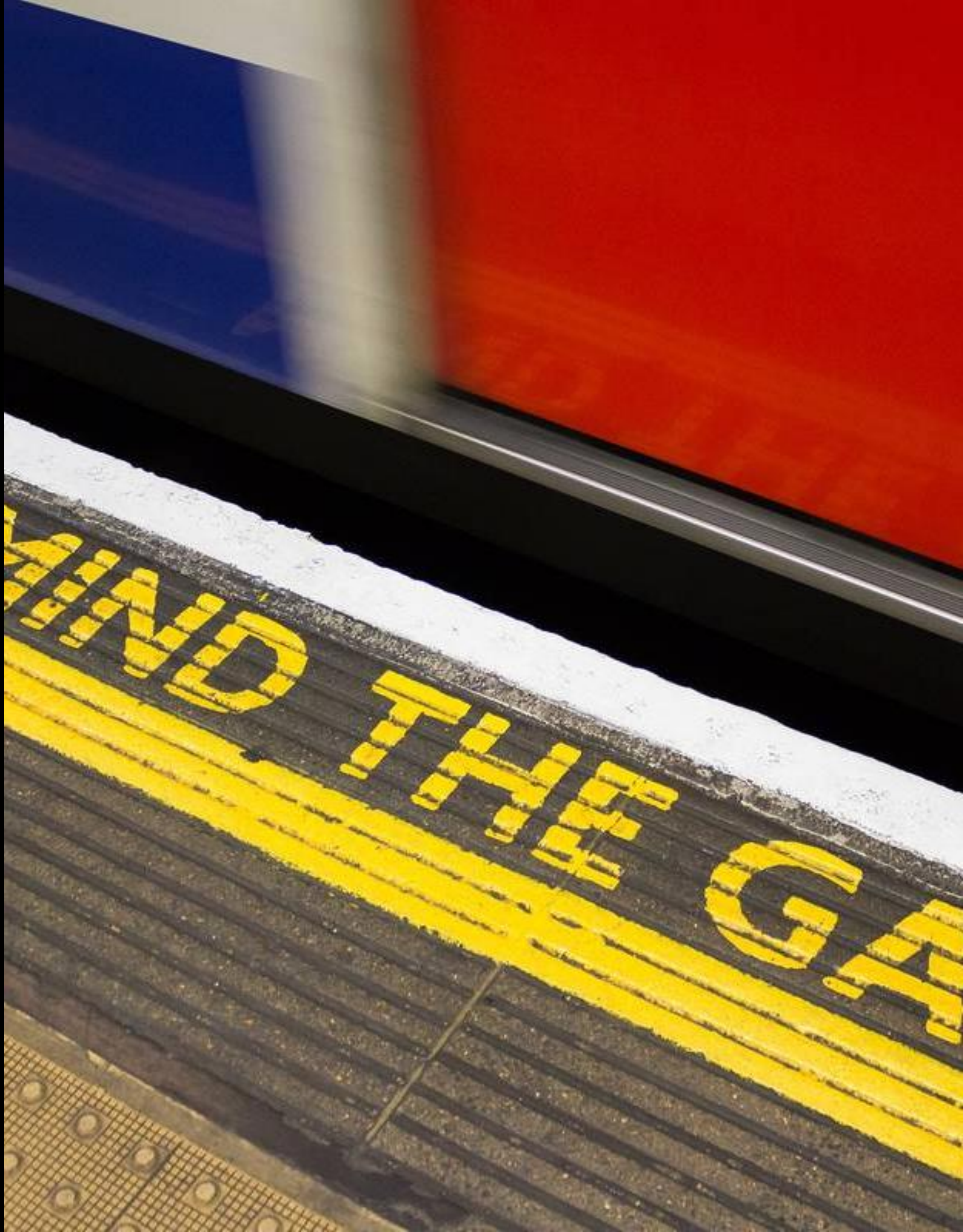
# Subsea CCS Pipelines

## State of the Art Gap in Subsea

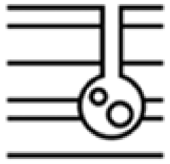
Callum Peace

October 15th , 2025



