

Strategic Research Area 2014–2023

**NTNU ENERGY**



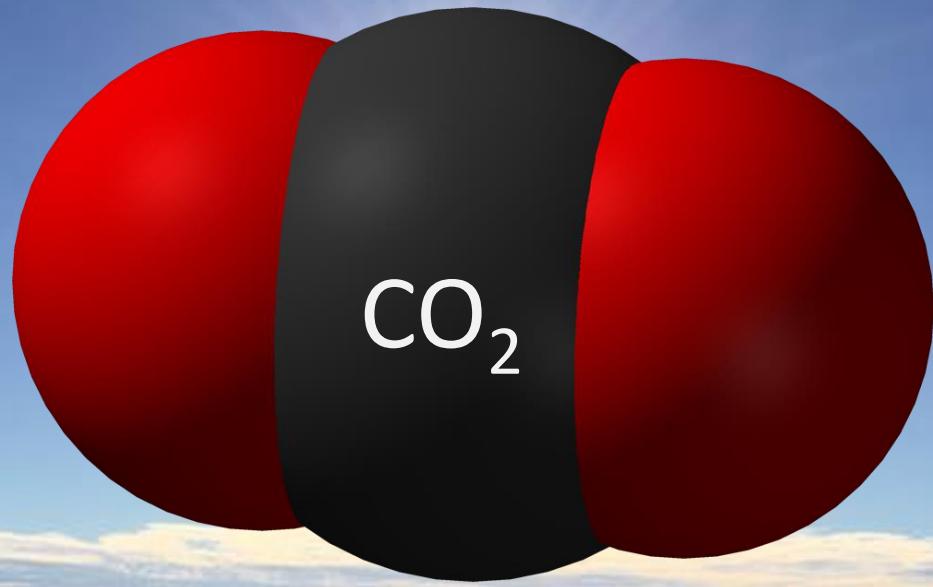
Kampen mot karbonet

NTVA-seminar Oslo 24.October 2018

Professor Johan E. Hustad, Director NTNU Energy



**NTNU – Trondheim**  
Norwegian University of  
Science and Technology

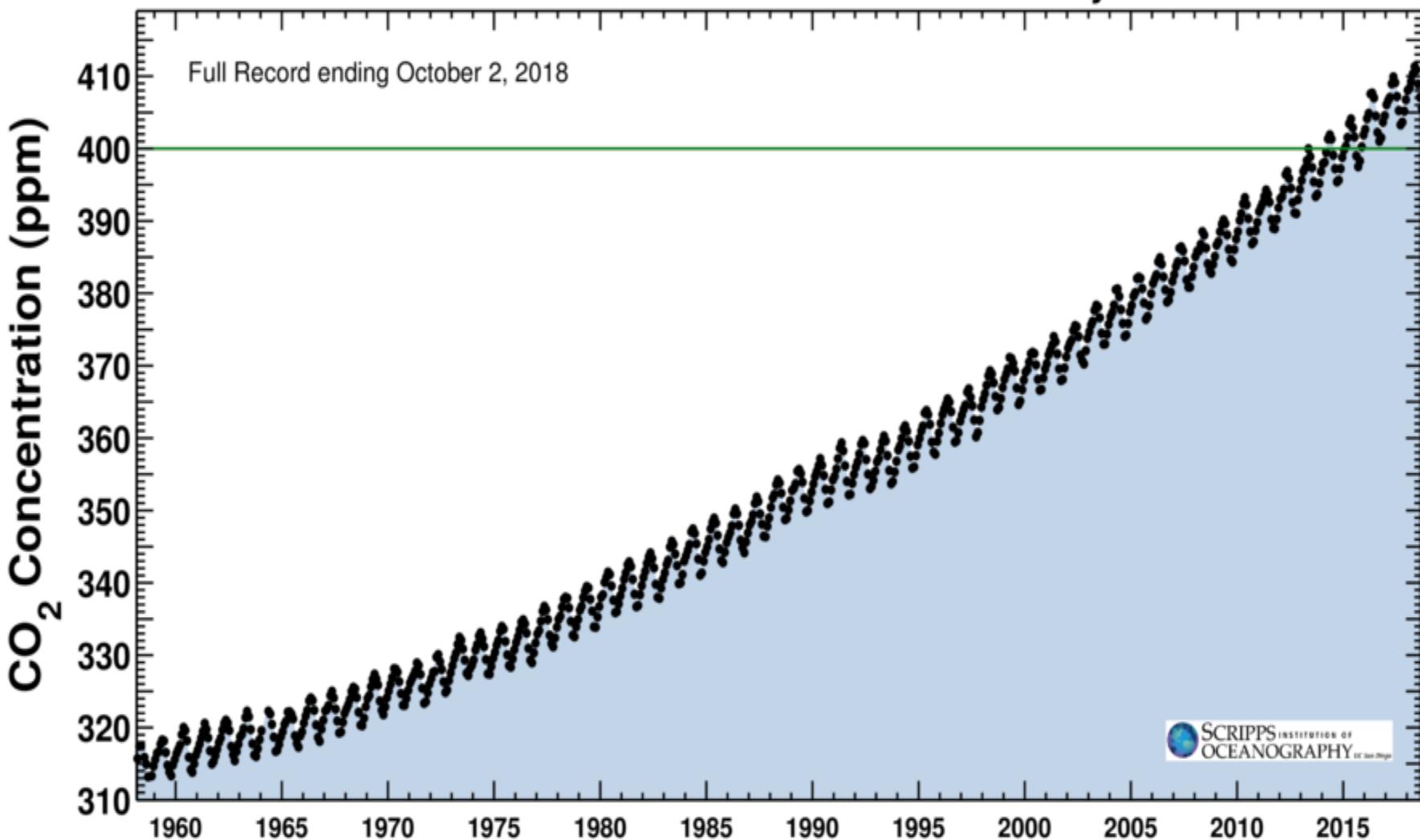


CO<sub>2</sub>

Latest CO<sub>2</sub> reading  
October 02, 2018

405.46 ppm

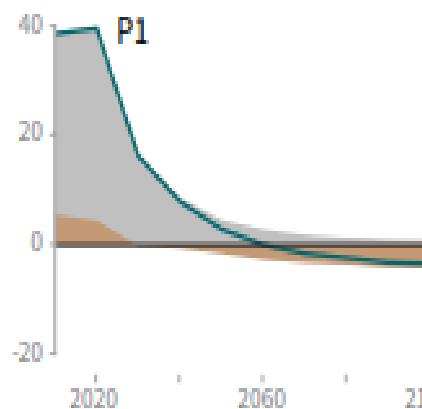
### Carbon dioxide concentration at Mauna Loa Observatory



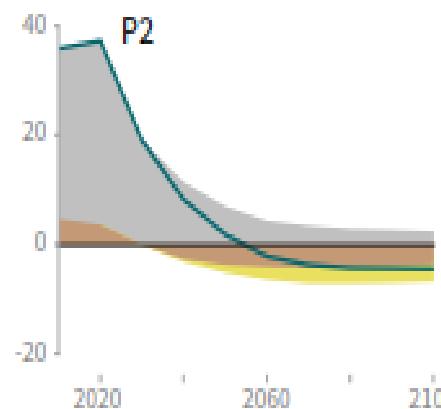
# Hvor mye mindre CO<sub>2</sub> kan vi slippe ut?

Fossil fuel and industry   AFOLU   BECCS

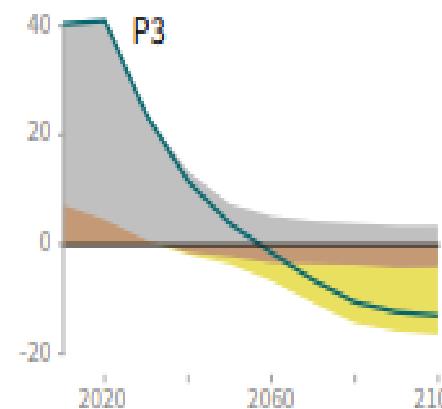
Billion tonnes CO<sub>2</sub> per year (GtCO<sub>2</sub>/yr)



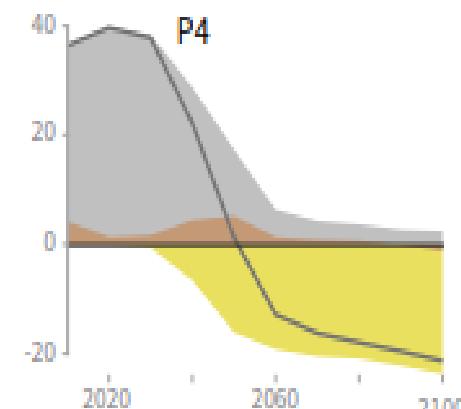
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P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

