VELKOMMEN

- SEMINAR OM CO2 STANDARDER M.M.

Klima-, Energi- og Forsyningsministeriet

DAGSORDEN

Velkommen
v. Anders Hoffmann, Afdelingschef i KEFM

CO_2-standarder og betydningen for opbygning af CO_2-lager
v. Søren Reinhold Poulsen, Project Director INEOS

Transport af CO_2 med lastbil, hvad betyder standarder?
v. Henrik Thomsen, Market Manager Linde Gas

Et perspektiv fra Aker Carbon Capture på behovet for standardisering indenfor CCUS
v. Peter Thoft Knudsen, Sales Director, Aker Carbon Capture

Paneldebat

Opsamling

SAMLET STRATEGISK RAMME FOR CCS/PTX

Del 1
Køreplan for lagring af CO_2

Tre principper for lagring af CO_2:

1. Muliggøre lagring i den danske undergrund via et nyt tilladelsesregime
2. Import og eksport af CO2 over landegrænser
3. Kortlægge yderligere potentialer for lagring af CO2 på sigt.

Juni 2021

Del 2
Køreplan for fangst og transport af CO_2

Fokus på resten af CCS-værdikæden:

1. Principper for udmøntning af CCUS-pulje
2. Hjemmel til CCS på affaldsforbrændings- og biomasseanlæg
3. Langsigtede pejlemærker for udrulning af CCS på markedsvilkår
4. Interessentforum + klyngesamarbejder

December 2021

Del 3
Køreplan for anvendelse af CO2 (PtX)

Regeringen præsenterede i 2021 sin PtX-strategi, der indeholder fire spor:

1. PtX' bidrag til DK's klimamål
2. Regulatoriske rammer og infrastruktur
3. PtX ift. energisystemet
4. Eksport af PtX-produkter/teknologier

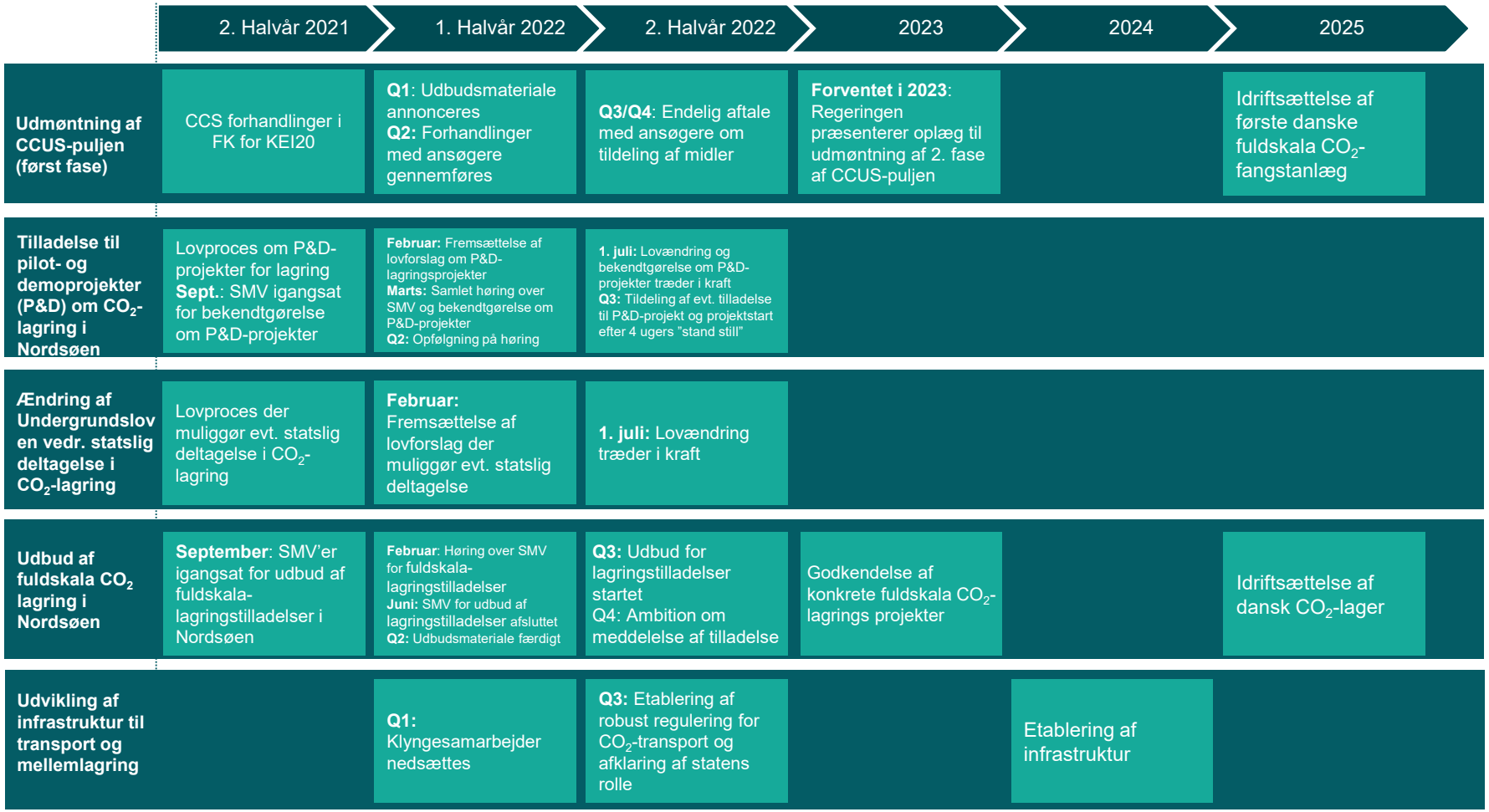
D. 15. marts 2022 indgik regeringen en aftale om udvikling og fremme af brint og grønne brændstoffer.