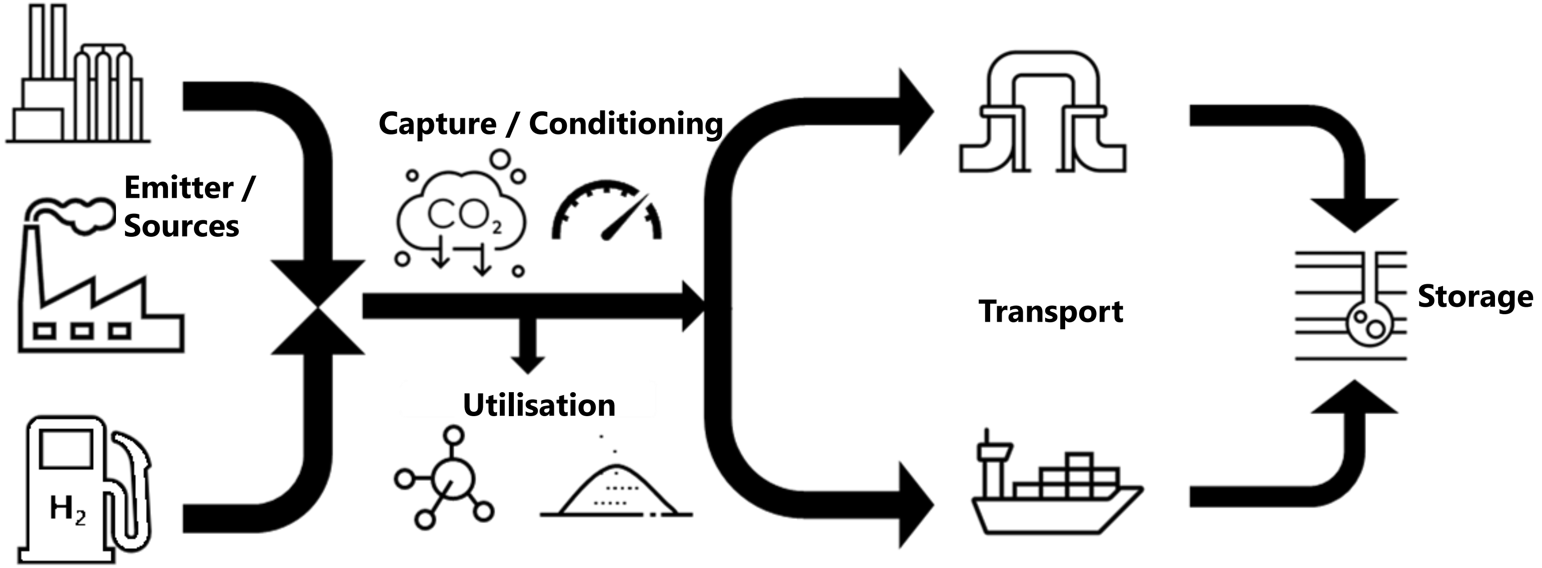
# Agenda

- Introduction
- CCS Value Chain
- Codes and Standards for CO2
- Corrosive Phase Development
- Subsea Technical Readiness
- CO2 Specification JIP (Some Key Insights)

