Fangst og lagring af CO_2 som klimavirkemiddel

Energistyrelsen

CCS konference

September 2020

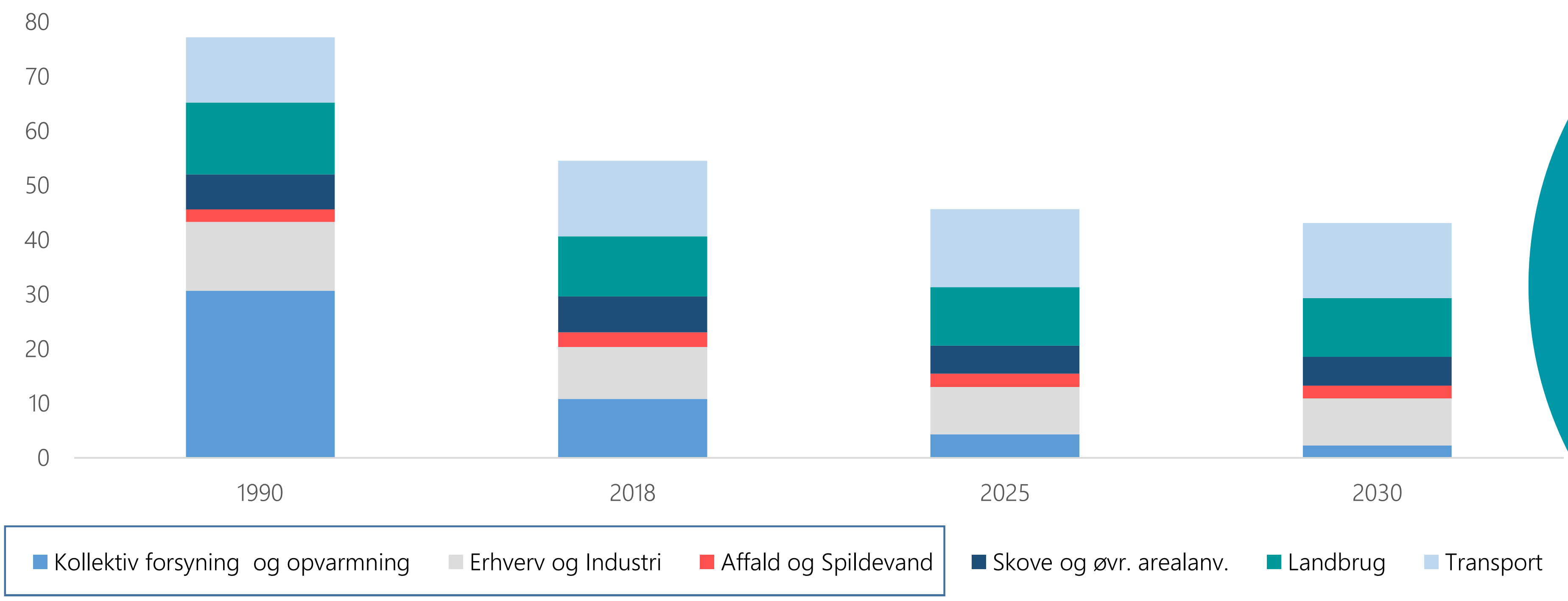
Fangst og lagring af CO2 som klimavirkemiddel

Dagsorden

1. CO_2-udledninger
2. Sæsonvariabilitet
3. Placering af CO_2-punktkilder
4. Anvendelse af indfanget CO_2

1. CO_2-udledninger

1.1. De samlede danske CO2-udledninger (mio. ton CO2-ækv.) opgjort på sektorniveau



Kilde: Basisfremskrivningen 2020, Energistyrelsen

Opgørelse af CO_2-udledninger (fossile/biogene) samt effekt af deponi

	Fossile udledninger	**Biogene udledninger**
Opgørelse af CO2 udledninger	Indgår	Indgår **ikke** (opgøres dog separat)
Opgørelse af CCS i FN / Klimalov	Reduktioner via CCS indgår **(nul-emissioner)**	Reduktioner via CCS indgår **(negative emissioner)**
Nuværende EU ETS marked	CCS sparer kvoteomkostning	CCS sparer **ikke** kvoteomkostning

1. CO_2-udledninger

1.3. Udledninger fra punktkilder: Nu og i fremtiden

Udviking i CO_2-udledninger fra punktkilder (mio. tons) er usikker – forventes at falde over tid

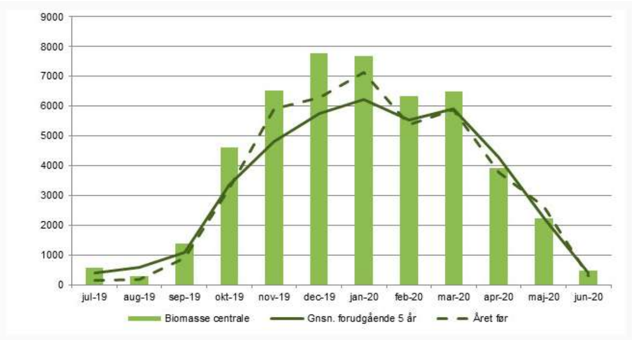
	2018		2030		2040	
	Fossil	Biogen	Fossil	Biogen	Fossil	Biogen
Kraftværker inkl. biogasanlæg	8	9		11		~8
Affaldsfyrede værker	1	2	1	2		~2
Industri	4		4		~4	

- Hvor meget biomasse i kraftvarmeværker på lang sigt?
  - Kraftværker på biomasse forventes reduceret fra 2030 til 2040
  - Biogas forventes at øges over tid
- Affaldsfyrede værkers udledning forventes halveret mod 2040
- Udviklingen i industrien afhænger i høj grad af få, store punktkilder
- Langsigtet årligt fangstpotentiale vurderes i niveauet 5-10 mio. tons

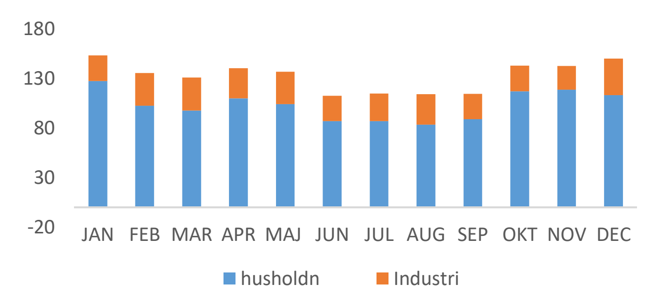
2. Sæsonvariabilitet på forskellige punktkilder

- Biogene CO_2-udledninger fra kraftværker følger varmesæsonen.
- Udledningerne fra de affaldsfyrede værker er relativt jævnt hen over året.
- CO_2-udledningen fra industrien forventes at fordele sig jævnt hen over året.

Biomasseforbrug (TJ) centrale værker



Produktionsmønster v. affaldsværker, 2019 (GWh)



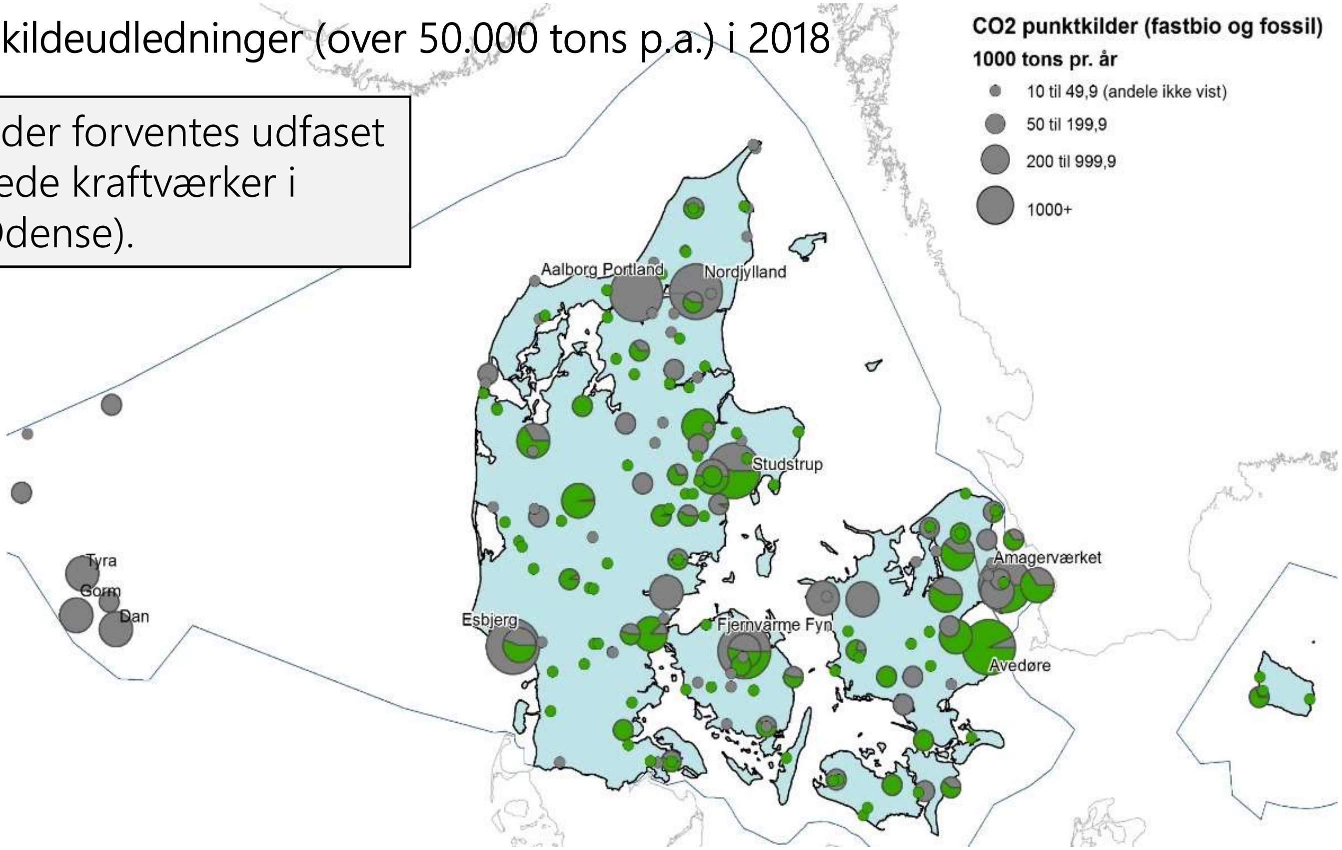
Sæsonvariabilitet kan have betydning for:

- Kapacitetsudnyttelsen af fangstanlægget (fangstpris pr. ton).
- Mellemlager-/transportomkostning.
- Attraktiviteten ift. anvendelse i PtX-produktion (samtidighed).

3. Placering af CO_2-punktkilder

Placeringen af CO_2-punktkildeudledninger (over 50.000 tons p.a.) i 2018

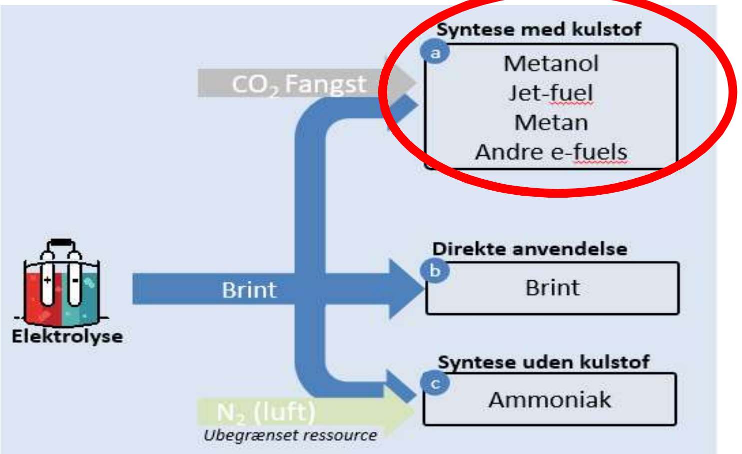
De største fossile punktkilder forventes udfaset frem mod 2030 (kulbaserede kraftværker i Nordjylland, Esbjerg og Odense).



4. Anvendelse af indfanget CO_2

CO_2-anvendelse i PtX

Muliggør reduktioner **i transportsektoren**



Kilde: Analyseforudsætninger

- 2030/40 elektrolyseanlæg GW: ½-3 / 1-6
- 1 GW elektrolyse ~ 0,5 mio. ton CO2
- Årligt CO_2-behov mod 2040: ½-3 mio. ton

CO_2-fangst

Transport og deponi af CO_2

Muliggør negative reduktioner

- Stort potentiale for dansk deponikapacitet
- *Storskala og fuld kapacitetsudnyttelse* er centralt for både transport af CO2 i rør og deponi
- Eksport af dansk CO_2 -fangst til deponi i udlandet - eller import af udenlandsk fangst til deponi i Danmark
- En langsigtet national og internatonal strategi for transport og deponi bliver vigtig

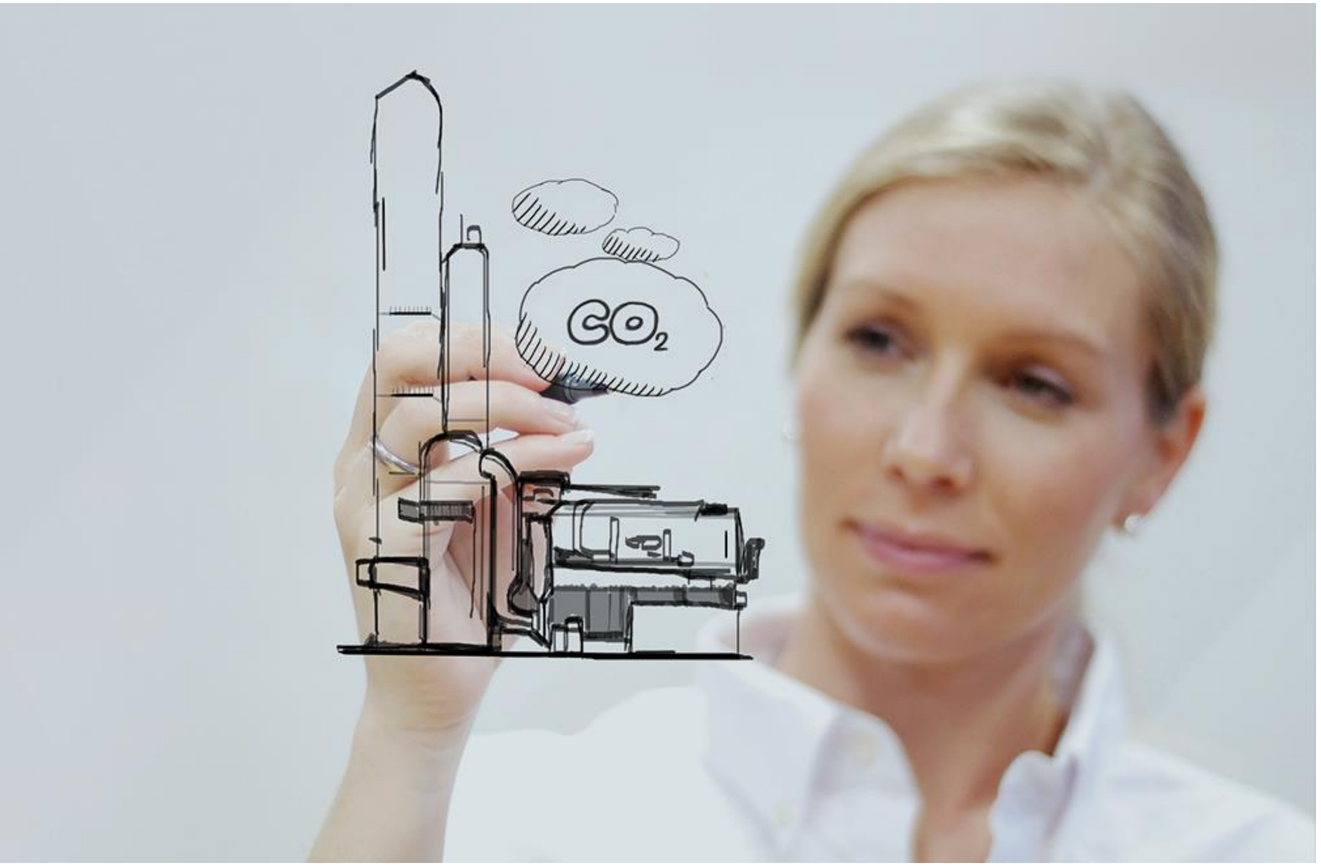
Aker Carbon Capture

Capturing CO2

AN OPPORTUNITY FOR DANISH INDUSTRY AND EMITTERS

22. September 2020

Jon C Knudsen, CCO, Aker Carbon Capture



Norway is moving ahead

An opportunity for a Danish fast track approach

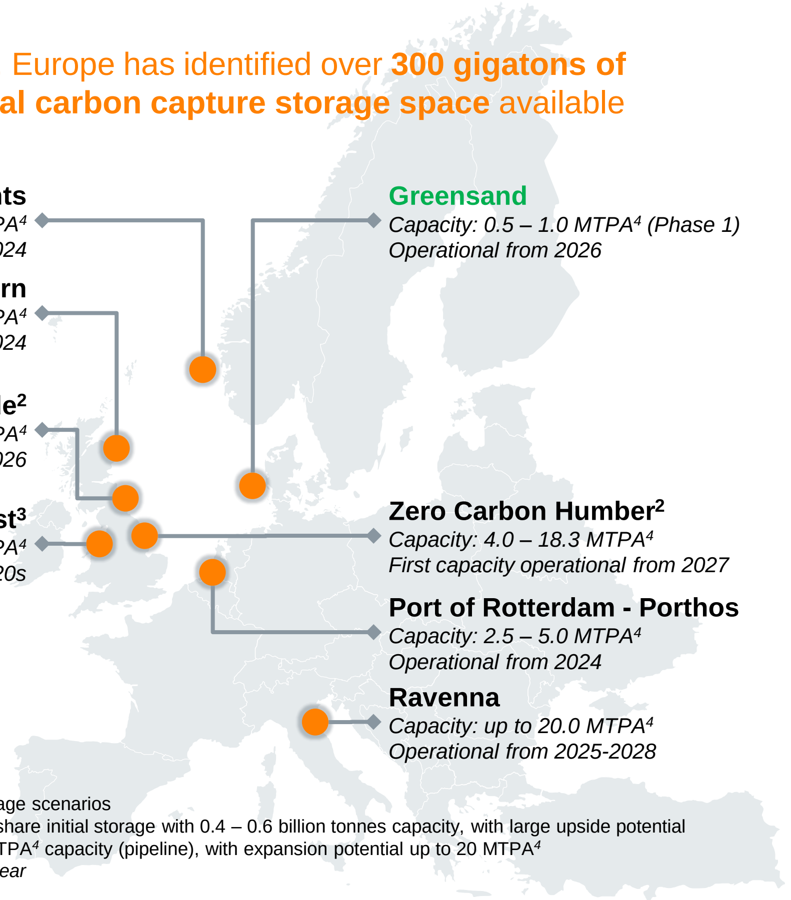
- We welcome today's decision to start full-scale CO2 capture and storage in Norway, and we look forward to working with Norcem HeidelbergCement, Norwegian authorities and all other stakeholders to realize this groundbreaking project, and to deploy Aker Carbon Capture's patented technology in a large scale EPC delivery to their site in Brevik.

Valborg Lundegaard, CEO – Aker Carbon Capture

Strong growth in carbon capture storage projects in Northern Europe...