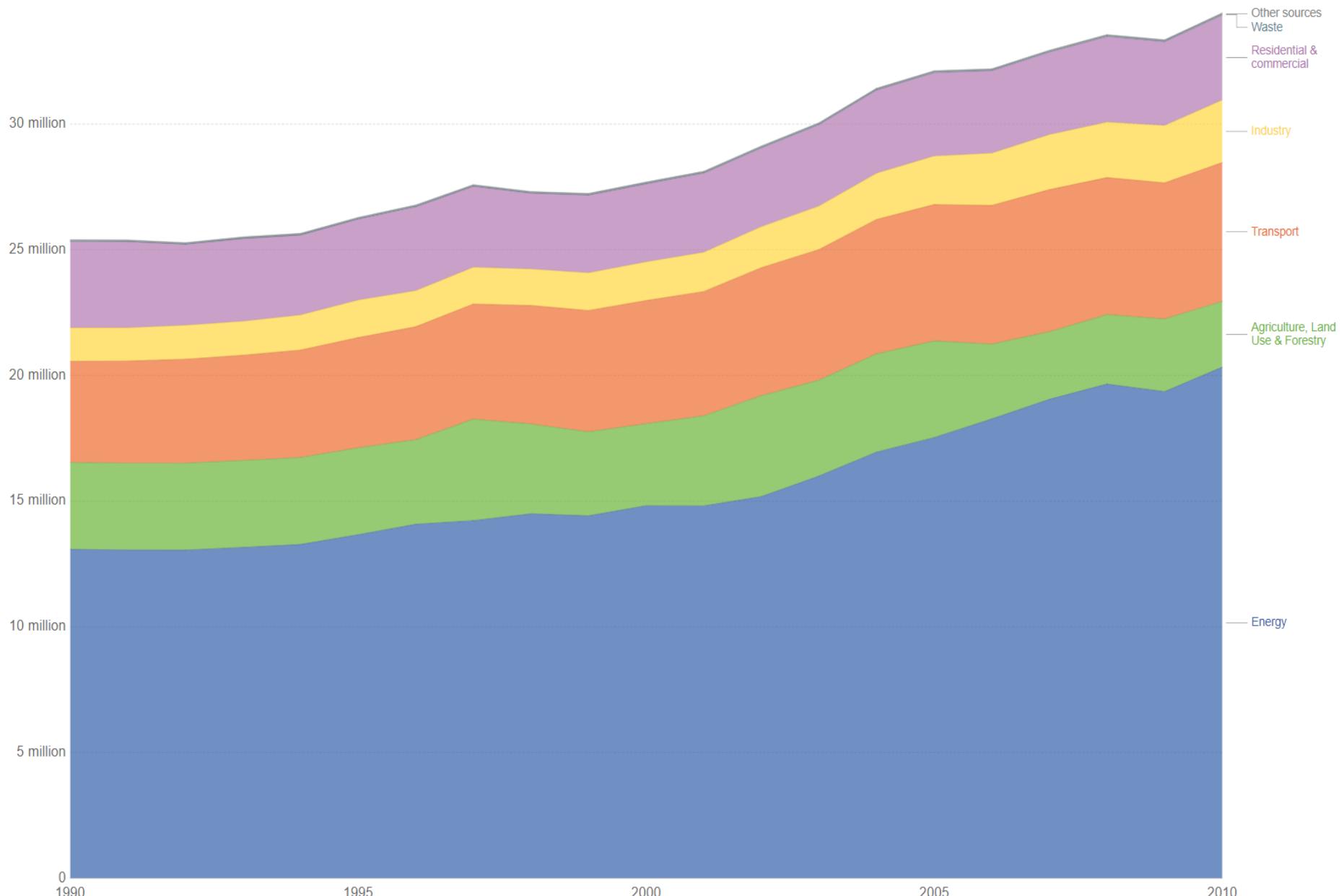
P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

# Global carbon dioxide emissions by sector (Gg CO<sub>2</sub>)

Global carbon dioxide (CO<sub>2</sub>) emissions, measured in gigagrams of CO<sub>2</sub> per year.

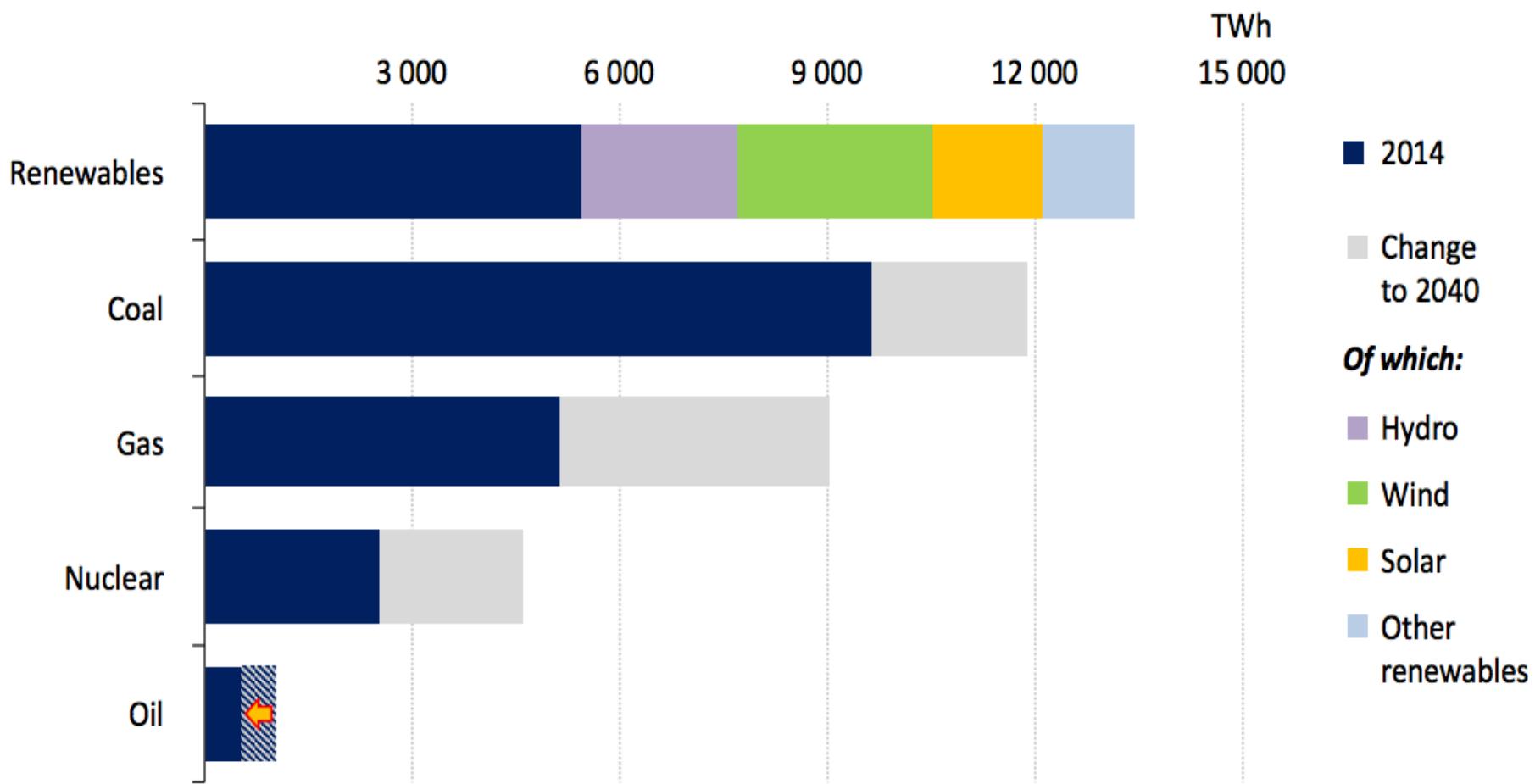


Source: UN Food and Agricultural Organization (FAO)

[OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/](http://OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/) • CC BY-SA

