of the demo scale
- Building experience before the running of the demo

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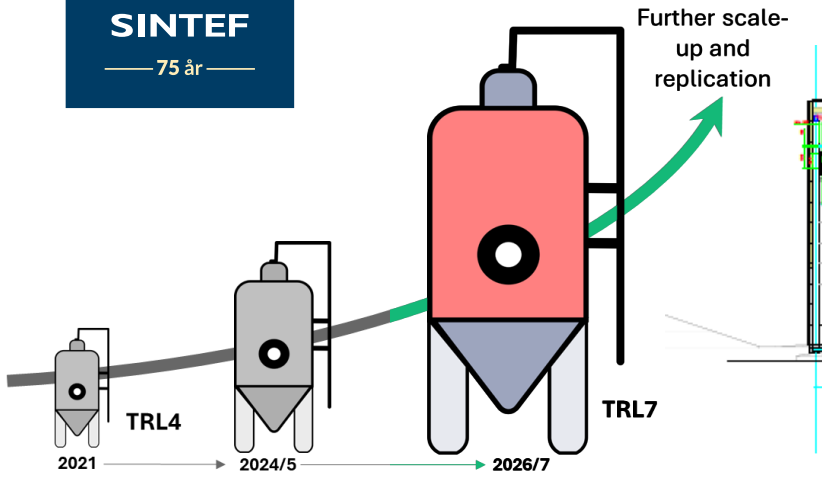
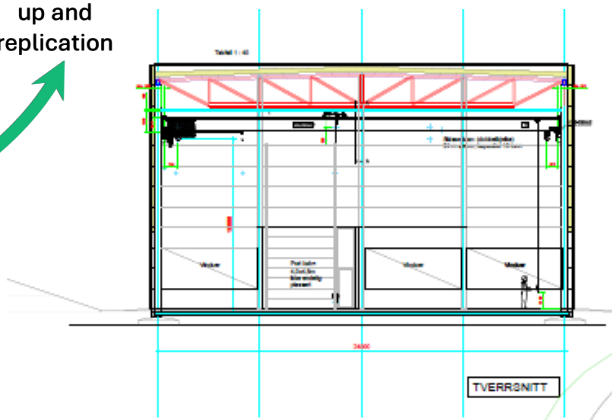
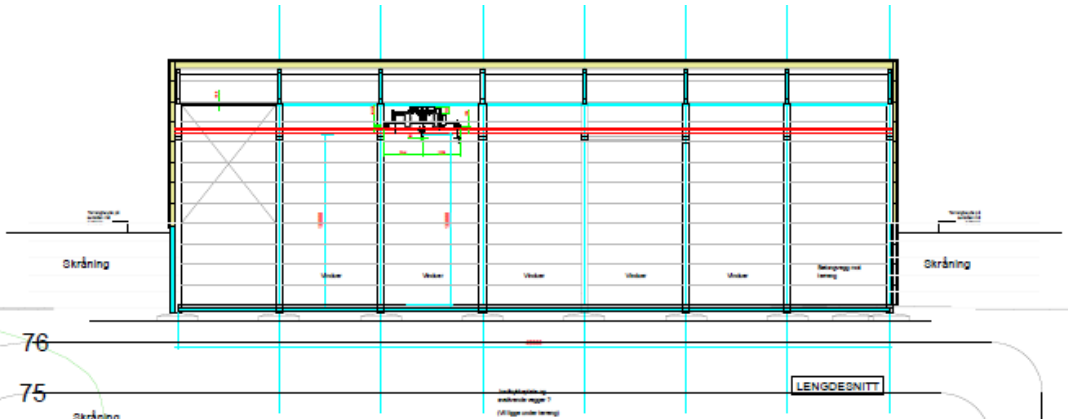
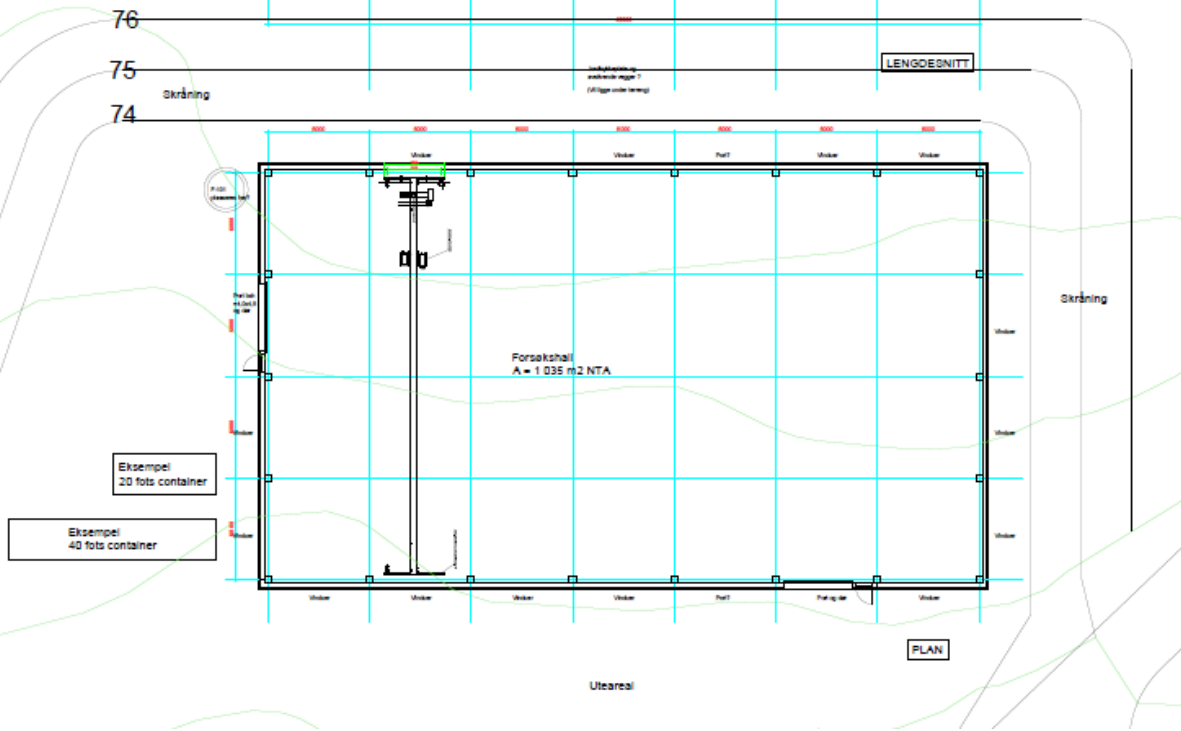
The PYROCO$_2$ Demonstrator