8 storage projects under development | **~78 MTPA[4]** planned storage capacity, equivalent to **~780 Just Catch™**

Currently, Europe has identified over **300 gigatons of geological carbon capture storage space** available



1) Potential second phase storage scenarios
2) Teesside and Humber may share initial storage with 0.4 – 0.6 billion tonnes capacity, with large upside potential
3) Initial system sized for 10 MTPA[4] capacity (pipeline), with expansion potential up to 20 MTPA[4]
4) *MTPA = Million tonnes per year*

UK remains focused on carbon capture, utilisation and storage

- Several storage locations in process
- CCS Infrastructure Fund of at least GBP 800 million established
- Ambition to reach net-zero carbon emissions by 2050

Project Greensand

- New Danish carbon capture storage (CCS) consortia with Ineos, Maersk Drilling and Wintershall Dea
- Received EUDP funding in June 2020
- Plan is to capture CO_2 in Ineos' Nini-felt

Project Ravenna

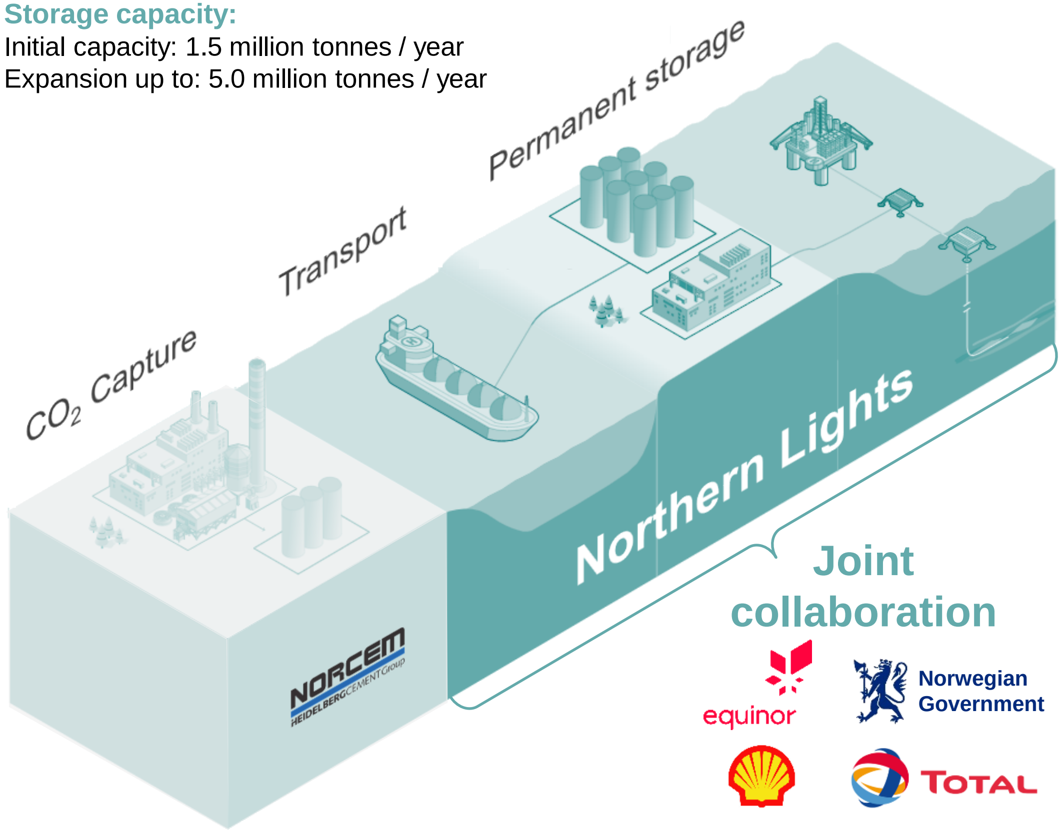
- New storage location by ENI in the Adriatic, off the coast of Ravenna, using exhausted natural gas fields
- Storage capacity of between 300 and 500 million tonnes
- Demonstration projects and full-scale projects in progress

Sources: GCC Global Status Report 2019; Project websites

...with Northern Lights being the Norwegian initiative

Up to **5 million** tonnes / year storage capacity | Serving plants **across Europe** | Operational from **2024**

Storage capacity:
Initial capacity: 1.5 million tonnes / year
Expansion up to: 5.0 million tonnes / year



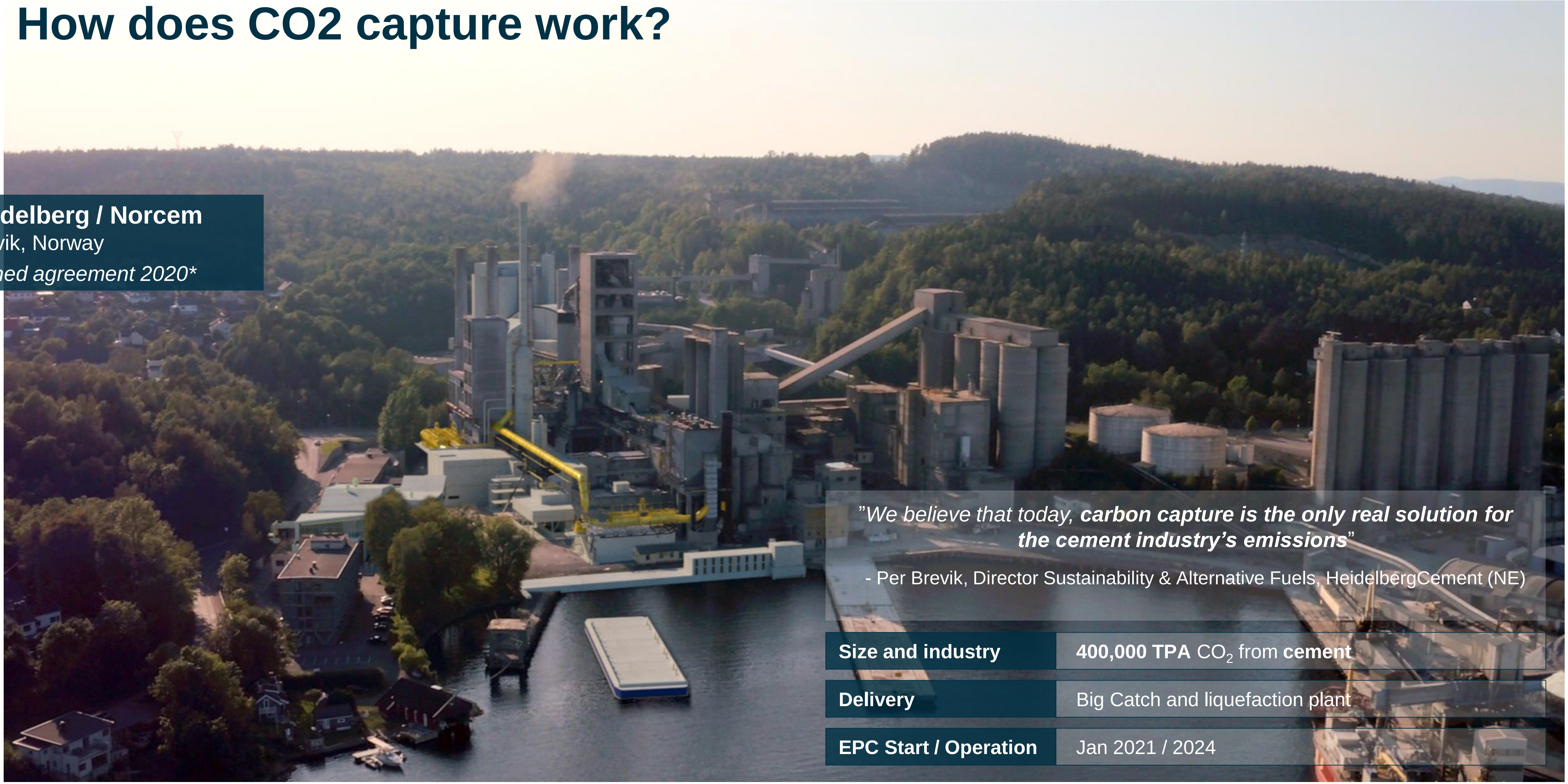
Northern Lights – CCS value chain development

- **First step** in developing a full-scale CCS value chain in Norway. Northern Lights comprises the **transport and permanent storage** stages
- Northern Lights to receive CO_2 captured at **Norcem cement plant in Brevik / Fortum waste-to-energy plant in Oslo** and other **European sites**
- **Excess capacity of ~0.7 million tonnes / year** in the initial phase as Norcem and Fortum will provide ~0.8 million tonnes / year combined

Norwegian Government participation

- The Norwegian government is considering to fund **~80% of costs**. Recommendation from the Norwegian Government to move forward was announced on **21. September 2020**

How does CO2 capture work?



Heidelberg / Norcem
Brevik, Norway
*Signed agreement 2020**

*”We believe that today, **carbon capture is the only real solution for the cement industry’s emissions**”*

- Per Brevik, Director Sustainability & Alternative Fuels, HeidelbergCement (NE)

Size and industry	**400,000 TPA** CO_2 from **cement**
Delivery	Big Catch and liquefaction plant
EPC Start / Operation	Jan 2021 / 2024

*) Contract dependent on final investment decision by the Norwegian Government in October

Carbon capture – a proven technology at scale

A comprehensive carbon capture technology with unique HSE characteristics from market leading solvent

Carbon capture process

1 Carbon capture

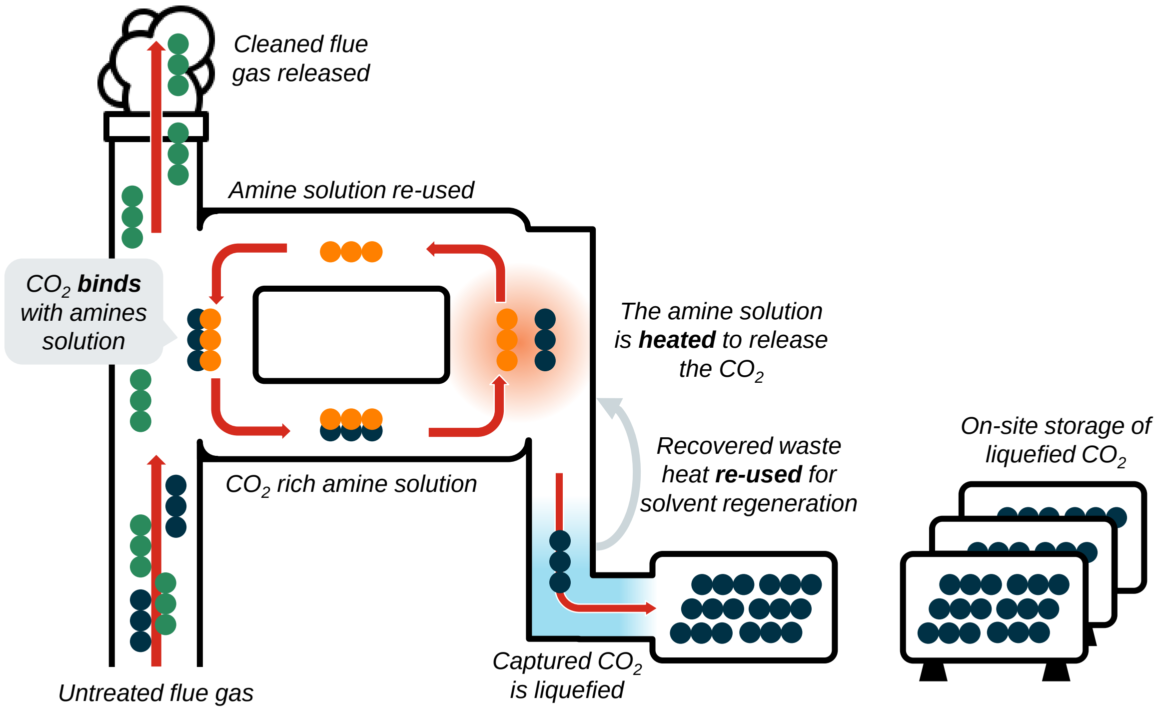
Relates to the amine loop of binding and releasing CO_2

2 Liquefaction

Relates to the cooling and compression of captured CO_2

3 On-site storage

Relates to storage of liquefied CO_2 before transportation



Superior HSE characteristics

- ✓ Minimum emission
- ✓ Non-toxic
- ✓ Biodegradable
- ✓ Minimum liquid waste
- ✓ Minimum corrosion

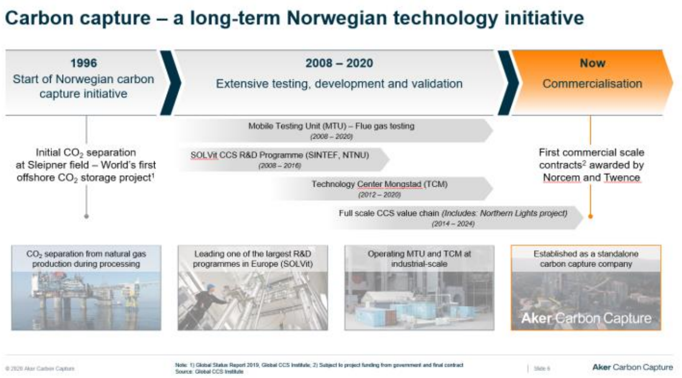
Energy efficient

- ✓ Energy efficient reclamation
- ✓ Superior energy plant integration
- ✓ Optimal integration toward conditioning

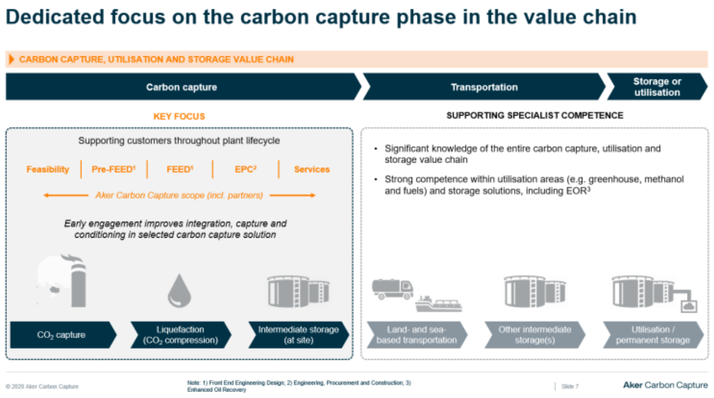
Proven

- ✓ 50,000+ operating hours
- ✓ Tested on 7 different flue gases

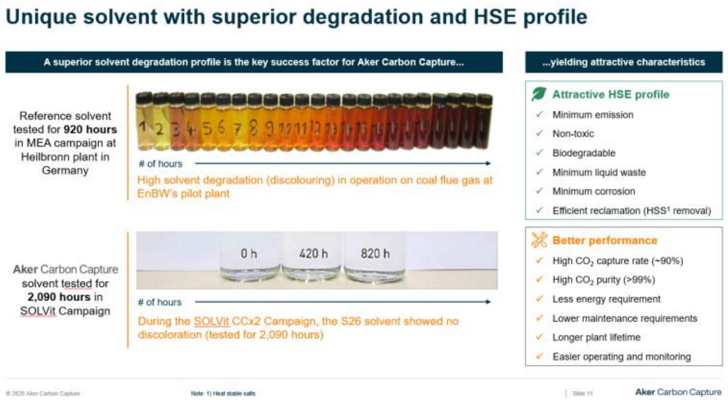
Key opportunities for Danish industry emitters



Experience matters

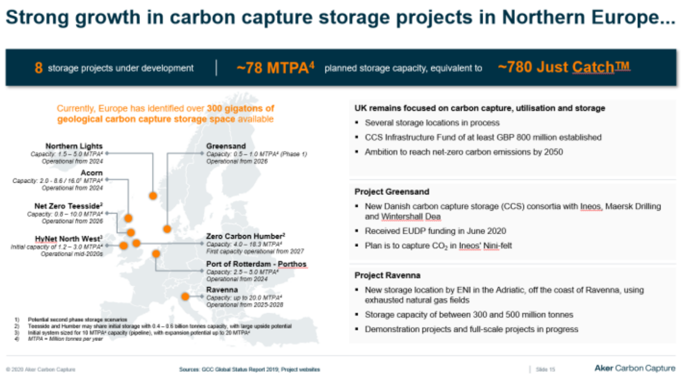


Scale matters



HSE a key differentiator

Delivery is important



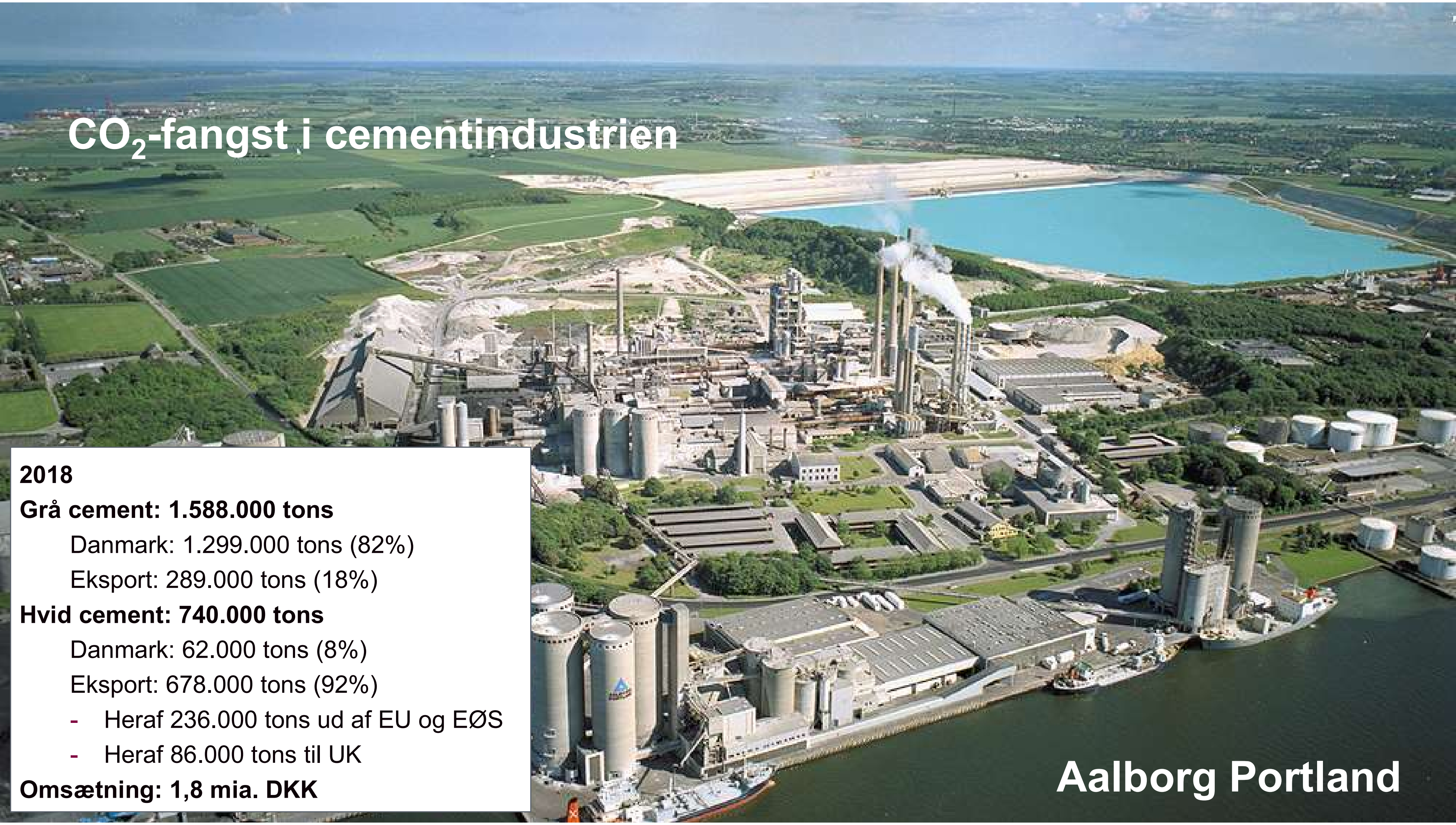
Danish storage a possibility

Aker Carbon Capture – an opportunity to fast track Danish initiatives

Note: 1) Health, Safety and Environment; 2) United Nations; 3) International Energy Agency
Source: United Nations

Aker Carbon Capture

CO_2-fangst i cementindustrien



2018

Grå cement: 1.588.000 tons

Danmark: 1.299.000 tons (82%)

Eksport: 289.000 tons (18%)

Hvid cement: 740.000 tons

Danmark: 62.000 tons (8%)

Eksport: 678.000 tons (92%)

- Heraf 236.000 tons ud af EU og EØS
- Heraf 86.000 tons til UK

Omsætning: 1,8 mia. DKK

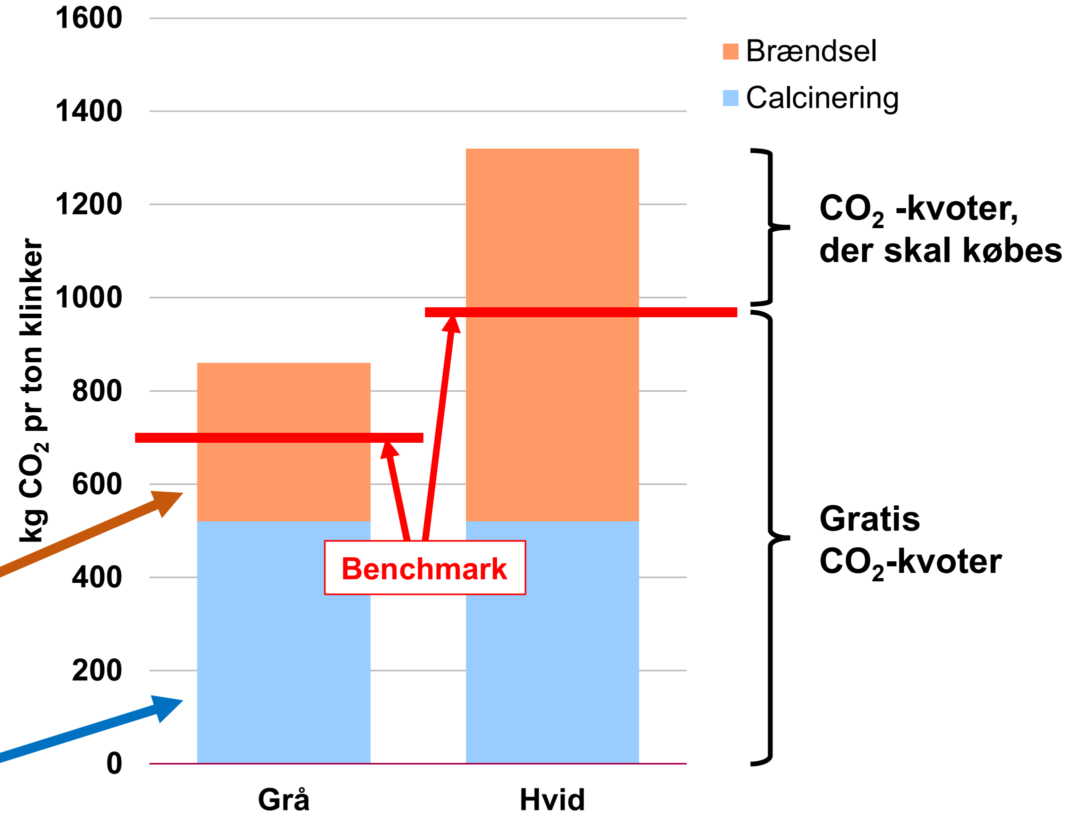
CO_2 og cement

CO_2-udledning i forbindelse med brug og produktion af cement i Danmark

- **Fra brug af cement: 1.3 millioner tons**
  - 1,5% af Danmarks udledning (ækv. CO_2)
- **Fra produktion af cement: 2,3 millioner tons**
  - 2,6% af Danmarks udledning (ækv. CO_2)

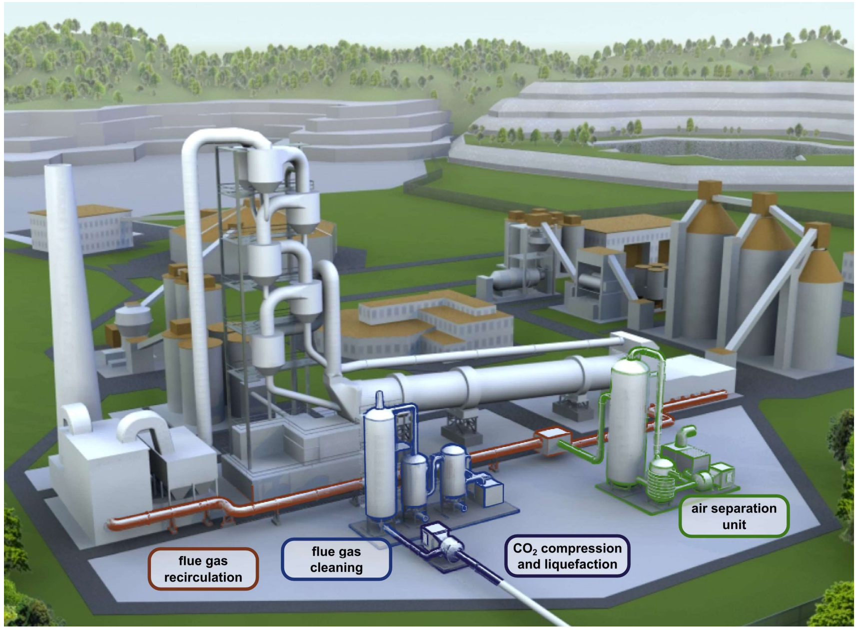
CO_2 kan mest effektivt reduceres ved brug af brændsler med indhold af biomasse. Kan tilføres ved brug af brændbart affald som brændsel

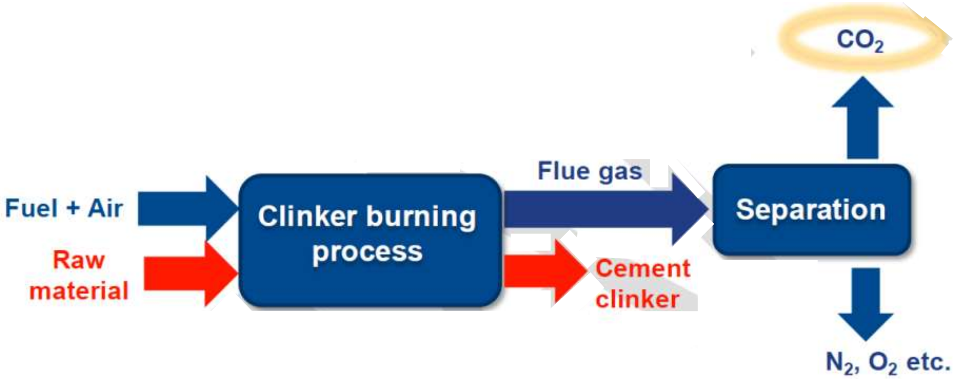
Kridt nedbrydes til brændt kalk og CO_2. Ingen reelle muligheder for at begrænse udledning pr. tons klinker



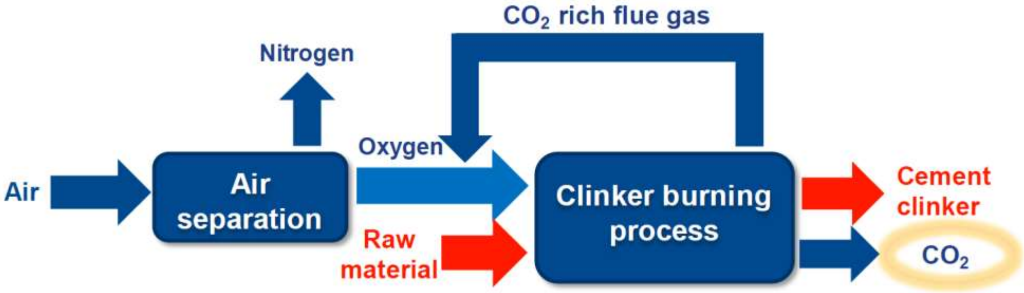
Anslået omkostning til CO_2-kvoter i 2021: 128 millioner kr.

