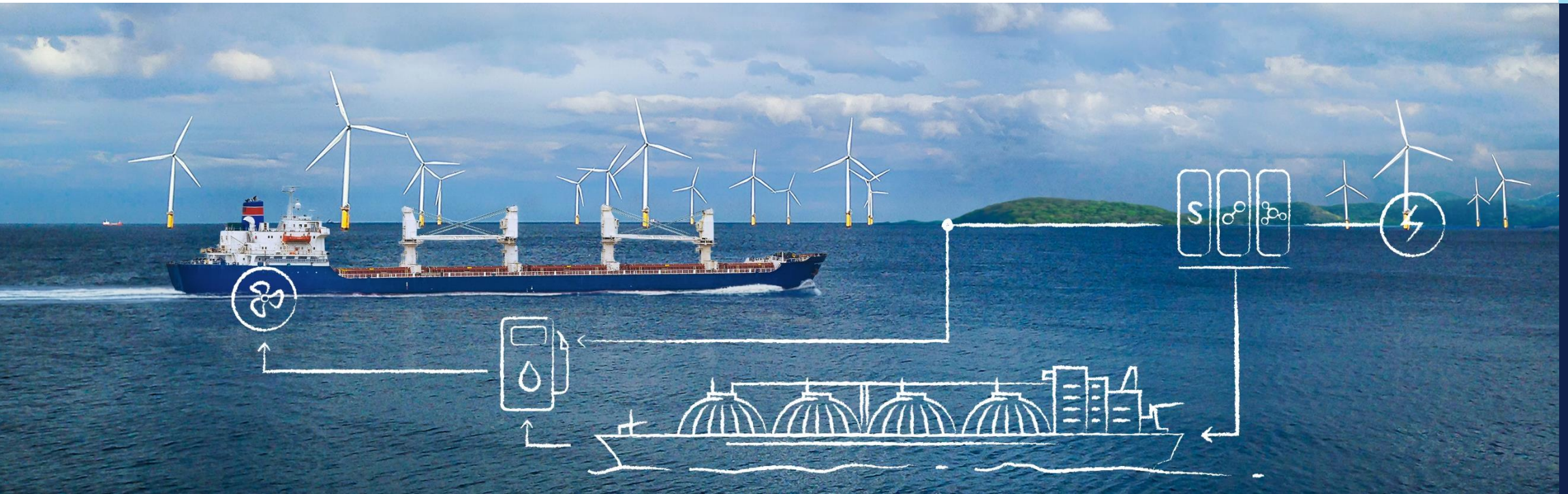
WHEN TRUST MATTERS

Quality Measurement of CO2

Understanding the impact of contaminants and how to analyse

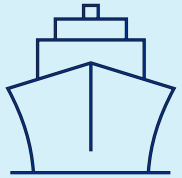
Audun Drageset
Sr. Engineer CCUS & Material Technology



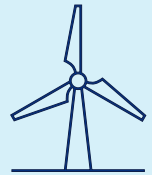
A global assurance and risk management company

160	~15,000	~100,000	100+	5%+
years	employees	customers	countries	of revenue in R&D

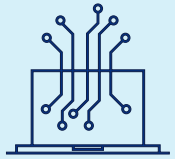
Ship and offshore classification and advisory



Energy advisory, certification, verification, inspection and monitoring



Software, cyber security, platforms and digital solutions



Management system certification, supply chain and product assurance

DNV

Driving development of international CCUS standards

DNV RESEARCH/JOINT INDUSTRY PROJECT

- CO2 RISKMAN – Guidance on CCS CO_2 Safety and Environment Major Accident Hazard Risk Management
- CO2 PIPETRANS – Guidance on transportation component of CCS projects
- CO2 SAFEARREST – Guidance on the efficient design of CO_2 pipelines
- CO2 QUALSTORE – Guidance for the selection and qualification of CO_2 storage sites
- CO2 WELLS – Guidance on the risk management of existing wells at CO_2 storage sites
- CO2 CAPTURE – Guidance on procedure for capture technology qualification
- HiPerCap – Development of novel Capture technologies
- ECO2 – Best environmental practice for offshore CO_2 injection

↓

DNV RECOMMENDED PRACTICE

DNV-RP-J201
Qualification procedures for carbon dioxide capture technology

DNV-RP-F104
Design and operation of carbon dioxide pipelines

DNV-RP-J203
Geological storage of carbon dioxide

DNV STANDARD

DNV-ST-F101
Submarine pipeline systems

↓

INTERNATIONAL STANDARD

ISO 27919-1
Carbon dioxide capture – Performance evaluation methods for post-combustion CO_2 capture integrated with a power plant