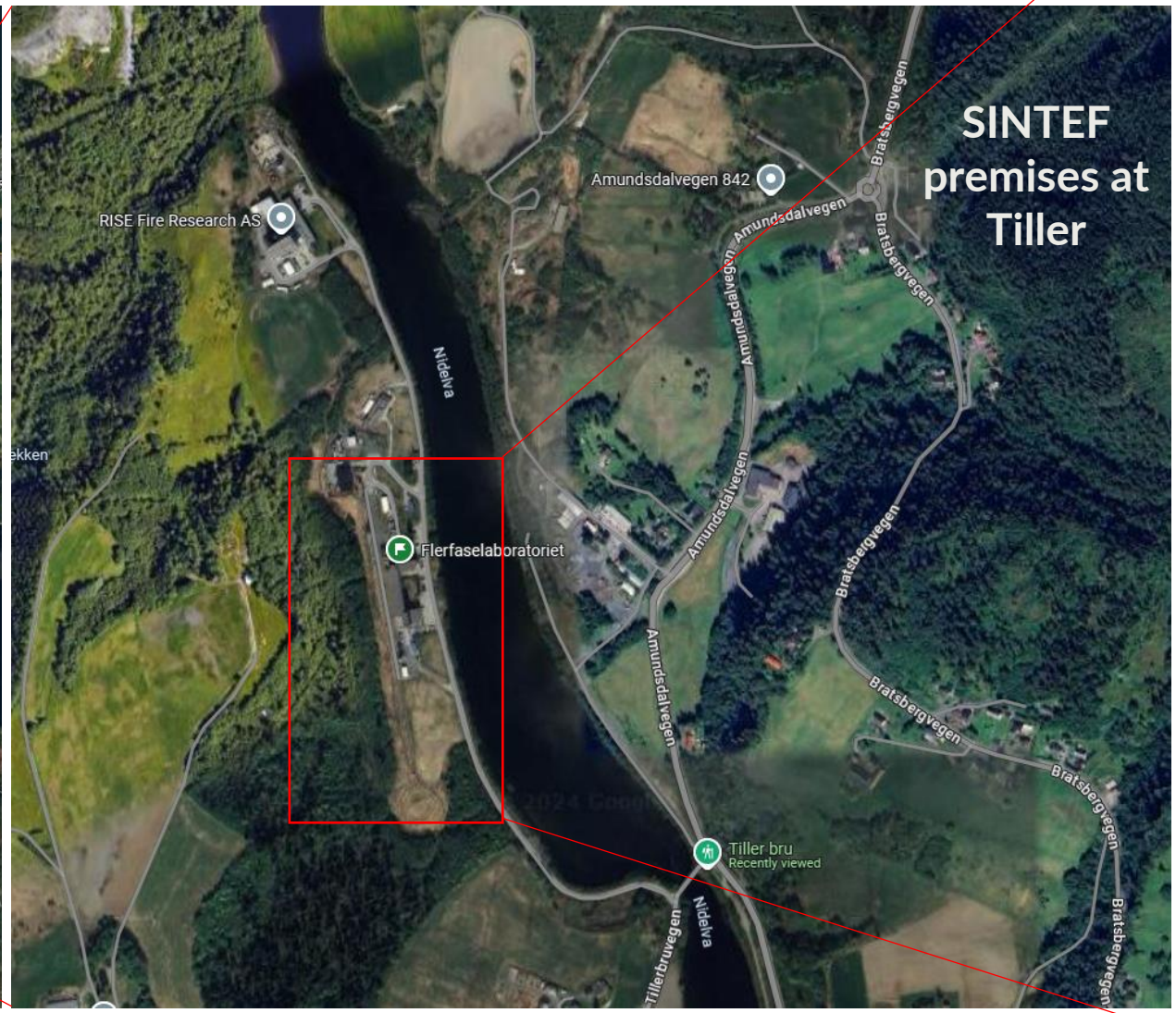






This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101037009.