CO_2 fangst fra cementproduktionen





Post-combustion

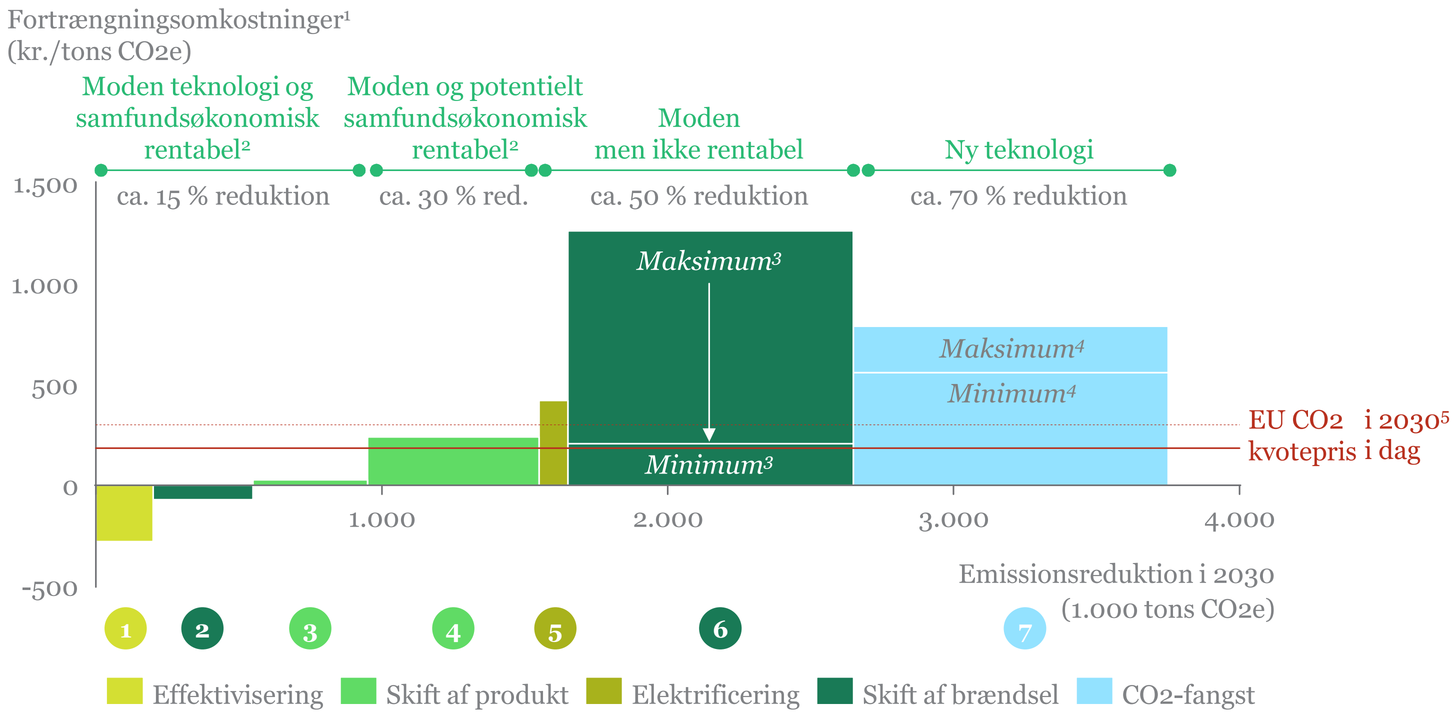


Illustrationer fra ECRA, European Cement Research Academy

Oxyfuel

Regeringens klimapartnerskab for energiintensiv industri:

Reduktioner over 30% kræver væsentlige investeringer



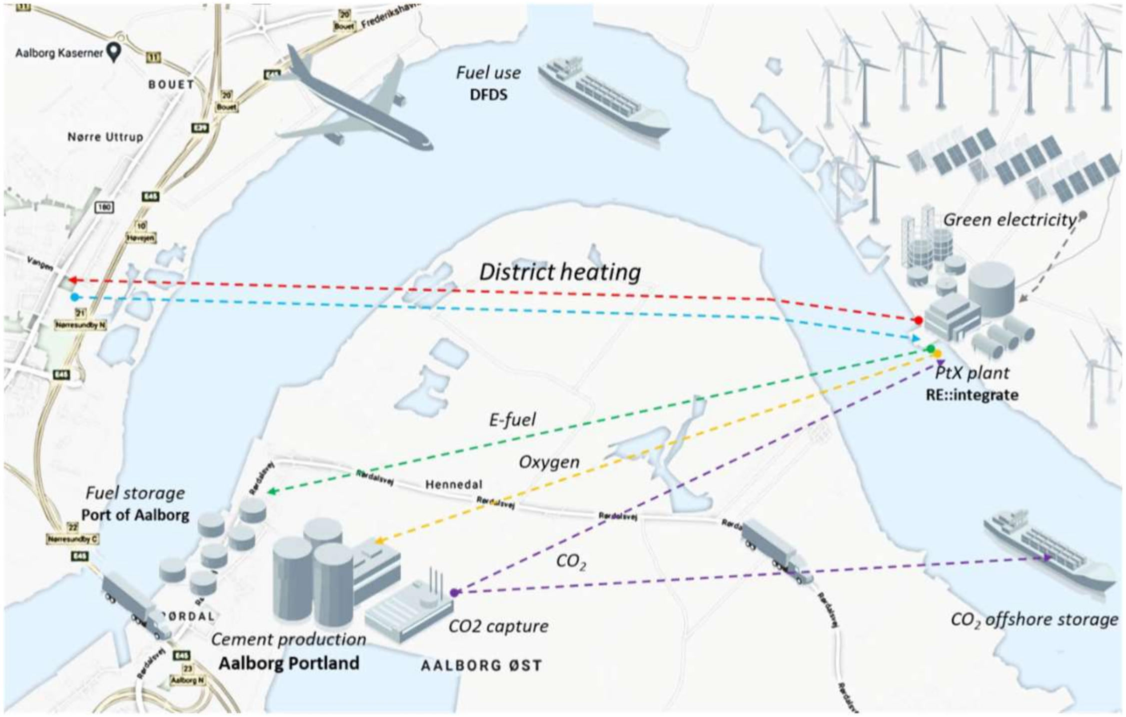
1. Samfundsøkonomisk fortrængningsomkostning, som ikke betragter afgifter, manglende likviditet, tilbagebetalingstid eller konkurrenceevne; 2. Rentabel ved inklusion af EU's CO2 kvotepris som skyggepris for samfundsomkostning ved udledning af CO2; 3. Maksimum med nuværende biogaspris uden tilskud, minimum inkluderer tilskud og en hypotetisk halvering af biogasprisen, som dele af biogassektoren har estimeret; 4. Usikkerhed i omkostningerne for CO2-fangst med estimeret minimum og maksimum; 5. Baseret på en undersøgelse af Carbon Pulse.
Kilde: Klimapartnerskabets analyse.

1. Effektivisering
2. Alternative brændsler
3. Skift af produkt (primært bæredygtig cement)
4. Skift af produkt (primært bioolie i raffinaderi)
5. Elektrificering
6. Skift til biogas
7. CO2-fangst

GreenCem

Formål: at identificere den mest lovende teknologi for CO_2 fangst hos Aalborg Portland

- Både CO_2 lagring og anvendelse vil bliver undersøgt
- Målsætningen er at etablere et beslutningsgrundlag for et demonstrationsanlæg og på sigt et anlæg i fuld skala.
- Synergierne i Aalborg-området skal udnyttes
- Budget: 11 mill. kr., støtte fra EUDP: 6,7 mill. kr.
- Partnere: Aalborg Portland, Aalborg Universitet, Aalborg Forsyning, Re::Integrate, Cemtec Foundation, DFDS, Aalborg Havn
- Sideløbende PhD-projekt under MADE: Juanita Gallego



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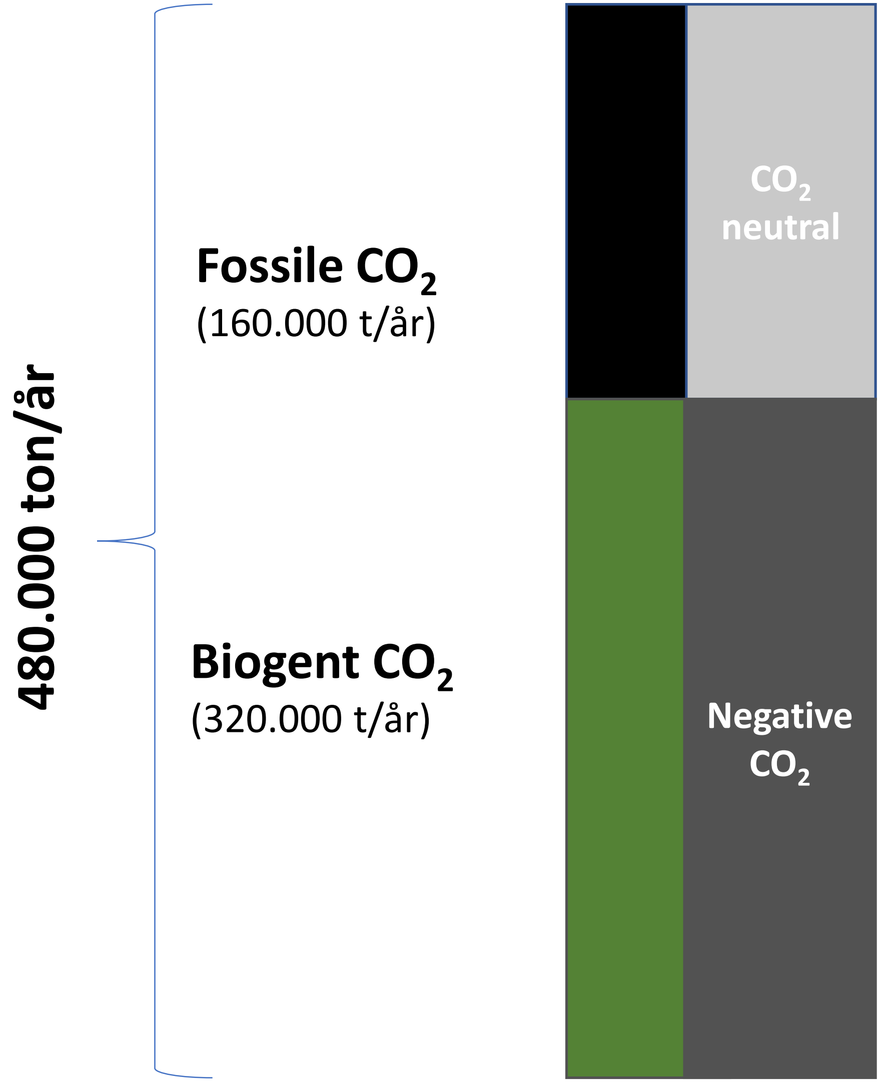
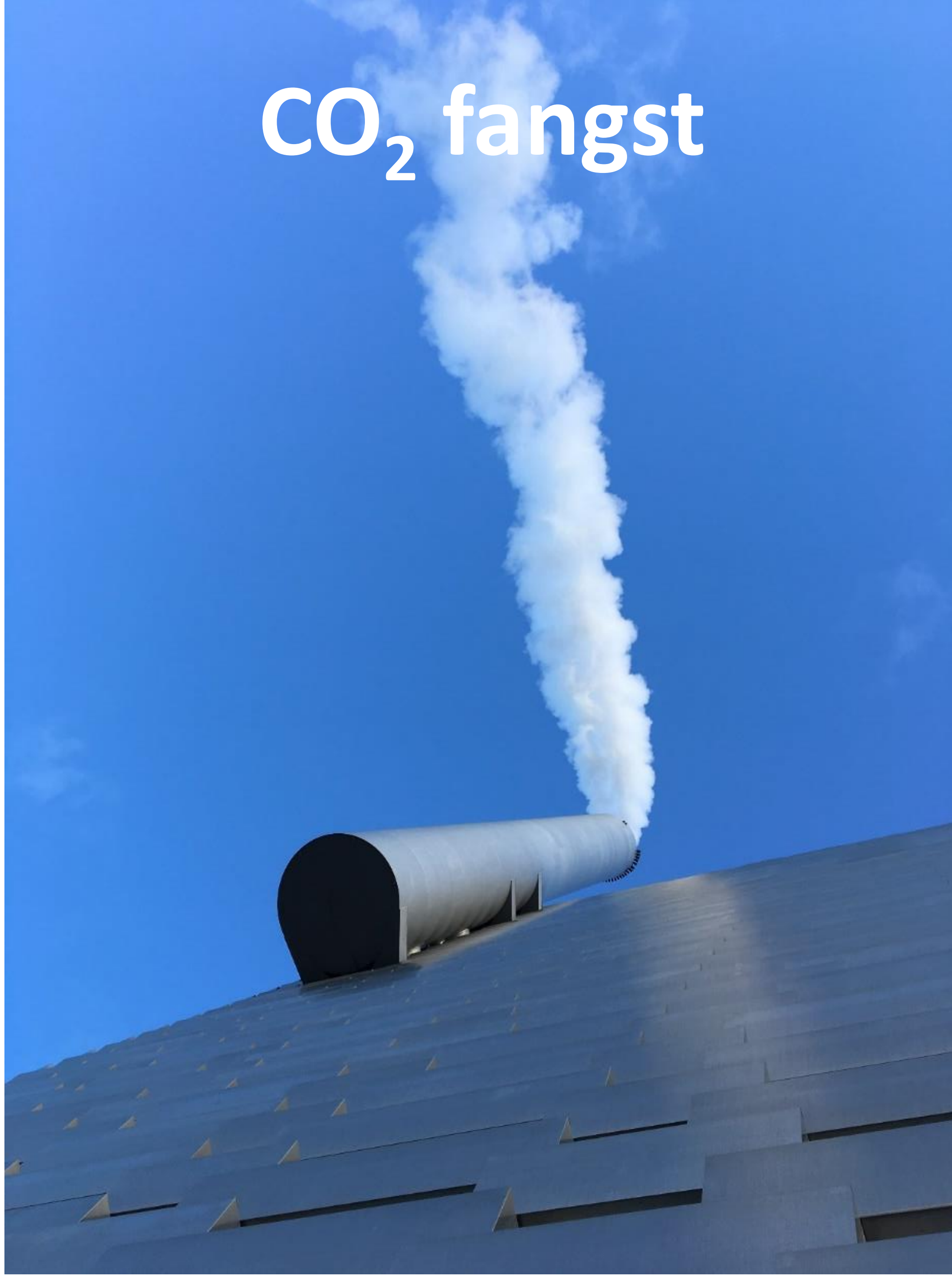
ARC CO_2 fangst


København
CO2-neutral
i 2025
KBH
2025
KLIMAPLANEN
EN GRØN, SM
OG CO2-NEUT


bENHAVN
-neutral
2025
BH
025
APLANEN
EN GRØN, SMA
OG CO2-NEUTR

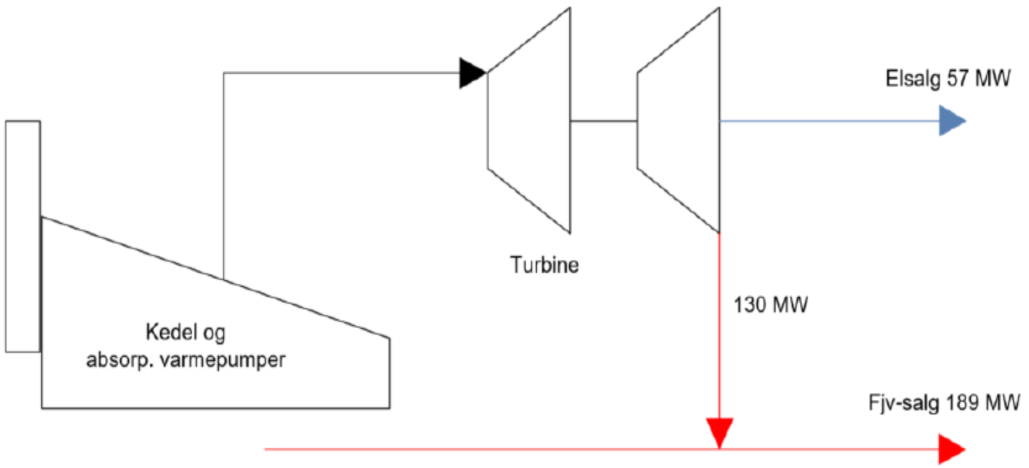

KBH2025
Klimaplanen
Roadmap 2017-2020
KØBENHAVNS KOMMUNE


480.000 ton/år
Fossile CO_2
(160.000 t/år)
Biogent CO_2
(320.000 t/år)
CO_2 neutral
Negative CO_2

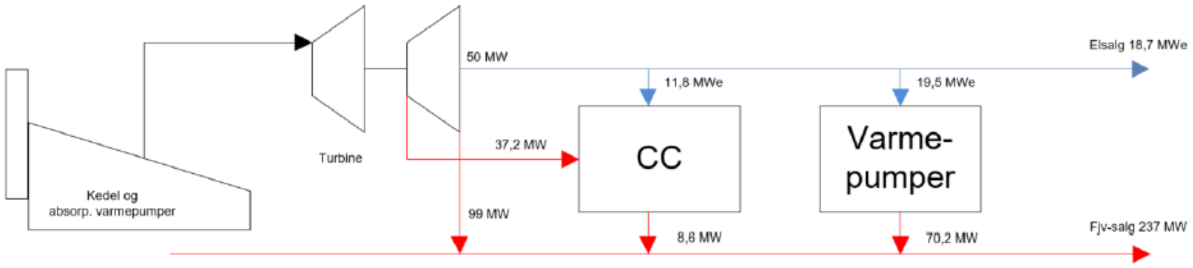

CO_2 fangst

ARC: med og uden CO_2-fangst

Basis: Uden Carbon Capture



Scenarie 1: Dampudtag og fuld varmepumpeudnyttelse

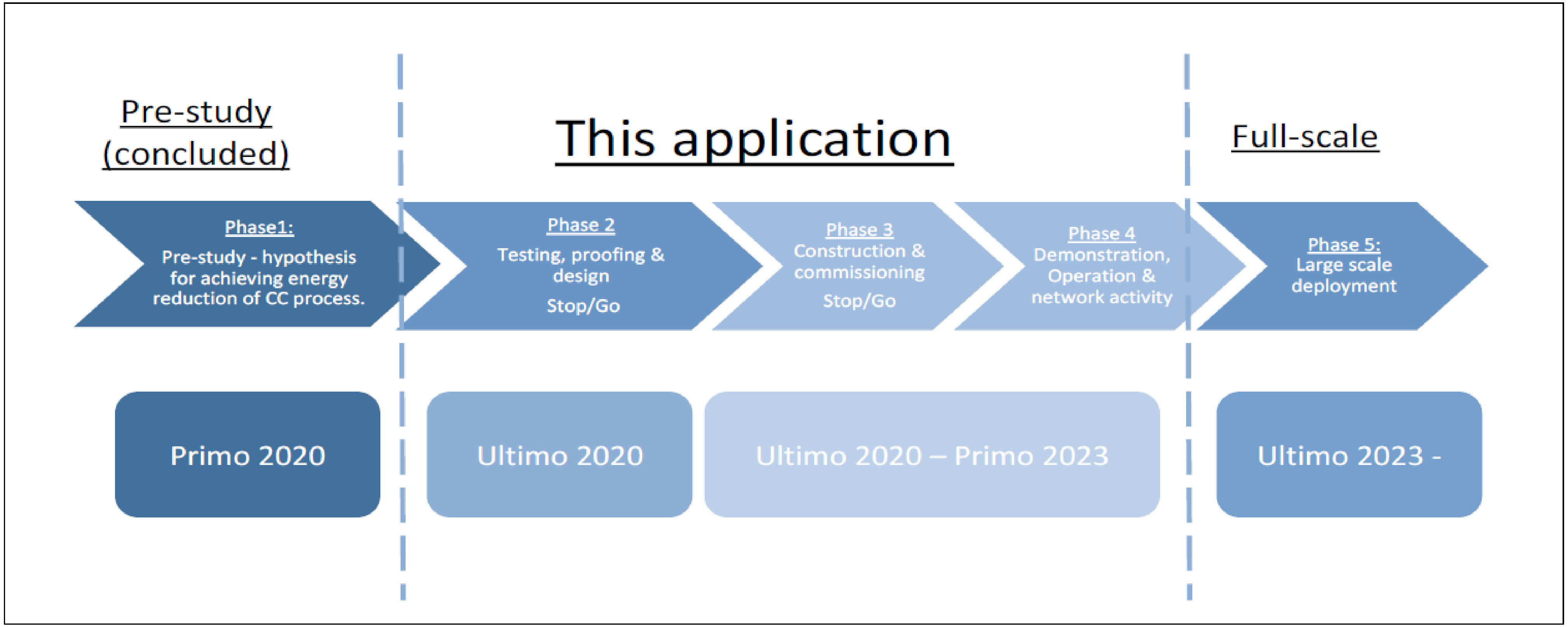


The applied project in a broader, collaborative perspective

The applied project is the second, third and fourth phase in ARCs journey to eliminate CO_2 from ARCs operations. These phases are:

- Phase 1: Pre-study and initial preparations (completed by Rambøll prior to this application)
- Phase 2: Testing, proofing and design – Stop/Go decision (this application)
- Phase 3: Construction and commissioning of 12 tons CO_2 per day pilot plant (this application)
- Phase 4: Demonstration & Operation of pilot plant and network activity
- Phase 5: Full-scale 480,000 tons/year CO_2 carbon capture at ARC and Project Greensand (2023 -)

The timeline in these five phases is shown in Figure 2.