Marts 2022

STATUS

- Politiske aftaler om de overordnede rammer for fangst, transport, lagring og anvendelse af CO2
- Danmark har tiltrådt de nødvendige artikler i London Protokollen om transport af CO2 på tværs af landegrænser mhbp. lagring
- Hjemmel til CCS på affaldsforbrændings- og biomasseanlæg
- CCUS-puljen prækvalifikation om lidt
- Nedsættelse af klyngesamarbejder om CO2 transport og infrastruktur

TIDSPLANEN FOR CCS FREM MOD 2025



BETYDNINGEN AF STANDARDER FOR UDVIKLING AF VÆRDIKÆDEN

- Vigtigt, at alle dele af værdikæden taler sammen
- CO2'ens "renhed" især vigtig ift. standarder
- Lang tidshorisont, beslutninger om fx materialevalg skal tages nu
- Fælles forståelse på tværs af fx EU for at sikre sammenhængende marked
- Hvad er det gode valg? Behov for dialog på tværs

Tak

Greensand Project on CO2 specification standards Still a way to go!

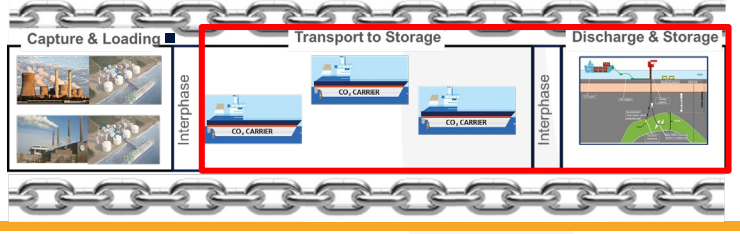
KEFM 06-04-2022

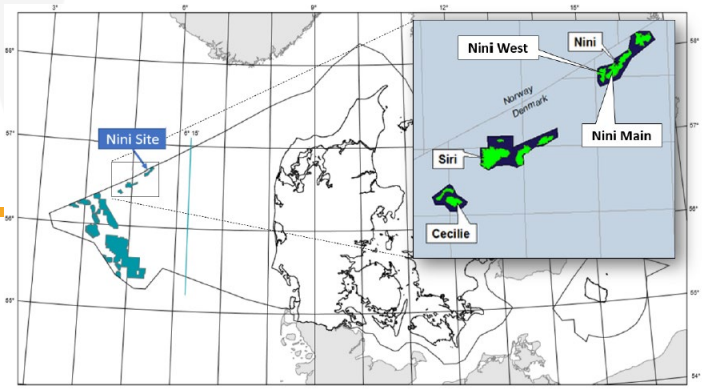
Søren Reinhold Poulsen, Greensand Project Director

INEOS Energy

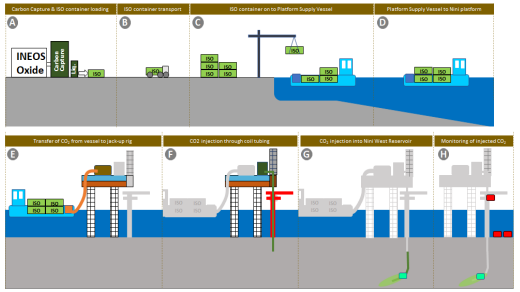
Greensand CCS Project

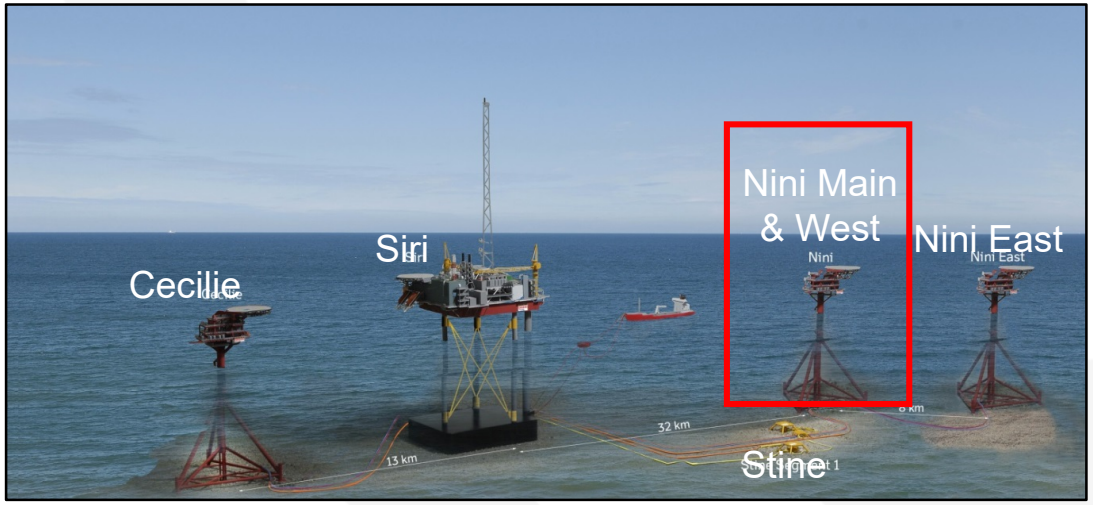
Overview!