The PYROCO$_2$ Demonstrator – piloting hub near SINTEF



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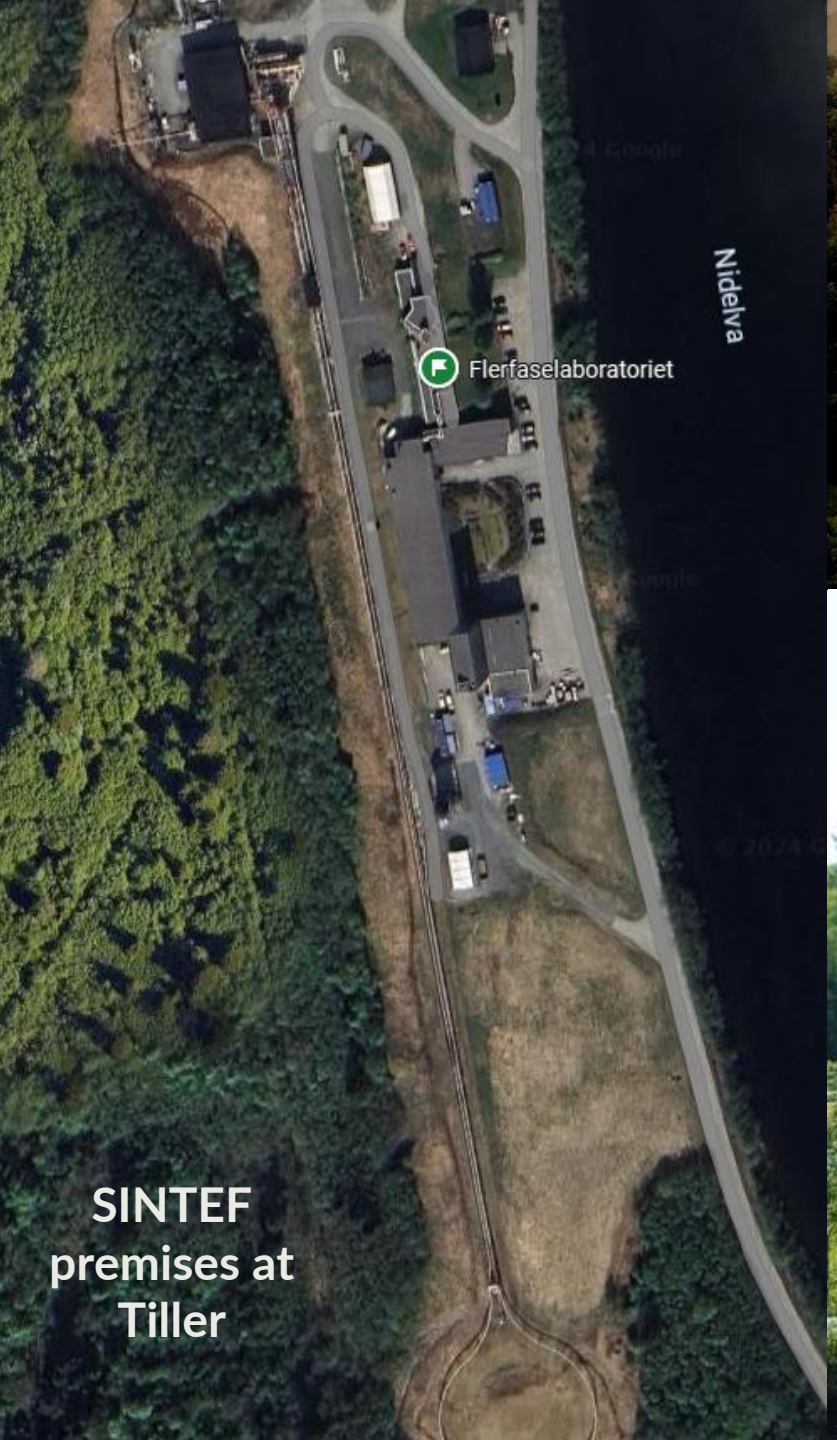