Tak

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Knutsen OAS Shipping

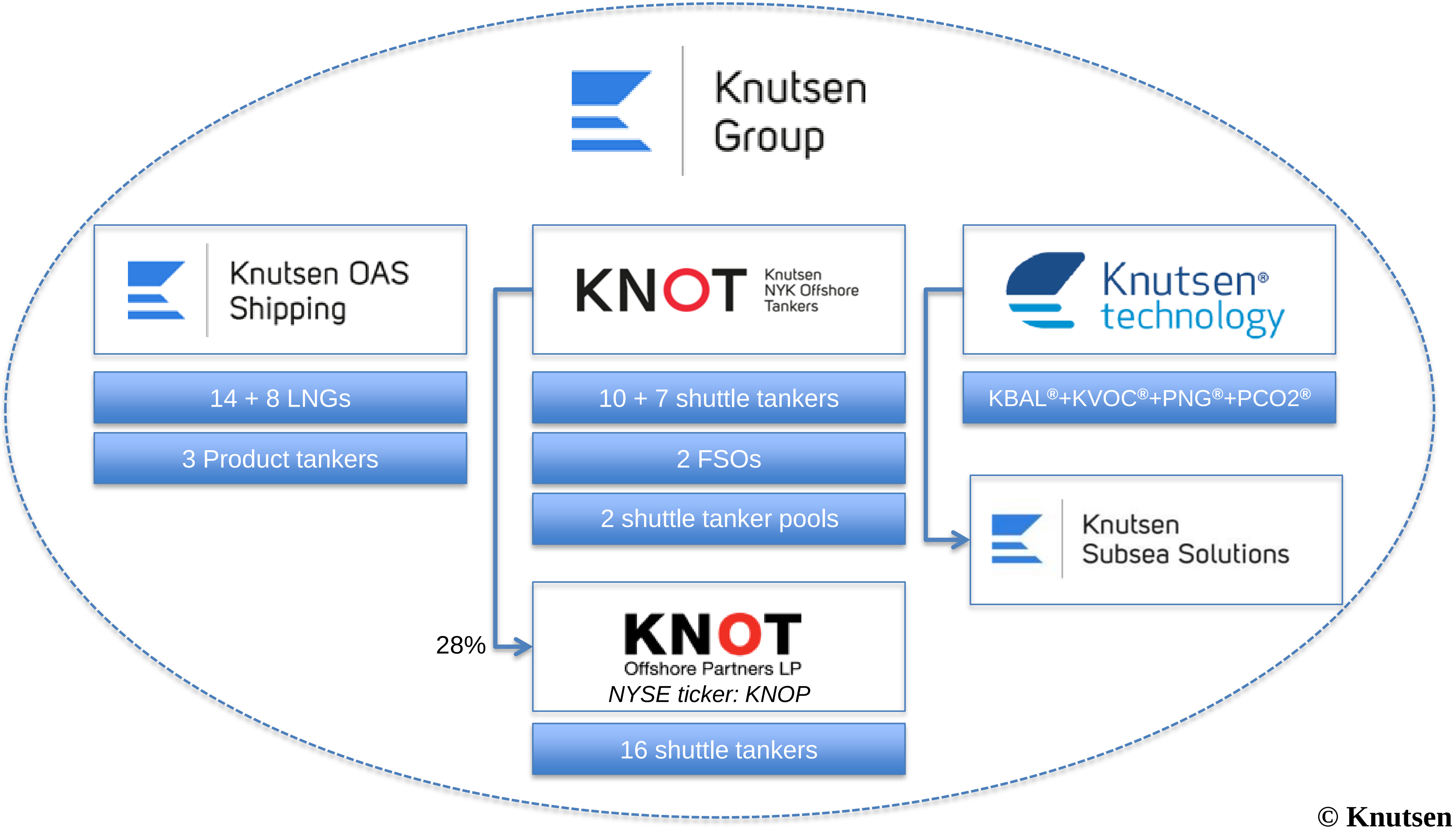
Fangst og lagring af CO2 som klimavirkemiddel
København 22.09.2020

Knutsen Group

Hvordan transporterer vi CO_2 mest effektivt med skib?

Knutsen OAS Shipping

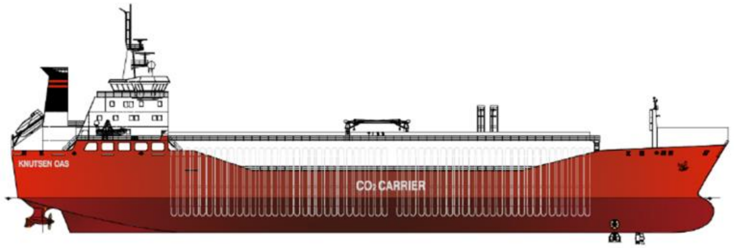
Integrated Shipping Group



Knutsen OAS Shipping

Owner of Advanced Technology

KVOC



PCO_2

KVOC® - reducing VOC emissions

KBAL® - ballast water treatment

PNG® - marine CNG transportation

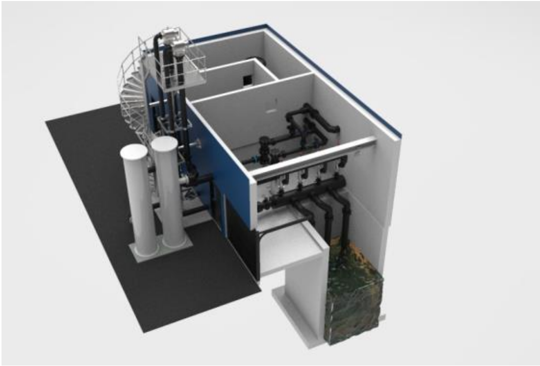
HTVP™ - marine high TVP liquid transport

PCO_2® - marine CO_2 transportation

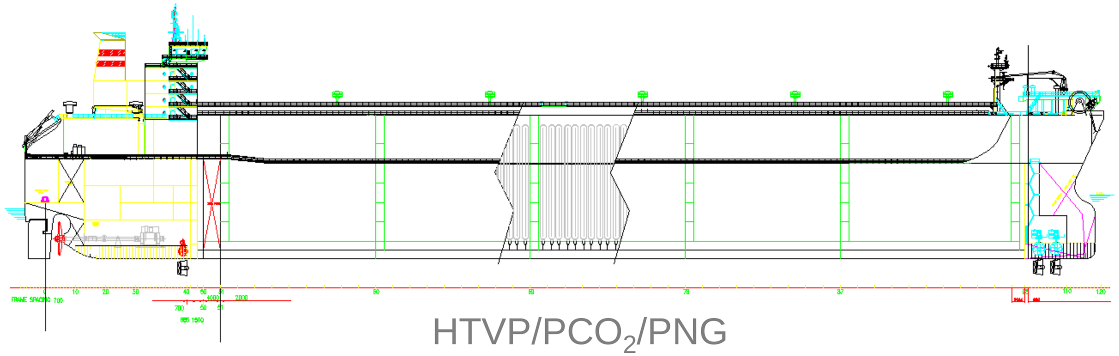
KO2 –removal of oxygen in water

Aquadrop - aquaculture water treatment

KBAL



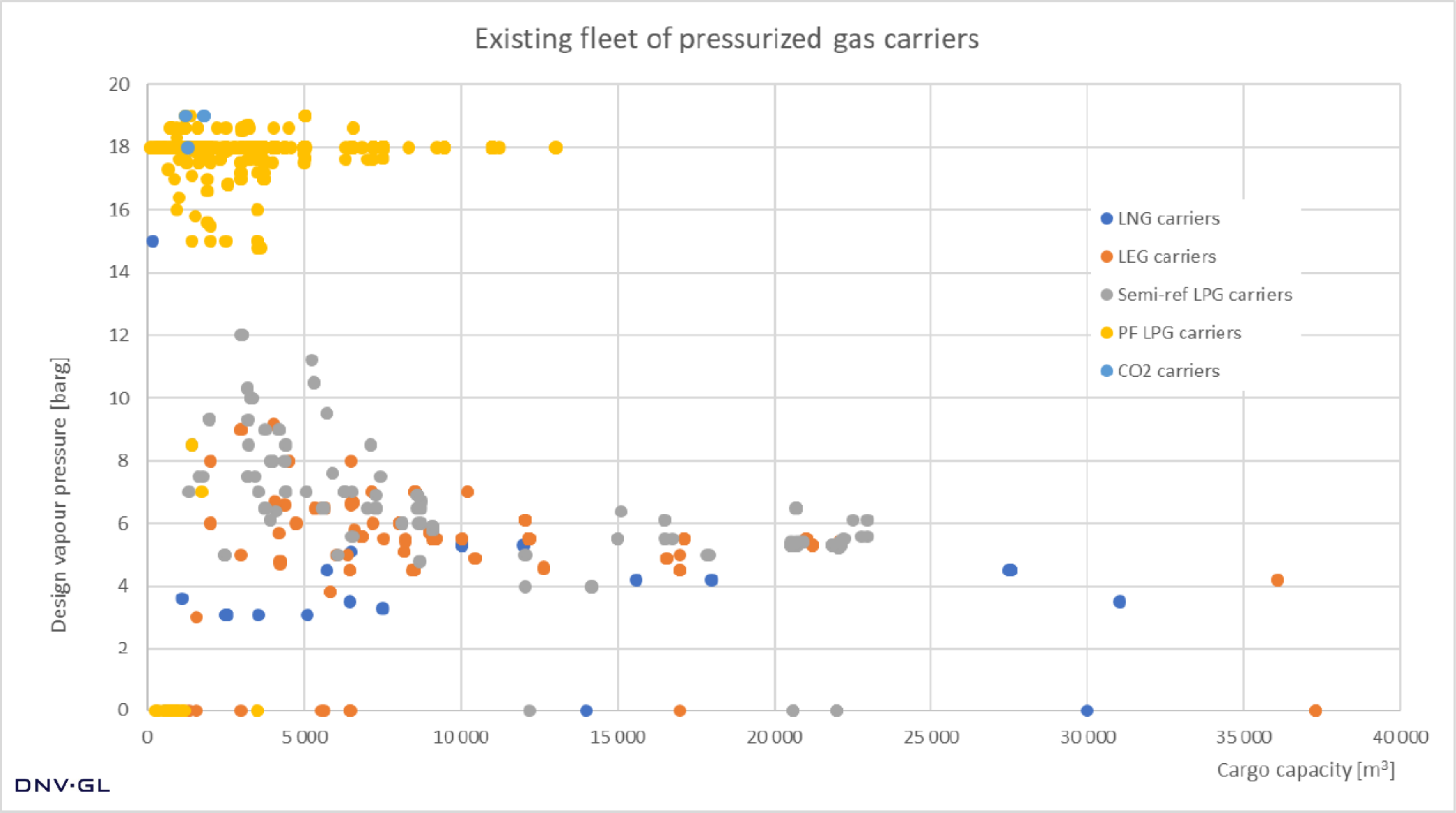
Aquadrop



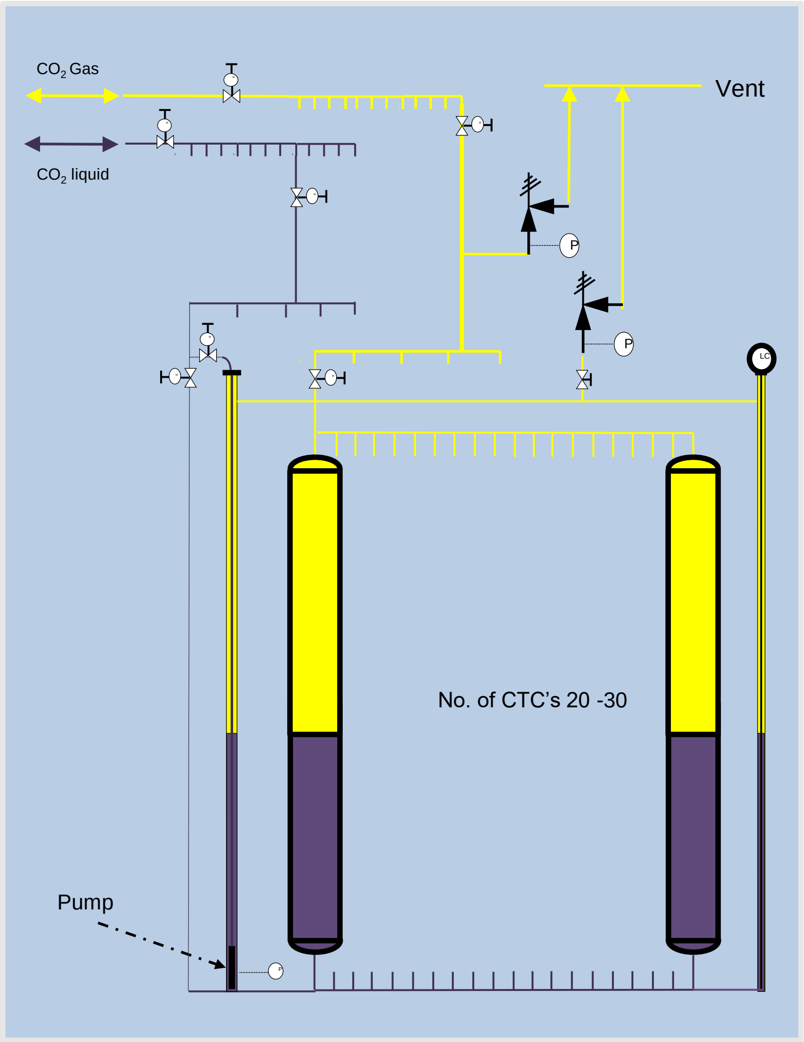
HTVP/PCO_2/PNG

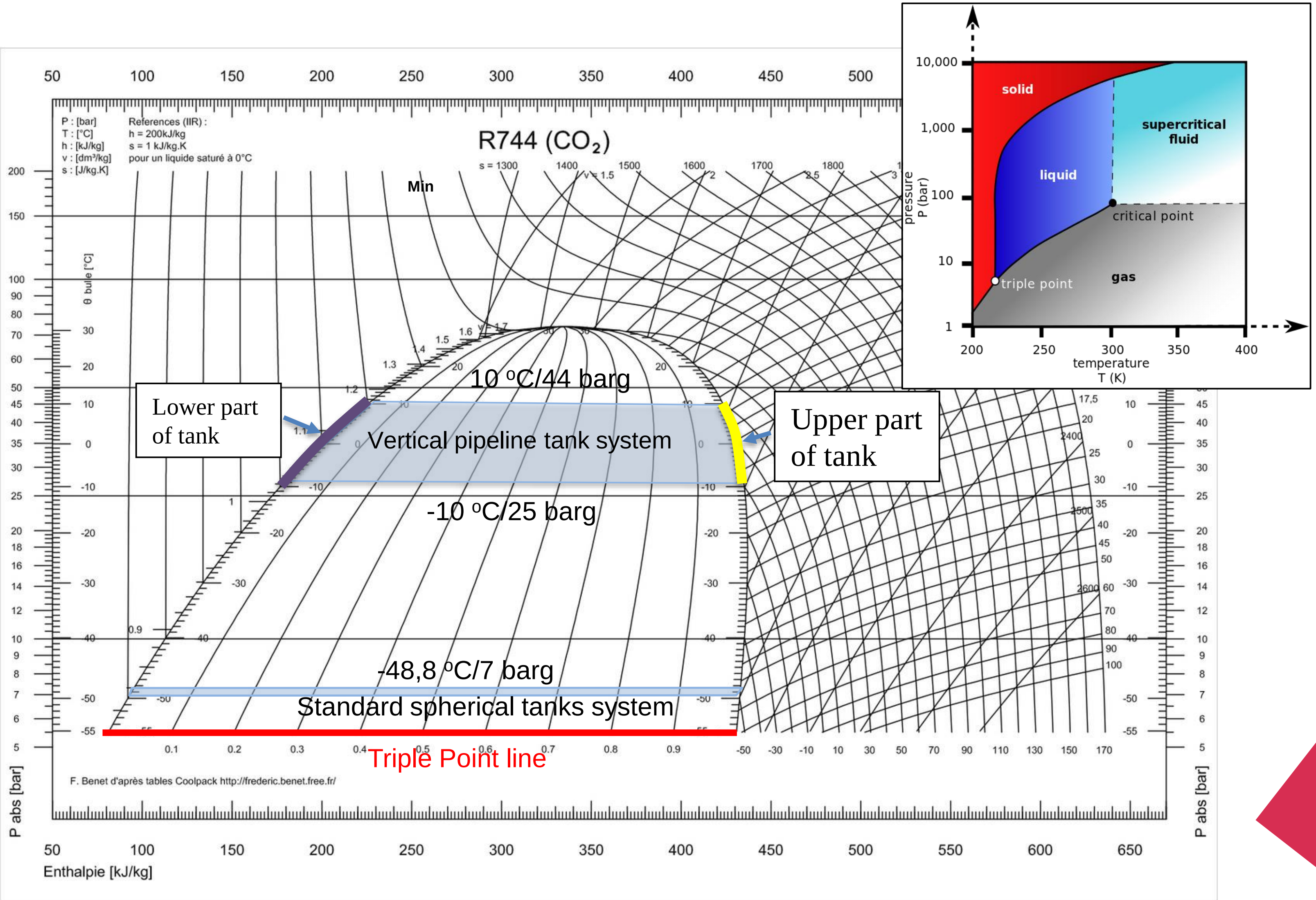
Knutsen OAS Shipping

World fleet of small & handy size gas carriers



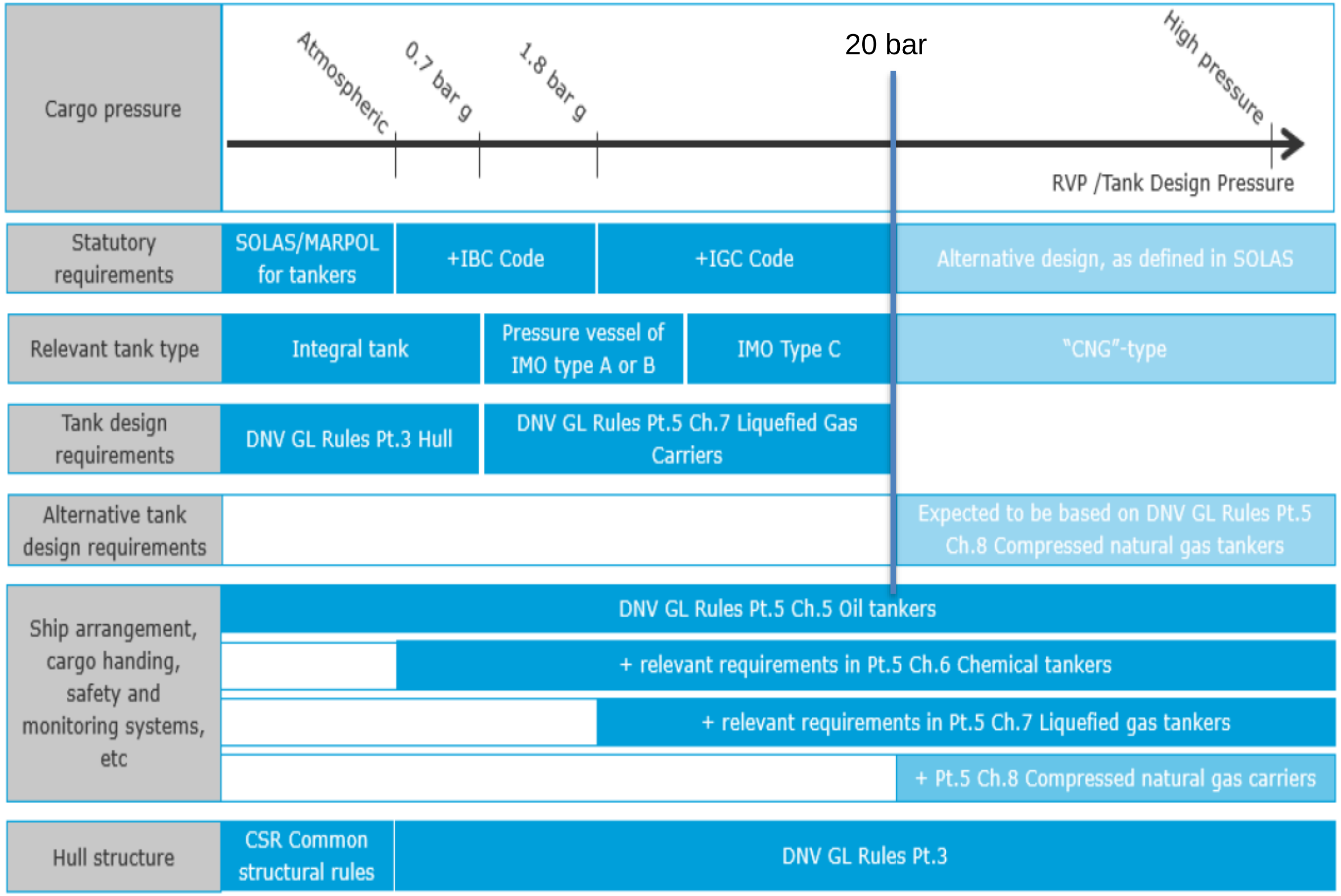
Operating envelope PCO_2





Knutsen OAS Shipping

The Knutsen pressurised transport solution PCO_2

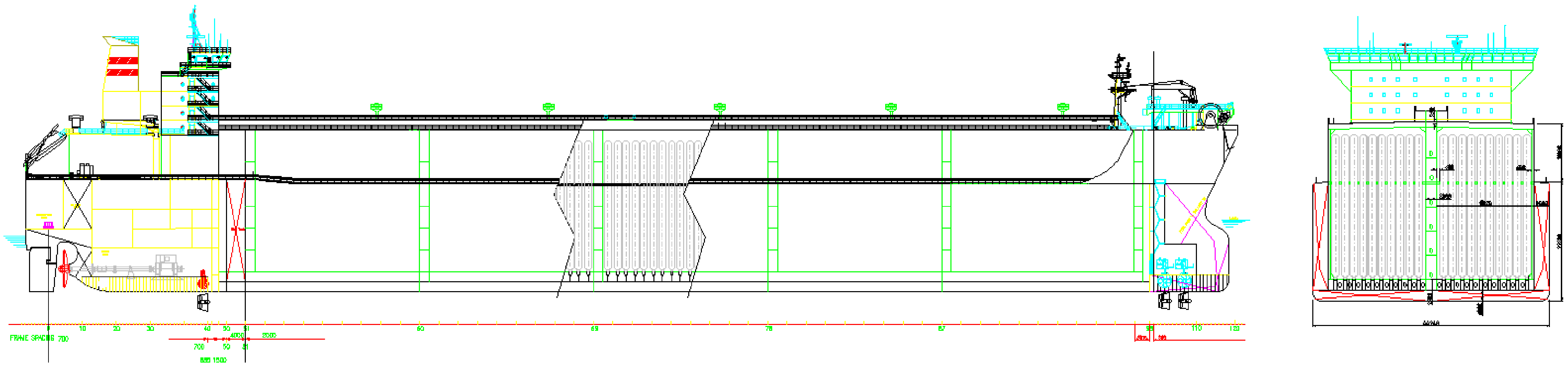


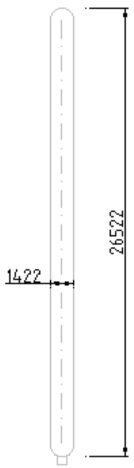
DNV·GL

- Rules and regulations for containment systems that can carry pressurised medium above 20 bar does not exist for IMO Type C tanks
- Only option that exist is to use DNV GL Rules for CNG to be able to scale and provide flexible design pressure
- The Knutsen PCO_2 apply CNG type containment according to DNV GL Class.
- The containment system has been qualified in close cooperation with Europipe, the world leading pipeline manufacturer.