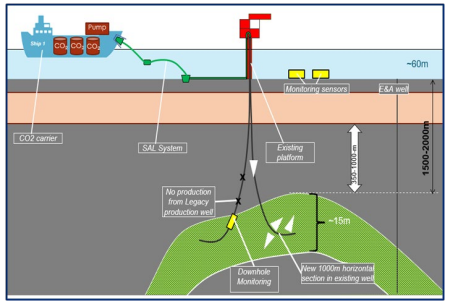


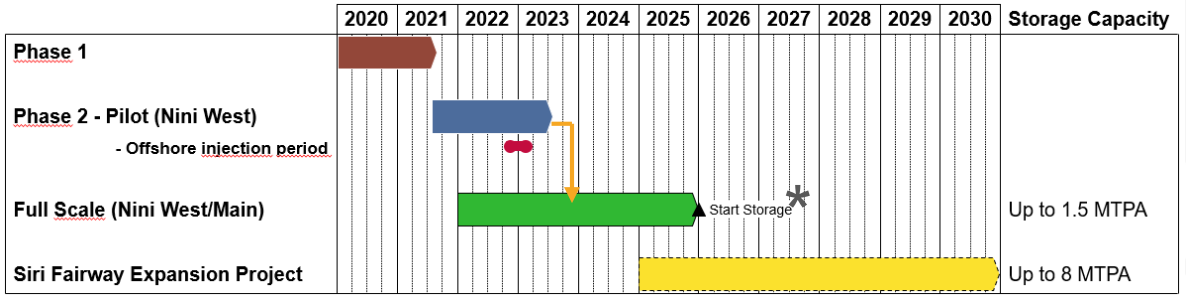


- Phase 2 ongoing (EUDP funded, 23 companies in consortium)
  - Offshore CO2 injection pilot trial
  - Monitoring set-up (development, testing & deployment)
  - Lab testing (cores and materials)
  - Environmental and Reservoir modelling
  - Ship design
  - Dissimination
  - Etc, etc….
- Nini Full Scale project (Nini Main & West)
  - Regulatory deliverables/ authority dialogue
  - Further concept maturation (transport, transfer, storage & modelling)
    - CO2 specifications
  - Logistical modeling
  - Interface modelling
  - Commercial maturation
    - Commercial full value chain modelling
    - Cross value chain dialogues/partnering









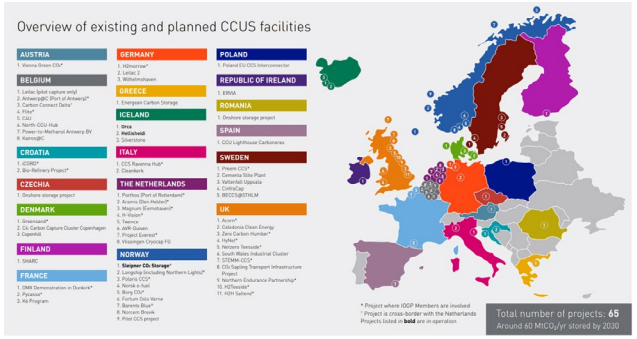
*) FID and start of storage carries multiple external dependencies

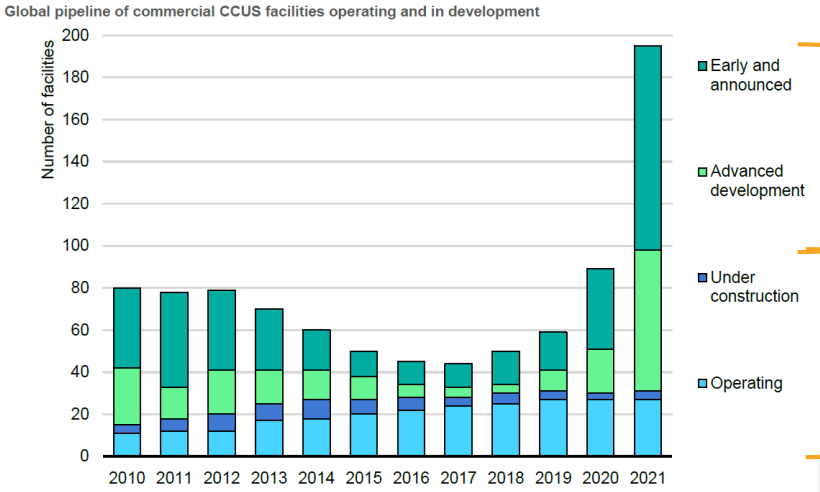
INEOS Energy

CCUS projects are mushrooming and CO2 specs are the talk of the town (again)

- CO2 specs are being investigated like hell!
  - No need to panic, but need for collaboration
  - A lot of good work are out
  - A number of specialist are here to assist
- Need for standardisation where applicable
  - Drive cost down or increase!
  - Create multi CCUS system redundancy, especially for storage
- However, every CCUS value chain has unique elements
  - Cluster up to de-unique where applicable as they all do to generate system flexibility, operability and cost effectiveness throughout