# Energibehov VIL øke

Global electricity generation by source

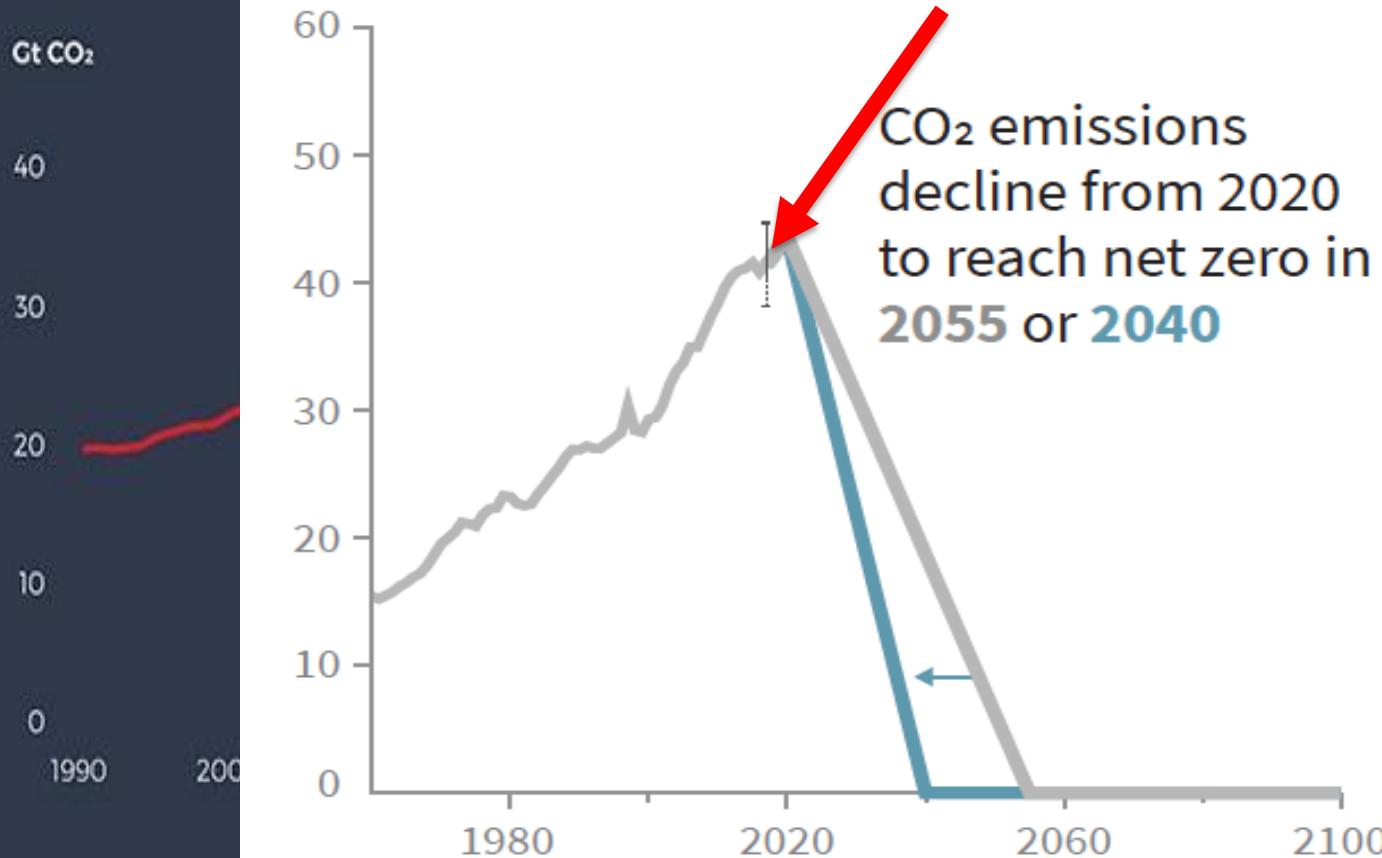


# Paris agreement



# Paris er ikke nok.

b) Stylized net global CO<sub>2</sub> emission pathways  
Billion tonnes CO<sub>2</sub> per year (GtCO<sub>2</sub>/yr)



2 °C target  
Sector must  
reach by 2100

9,4

MRD. TONN CO<sub>2</sub> | 1960

9,4

MRD. TONN CO<sub>2</sub> | 1960

36,2

MRD. TONN CO<sub>2</sub> | 2016

# CO2-håndtering status

- mer enn 220 millioner tonn CO2 er allerede lagret under bakken
- Ingen enkel historie i Norge



# Læring eller Kræsjlanding?

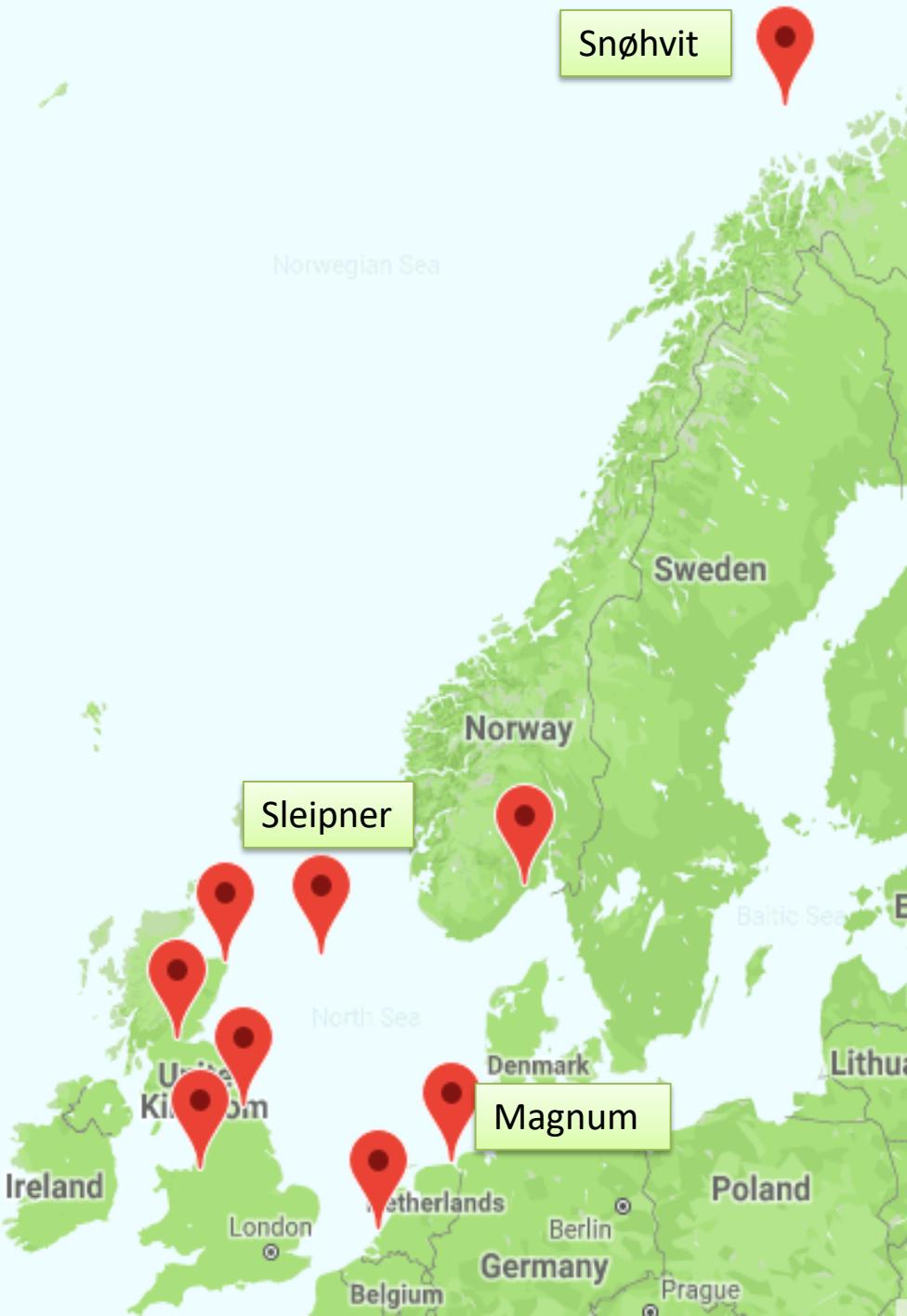
«Veien frem til utvikling av lagringsteknologi har vært lengre og tyngre og mer kostbar enn det vi forutså. Jeg er redd for at Mongstad ikke vil være et prosjekt som vil være et eksempel til etterfølgelse.»