ISO 27913
Carbon dioxide capture, transportation and geological storage – Pipeline transportation system

ISO 27914
Carbon dioxide capture, transportation and geological storage – Geological storage

DNV FRAMEWORKS FOR ASSURANCE SERVICES

DNV-SE-0160: Technology qualification management and verification

DNV-SE-0657: Re-qualification of pipeline systems for transport of hydrogen and CO2 (2023)

DNV-SE-0473: Certification of sites and projects for geological storage of CO_2

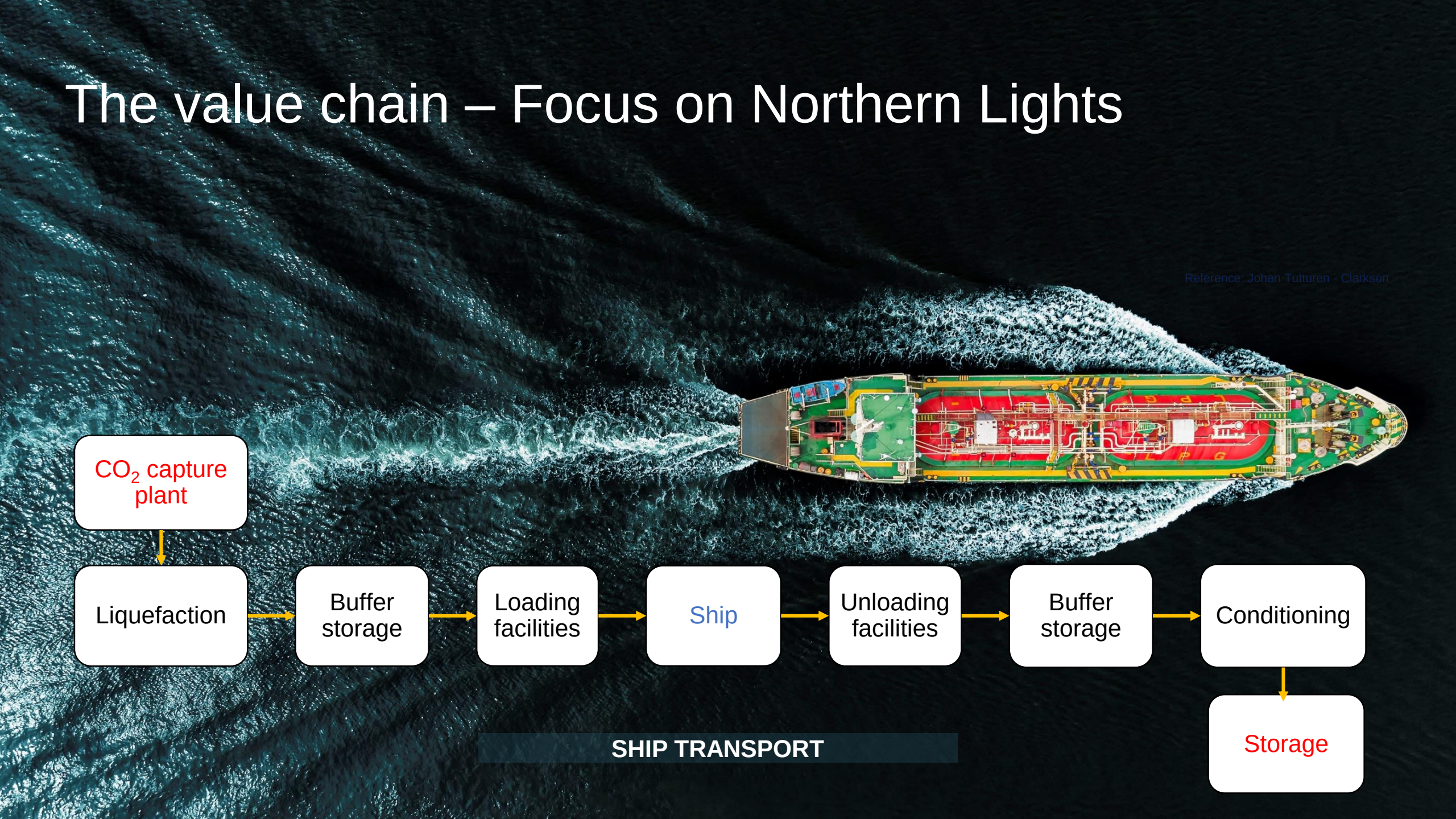
DNV-SE-0617: Qualification management for geological storage of CO_2