SINTEF premises at Tiller

Multiphase Flow Laboratory

One of the world's largest multiphase test facilities and a research infrastructure of national importance for oil/gas production and CCS

Tiller CO_2 capture pilot plant

>100,000 hours of capture R&D

Capacity of 50 kg CO_2/h

INGREDIENTS (PROTEINS AND LIPIDS)

FROM

AND H2, N-SOURCES …

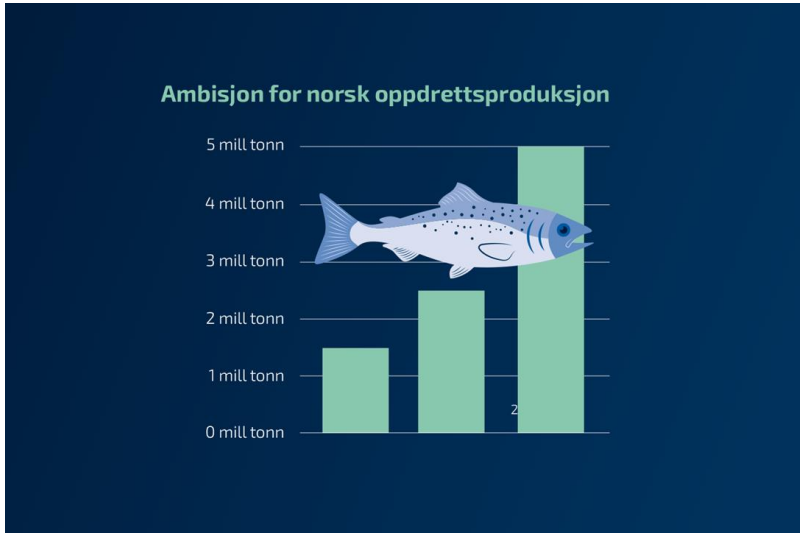
SIP Sustainable Food and Feed
SINTEF strategic funding

SFI
Industriell bioteknologi
Industrial biotechnology

SFI industrial biotechnology
Centre for Research Based Innovation

Converting CO_2 emission into feed ingretients

CO_2 into feed ingredients, a strategy poised to disrupt the traditional feed industry by significantly reducing costs and dependency on imported materials.



In **2024**, Norway produced about **1.3 million tonnes of salmon**, requiring **~2 million tonnes of feed.** Because feed can account for up to **70–75% of the total climate footprint of farmed salmon**, both industry stakeholders and the Norwegian government have prioritized **developing more sustainable raw materials for feed.**

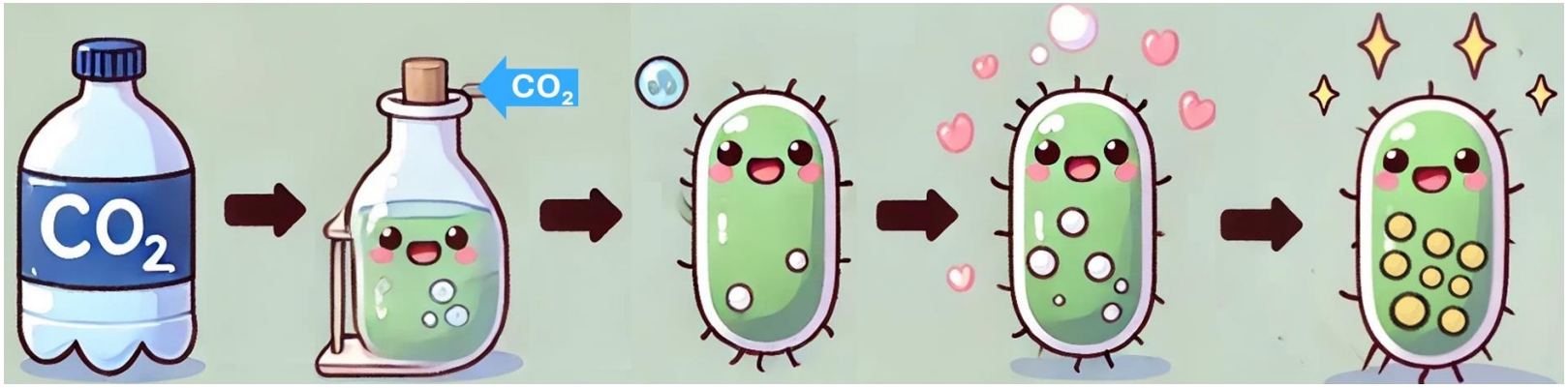
According to the **OECD-FAO Agricultural Outlook 2023–2032, global fish production (capture & aquaculture) is projected to grow by about 14% by 2032. Aquaculture's share is expected to rise to around 60% of the world's fish supply, highlighting the sector's continued expansion and the urgent need for sustainable feed solutions.**