# CCS Value Chain

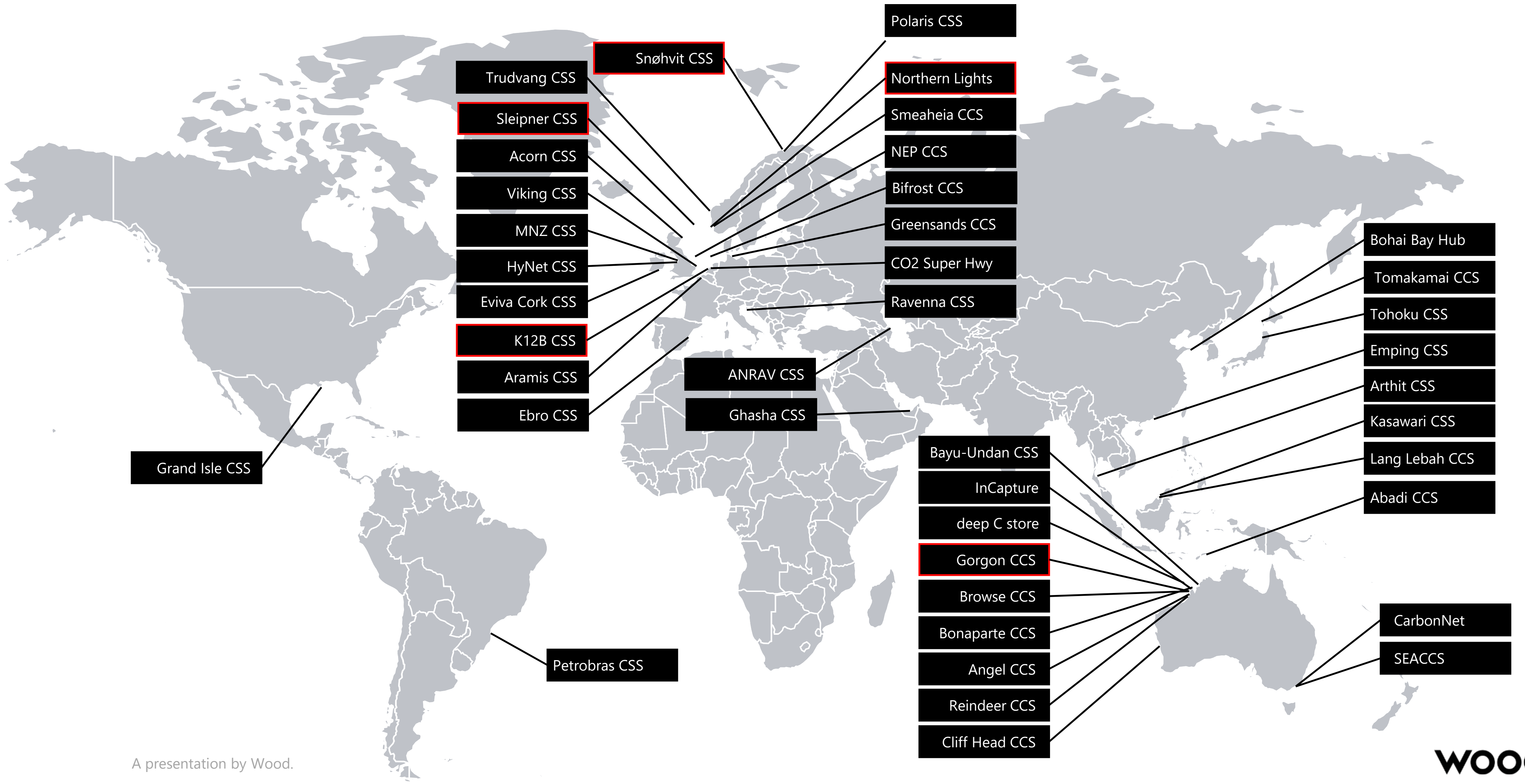
Carbon Capture and Storage (CCS) value chain is a three-part process that includes capturing CO2 from industrial emissions, transporting it to a storage site, and storing it permanently in injection wells.




***"If we are to reach our global Net Zero Emission target, we need to move quickly to get a CCS industry read for operation"***

**International Energy Agency**

# Global Subsea CCS Injection Projects





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# Codes and Standards

Decreasing Order of Precedence

**Regulations**

Pipeline Operator's **Standards**

Pipeline Operator's **Guidelines and Design Practices**

International/local **Codes and Standards**

Industry **Best Practice**

| Code / Standard |
| --- |
| AS(/NZS) 2885 Series |
| ASME B31.4-2022 |
| ASME B31.8-2022 |
| CSA Z662:23 (Errata March 2024) |
| DNV-ST-F101 (Aug 2021, amended Dec 2021) |
| DNV-RP-F104 (Feb 2021, amended Sep 2021) |
| EN 14161:2011+A1:2015 |
| ISO 13623:2017 + ISO 13623:2017/Amd 1:2024 |
| ISO 27913:2016 |
| PD 8010 Series |





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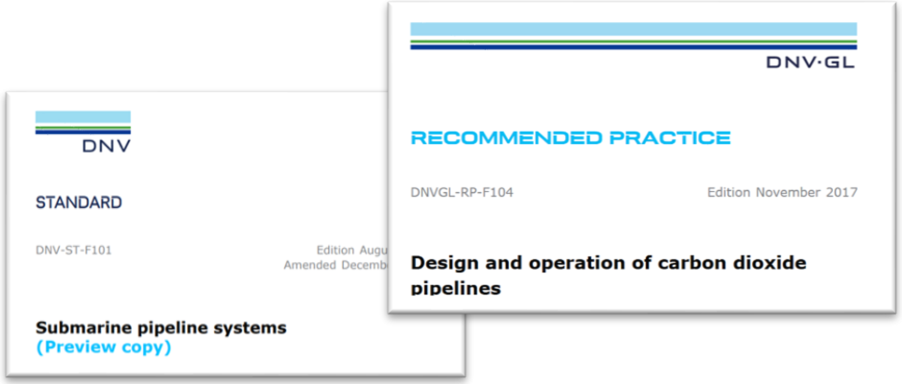
**Indicative only** – Selection based on project and client requirements