Porthos CCUS cluster

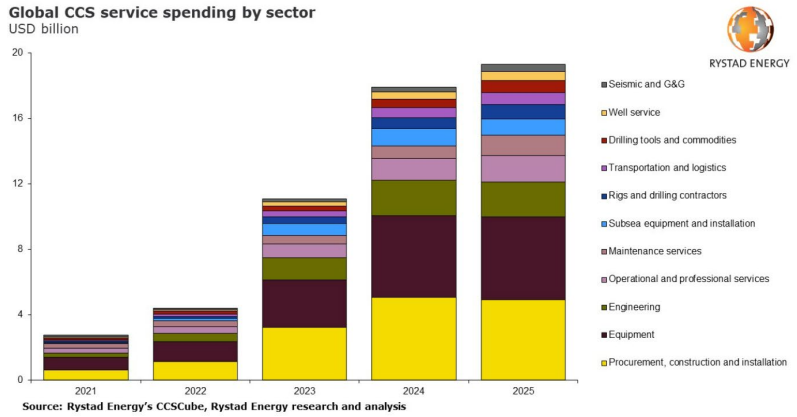




Source: IEA analysis and tracking; Global CCS Institute CCS Facilities Database https://co2re.co/

Dialoque across and between, develop standards if possible, learn from the past and engage with the specialist

Design specs , data bases and lessons learned



Source: Rystad Energy's CCSCube, Rystad Energy research and analysis

Velkommen til Linde

Making our world more productive

Det nye Linde plc

→ Verdens førende industrigas- og ingeniørvirksomhed.

→ Dannet i 2018 med sammenlægningen af Linde AG og Praxair, Inc, to firmaer i verdensklassse med næsten 140 års fælles historie og fremragende resultater.

One Linde

Forenet under fælles vision, mission og strategisk retning, og arbejder ud fra fælles værdier i alt, hvad vi gør

2
kunder

millioner+
afbalanceret porteføl
afbalanceret porteføljje

100+
lande
Muliggør stærke, komplementære positioner i alle centrale markeder

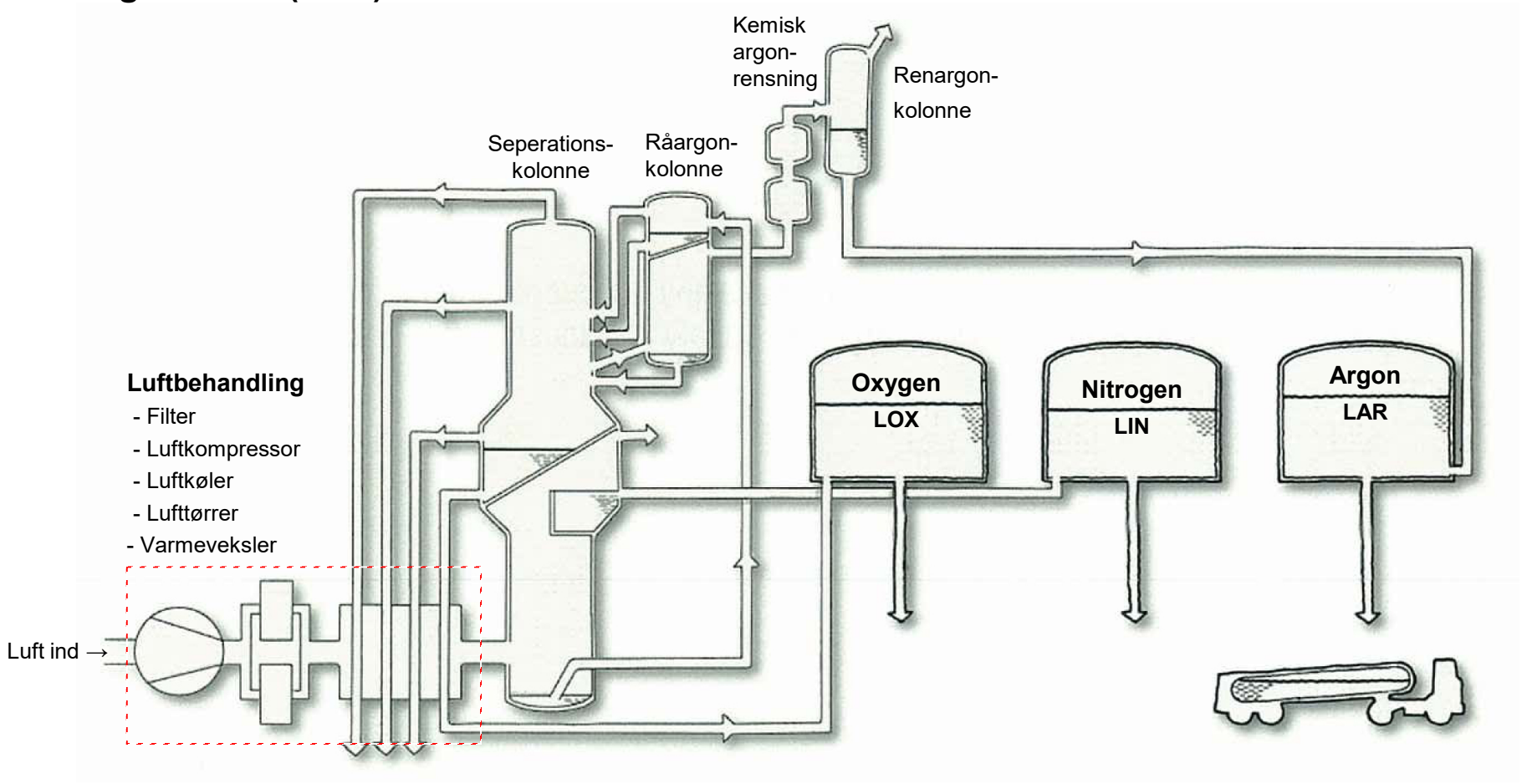
~80,000
medarbejdere
Muligt at opnå vores fulde potentiale, individuelt og i fællesskab