From 2012 to 2022, **fish feed prices rose significantly**—some by 60–110%—with the steepest increases post-2019, underscoring the **urgent need for more cost-effective and sustainable feed solutions.**

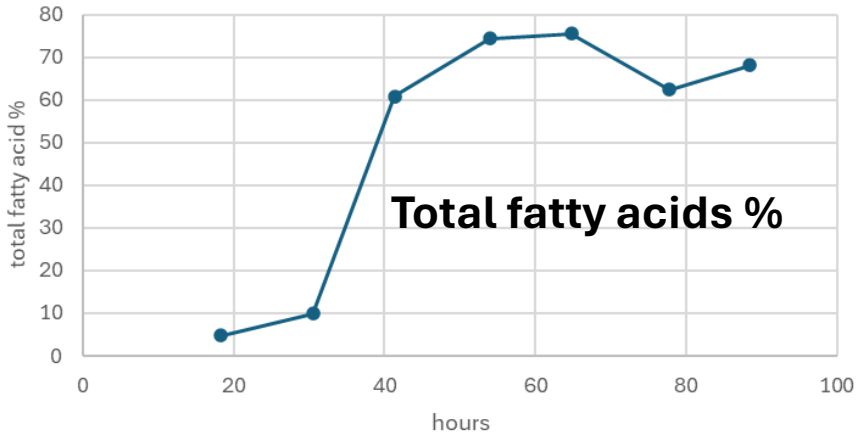
The **2019 National Academies of Sciences report** estimates that **biological systems** could theoretically convert **0.5–2.3 gigatonnes of CO_2 into feed ingredients each year**, though actual **near-term deployments remain well below this upper-bound potential.**

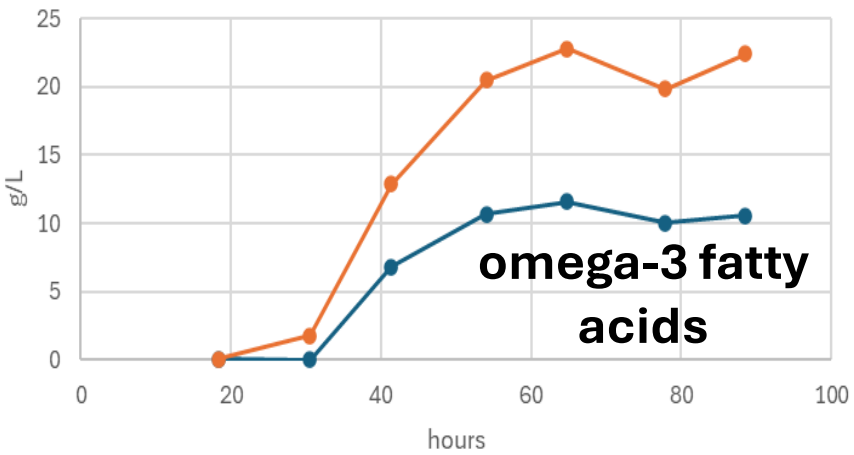
Omega-3 Fatty Acids from CO_2

Bioprocesses for production of sustainable food and feed



Ongoing bioprocess optimization
Production of up of 80% lipids of tot. biomass Approx. 30% is ω-3 FA.