# Onshore and Offshore Application

## ISO 13623/27913


## DNV-ST-F101/DNV-RP-F104




**Onshore Pipeline**

**Offshore Pipeline**

**Supplement to fill gaps with industry best practise:**

- Technical Safety
- Valves / spacing
- Materials Selection
- Fracture Control
- Welding
- CO2 Specification



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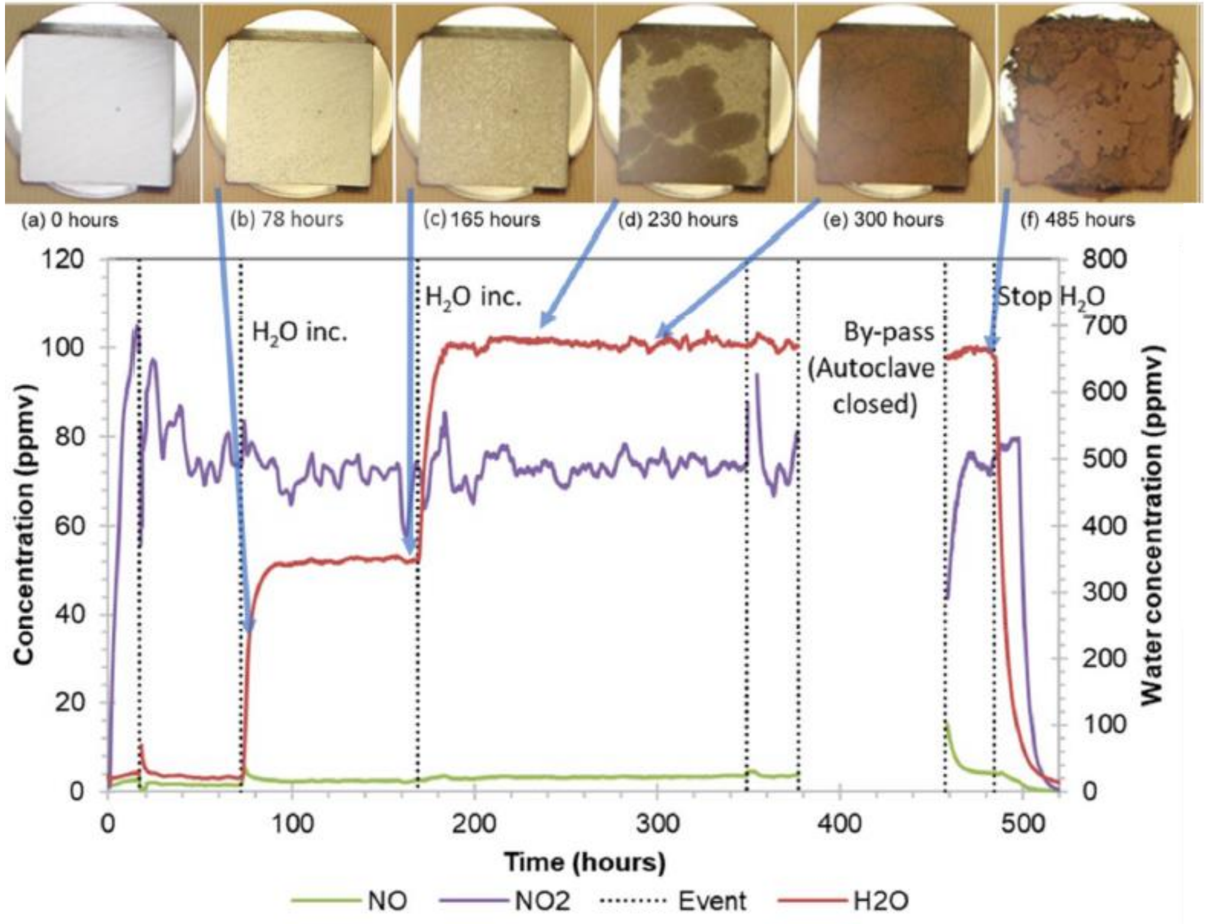
# Mind the Code Gaps

A few **gaps still remain** and are undergoing industry research/development to close the gap:

- **Materials both metallic and non-metallic**
  - Additional Qualification and Testing
- **Leak Detection Systems (subsea)**
  - No sufficient industry standard
  - Technology development
- **Pre-commissioning / Commissioning**
  - No sufficient industry standard
  - Required in-depth project knowledges and experience
  - Acceptable drying limit and how to get it dry
- **Repurposing**
  - Limited knowledge
  - Requires comprehensive assessment to bridge across the codes.
  - Existing design/procurement data required.
- **Specification**