~$15 millioner
velgørenhed og sponsorater i 2018
Støtte til vores samfund gennem bidrag og medarbejdere, der arbejder som frivillige

6,500+
aktive patenter globalt
Vi går foran med innovative produkter, løsninger og teknologier

Lindes 100 år gamle patent er stadig udgangspunktet for produktion af luftgasser

Luftgasfabrik (ASU)

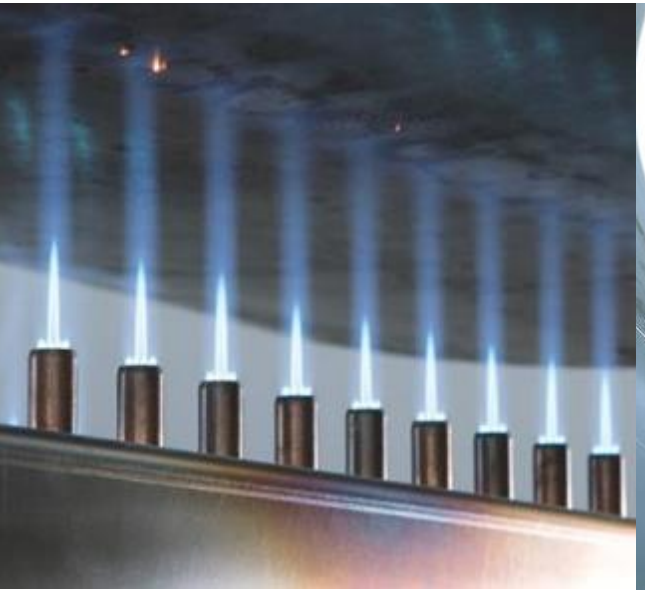


13




Gas er en del af hverdagen.

Anvendes til alt fra mad, drikke, forskning og healthcare til svejsning & skæring.