ISO 13623 Pipeline Transportation Systems (2009)

Contaminants on CO_2

- Understanding the problem
  - The value chains
  - Example specifications
  - Why are the chemicals on the list?
- Sampling and analysis

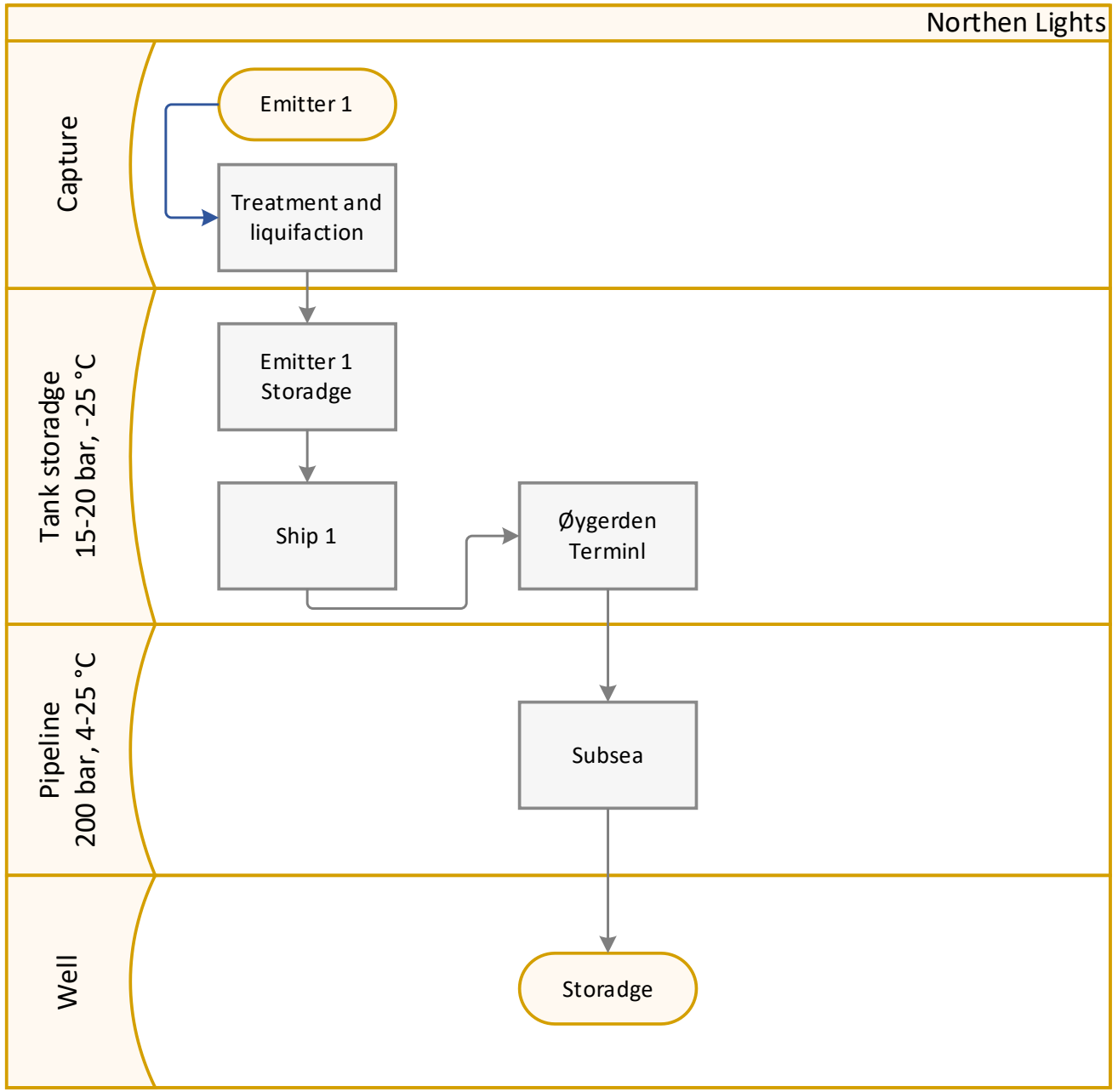
The value chain – Focus on Northern Lights