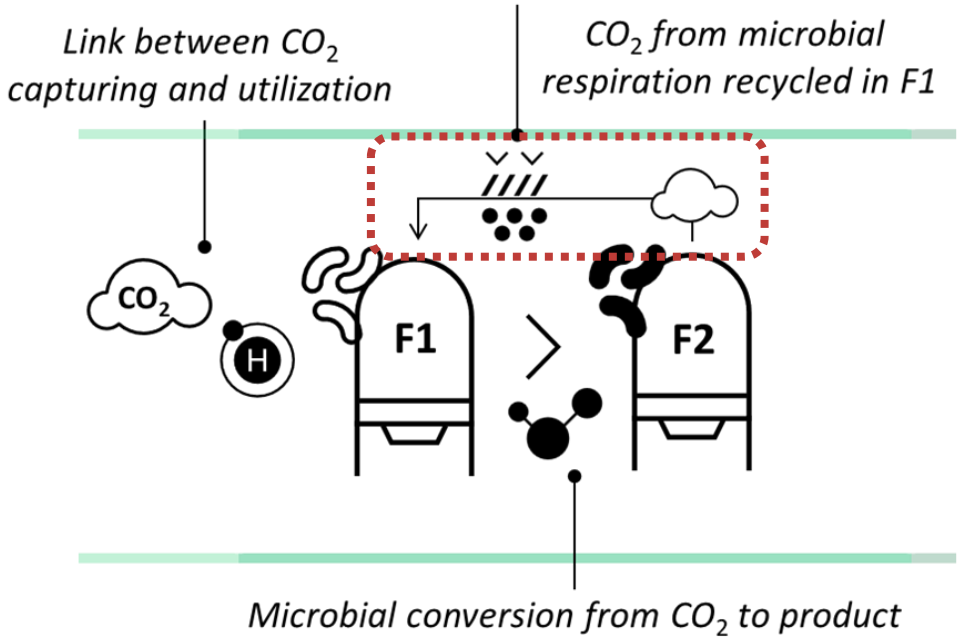


Meeting the demand for sustainable omega-3 sources, SINTEF utilizes **non-GMO microbial strains to produce omega-3 fatty acids** with lipid content reaching 80% of total cell mass.

This innovative process not only meets food-grade standards but also **reduces reliance on marine resources, supporting aquaculture and human nutrition** in alignment with global sustainability goals.

CO_2 recovery from secondary fermentation process

Use and optimization of ultraselective polymer membranes

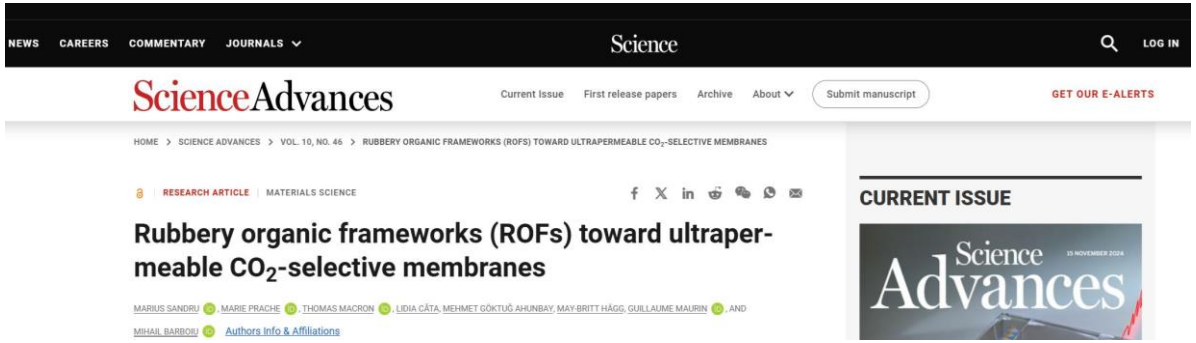


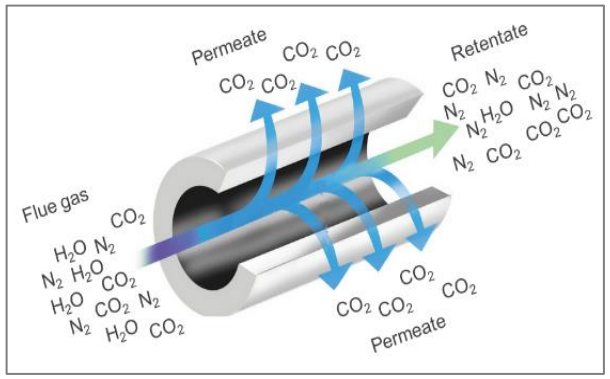
Publications on membrane for CO_2 capture:

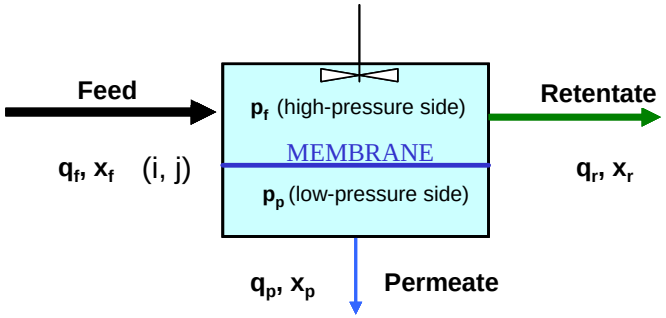
An integrated materials approach to ultrapermeable and ultraselective CO_2 polymer membranes