Ola Borten Moe, 2014



# Europa

- Norge, England og Nederland eneste med CCS prosjekter i Europa nå.
- Ikke populært i EU



# Implementation

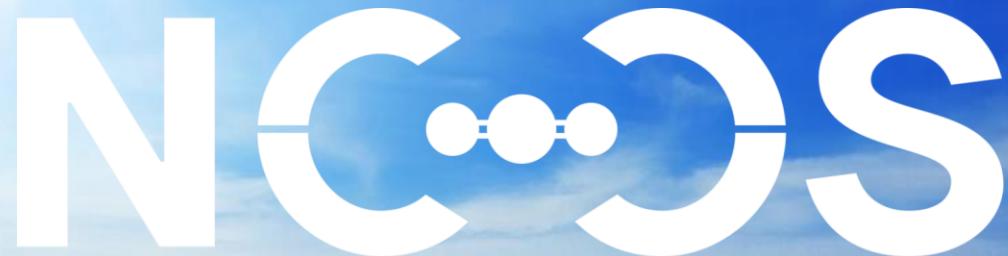
## ECCSEL preparatory phase

- Legal & governance
- Financing strategy
- Infrastructure development plan
- Access Policy & IPR
- Communication
- Outreach strategy
- Business Plan



**H2020 Infradev3 Consortium (2015 - 2017)  
with 42 research facilities/installations**

F  
m  
E



**NORWEGIAN CCS RESEARCH CENTRE**

Industry-driven innovation for fast-track CCS deployment

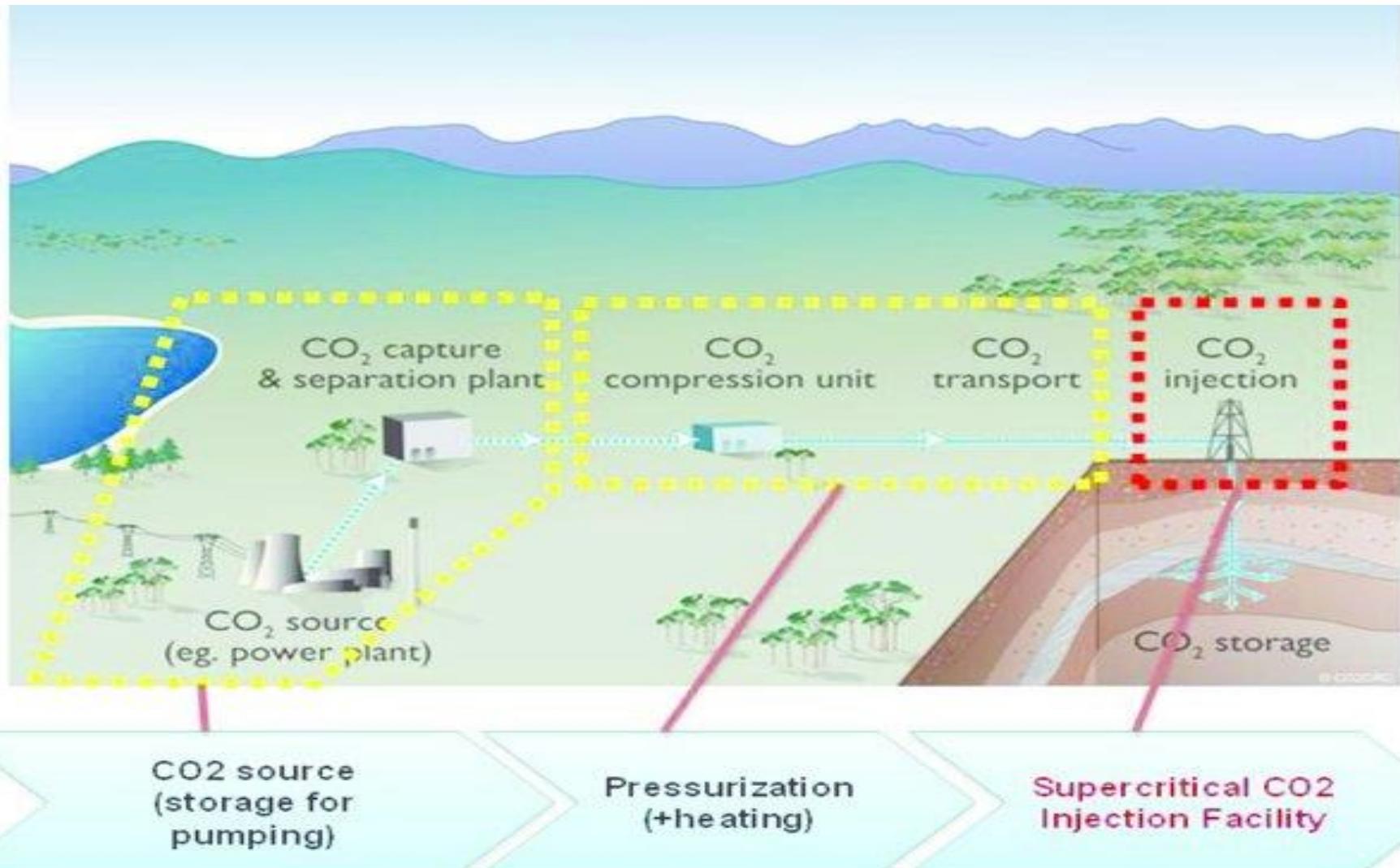
## Vision

*NCCS will enable fast-track CCS deployment through industry-driven science-based innovation, addressing the major barriers identified within demonstration and industry projects, aiming at becoming a world-leading CCS centre*

# A world-leading partnership

users		associated
vendor, in-kind	 	 Norges Rederiforbund Norwegian Shipowners' Association  U.S. DEPARTMENT OF ENERGY  GASSNOVA
university		
research inst.	 	

# CO<sub>2</sub> verdikjede

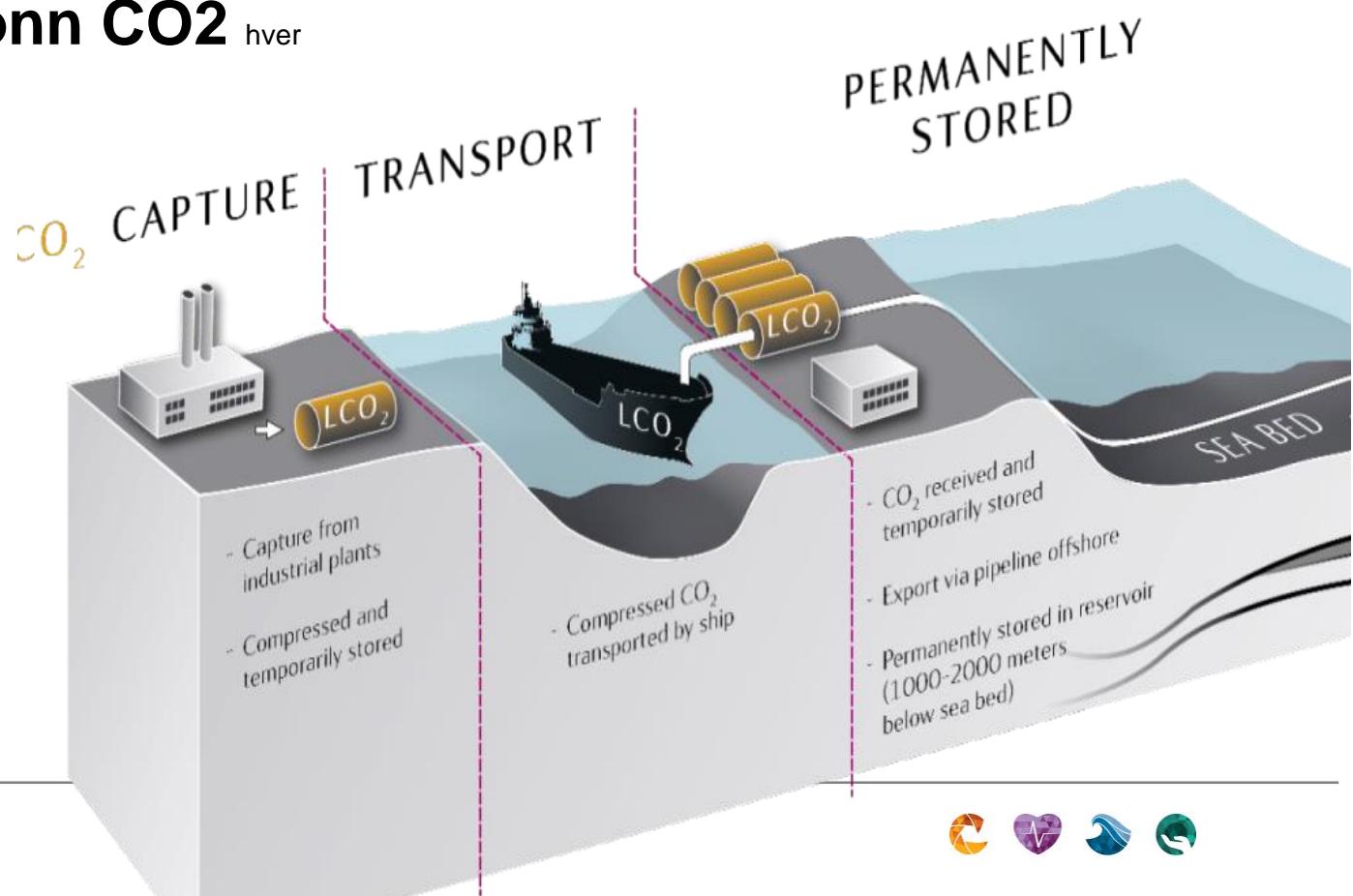


# Fullskala: Karbon fangst og lagring

Det norske fullskalaprosjektet:

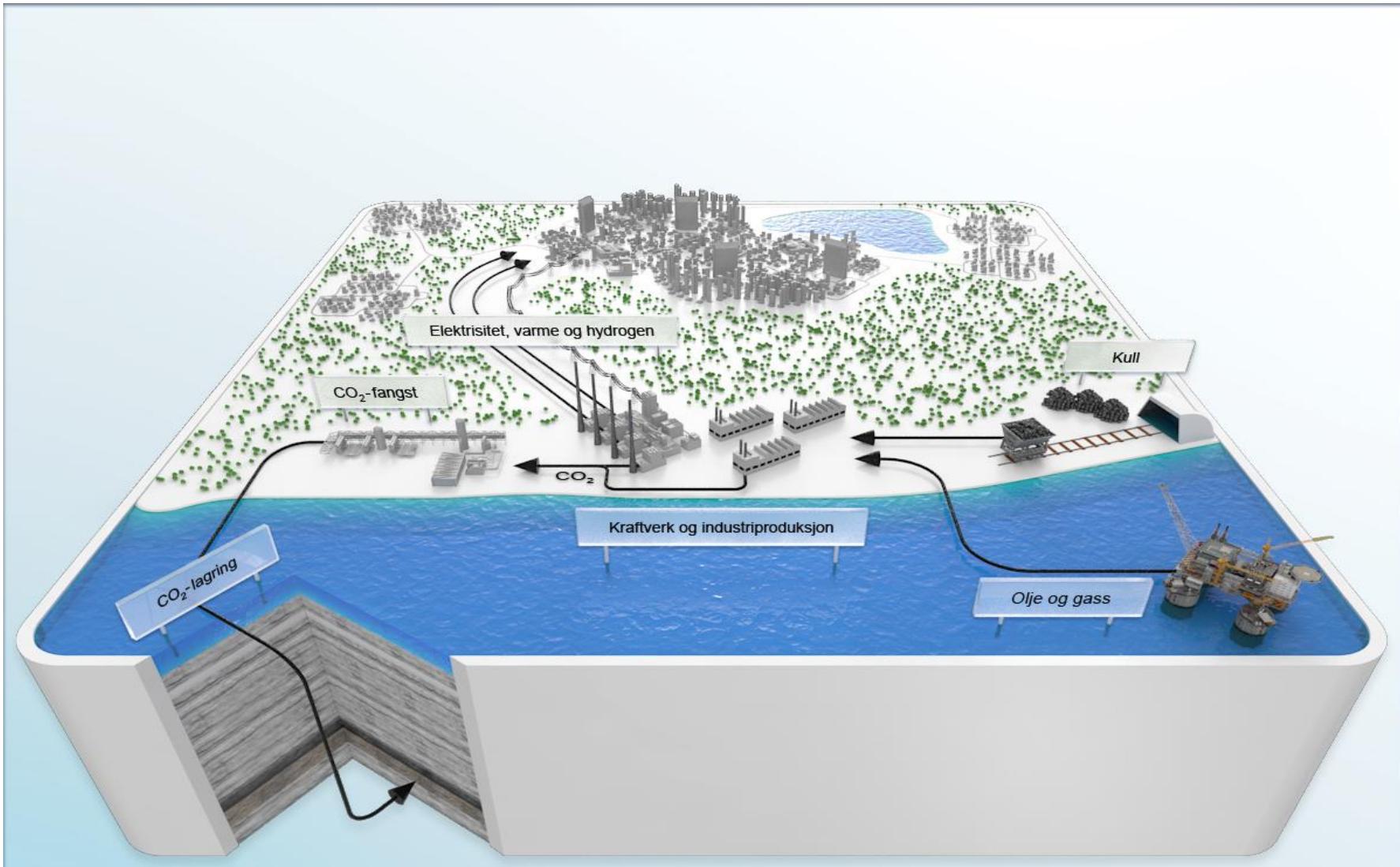
Norcem og Fortum Oslo Varme  
planlegger å fange  
ca.