Knutsen OAS Shipping

Typical 60 000 tons CO_2 Carrier





- Maximum design pressure 55 barg
- Operating pressure from 18 - 40 barg
- Minimum design temperature -30 deg. C
- Operating temperature: -10 - +10 deg. C

LENGTH O.A.	abt.	250,800	M
LENGTH B.P.		244,600	M
BREADTH MLD.		44,240	M
DEPTH MLD.		22,200	M
DRAFT DESIGN		13,000	M
DRAFT SCANTLING		15,000	M

Knutsen OAS Shipping

The Knutsen pressurised transport solution PCO_2

- Transport at high pressure and temperatures around ambient condition
- Transport volume can easily be scaled (up to 80.000 tons per cargo)
- Very suitable in combination with offshore offloading (pressure and liquid state)
- Simple and reliable process
- Based on well known technology elements
- Also suitable for onshore application to match ship transport.
- Apply the DNV GL rules for CNG transport

ENERGINET

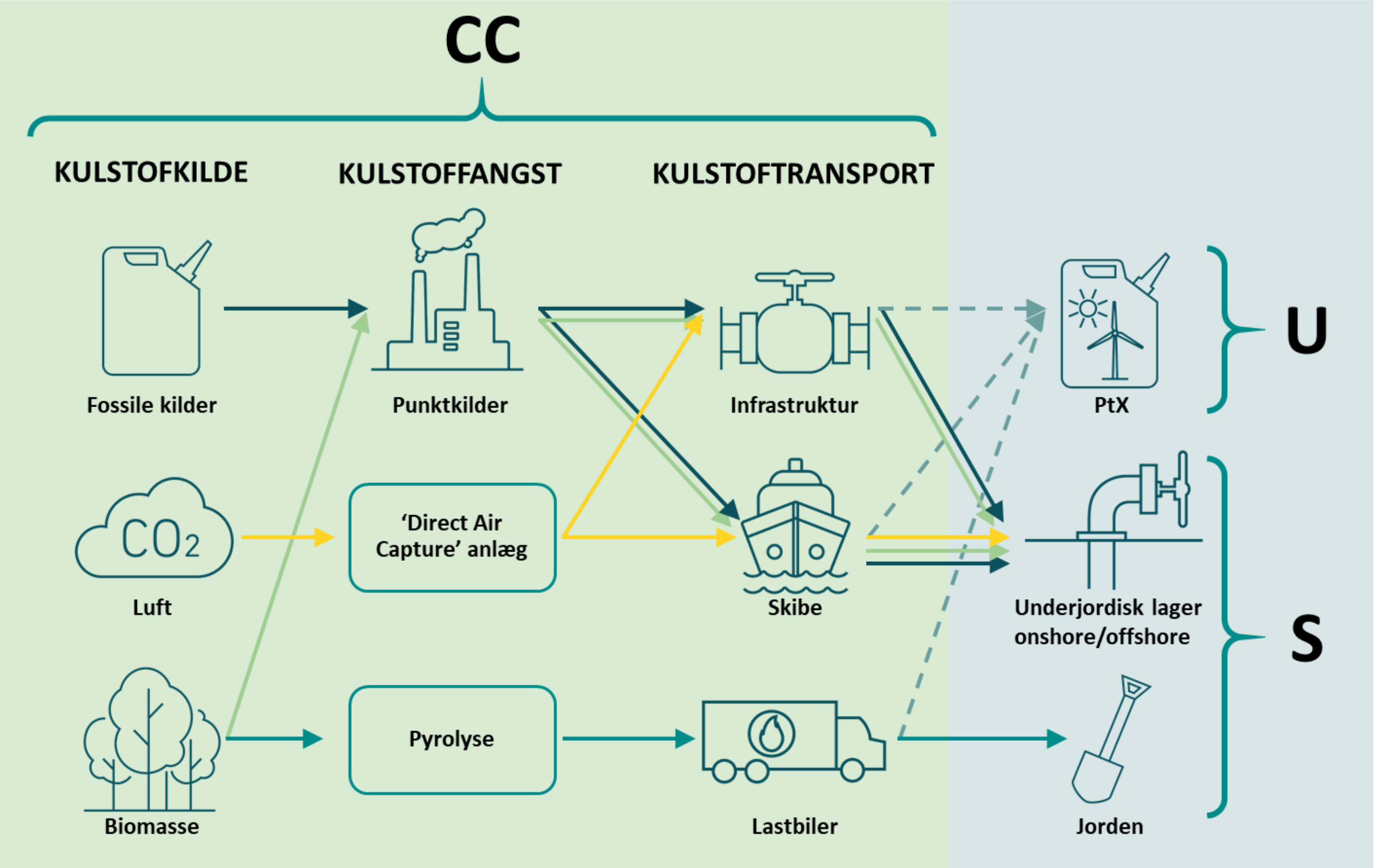
TRANSPORT AF CO2

Hvordan transporterer vi CO2 og hvilken infrastruktur bliver der brug for?

Tor Elmelund
Ingeniør, Gassystem Innovation, Energinet

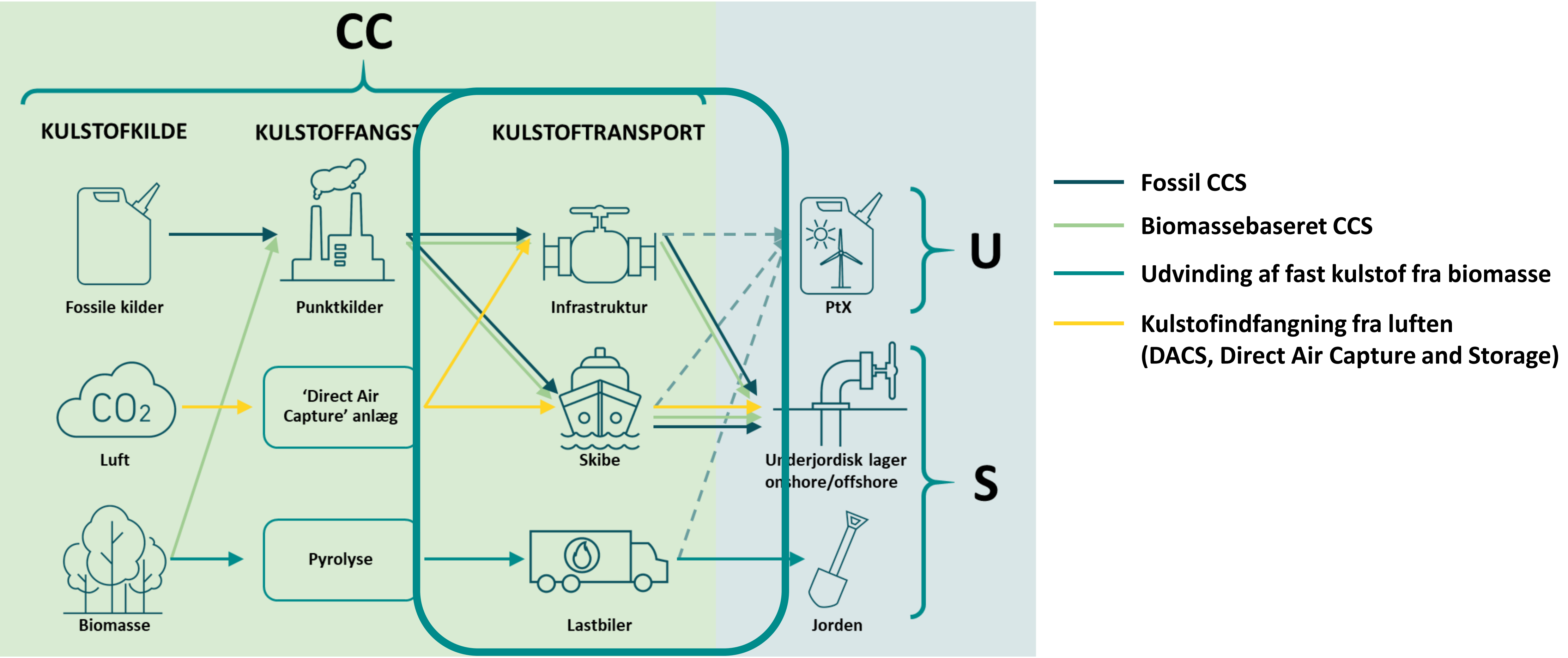
ENERGINET

FORSYNINGSKÆDEN FOR CCS OG CCU



- Fossil CCS
- Biomassebaseret CCS
- Udvinding af fast kulstof fra biomasse
- Kulstofindfangning fra luften (DACS, Direct Air Capture and Storage)

FORSYNINGSKÆDEN FOR CCS OG CCU



DRIVERS FOR VALG AF CO2 INFRASTRUKTUR

- Årlig CO2 kapacitet der skal transporteres
- Valg af CO2 lagringsområdeområde på land eller i havet
- Afstand fra punktkilde til lagring (CCS) og/eller udnyttelse (CCU)

INFRASTRUKTUR

For store punktkilder til CCU, og til CCS på land/hav

SKIBE

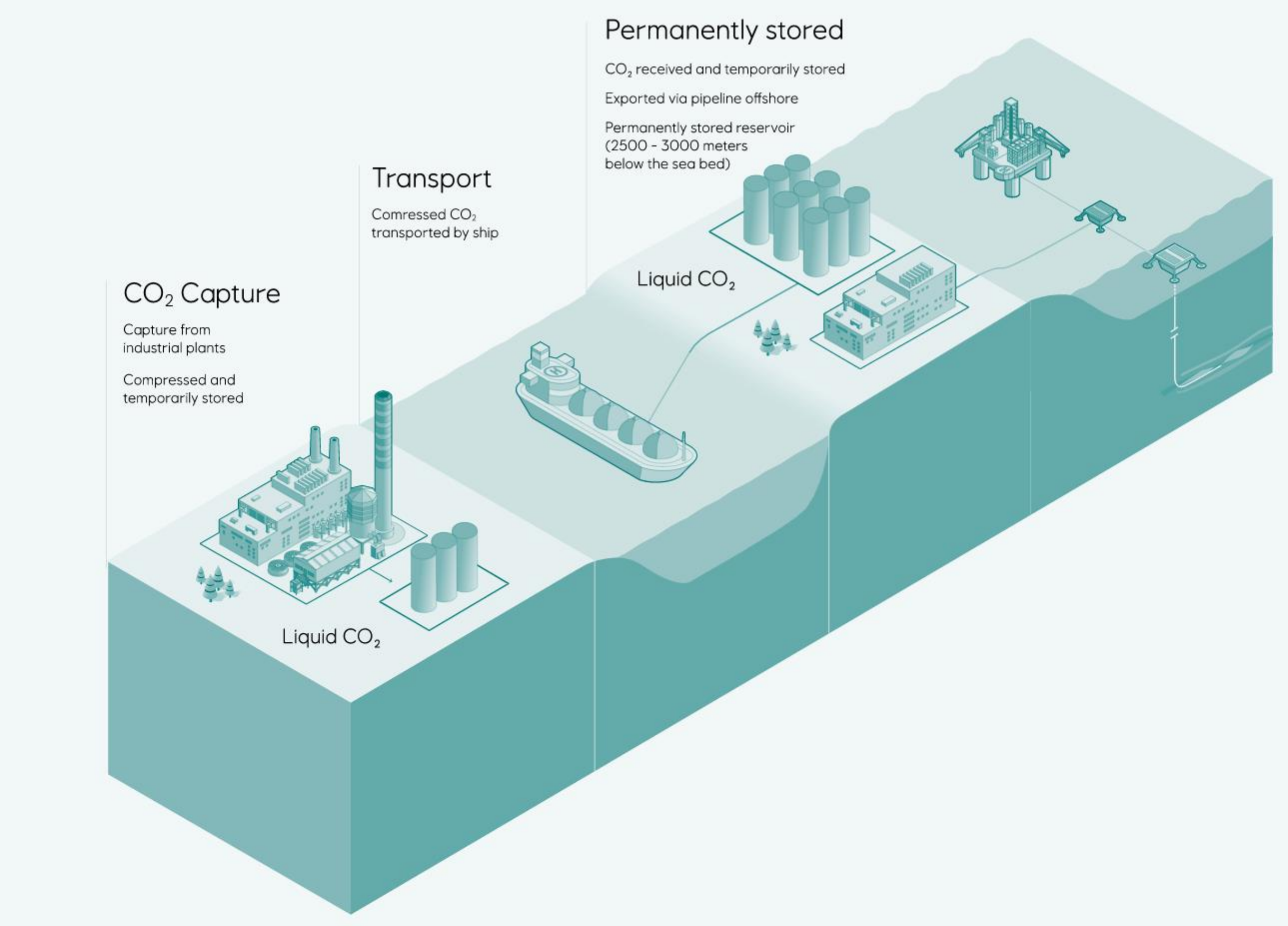
For punktkilder tæt på havet og til CCS

LASTBILER

Mindre mængder CO2 fra afsidesliggende punktkilder

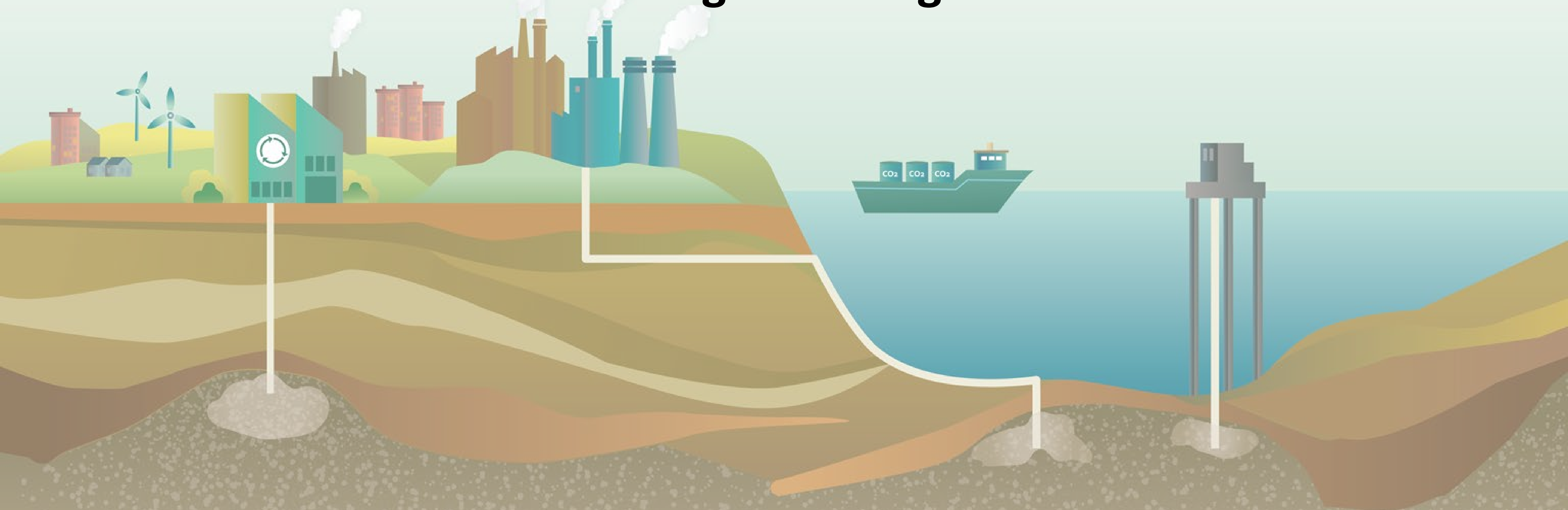
ENERGINET

NORTHERN LIGHT PROJEKTET – ET CASE EKSEMPEL

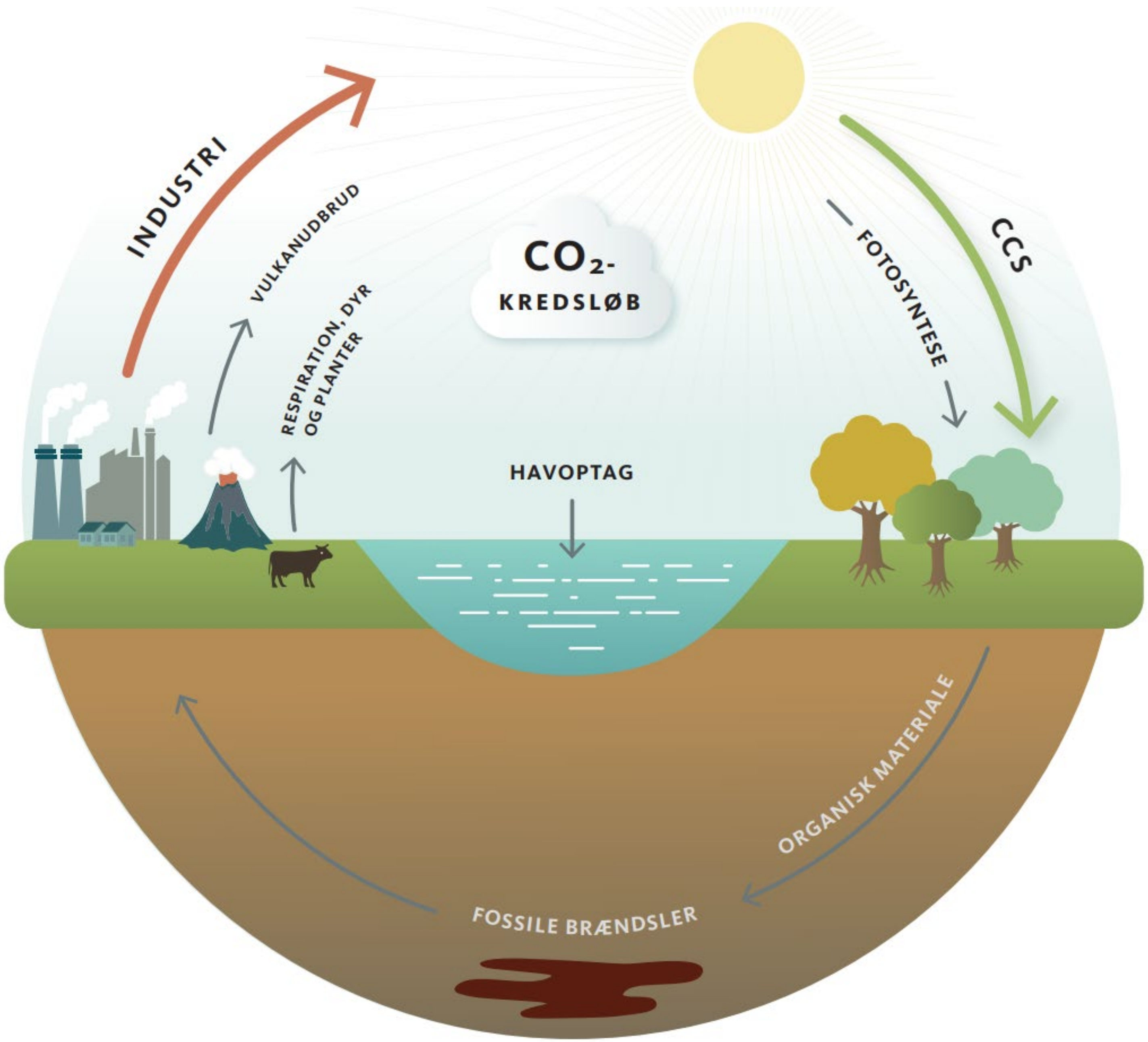


Kilde: Equinor – Northern Lights Project
Kilde: DNV GL – Northern Lights Project

Fangst og lagring af CO_2 i undergrunden som klimavirkemiddel
Hvor og hvor meget?