MARIUS SANDRU, EUGENIA M. SANDRU, WADE F. INGRAM, JING DENG, PER M. STENSTAD, LIYUAN DENG, AND RICHARD J. SPONTAK Authors Info & Affiliations

SCIENCE · 31 Mar 2022 · Vol 376, Issue 6588 · pp. 90-94 · DOI: 10.1126/science.abj9351



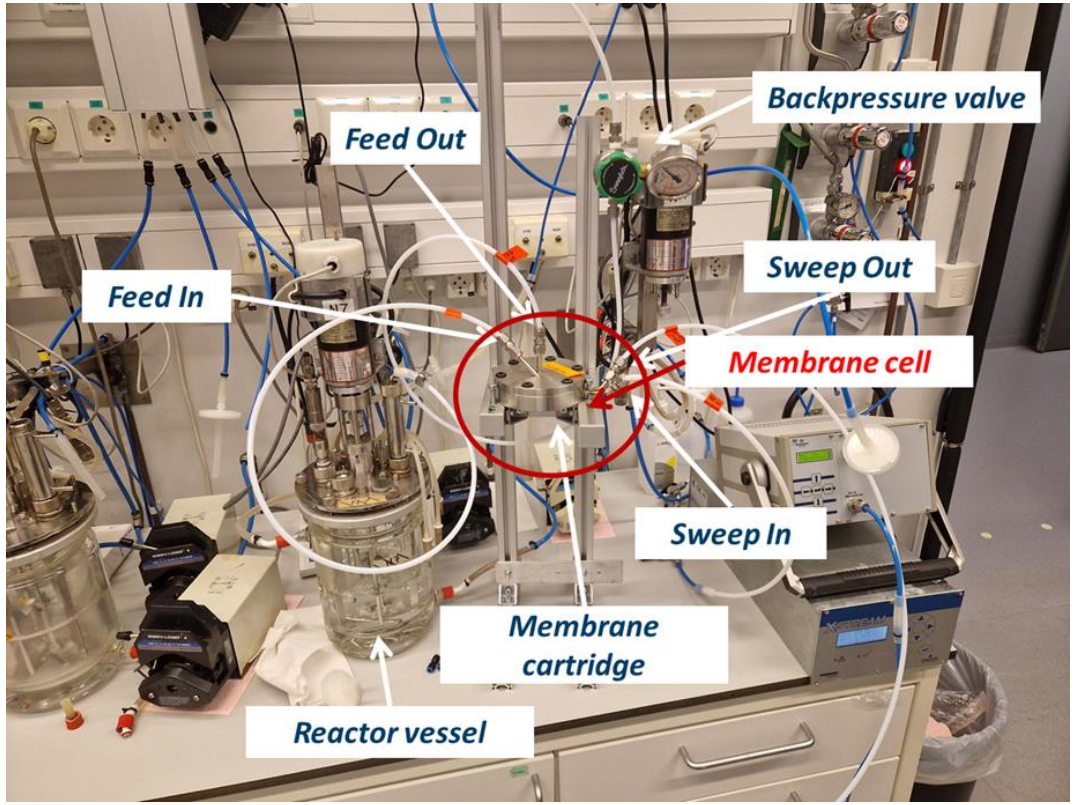




Plus several SINTEF patents developed on the topic

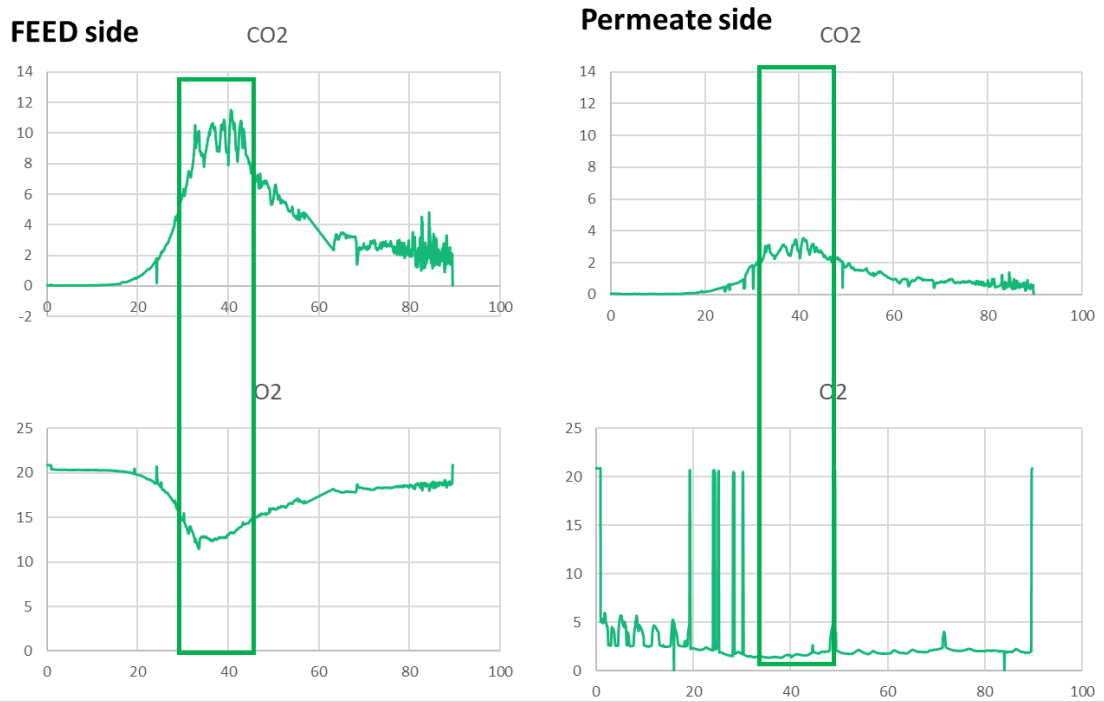
CO_2 recovery from secondary fermentation process

Use and optimization of ultraselective polymer membranes



CO_2 enriching selective membrane
Recycling of CO_2 derived from aerobic fermentation

Enrichment of CO_2 vs O_2 gives consistent values. Better selectivity of the CO_2 vs O_2 and faster transport of the CO_2 over O_2



Membrane	Feed Gas composition	Permeate Gas composition	Temperature (°C)	Membrane separation properties	
				CO_2 Permeance [m3(STP)/(m2 bar h)]	CO_2/O_2 Selectivity
Reference PDMS/PAN	16% CO2/ 9% O2	6,8 % CO2/ 1,25 %O2	33	0,81	4
Modify PDMS/PAN-F34	8.22 CO2/14.09 O2	2.52 CO2/1.67 O2	30	0.5669	7
Modify PDMS/PAN-F35	11.32 CO2 / 14.22 O2	3.49 CO2/ 1.54 O2	30	0.836	6

The gas separation performance of the unmodified and modified PDMS/PAN **membranes under fermentation conditions**

True CO2 valorisation need full value chain optimization