**400.000 tonn CO<sub>2</sub> hver**

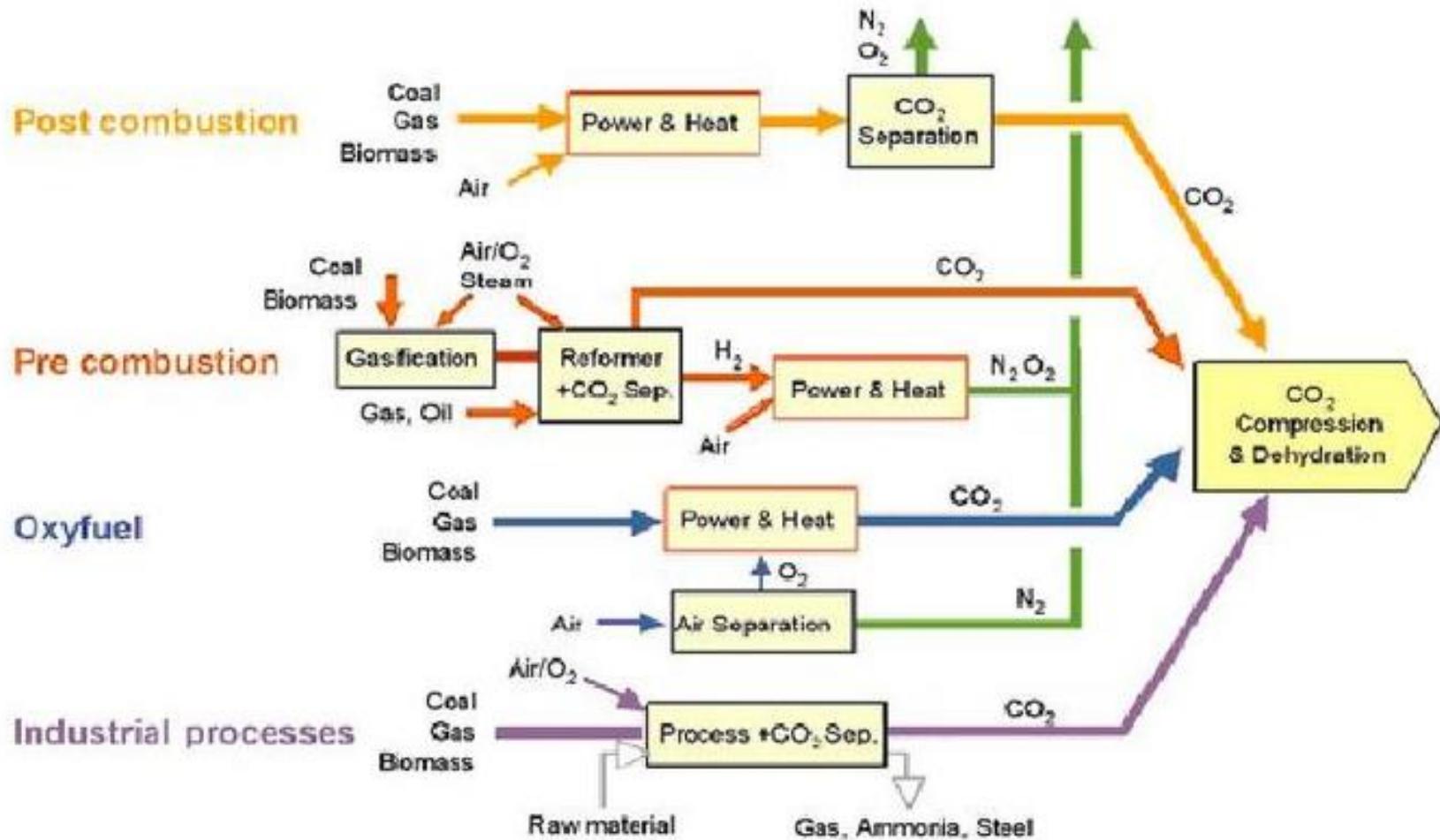


# Muligheter: Karbon fangst og lagring

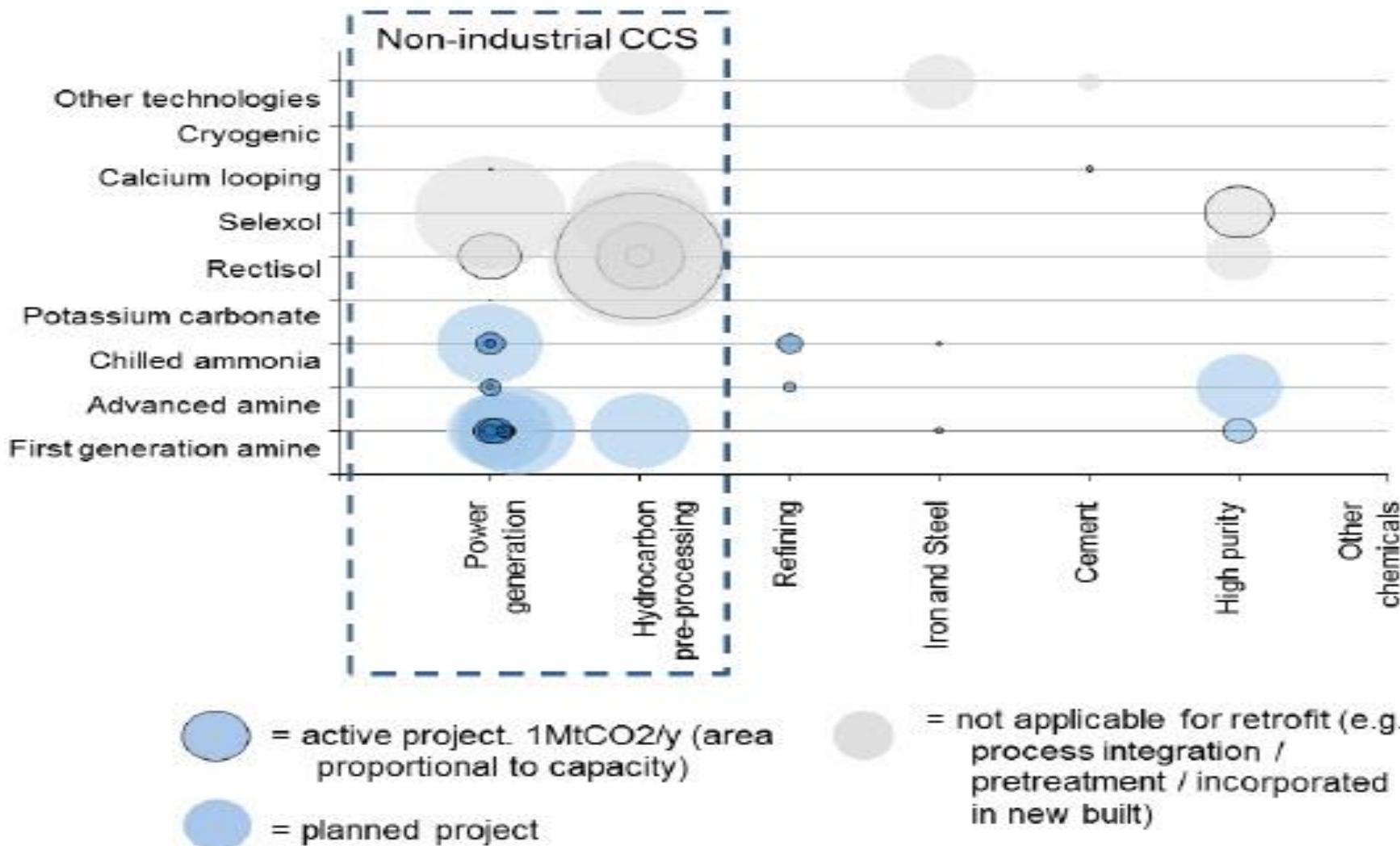
CCS er muliggjørende for fremtidig norsk utnyttelse av naturgass via hydrogen.