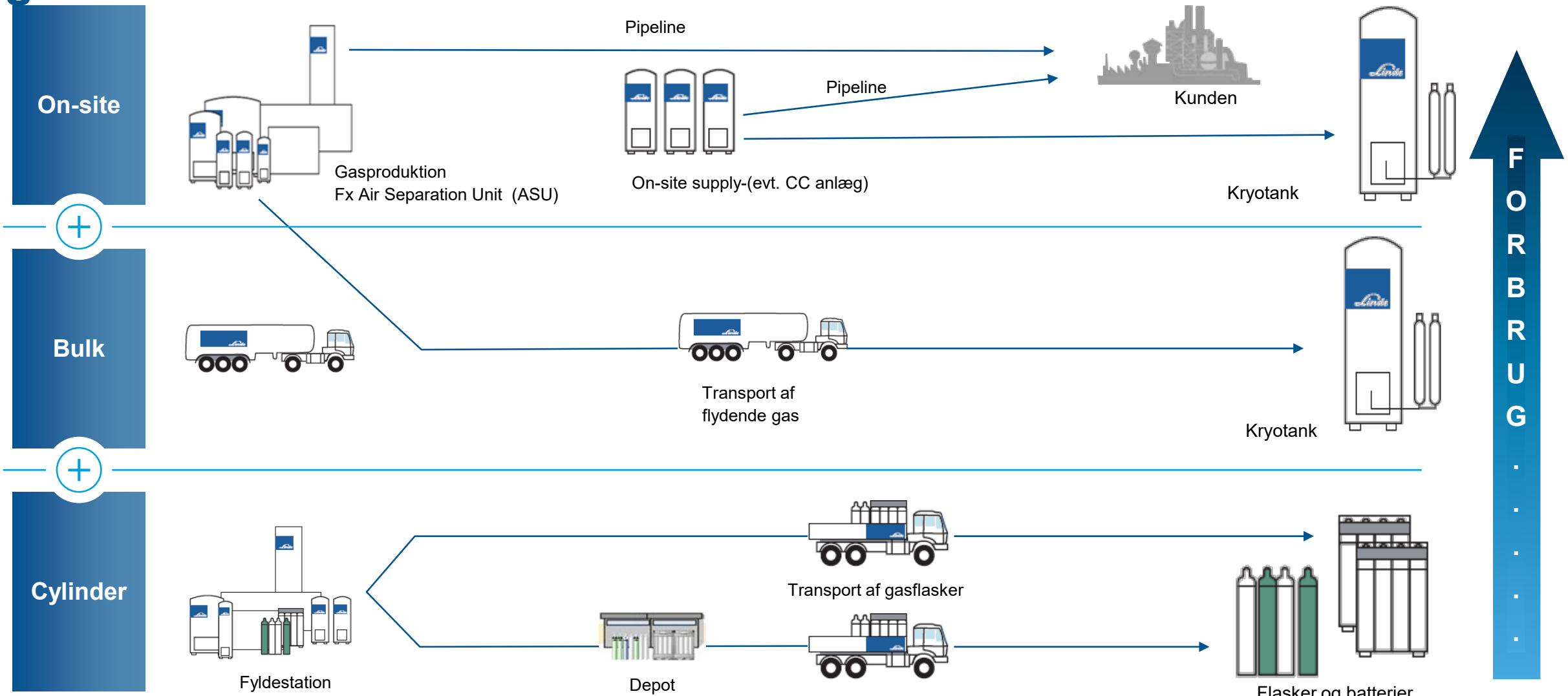



Sikring af gaskvaliteten

	Flaskeforbehandling	Analyse og kontrol	Dokumentation
Industrigas	— Tømmes ved afblæsning — Vakuumsuges tom	— Stikprøveanalyser	— Ingen
Foodgas	— Vakuumsuges tom — (analyse afblæsning CO_2)	— Stikprøveanalyser	— Ingen
Standardgas-blanding	— Tømmes ved afblæsning — Vakuumsuges tom	— Stikprøveanalyser eller — Måling på 1 ud af 12 fyldte	— Ingen — Eller Batchcertifikat (CoC)
Rene gasser	— Tømmes ved afblæsning — Vakuumsuges tom	— Måling på 1 ud af 12 fyldte	— Ingen — Eller Batchcertifikat (CoC)
Kalibrerings-gasblanding	— Vakuumsuges tom evt. under opvarmning	— Alle flasker	— Analysecertifikat (CoA)
Akkrediterede gasser	— Vakuumsuges tom evt. under opvarmning	— Alle flasker efter akkrediterede analysemetoder	— Analysecertifikat (CoA)
Farmaceutisk gas VERISEC	**— Tømmes ved afblæsning** **— Vakuumsuges tom**	**— Alle flasker med kvalificeret og valideret udstyr og metode**	**— Analysecertifikat (CoA)**

PROCESKONTROL PRODUKTKO

Produktion og distribution: industrielle gasser



Lindes kuldioxidforsyning fra 2019

Making our world more productive

- Linde CO_2 Plants FSSC 22000
- Linde CO_2 Terminals
- Linde CO_2 Terminal Odense
- Linde CO_2 Plants industrial
- Linde CO_2 Lager Taulov, CO_2 leveres via jernbane

Backup fra Linde FSSC 22000

Linde skib i Østersøen

Linde Gas A/S.
Certificering.

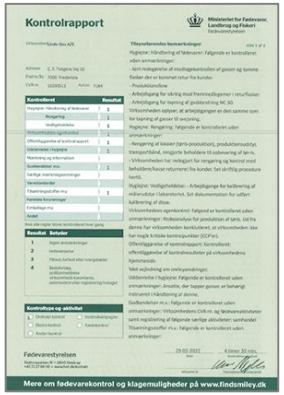
CO2 I henhold til Linde Specification
- ISBT Standard

Batch Certifikat

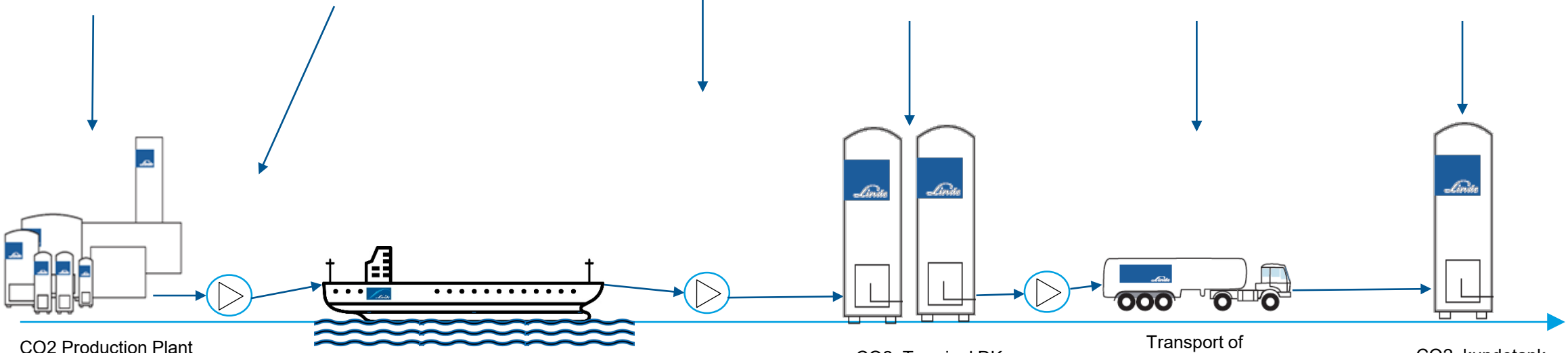
COA analysecertificat

Batch Certifikat

- E290 Certifikat
- ISBT Standard



Fødevarekontrol



Tak for opmærksomheden

Making our world more productive

AKER CARBON CAPTURE

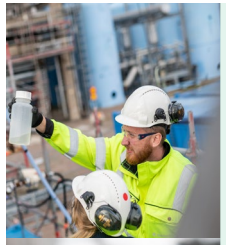
Et perspektiv fra Aker Carbon Capture på behovet for standardisering af CO_2 specifikationer indenfor CCUS