The value chain

Each project will be unique

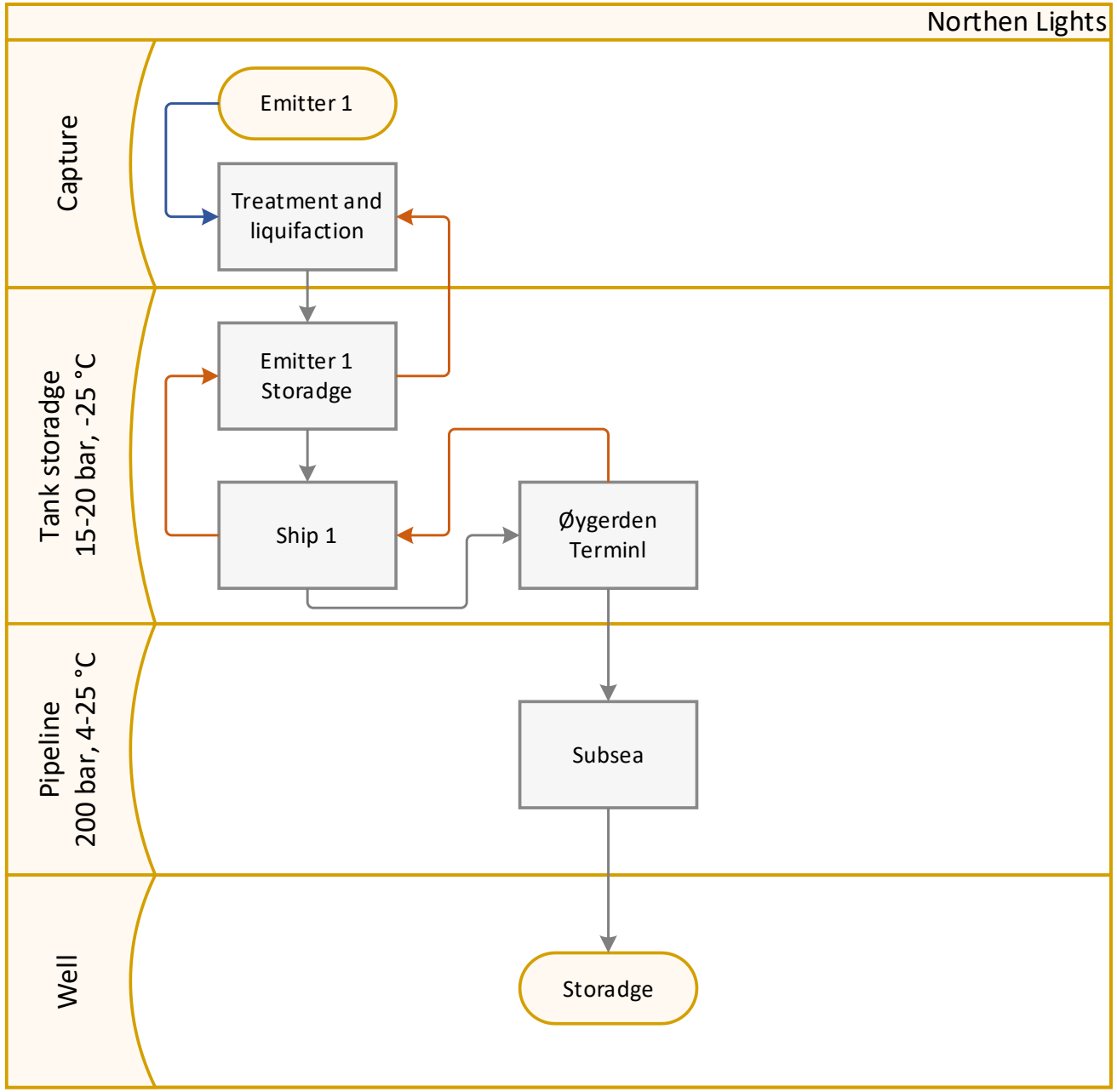
- Locations of emitters (industrial hubs or scattered?)
- Availability of storage
- Distance and complexity in transport
- What type of emitters are in the network?



1) https://ccsnorway.com/app/uploads/sites/6/2020/05/Northern-Lights-Project-Concept-report.pdf
2) https://norlights.com/news/webinar-on-updated-co2-specifications-for-the-northern-lights-value-chain/
3) Sonke et al. CO2 Transport and Injection, Effects of Impureties, Understanding or Reactions and Consequences, AMPP March 19-23, 2023, Paper 18756

The value chain

Gas return – To keep a stable pressure, an equal volume of Liquid and Gaseous CO_2 is loaded/off-loaded between stages.