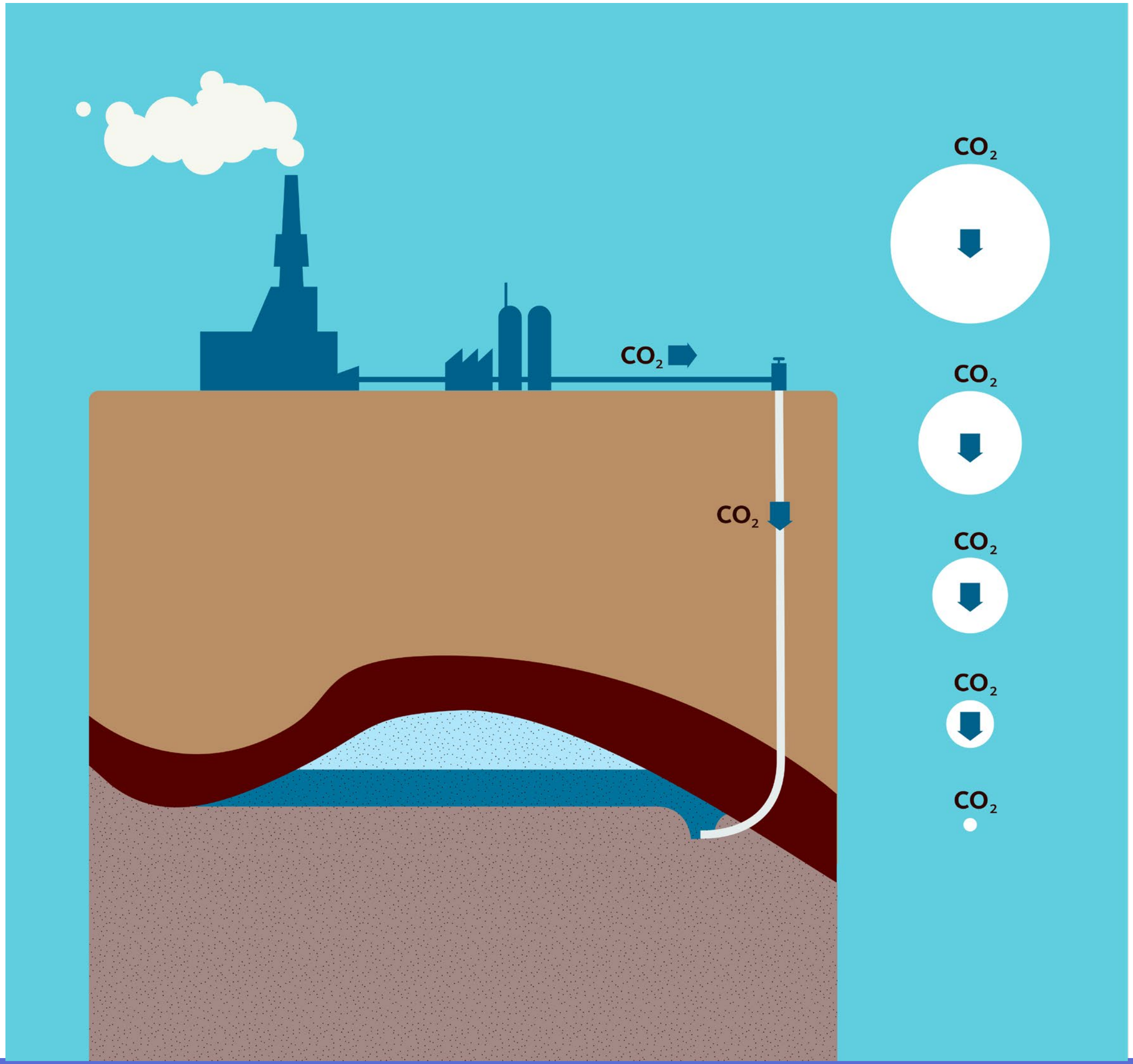


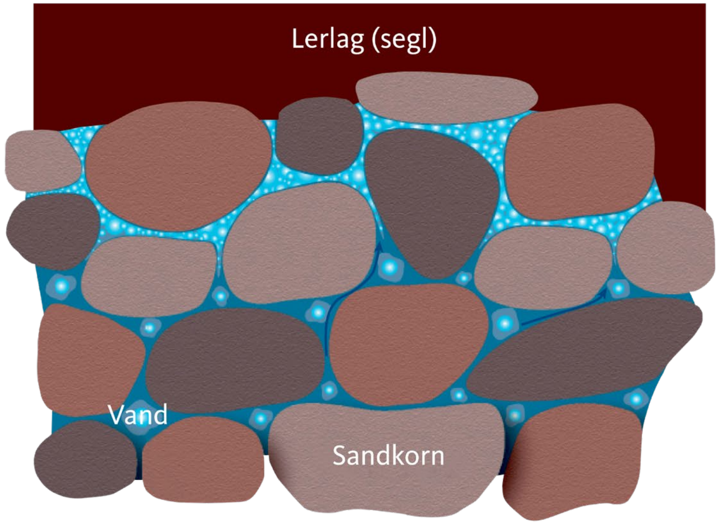
Lars Henrik Nielsen
Chef for Afdeling for Stratigrafi
De Nationale Geologiske Undersøgelser for Danmark og Grønland (GEUS)

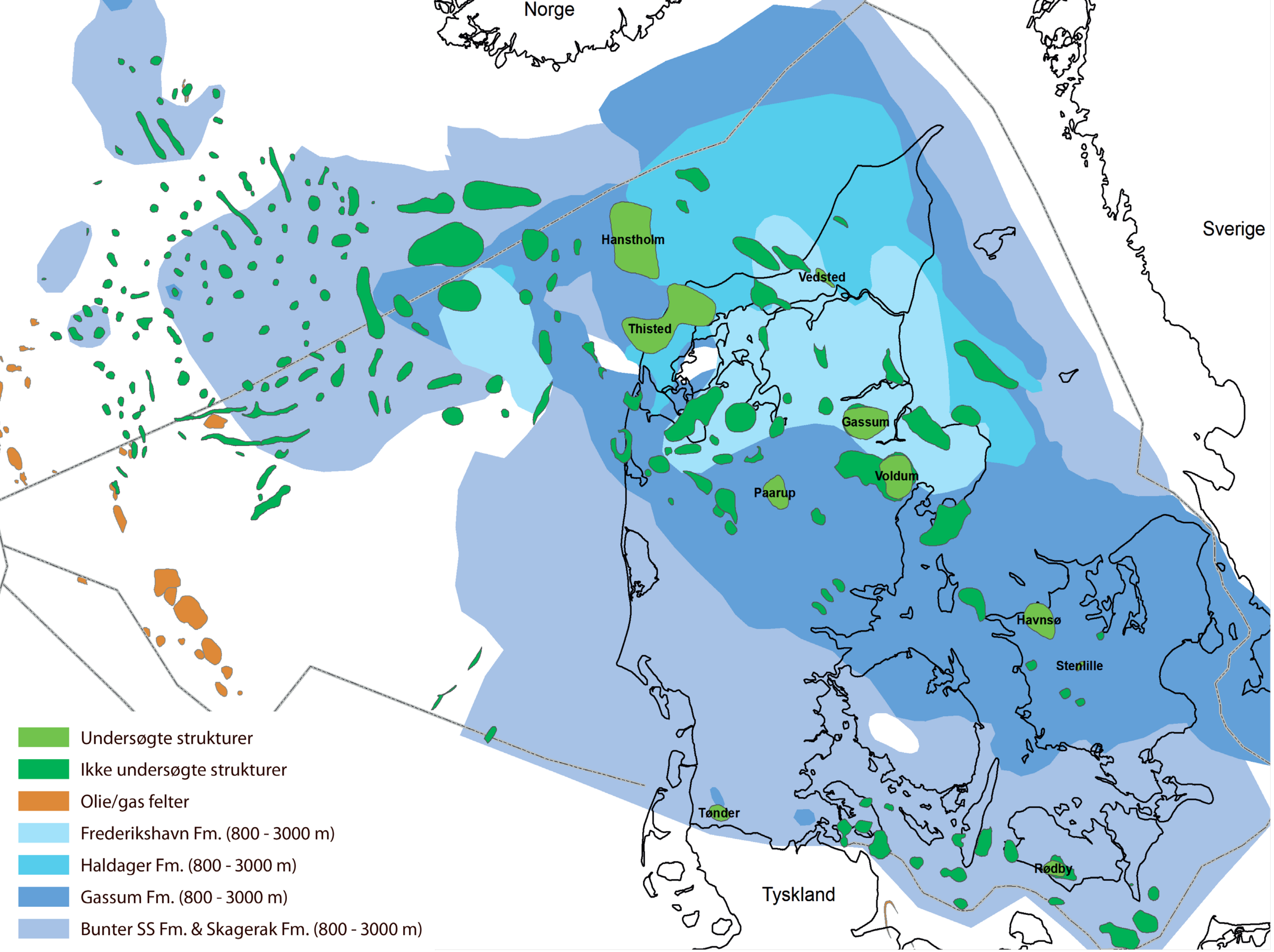


INDUSTRI
VULKANUDBRUD
RESPIRATION, DYR
OG PLANTER
CO_2-
KREDSLØB
HAVOPTAG
FOTOSYNTESE
CCS
ORGANISK MATERIALE
FOSSILE BRÆNDSLER

Lagringskonceptet er simpelt og svarer til den måde, olie og naturgas har været lagret i millioner af år







Danmarks CO_2-lagringskapacitet

i millioner tons

Hanstholm	2753
Gassum	630
Havnsø	926
Paarup	91
Rødby	152
Stenlille	51
Thisted	11039
Tønder	91
Vedsted	162
Voldum	288
Sum	**16183**

Udledningen af CO_2 fra de 15 største stationære kilder i 2018 var ca. 15 millioner ton.

Opsummering

Opsamling og lagring af CO_2 vurderes som et nødvendigt redskab, hvis de uønskede menneskeskabte klimaændringer og konsekvenserne af dem skal undgås eller reduceres – og der er gode muligheder for det i Danmarks undergrund.

- Det internationale klimapanel (IPCC) anbefaler, at atmosfærens indhold af CO_2 reduceres fra det nuværende høje niveau ved bl.a. at en del af det kulstof, som vi har lagret i atmosfæren, opsamles og lagres i undergrunden og dermed trækkes ud af kulstofregnskabet.

- Der er rigeligt med plads i den danske undergrund til sikker og permanent lagring af meget store mængder CO_2.

- Danmark har mulighed for også at tilbyde lagerplads til CO_2 fra vores nabolande og kan formentlig udvikle en forretningsmodel for permanent lagring.

- Foreløbige vurderinger og beregninger peger på, at det formentlig vil være hensigtsmæssigt med et lille antal lagre for at sikre tilstrækkelig stor skala og dermed reduktion af lagringsomkostningerne.

Project Greensand

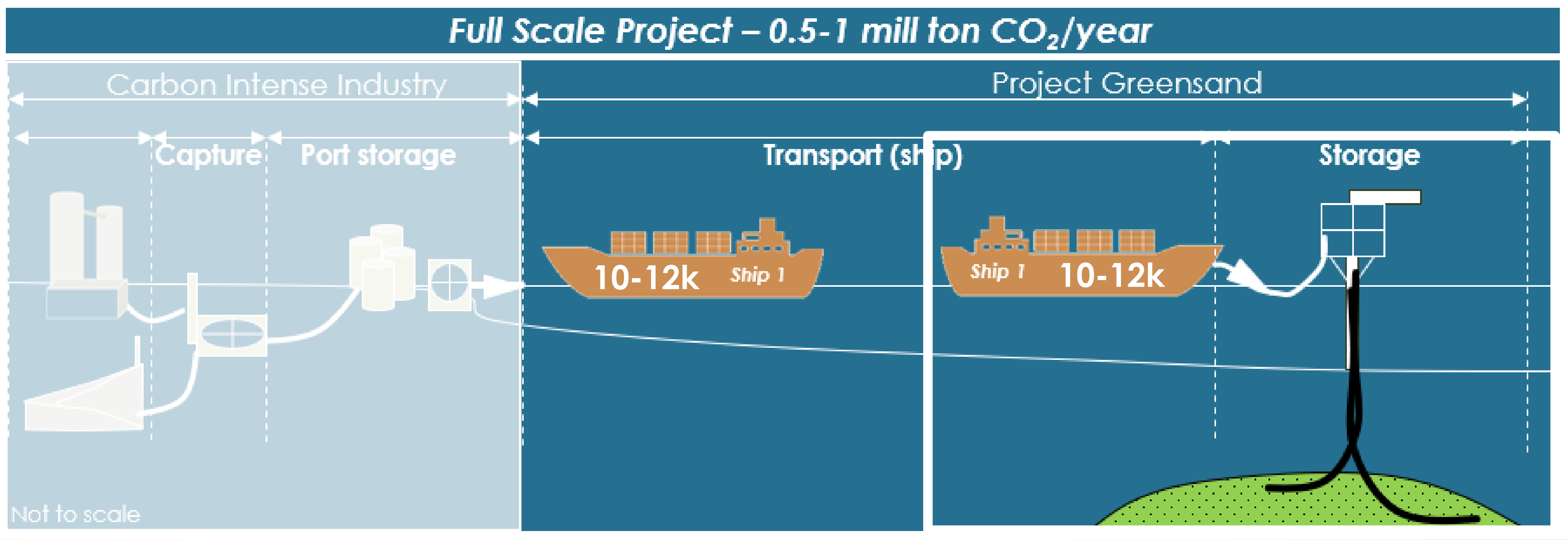
22 Sept 2020

International consortium

INEOS Oil & Gas
wintershall dea
MAERSK DRILLING

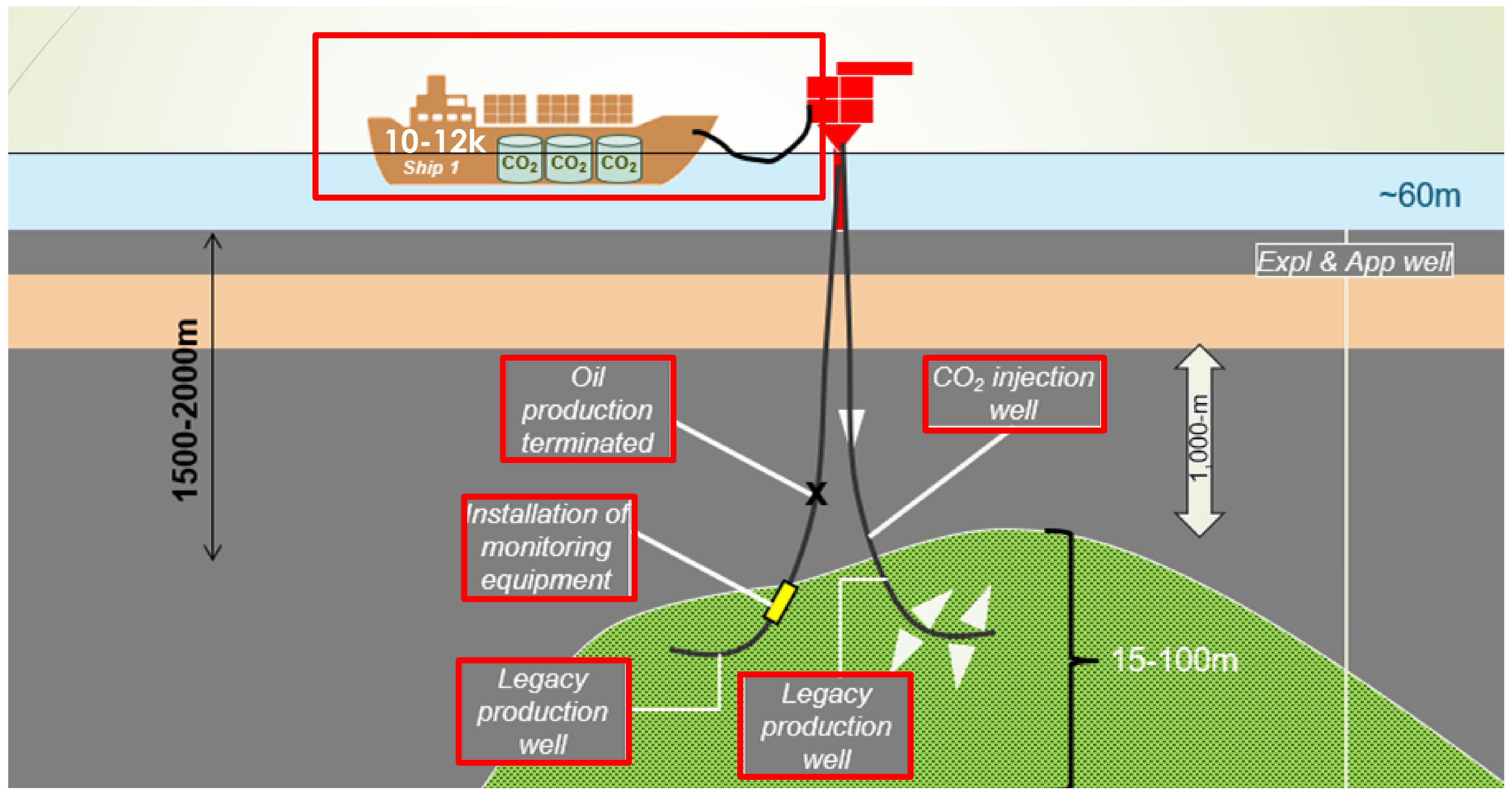
eUDP

Project Greensand – CO_2 storage in depleted oil field



- Transport of CO_2 by low/zero emission ship and offshore discharge,
- CO_2 storage in depleted sand reservoir using existing drill center and wells

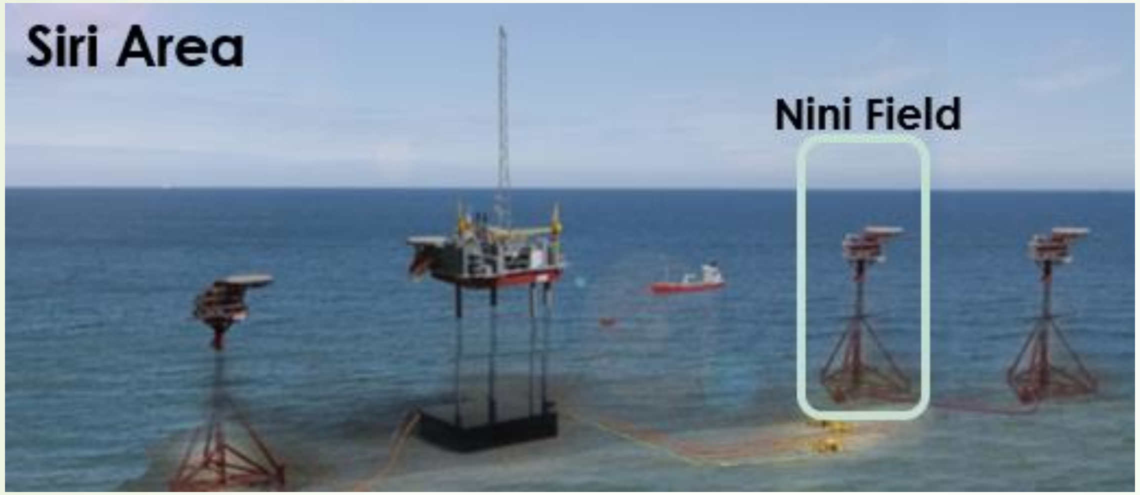
Project Greensand
Storage setup



22 Sept 2020

Project Greensand

Advanced CO_2 storage project in Denmark



- ✓ **Fast-track maturation storage site**
  - Large data pool already in place (~$150m & 5 years)
  - CO_2 storage within 4-6 years
- ✓ **Direct scalability**
  - Three identical platforms – six reservoirs
  - Up to 3.5 mt CO_2/y when fully developed

Cost effective CO_2 Storage in the Nini Field can be a reality by 2025 given:

- Concurrent oil production from neighboring platforms → reduce OPEX
- Funding beyond Danish State Pool (22 June 2020)
- Agreement on liabilities: CCS @ cost → liability @ emitter
- **Regulatory framework → use of existing licences + state pool clarification**

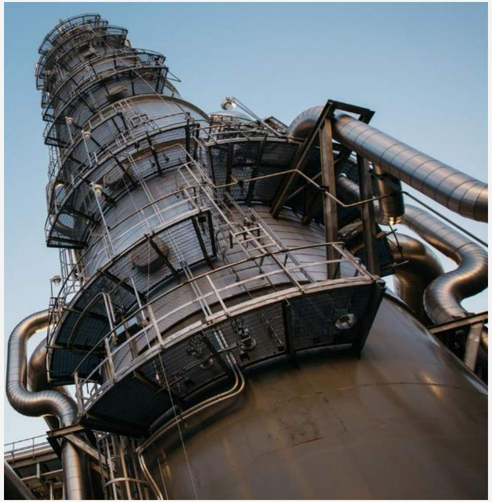
Miljø og sikkerhedsforhold ved CO_2 capture
(Webinar Fangst og lagring af CO_2 som klimavirkemiddel)

Jacob Nygaard Knudsen, Project Manager,
Afd. Bioenergy & Thermal Power

COWI

CO_2 capture – Er det sikkert? (1)

- Generelt er der få sikkerhedsmæssige udfordringer knyttet til de mest modne CO_2 fangst processer (absorptionsprocesser):
  - Anvendt i industrien i mange år (naturgas/biogas oprensning)
  - Opererer ved forholdsvis lave tryk og temperaturer
  - Anvender vandige absorbenter af amin/ammoniak (lav brand og eksplosionsfare)
  - Sikkerhedsforanstaltninger ved håndtering af kemikalier for at undgå eksponering af driftspersonale