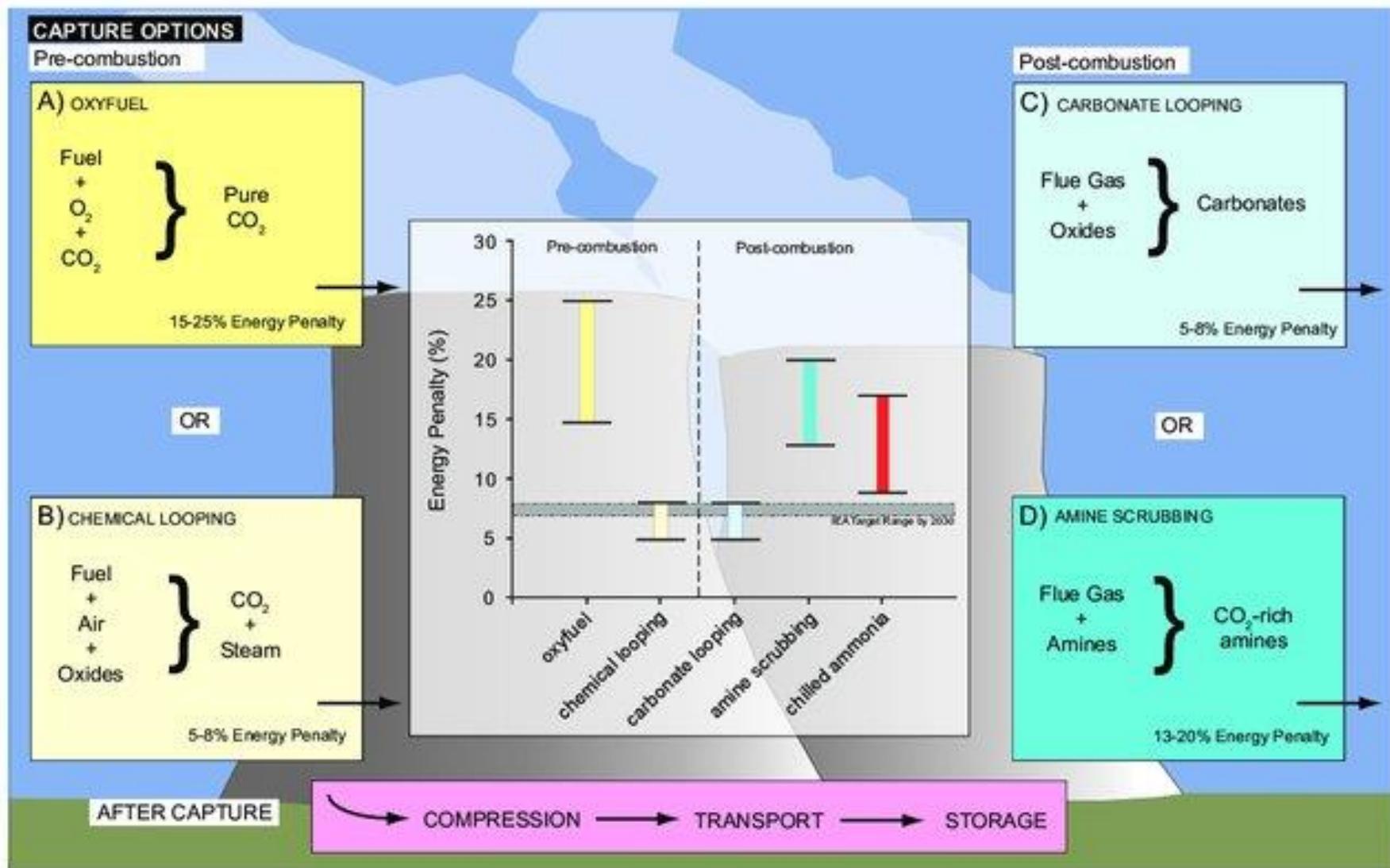
# CO<sub>2</sub> fangst systemer

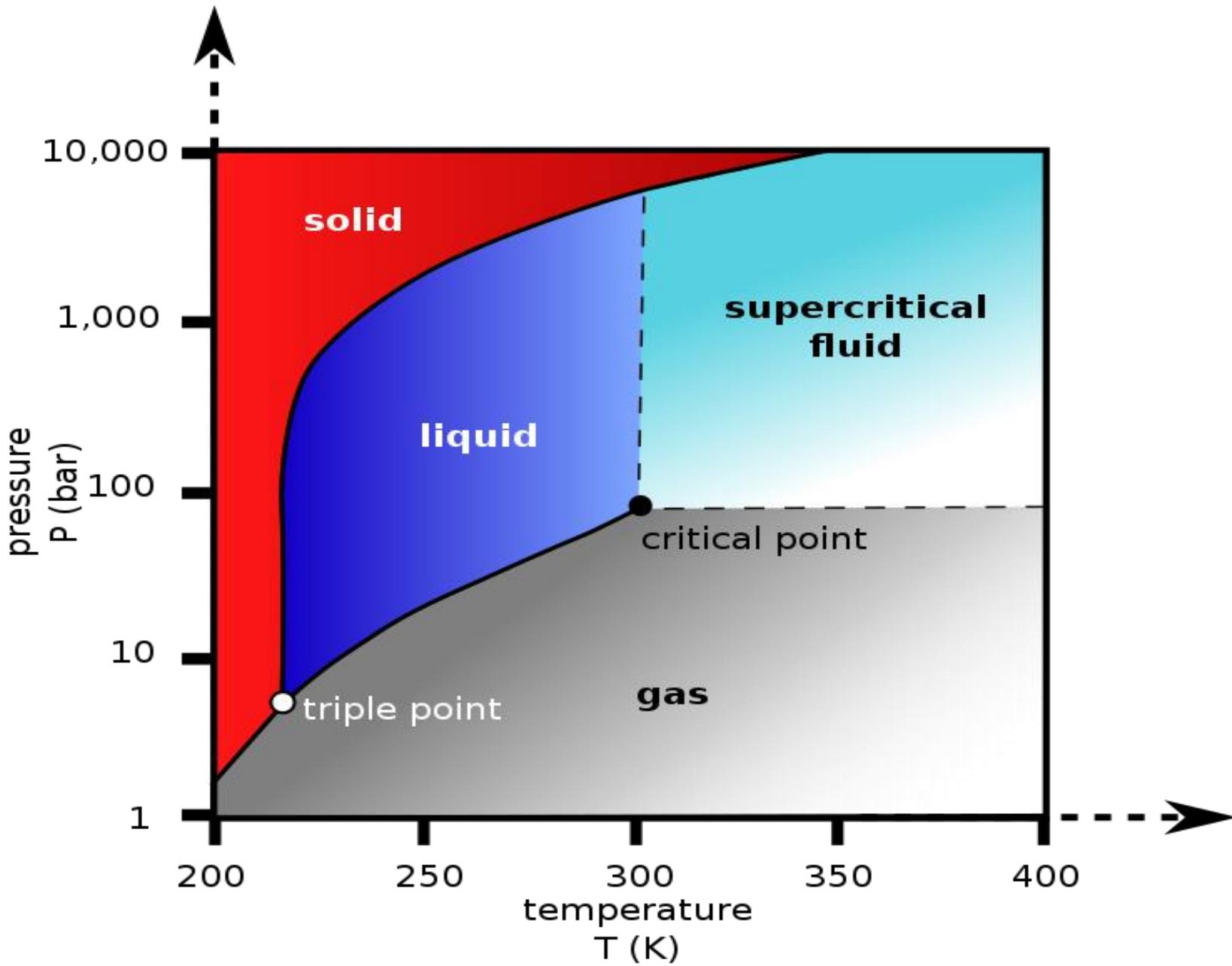


# Fangstteknologier/prosesser



# Energy penalty – Capture options





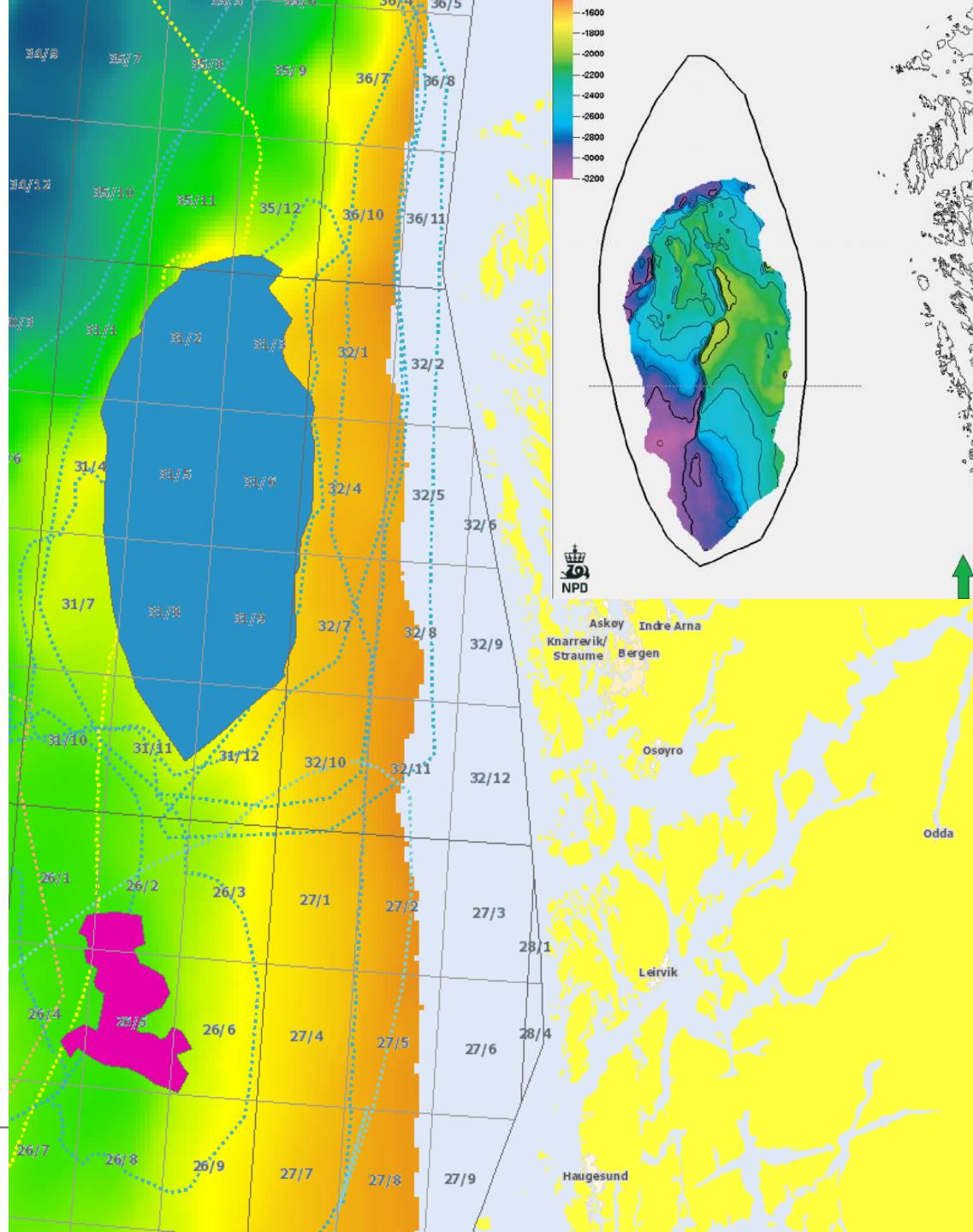
# Transport



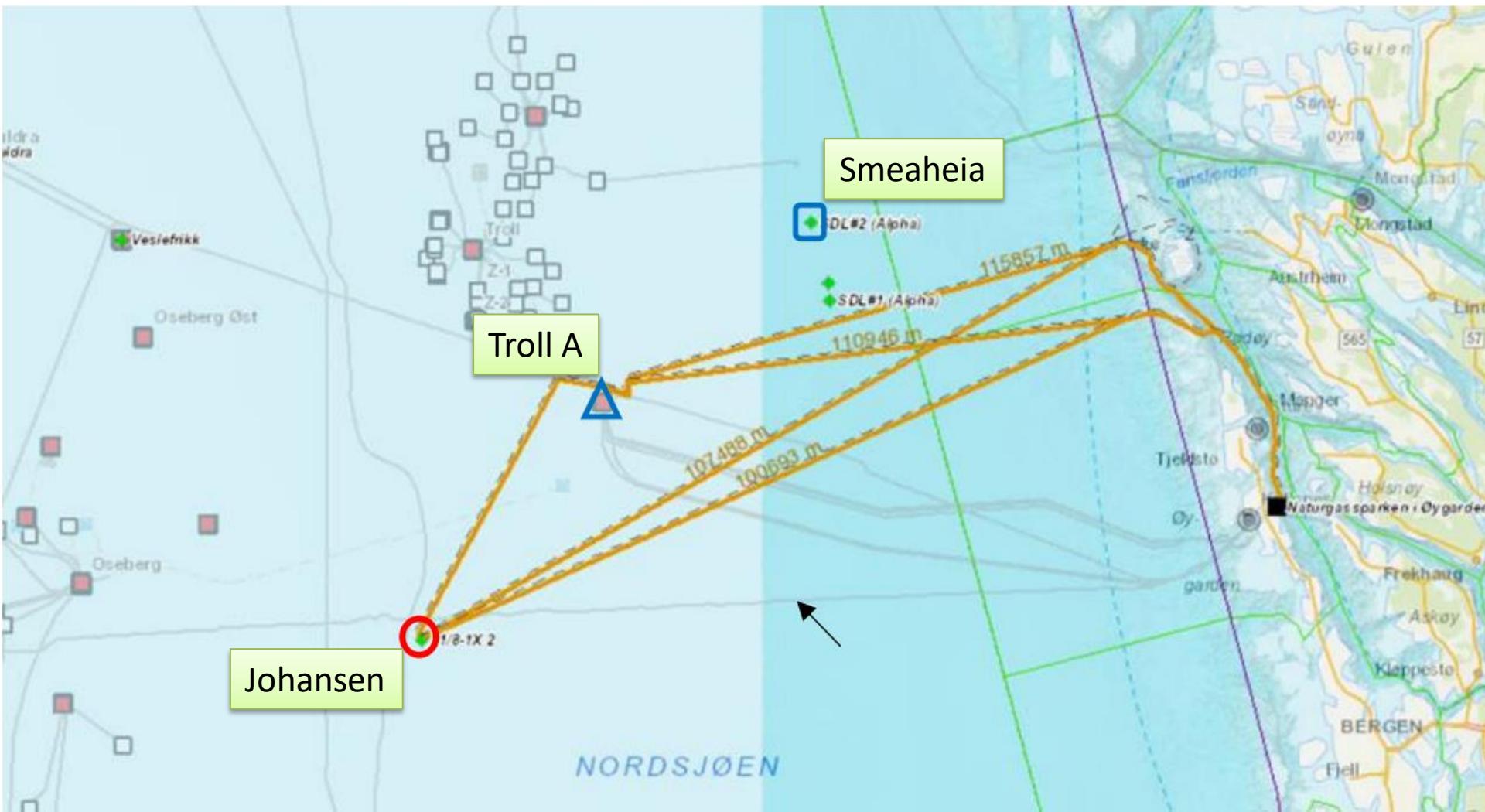
# Lagring

Equinors Northern Lights prosjekt

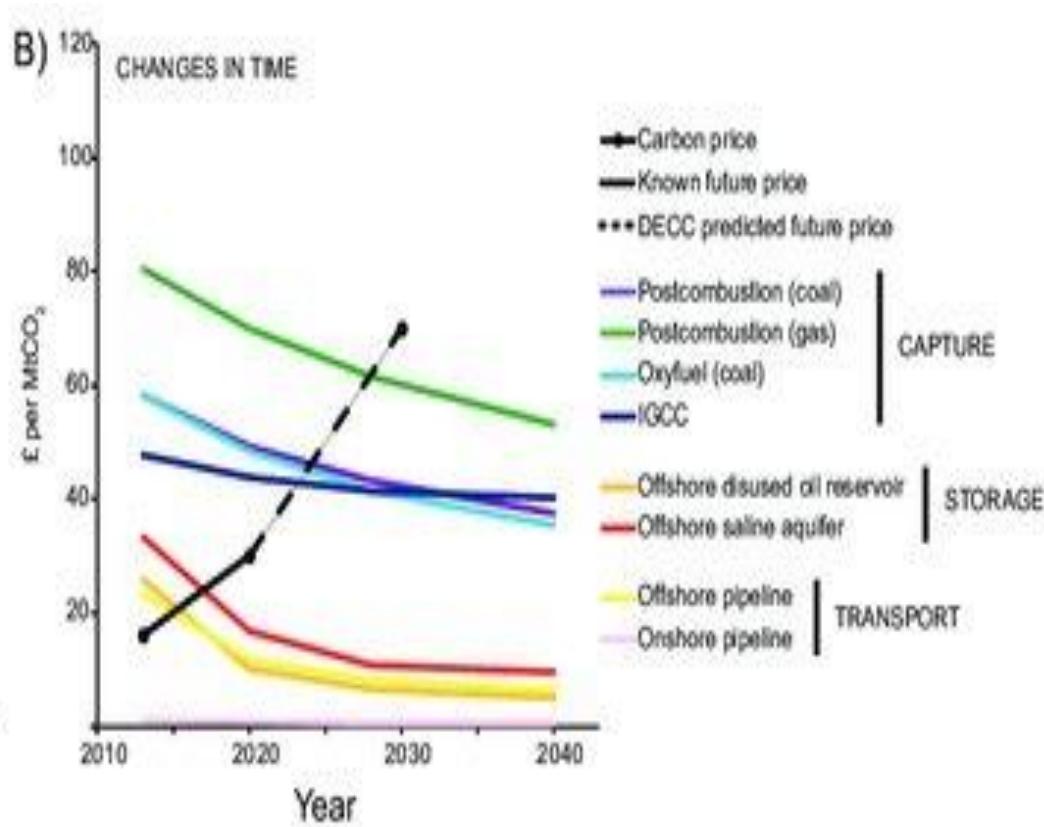
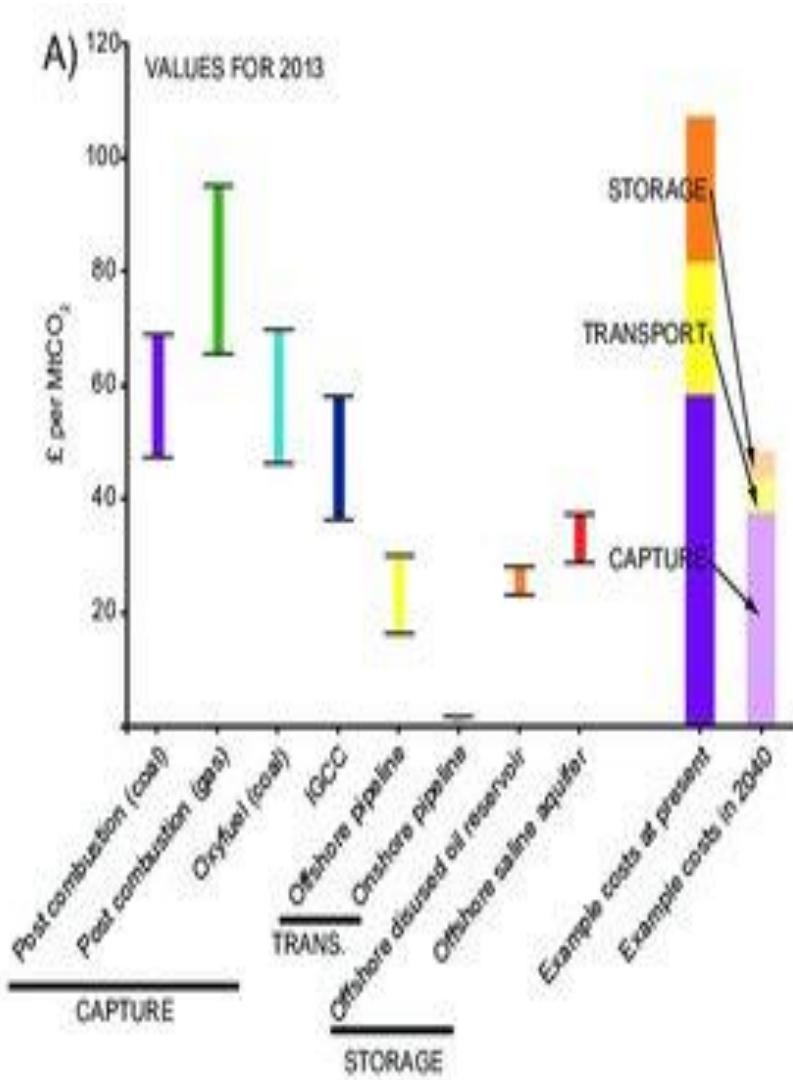
- Smeaheia utgår.  
Johansen er det nye  
stedet.
- Kan lagre 150  
millioner tonn CO<sub>2</sub>
- Johansen-  
formasjonen er vist i  
blått, som omfatter  
Trollfeltet
- Utsnitt i lite bilde viser  
dybde
- Lys fiolett farge viser  
et dyp på 3.200 meter



# Lagring – nytt forslag



# Kostnader



# Norske aktører

- Gassnova SF (2007-)
  - Climit er et program for forskning, utvikling og demonstrasjon av teknologi for CO<sub>2</sub>-håndtering i samarbeid med NFR.
  - Technology Center Mongstad (TCM DA) er verdens største testsenter for testing og forbedring av CO<sub>2</sub>-fangstteknologier
- NTNU, UiO ++
- SINTEF, IFE +
  - > NCCS
- Equinor, Total, Shell, Aker Solutions
- Gassco
- Norcem
- Fortum Varme
- (Yara)
- Forskningsrådet
- OED
- ++

# .....Myteknusing....?

- MYTH #1 - Europe has tried CCS, it failed. It will fail again.
- MYTH #2 - CCS is about saving the fossil fuels industry.
- MYTH #3 - CCS is not a climate mitigation technology.
- MYTH #4 - CCS is expensive and uncommercial.
- MYTH #5- CCS is unsafe and untested.
- MYTH #6 - There is not enough underground storage capacity.
- <https://www.linkedin.com/pulse/demystifying-carbon-capture-storage-olav-aamlid-syversen/?published=t>

# Finansiering (til diskusjon under middagen?)

- ❖ CCS-avgift? (på toppen av CO<sub>2</sub>-avgift)?
- ❖ Forretningsmodell forutsetter verdikjede
- ❖ Hvem skal betale investering?
- ❖ Hvordan tjene penger på fangst, transport og lagring av CO<sub>2</sub>?