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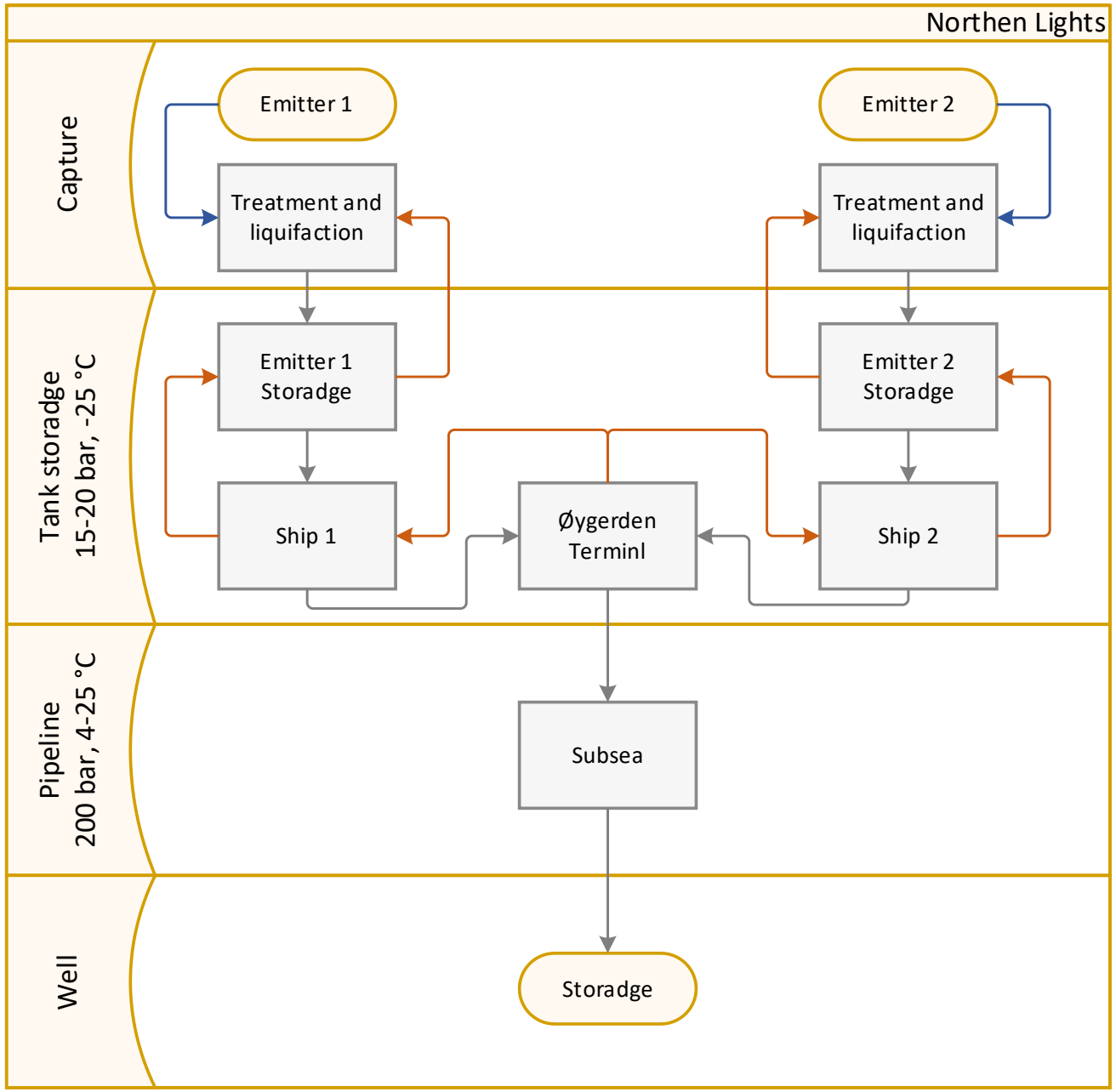
The value chain

Gas return – To keep a stable pressure, an equal volume of Liquid and Gaseous CO_2 is loaded/off-loaded between stages.

Contaminants from emitters impact everyone in the network.