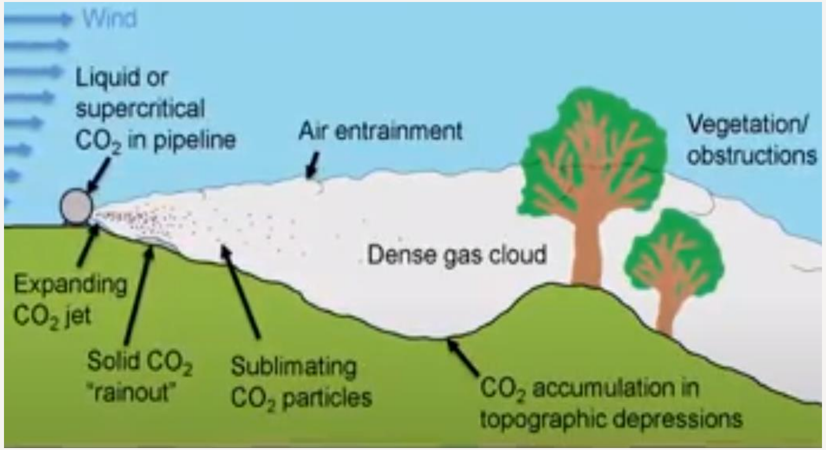


CO_2 desorber, source: Petra Nova

COWI

CO_2 capture – Er det sikkert? (2)

- Største sikkerhedsrisiko er knyttet til håndtering af koncentreret og tryksat CO_2:
  - CO_2 under højt tryk (20-200 bar) for transport i pipeline eller som flydende CO_2 i tryktanke
  - Oplag af store mængder flydende CO_2 i mellemlager
- Lækage vil resultere i en kold gas sky af koncentreret CO_2 der langsomt opløses
- Mellemlager af CO_2 kræver risikovurdering
- Erfaringer fra bl.a. Norge viser at risici fra selv et større mellemlager af flydende CO_2 kan håndteres i nærheden af bebyggelse (Oslo havn)



Source: ComputIT

COWI

Miljøforhold ved CO_2 capture

- Potentielle negative miljøpåvirkninger ved CO_2 fangst processer:
  - Emissioner til luft og vand
  - Forbrug af proceskemikalier f.eks. aminer
  - Generering af kemisk affald
  - Indirekte miljøpåvirkning fra brug af energi (strøm, procesvarme)
  - Bortledning af overskudsvarme
- Positive miljøpåvirkninger ved CO_2 fangst processer:
  - Reducere CO_2 udslip markant
  - Reducere eksisterende emissioner af støv, SO_2, HCl, etc. yderligere

Miljøpåvirkning fra CO_2 capture er håndterbar

Studier og demonstrationsprojekter har bl.a. vist at:

- Der kan vælges absorptions kemikalier der er bionedbrydelige
- Begrænset kemikalieforbrug ved god kontrol på procesbetingelser
- Emissioner til luft:
  - Flere teknologileverandører har demonstreret bl.a. ved Technology Centre Mongstad (TCM) at meget lave emissioner kan opnås
  - Petra Nova (USA) med fangst af 1.4 mill ton CO_2/år har kun udledt 10-20% af grænseværdier/emissionskvote (baseret på 3 års drift)
- Energiforbrug ved CO_2 fangst er betydelig, men kan reduceres ved:
  - Energioptimering ved varmeintegration med CO_2 kilde
  - Udnytte restvarme til fjernvarme

GAS STORAGE DENMARK

CO_2-LAGRING

Rune Gjermundbo, rhg@gasstorage.dk

RISIKO OG FARE

Personfare naturgas:

- Trykbølge ved brist på trykbærende udstyr (gassen opbevares ved højt tryk)
- Eksplosion (ved antændelse af lækage)
- Forbrænding (ved antændelse af lækage)

Personfare CO_2:

- Trykbølge ved brist på trykbærende udstyr (gassen opbevares ved højt tryk)
- Kvælning (CO_2 er tungere end luft)

Miljøfare naturgas:

- Meget stærk drivhuseffekt
- Lokal antændelse

Miljøfare CO_2:

- Drivhuseffekt

MINIMERING AF RISIKO

Minimere sandsynlighed for hændelse:

- Stringent sikkerhedsledelse
- Sikkerhed er 1. prioritet i design, drift, uddannelse og optimering
- Alle er sikkerhedsmæssigt kompetente
- Alle optimeringer/ændringer reviewes gennem stringente risikovurderinger
- Systematisk erfaringsopsamling
- Jævnlige audits af sikkerhedsledelsen
- Omfattende overvågning af driften
- Fuldt automatiseret nedlukning af anlæg og brønde når givne grænseværdier overskrides
- Brønde designes med dobbelte barrierer – livrem og seler.
- Realtidsovervågning af alt i anlægget og brøndene.

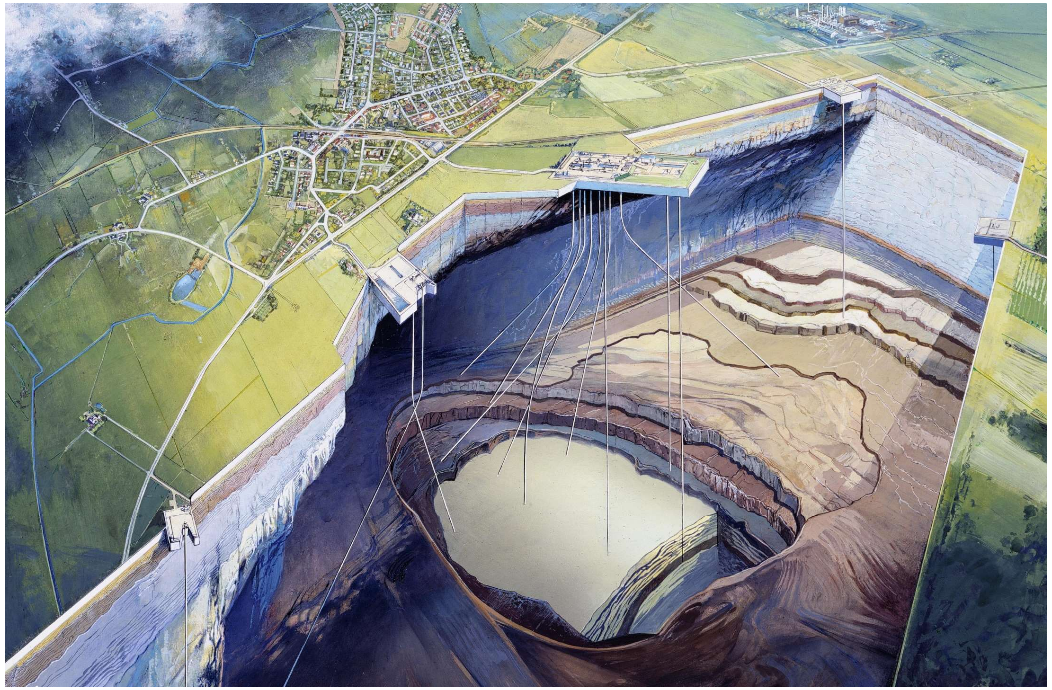
Minimere konsekvens ved hændelse:

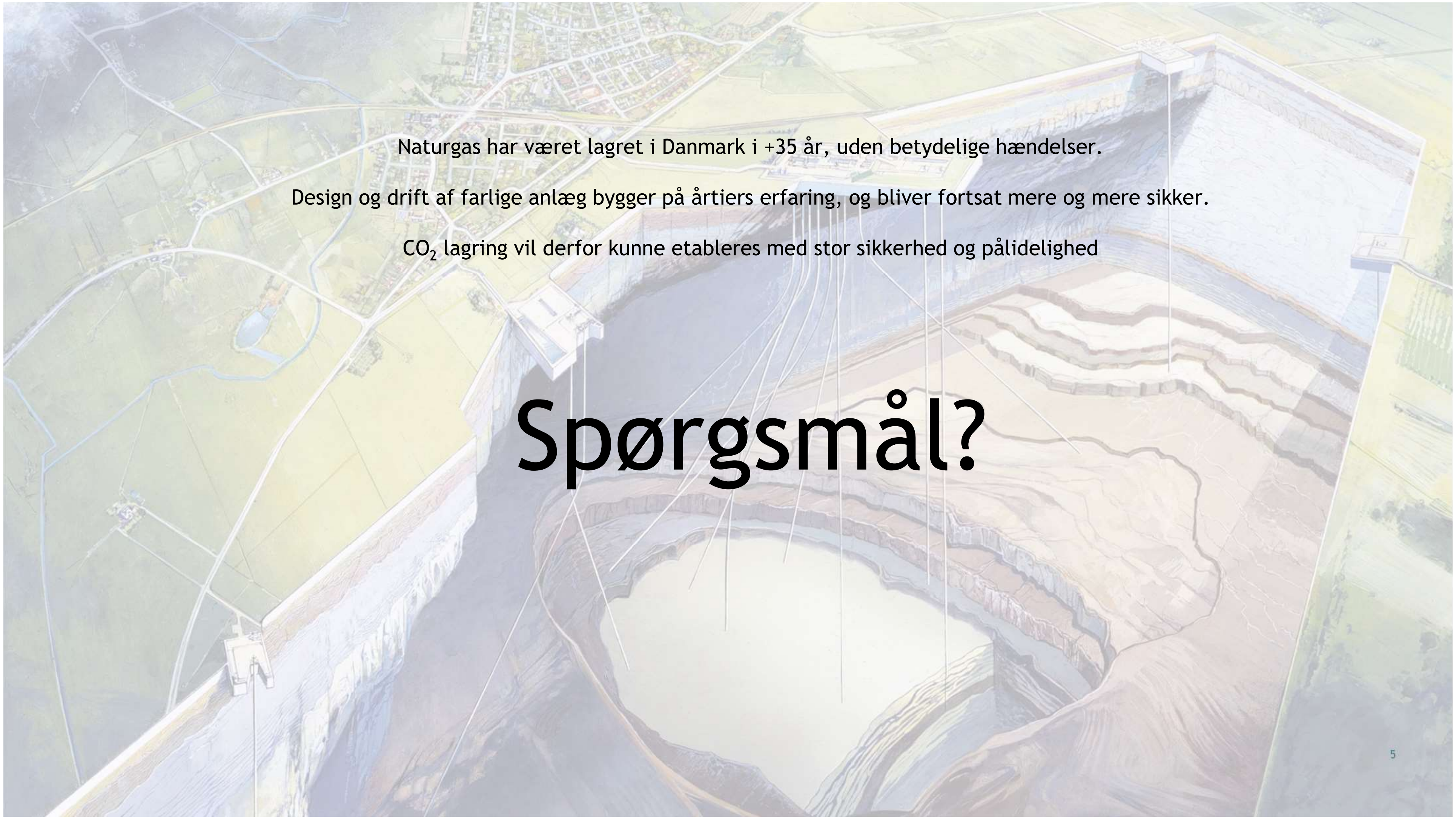
- Fuldt automatiseret nedlukning og sektionering af anlæg
- Talrige systemiske sikkerhedsbarrierer (mekanisk aktuerede ventiler som lukker ved lavt/højt tryk, automatisk tryksænkning mv).
- Anlæg designes med point-of-failure, så det sikres at eventuelle hændelser finder sted der hvor konsekvensen er mindst
- Der er indlagt betydelige sikkerhedsmarginer i alle grænseværdier og reaktionstider
- Anlæg designes med kontrollerede outlets, således at situationer som er på vej til at blive farlige automatisk afværges på sikreste måde.

UNDERGRUND

- Grundige forundersøgelser
  - Seismik
  - Prøveboringer
  - Tæthedstest af cap-rock

- Omfattende overvågning
  - Alt på overfladen overvåges i realtid
    - Temperaturer, tryk, flow, væske mv.
  - Undergrunden overvåges i realtid
    - Observationsboringer på flankerne
    - Trykovervågning *over* cap-rock
    - Unaturlige variation i indholdet i overfladenære lag





Naturgas har været lagret i Danmark i +35 år, uden betydelige hændelser.

Design og drift af farlige anlæg bygger på årtiers erfaring, og bliver fortsat mere og mere sikker.

CO_2 lagring vil derfor kunne etableres med stor sikkerhed og pålidelighed

Spørgsmål?

Quality assurance of CO_2 storage

Verification against ISO 27914:2017

Jørg Aarnes

22 September 2020

SAFER, SMARTER, GREENER

ISO 27914

- **Objective:**
  - Provide recommendations for the safe and effective storage of CO_2 in subsurface geologic formations.
- Applies to injection of CO_2 into geologic units **for the sole purpose of storage.**
- **Does not apply to** [...] storage of CO_2 that occurs in association with CO_2 *enhanced* hydrocarbon recovery.
- Does not address accounting of emissions stored or avoided.
- Developed over 4 (7) years by ~100 individuals from 10+ countries.

INTERNATIONAL STANDARD

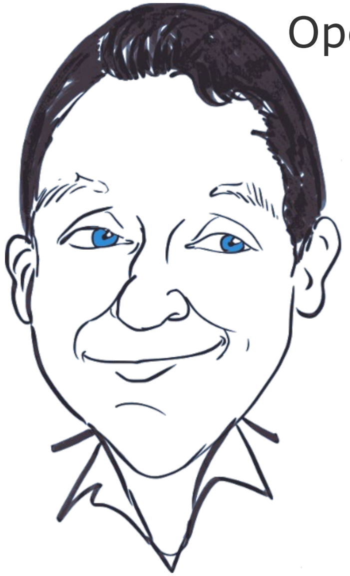
ISO 27914

First edition
2017-10

Carbon dioxide capture, transportation and geological storage — Geological storage

Capture, transport et stockage géologique du dioxyde de carbone — Stockage géologique

Potential users of ISO 27914



Operator

- Project execution
- Reference for dialogue with
  - Regulators
  - Partners
  - Investors
  - Public

Regulator

- Additional guidance relative to regulations
- Sanctioning of projects in absence of regulations

Investor

Venture partner

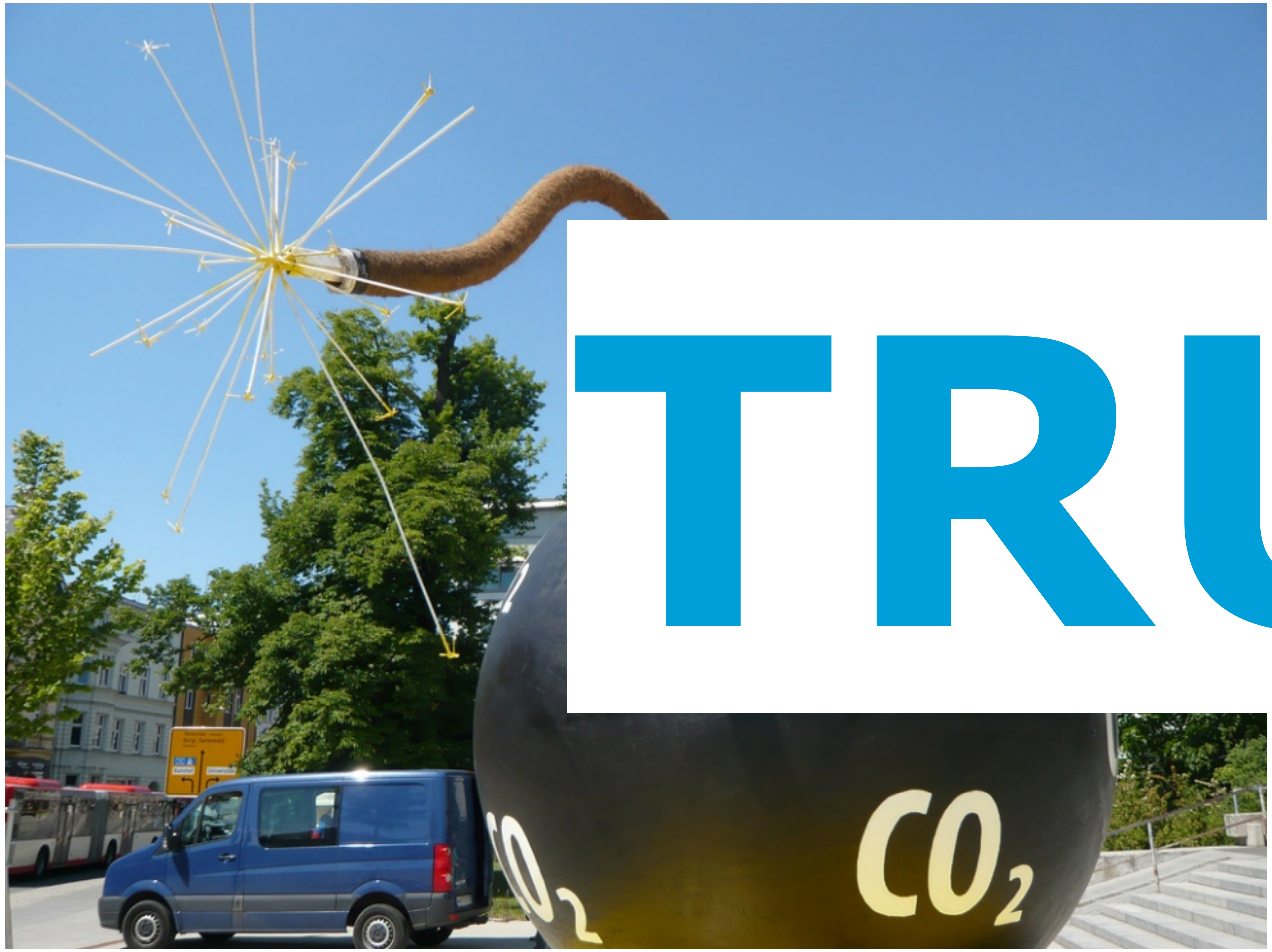
Emitter

- Technical 'due diligence' for investment decision
- Understand management of risk and uncertainty

Policy makers

- Developing regulations
- Apply for funding support for CCS projects

Why verify conformity with ISO 27914?



Demonstration in Cottbus, Germany against Vattenfall's CCS plans, primarily storage.

Credit: GuenterHH, flickr.com

TRUST

INTERNATIONAL STANDARD

ISO 27914

First edition
2017-10

Carbon dioxide capture, transportation and geological storage — Geological storage

Capture, transport et stockage géologique du dioxyde de carbone — Stockage géologique

DNV·GL

Our experience in review and certification of storage projects

- QUEST: Review, and issuance of
  - Statement of Fitness for Purpose of QUEST Storage Development Plan

- CarbonNet: Review/verification relative to DNVGL-RP-J203, and issuance of:
  - Statement of Feasibility
  - Statement of Conformity – Appraisal plan
  - Verification of documentation to support Declaration of Storage site

- Gorgon: Review commissioned by the Western Australia D. of Mines and Petroleum

Thank you for your attention!

Questions?

Jørg Aarnes
Jorg.Aarnes@dnvgl.com

www.dnvgl.com

SAFER, SMARTER, GREENER

CCS IN A EU PERSPECTIVE

Nils A. Røkke, EVP Sustainability SINTEF, President EERA, Co-chair ZEP

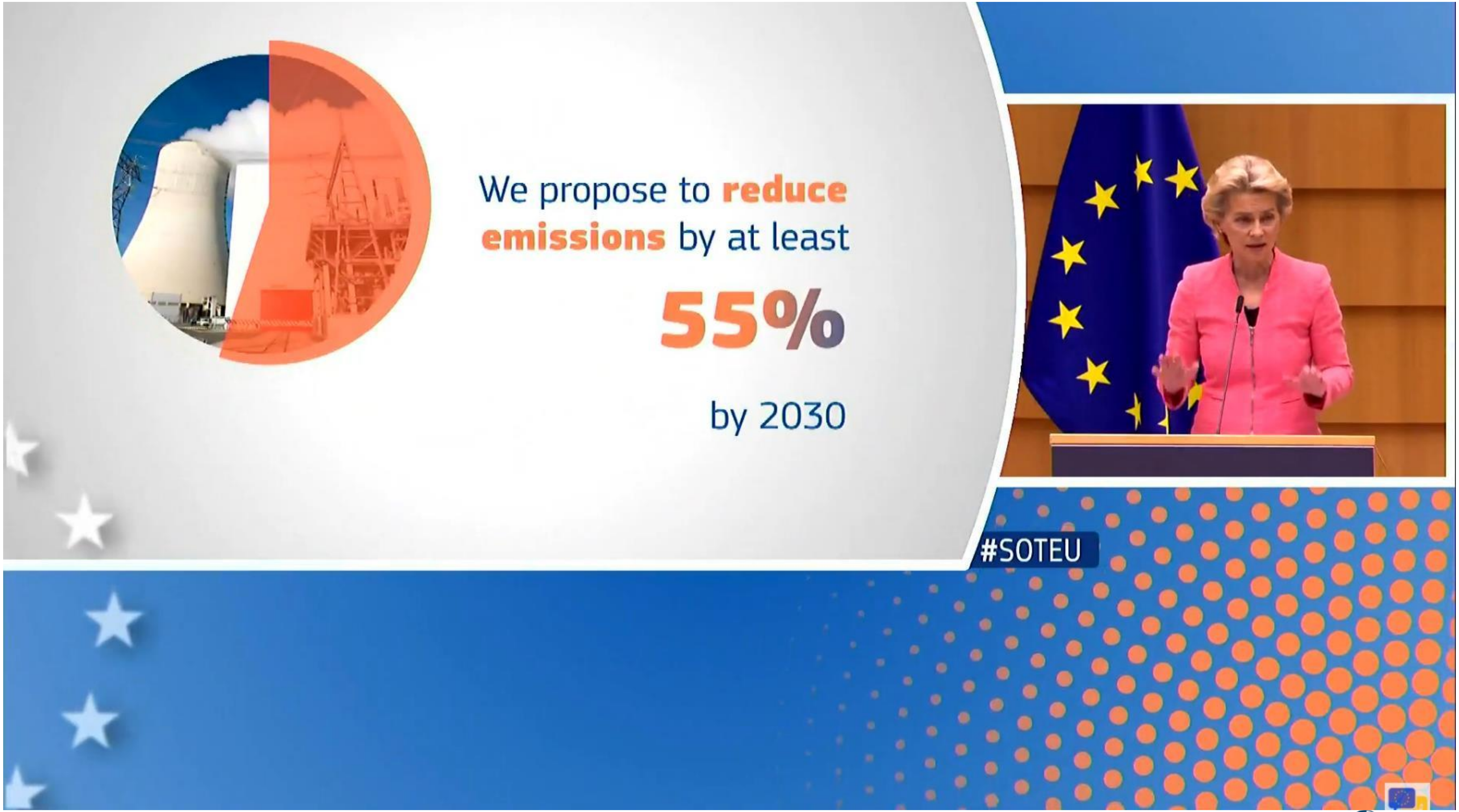
"Fangst og lagring af CO2 som Klimavirkemiddel", CPH 22/9/2020

Topics

- Policy framework
- Indispensability of CCS
- The tide has turned..
- Focus areas
- Conclusions

European Green Deal – the framework for the foreseeable future

- “Europe’s new growth strategy”
- Breakthrough technologies such *as CCUS will support “climate and resource” industrial frontrunners*
- Focus on “smart infrastructure” to support the transition to climate neutrality
- Clean hydrogen as an innovative technology


We propose to reduce emissions by at least
55%
by 2030
#SOTEU

- **"Much of the energy transition will focus on direct electrification**. However, in sectors like steel, cement, chemicals, air traffic, heavy-duty transport and shipping, we need something else: continued development of carbon capture and storage, as well as energy carriers that can be stored longer and transported more easily over longer distances.
- This is why **scaling up the use and production of clean hydrogen in Europe is such an important piece of the puzzle**."