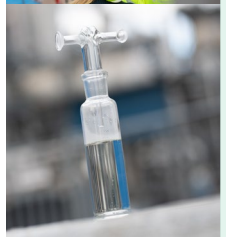
April, 2022

Peter Thoft Knudsen

Aker Carbon Capture in brief

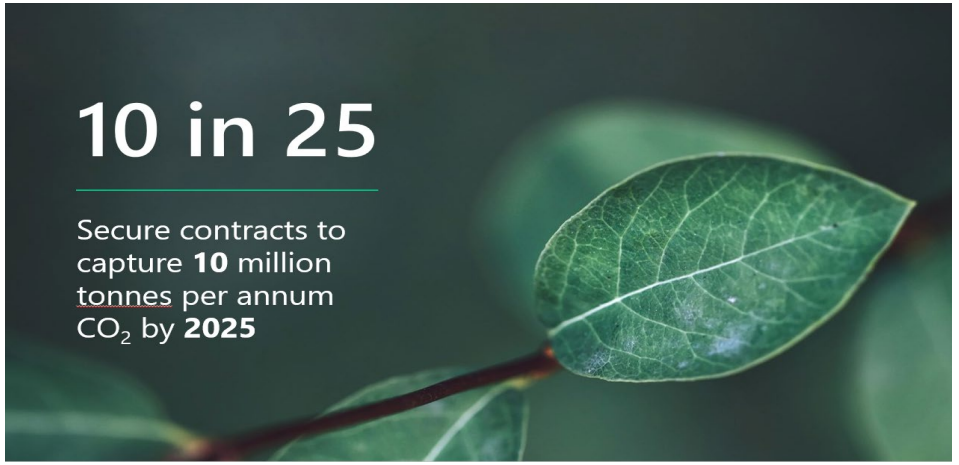
Pure play carbon capture company





- **Pure play** carbon capture company with **certified and validated** market-leading proprietary technology
- Delivering ready-to-use carbon capture plants utilizing **best in class HSE** friendly solvent and patented plant technologies

… with a strong ambition

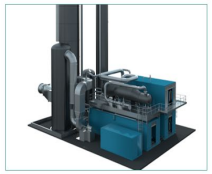


… proven at large scale

… with a strong technology portfolio

Big Catch
Launched: 1996
Capacity: > 400,000 tonnes/year

- Made to order
- ~30-36 months delivery time[1]
- Larger footprint
- Using bulk materials – cost efficient
- Retrofit potential



Just Catch™
Launched: 2018
Capacity: 40,000 & 100,000 tonnes/year

- Modularized and cost efficient
- ~15 months delivery time[1]
- Easy transport and installation
- Compact design – 25m x 20m
- 100% automated

Offshore Just Catch™
Launched: 2019
Capacity: 120 – 360,000 tonnes/year

- Modularized and cost efficient
- ~20 – 24 months delivery time[1]
- Self-contained system
- Compact design
- Retrofit potential

… already delivering large scale projects

… and flexibility in business models

Big Catch™
Capacity: > 400,000 tonnes/year

- Made to order
- ~30-36 months delivery time[1]
- Larger footprint
- Using bulk materials – cost efficient
- Retrofit potential

Just Catch™
Capacity: 40,000 and 100,000 tonnes/year

- Modularized and cost efficient
- ~15 months delivery time
- Easy transport and installation
- Compact design – 25m x 18m
- 100% automated

Delivery models

	EPC	License and key equipment	Carbon Capture as a Service
Big Catch™	✓	✓	✗
Just Catch™	✓	✗	✓

AKER CARBON CAPTURE

CO_2 specifications are necessary for several reasons

- No single entity is responsible for the full value chain, and when custody of CO_2 is transfer from one party to another, there must be agreement on both the composition and physical properties of the CO_2.
  - One CO_2 source – one shipper – one storage/utilization route
  - Clusters (Multiple CO_2 sources –multiple shippers –multiples storages/utilization routes)
- In order to ensure good operability of the full value chain, the CO_2 composition and conditions must be consistent with the intended handling method and material selection.
- Meeting a specific set of CO_2 specifications can have a significant cost impact on both the selected capture method as well as the post treatment process. It is therefore important to establish specifications that are aimed at achieving only the minimum acceptable requirements of the downstream transport and storage system, and not impose any requirements that have no material impact.
- The need for reducing CCUS cost drives the requirements for standards in general

CO_2 specification drivers

- The selection of a specification for a given project is generally driven by a combination of the end recipient and the transport system. As a rule
  - Pipeline transport has low specifications
  - Ship transport results in higher specification because the low temperatures require the concentrations of any components that might freeze, precipitate or affect vapour pressure to be removed to an acceptable level
  - Food Grade typically has the highest requirements, but the specific contaminants in question may not be relevant for CCS
- It is recommended that existing specifications be thoroughly reviewed with respect to each contaminant to verify the basis and the validity of each value. Additionally, when new storage and transport systems are developed, care should be taken in simply copying existing specifications as this may impose unnecessary constraints

Categorization of CO_2 contaminants

Contaminants in CO_2 can generally be divided into 3 categories:

- Contaminants that can have an impact on corrosion these include;
  - O_2, H_2O, NO_X, SO_X, Glycol, Hydrogen (can cause embrittlement)
- Contaminates that are human safety concern such as:
  - CO, NO_X, SO_X, Hg
  - These contaminants need to be considered from a short term exposure perspective in the event of containment failure perspective in CCS projects, but from a long term exposure perspective in the case of food grade CO_2
- Contaminants that could affect the physical properties of the CO_2 stream
  - H_2O (Risk of Hydrates) – note that in general if H2O is low enough to avoid corrosion, then hydrates are not expected.
  - Inert gasses - impact on vapour pressure in the case of liquid phase and impact on critical pressure in the case of dense phase
  - Non Corrosive Components that could precipitate as liquids – leading to flow assurance problems. (see trace components for Norther lights specification)
  - Non Corrosive components that could freeze and cause blockage issues (see trace components for Norther lights specification)

The values for each of the contaminates is a function both of the operating conditions of the transport and end use and may need additional modification on a project by project basis.

CO_2 Compositional Specifications currently in Use

- **National Grid Specification:**
  - Based on White Rose CCS project;
  - Dense phase injection;
- **EOR Specification:**
  - Dense phase reinjection for EOR purposes;
- **Northern Lights Specification:**
  - Capturing CO_2 from northern Europe and transporting via ship to western Norway;
  - Liquid CO_2 at set pressure and low temps
- **ISO 27913:2016 Specification (taken from ISO 27921:2020):**
  - States that CCS operators must develop their own purity specification tailored to their process.
- **Food Grade project**
  - Similar to Northern lights due to transport conditions, but with much greater focus on contaminants that are harmful to humans

Component	Category	Composition				
		National Grid	EOR project	Northern Lights	ISO 27913:2016	Food Grade project
CO_2		≥ 91 mol% (gas) ≥ 96 mol% (dense)	≥ 95 mol%	-	≥ 95 mol%	≥99.9
H_2O	Corrosion / Hydrates	≤ 50 ppmv	≤ 630 ppmv	≤ 30 ppmv	**20 – 630 ppmv ***≤ 200 ppmv	≥20 ppm
H_2S	Corrosion / Toxic	≤ 80 ppmv (gas) ≤ 20 ppmv (dense)	≤ 20 ppmv	≤ 9 ppmv	≤ 200 ppmv	
CO	Toxic	≤ 2000 ppmv	-	≤ 100 ppmv	≤ 2000 ppmv (0.2 mol%)	≥10 ppm
NOx	Corrosion / Toxic	≤ 100 ppmv	-	≤ 10 ppmv	*≤ 100 ppmv **≤ 50 ppmv	≥2.5 ppm
SOx	Corrosion / Toxic	≤ 100 ppmv	-	≤ 10 ppmv	*≤ 100 ppmv **≤ 50 ppmv	
N_2	Physical Properties	Critical pressure ≤ 80 barg	≤ 4 mol%	-	≤ 2 mol%	
O_2	Corrosion	≤ 10 ppmv	≤ 10 ppmw	≤ 10 ppmv	Note 1	≥30 ppm
H_2	Corrosion	≤ 2 mol%	-	≤ 50 ppmv	0.75 mol%	
Ar	Physical Properties	≤ 80 barg	-	-	Note 2	
CH_4	Physical Properties	≤ 80 barg	≤ 5 mol% -29°C dew point	-	Note 2	
Glycol	Corrosion	-	≤ 0.3 USgal/MMSCF	-	-	
Total sulphur	?	-	≤ 35 ppmw	-	-	≥0.1
Total Hydrocarbon	Physical Properties					≥50 ppm
Amines	Toxic	-	-	≤ 10 ppmv	-	
Ammonia	Toxic /Physical Properties	-	-	≤ 10 ppmv	-	≥2.5 ppm
Formaldehyde	Toxic	-	-	≤ 20 ppmv	-	
Acetaldehyde	Toxic	-	-	≤ 20 ppmv	-	≥ 0.2
Mercury (Hg)	Toxic /Corrosion	-	-	≤ 0.03 ppmv	-	
Cadmium + Thallium	Toxic /Corrosion	-	-	≤ 0.03 ppmv	-	
Methanol	Physical Properties	-	-	-	-	≥10ppm
Ethanol	Physical Properties	-	-	-	-	

Extensive technology application experience from multiple flue gases

Unique track record from Mobile Test Unit (MTU) – advanced CO_2 capture pilot

8 different flue gases tested (high process flexibility) | 50,000+ operating hours | Performance data is paramount for technology qualification

Continuously upgraded and developed since 2008

Natural gas
Risavika Gas Center

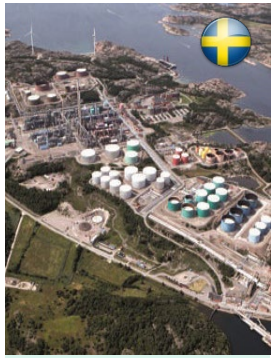
Coal
Longannet Power

Coal
National CCC

Natural gas & Heavy oil cracker
Dong CHP
Equinor oil refinery

Cement
Heidelberg/ Norcem

Waste to Energy
Klemetsrud WtE



Hydrogen
Preem refinery

Char
Polchar (2021)