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Specification example

Porthos
CO_2 TRANSPORT & STORAGE

CO_2 specifications

Component	Mole Base
CO_2	≥ 95%
H_2O	≤ 70 ppm
Sum [H_2+N_2+Ar+CH_4+CO+O_2]	≤ 4%
H_2	≤ 0.75%
N_2	≤ 2.4%
Ar	≤ 0.4%
CH_4	≤ 1%
CO	≤ 750 ppm
O_2	≤ 40 ppm
Total sulfur-contained compounds (COS, DMS, H_2S, SOx, Mercaptan)	≤ 20 ppm Of which H_2S ≤ 5 ppm
Total NOx	≤ 5 ppm
Total aliphatic hydrocarbons (C2 to C10)[i]	≤ 1200 ppm
Total aromatic hydrocarbons (C6 to C10, incl. BTEX)[i]	≤ 0.1 ppm
Total volatile organic compounds[ii] (excl. methane, total aliphatic HC (C2 to C10), methanol, ethanol, and aldehydes)	≤ 10 ppm
Total aldehyde compounds	≤ 10 ppm
Ethanol	≤ 20 ppm
Methanol	≤ 620 ppm
Hydrogen cyanide (HCN)	≤ 2 ppm
Total amine compounds	≤ 1 ppm
Total glycol compounds	Follow dew point specification
Ammonia (NH_3)	≤ 3 ppm
Total carboxylic acid and amide compounds	≤ 1 ppm
Total phosphorus-contained compounds	≤ 1 ppm
Toxic compounds[iii]	
Dew point limit value measurement (for all liquids, i.e. for complete CO_2 composition)	< -10 °C (at 20 bara)

Northern Lights

Liquid CO_2 (LCO2) Quality Specifications

	Component	Unit	Limit for CO_2 Cargo within Reference Conditions[1]	
Original CO_2 spec	Carbon Dioxide (CO_2)	mol-%	Balance (Minimum 99.81%)	
	Water (H_2O)	ppm-mol	≤ 30	
	Oxygen (O_2)	ppm-mol	≤ 10	
	Sulphur Oxides (SO_x)	ppm-mol	≤ 10	
	Nitrogen Oxides (NOx)	ppm-mol	≤ 1.5	Updated component
	Hydrogen Sulfide (H_2S)	ppm-mol	≤ 9	
	Amine	ppm-mol	≤ 10	
	Ammonia (NH_3)	ppm-mol	≤ 10	
	Formaldehyde (CH_2O)	ppm-mol	≤ 20	
	Acetaldehyde (CH_3CHO)	ppm-mol	≤ 20	
	Mercury (Hg)	ppm-mol	≤ 0.0003	Updated component
	Carbon Monoxide (CO)	ppm-mol	≤ 100	
	Hydrogen (H_2)	ppm-mol	≤ 50	
	Cadmium (Cd), Thallium (Tl)	ppm-mol	Sum ≤ 0.03	Moved to solids
Clarification from original CO_2 spec	Methane (CH_4)	ppm-mol	≤ 100	
	Nitrogen (N_2)	ppm-mol	≤ 50	
	Argon (Ar)	ppm-mol	≤ 100	
	Methanol (CH_3OH)	ppm-mol	≤ 30	New component
	Ethanol (C_2H_5OH)	ppm-mol	≤ 1	
	Total Volatile Organic Compounds (VOC)[2]	ppm-mol	≤ 10	
	Mono-Ethylene Glycol (MEG)	ppm-mol	≤ 0.005	
	Tri-Ethylene Glycol (TEG)	ppm-mol	Not allowed	
	BTEX[3]	ppm-mol	≤ 0.5	
	Ethylene (C_2H_4)	ppm-mol	≤ 0.5	
	Hydrogen Cyanide (HCN)	ppm-mol	≤ 100	
	Aliphatic Hydrocarbons (C_3+)[4]	ppm-mol	≤ 1,100	
	Ethane (C_2H_6)	ppm-mol	≤ 75	
	Solids, particles, dust	Micro-meter (µm)	≤ 1	