- F. Timmermans, 8 July 2020

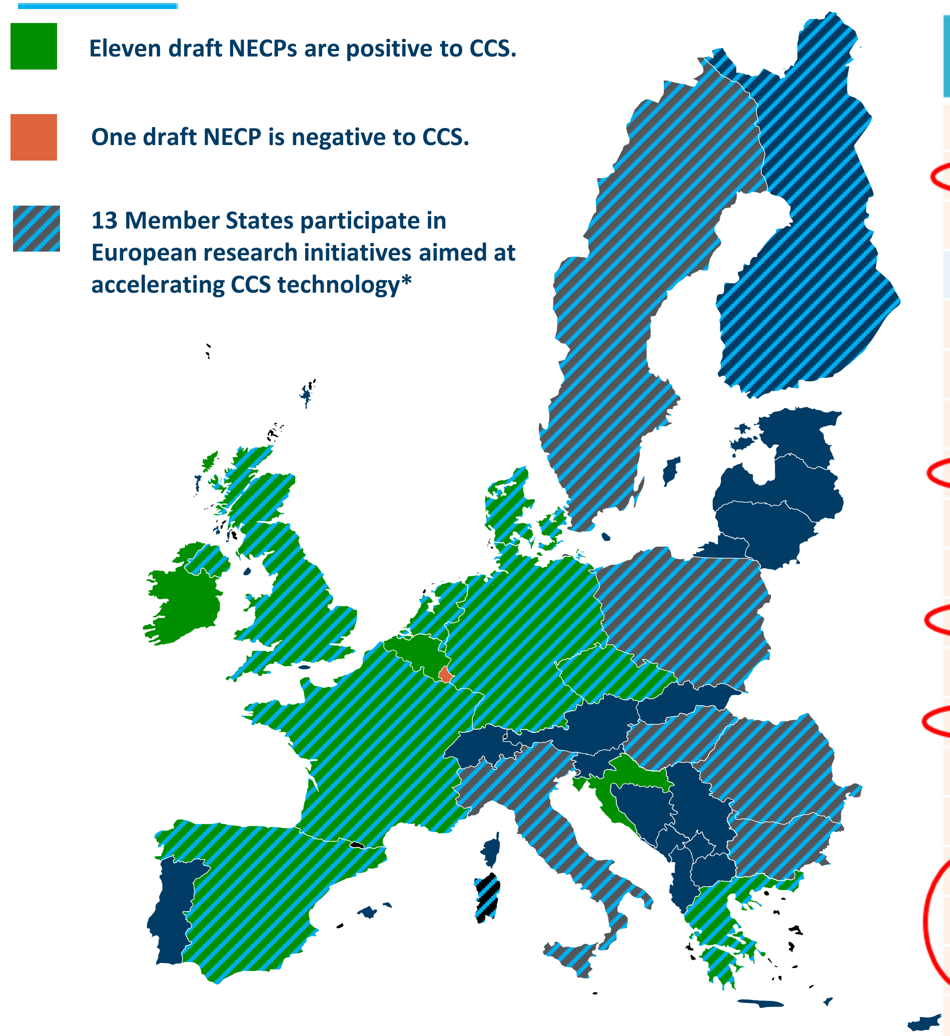
Additional moves..

- London Protocol – opening up for cross-border CO_2 transport for offshore storage
- EC scenarios on pathways to 2050 – only two valid scenarios (carbon capture)
- CCUS and hydrogen well described in EC reports underpinning Industrial strategy …
- Horizon Europe – Clean Energy Transition and Clean hydrogen partnerships …
- EIB changes its lending policy to end lending to fossil fuel projects
- EU Sustainable taxonomy includes CCS, can though be improved for bioccs
- EP adopts resolution on EGD "environmentally safe CCS in making heavy industry climate neutral" "where no direct emission reduction options are available"
- European Parliament adopts PCI list with five CO_2 transport projects – " … fifth PCI list will have focus on smart clean CO_2 infrastructure projects …"


EUROPEAN COMMISSION

SINTEF

Member States: CCS in NECP and participation in European CCS research



18 MS	Attitude to CCS in draft NECP	Member State is part of European CCS research initiatives
BE	POSITIVE	
BG		YES
CR	POSITIVE	
CZ	POSITIVE	YES
DE	POSITIVE	
DK	POSITIVE	YES
ES	POSITIVE	YES
FI		YES
FR	POSITIVE	
GR	POSITIVE	YES
HU		YES
IE	POSITIVE	
IT		YES
LU	NEGATIVE	
NL	POSITIVE	YES
PL		YES
RO		YES
SE		YES
UK	POSITIVE	YES

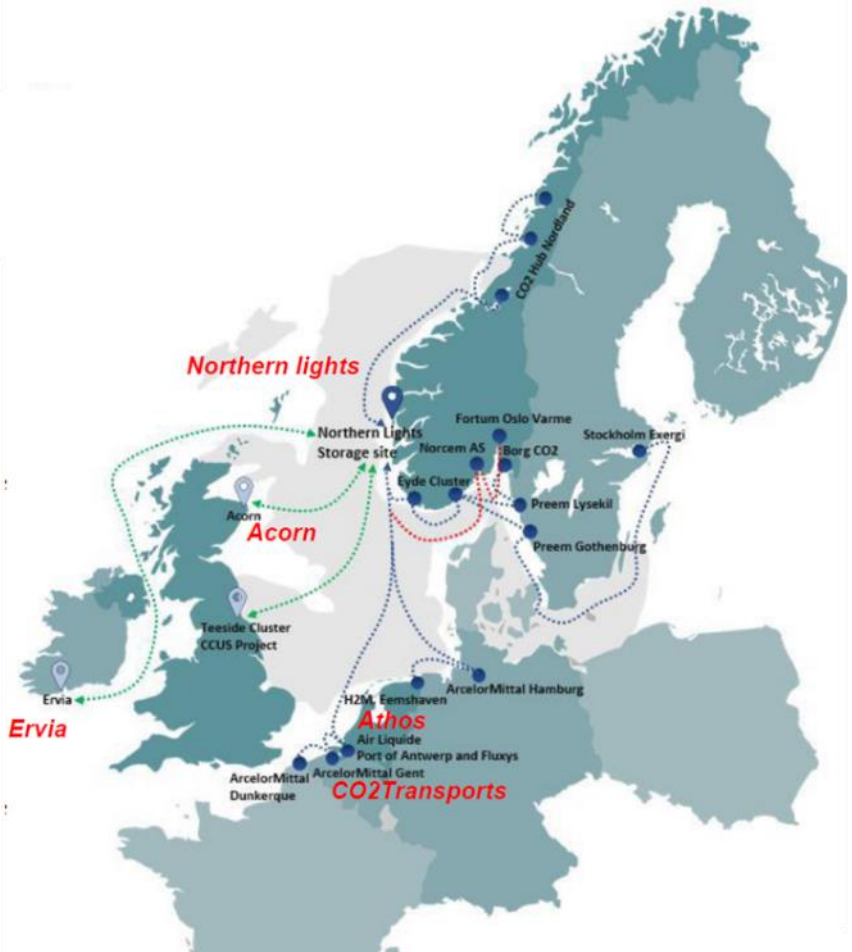
Source: IOGP

*including under the SET-Plan, ERA-NET CoFund ACT and EEA-grants 2014-2021

SINTEF

Summary: key drivers for CCUS, Europe

- Industrial CO_2 emission mitigation from hard to abate sectors
- Clean hydrogen from decarbonising fossil fuels with CCS
- Gas power plants with CCS
- Climate positive solutions (BECCS, Waste to Energy, ..)
- Use of CO_2 in a sustainable way providing permanent storage
- Policy is finally getting around to acknowledge the importance of CCUS



Adapted version of map from the report "Industry in a changing climate" (Bellona Europa, 2018).

Key requirement?

Ability to return and store CO_2- crucial infrastructure for Europe

SINTEF

Photo: Eirin Larsen,
Statsministerens kontor

THANK YOU!

The European Technology Platform ZEP and the European Energy Research Alliance are acknowledged for providing parts of the presentation material

nils.a.rokke@sintef.no *@Nils_Rokke (Twitter)*

SINTEF

SINTEF

70 years

1950-2020

Technology for a better society

ØKONOMIEN I CCS VÆRDIKÆDEN

Største omkostninger ved CCS

- **CO2 fangst**
- Landtransport
- Kompression (og liquifaction)
- **Skibstransport** fra havn til injektionsfaciliteter (på land eller offshore)
- **Geologisk lagring (og monitorering)**

CARBON CAPTURE – LEARNING COSTCURVE
- GLOBAL CCS INSTITUTE

Learning - Example

"The most recent studies show capture costs (also using mature amine-based capture systems) for facilities that plan to commence operation in ***2024-28, cluster around USD43 per ton of CO2****. "*

New technologies?

"New technologies at pilot plant scale promise capture costs around ***USD33 per ton of CO2****."*

Forbrændingsanlæg i DK

- Kort sigt (0,5Mtpa): 65 EUR/t
- Længere sigt: ?

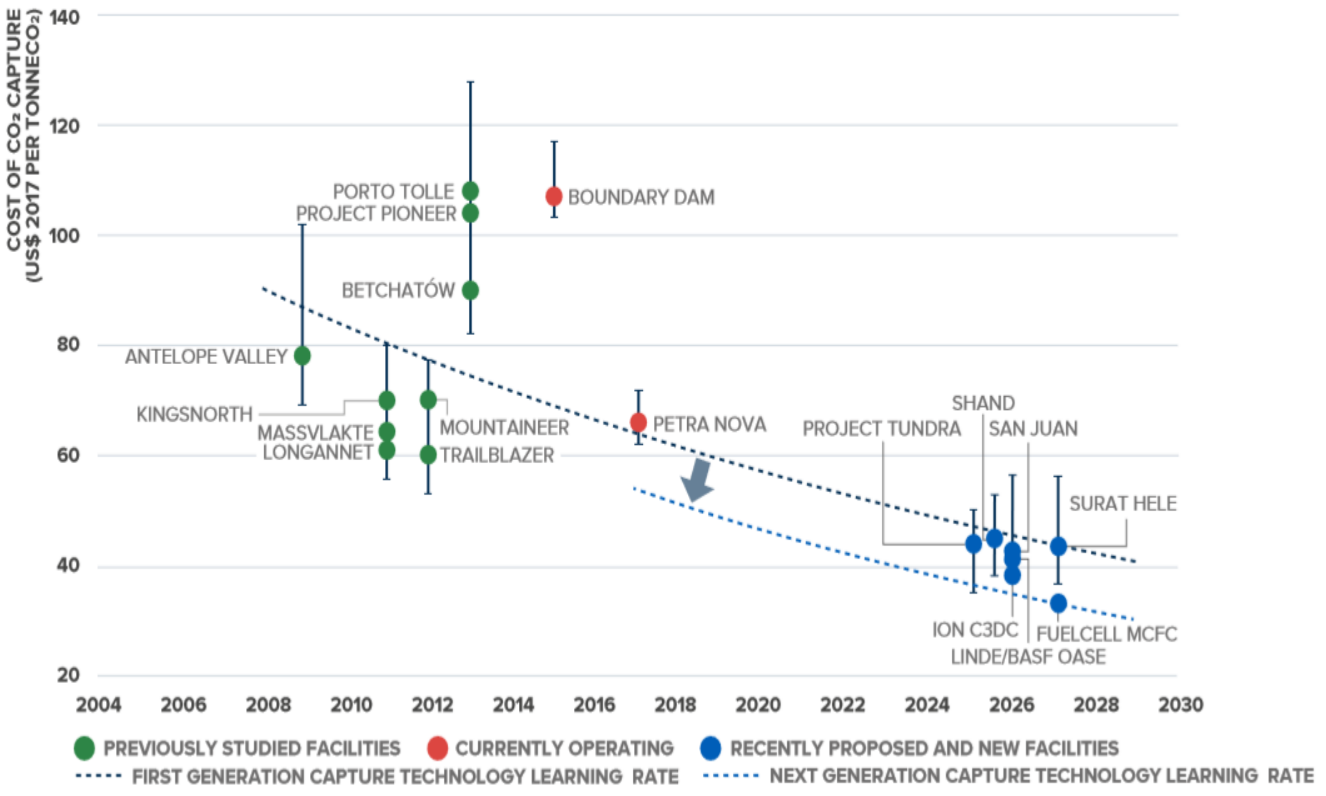


FIGURE 8 LEVELISED COST OF CO_2 CAPTURE FOR LARGE SCALE POST-COMBUSTION FACILITES AT COAL FIRED POWER PLANTS, INCLUDING PREVIOUSLY STUDIED FACILITIES[vii]

Source: Global CCS Institute

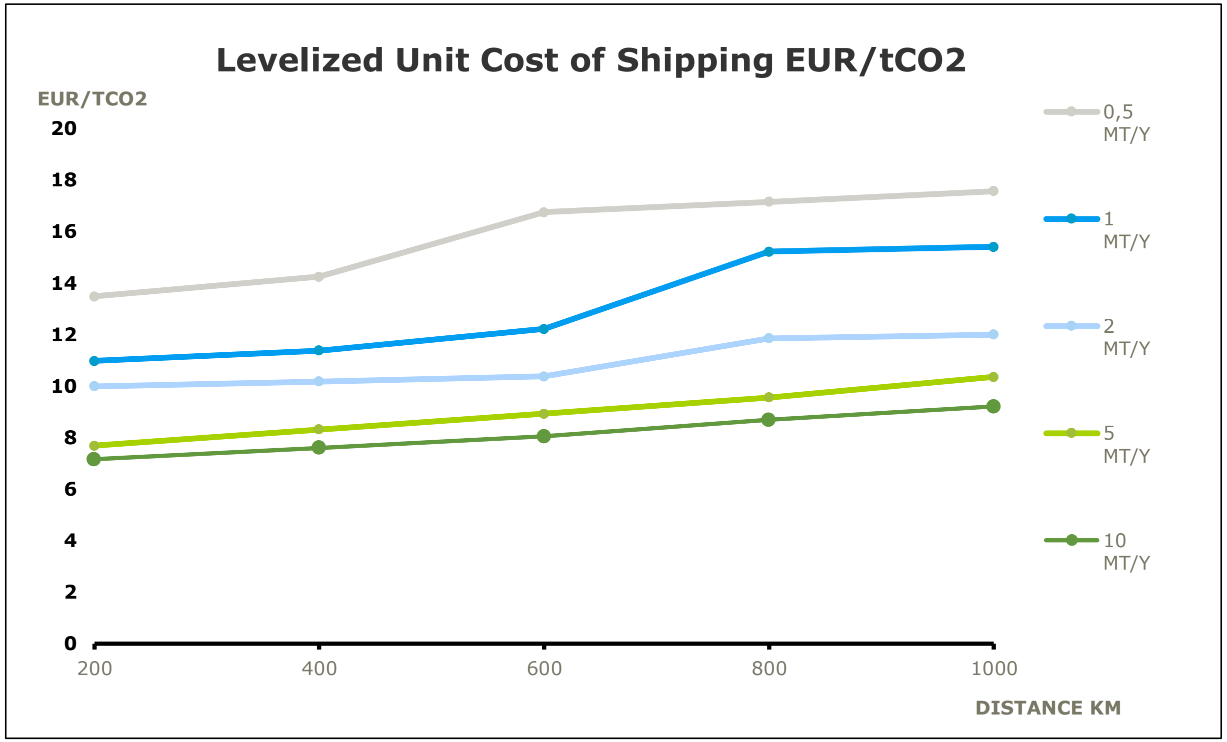
RAMBØLL

SKIBSTRANSPORT

Shipping CO2 – UK Cost Estimation Study (BEIS 2018)

- **Levelized Unit cost of Shipping**
- Med havnefaciliteter og liquifaction
- 0,5 Mtpa
    - 600 km: 17 EUR/t
    - 1000 km: 18 EUR/t
- 1,0 Mtpa
    - 600 km: 12 EUR/t
    - 1000 km: 15 EUR/t

=> Et internationalt marked for CO2?



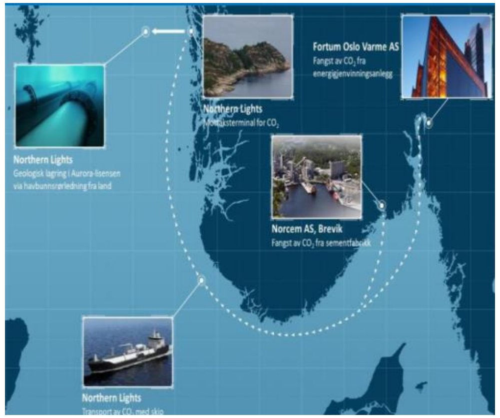
RAMBØLL

BEIS: UK Business, Energy & Industrial Strategy Department

LAGRING

Projekter med transport og lagring

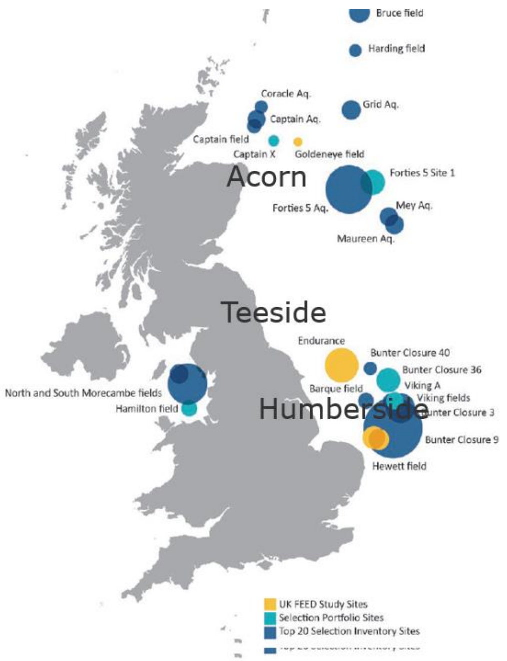
Skandinavien	Størrelse	LUC (EUR/t)	Start
Greensands	0,5Mtpa	80 (?)	2024
Northern Lights I	1,5Mtpa	83 (?)	2024



Projekter med lagring alene

The Strategic UK CO2 Storage Appraisal Project (2016)

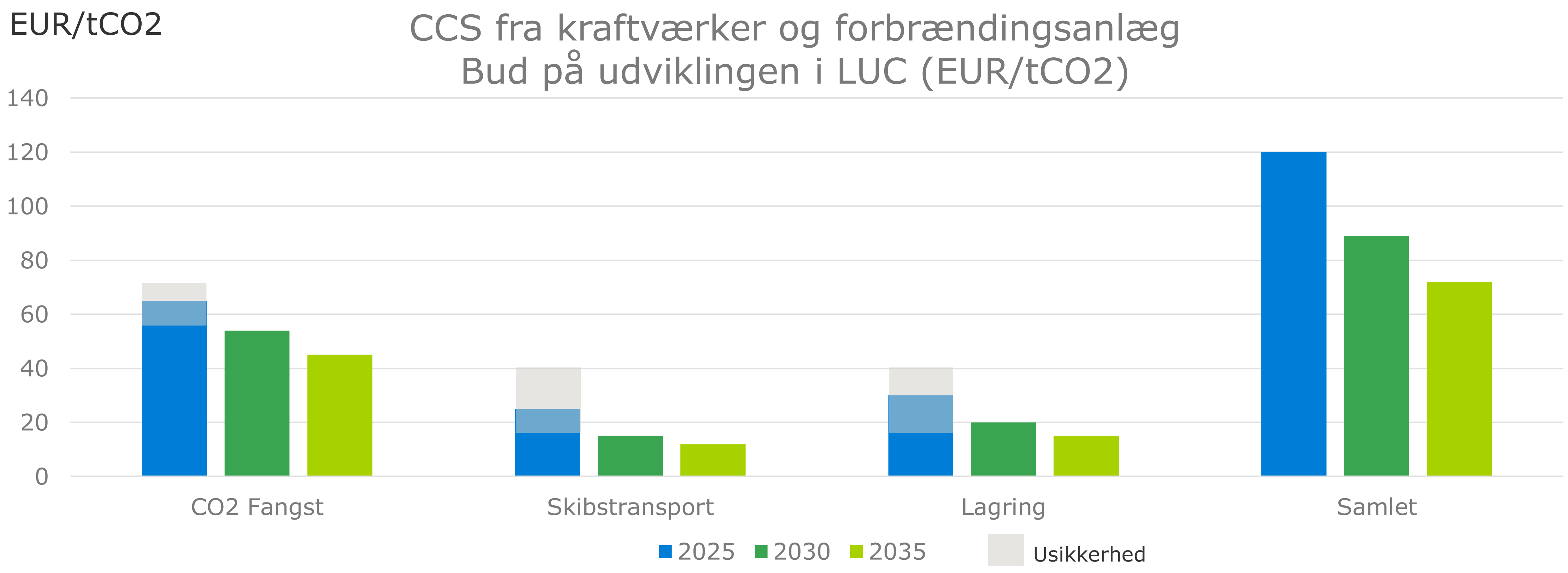
UK	Størrelse	LUC (EUR/t)*	Start
Gennemsnit	-	16,4	-
Range	3-8 Mtpa	12-21	-
ACORN	+4 Mtpa	21	2025?
Teeside	5 Mtpa	20	2026?
Humberside	7 Mtpa	14	2025?



RAMBOLL

*LUC: Levelized Unit Cost

UDVIKLING I CCS OMKOSTNINGER



KONKLUSIONER

- CCS koster mindre end mange tror?
- \- og det bliver billigere
- Billigere at fange CO_2 i DK
- Size matters => ”Klynger”
- Et ambitiøst mål
- Forretningsmodeller
- CCS kan spille en væsentlig rolle