Kicked off April 1st

CO_2Value - Advanced Conversion of Industrial Biogenic Gas Streams into Fish Feed via CO_2 Capture and Microbial Fermentation.

Biomass

Mixed gas stream from biomass combustion at Verdal Industry Park/Skogn

OGL Skogn facility TRL 6-7

OGL Tiller facility TRL 4-5

Advanced CO_2 capturing facility at point source

CO_2 from microbial respiration recycled in S1

S1

S1 from CO_2 to acetate

S2

S2 from acetate to feed ingredients

Microbial conversion from CO_2 to product

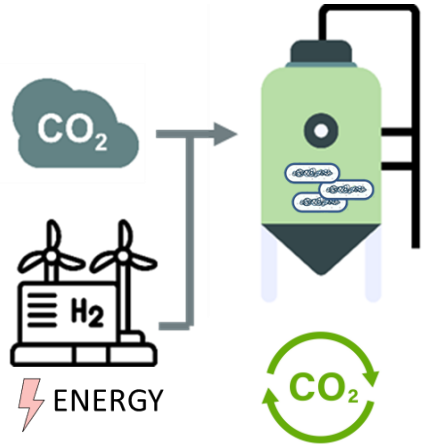
CO_2 derived lipid and protein biomass used in feed formulation and feeding trials

Extraction and DSP

Feed formulation

SINTEF civac Ocean GeoLoop again NTNU NoMy SINTEF SKRETTING a Nutreco company

Biogenic Carbon



Take a look at who we are and what we do …

SINTEF industry
Department of Biotechnology and Nanomedicine

SFI
Industriell bioteknologi
Industrial biotechnology

SFI Industrial Biotechnology -
Centre for Research-based Innovation

PYROCO$_2$

EU Green Deal project - PYROCO2

Francesca Di Bartolomeo
Senior Scientist at SINTEF Industry

SINTEF
75 år

75 år med teknologi for et bedre samfunn

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