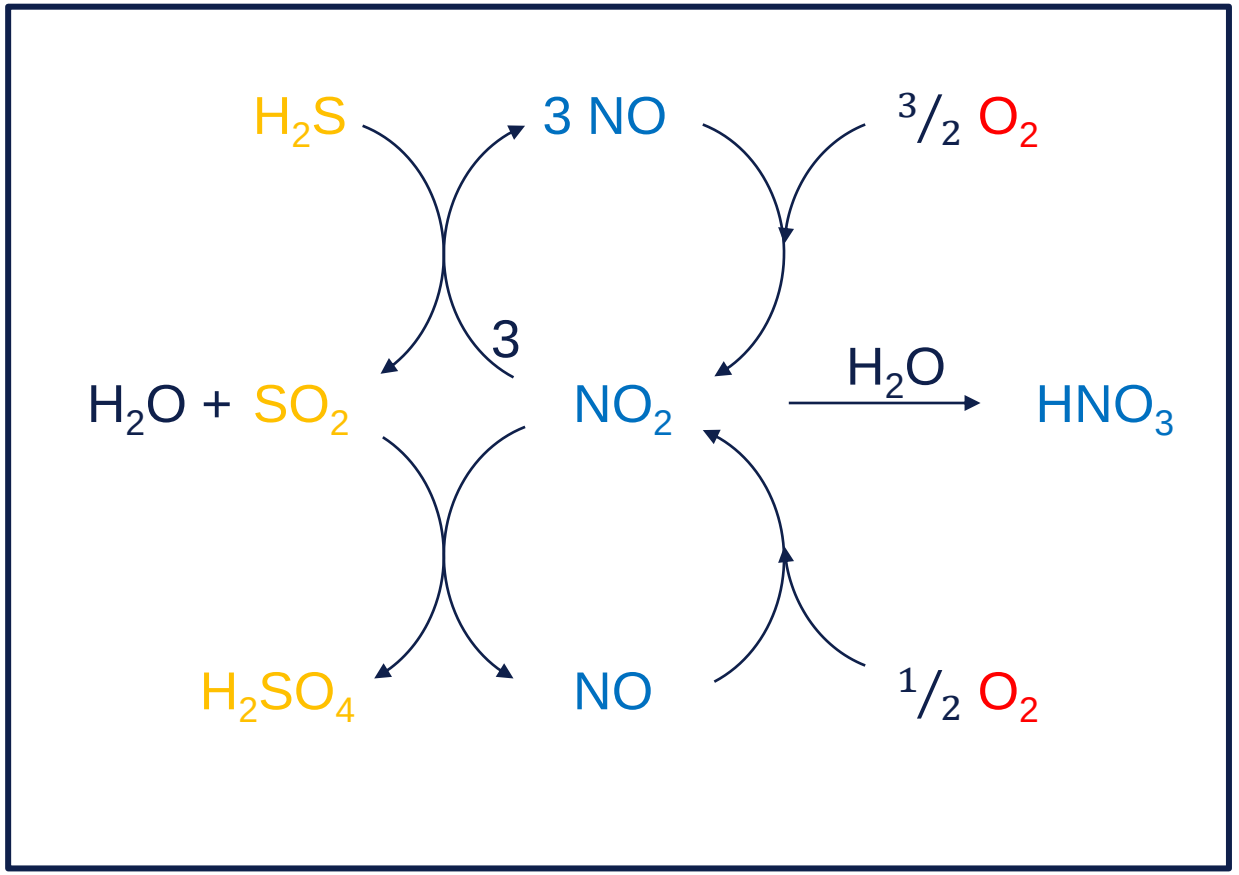
4) https://norlights.com/wp-content/uploads/2024/02/Northern-Lights-GS-co2-Spec2024.pdf

5) https://www.porthosco2.nl/wp-content/uploads/2021/09/CO2-specifications.pdf

DNV

Why are the chemicals on the list?

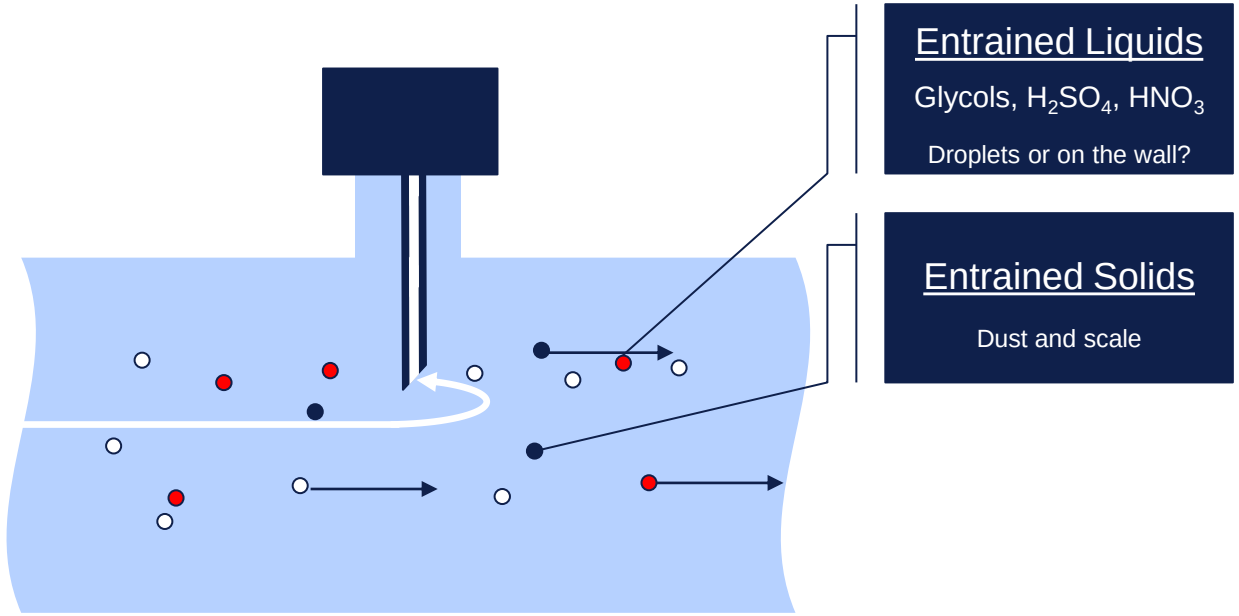
- Majority of pipelines transporting CO_2 are from natural gas processing or single source.
- Mixing contaminants from industrial sources are a key concern.
  - Cross reactions and acid formation
  - Acids have low solubility and could drop out as a separate liquid phase



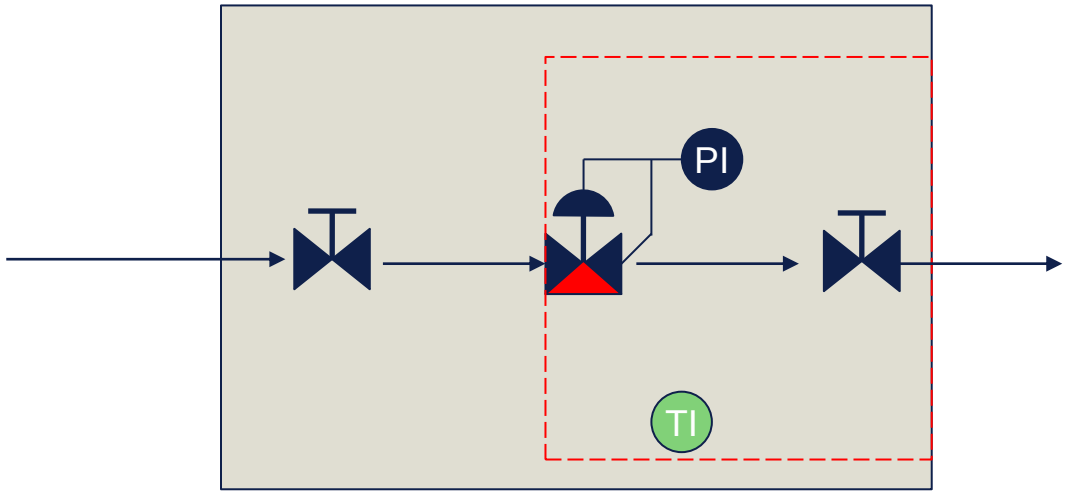
G. Svenningsen et al, Corrosion of carbon steel in simulated CCS Streams, 15th International Conference on Greenhouse Gas Control Technologies, GHGT-15, 15th - 18th March 2021 Abu Dhabi, UAE

Sampling – Probe and scope of analysis

- Representative sample?
  - Probes can act as a filter, omitting particles and liquids
  - Should we only measure the dissolved components?



Sample conditioning field station



Not a complete system!

Additional considerations to various ISO standards for Oil & Gas?

- Sample vaporization and time delay
- Do we need to take special precaution for some components? Amines and ammonia have longer residence time due to wall effects
- Bypass vs fast-loop
  - High flow on bypass to

Do we stay with good old GCs and spectroscopy?

Example orientation table to identify suitable instruments, will be project dependant! (what and where to measure, etc.)

	Atomic Abs.	GC (FID..)	IR	FTIR	…	MS	Laser	El.Chem	…
CO_2, O_2, N_2, Ar…		✓				✓			
Ammonia, Amine, Aldehyde,…		✗		✓		✓			
NO, NO_2, H_2S, SO_2,..				?		✓	✓		

Instrument and automation engineer's handbook, Volume II, Analysis and Analysers, B. G. Lipták, CRC Press

Joint Industry Projects – Update DNV-RP-F104

CO_2 Safe Pipe

[Design and Operation of CO2 pipelines – CO2SafePipe (dnv.com)]

- CO_2 stream composition from various sources
- Running ductile fracture (RDF) and fracture arrestors (solutions and spacing)
- Low temperature brittle fracture
- Environment & safety
- Requalification / repurposing
- Leak detection
- Pre-commissioning - Replace hydrotesting

CO_2 Safe and Sour

[Hydrogen sulfide challenges in carbon dioxide pipelines (dnv.com)]

- Increase tolerance levels for impurities resulting in sour service conditions
- Enable cost effective development of Northern Lights and other CCS Hub projects
- Understand the implication of H_2S on the integrity of CO_2 pipelines and quantify limits for safe operation

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