# Corrosive Phase Development

- Water within a $CO_2$ stream can cause an aggressive corrosion.
- Corrosive phase can form even if there is no free water present in $CO_2$ stream.
- Chemical reactions between impurities within the stream must be assessed, as reaction products can be **corrosive** (acid forming)
- Small amounts of SOx and NOx can cause chemical reactions to make **Sulphuric Acid** and **Nitric Acid.**
- **NOx the most concerning** impurities in terms of participation in acid forming reactions. Only a few ppm needed to generate reactions.
- **Many gaps still exist with more testing required:**
  - Impurity limit
  - Localized corrosion or accumulate
  - Corrosion allowance




*Ref. https://www.sciencedirect.com/science/article/pii/S1750583622001153*

*Experimental and Simulated Solubility of HNO3 and H2SO4 in CO2 (Morland et. al. 2019)*

# Technical Readiness of $CO_2$ Subsea Equipment

**API 17N TRL Scale**

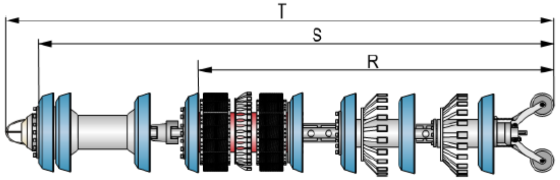
**Indicative scoring only** – Actual scoring are project and supplier specific

| Unproven Concept | Proven Concept | Validated Concept | Prototype Tested | Environment Tested | System Tested | System Installed | Field Proven |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

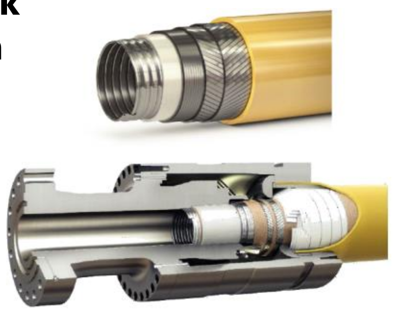
Subsea XT (TRL 6)


Subsea Flowmeter (TRL 6)

**Subsea Leak Detection**




ILI Pigging (TRL 7)



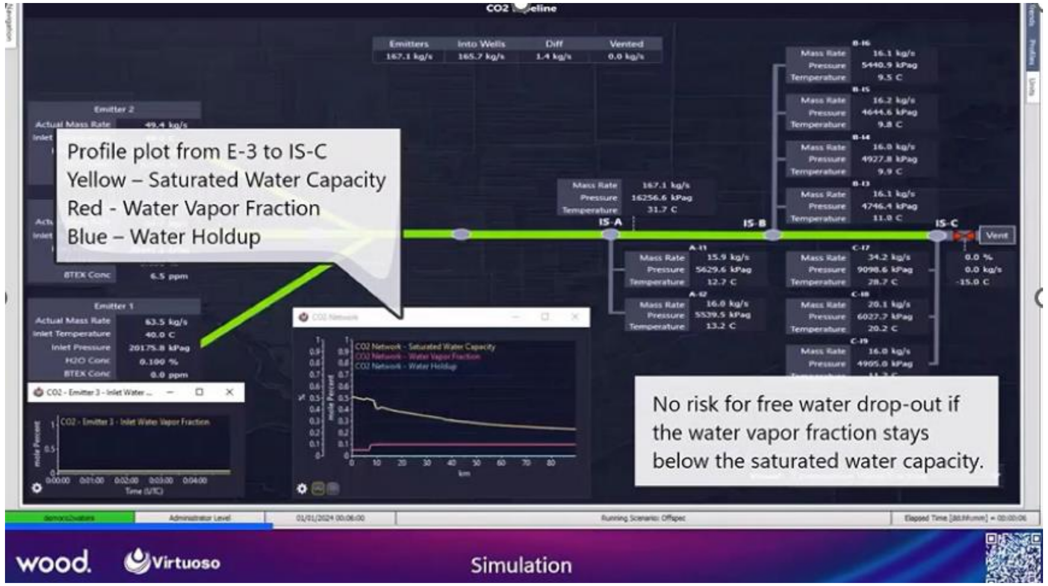
Flexible Flowline (TRL 7)

**Subsea Valves**
**Flexible Flowlines**
**Subsea XTs**
**Subsea Flowmeters**
**Subsea Pig Traps**

**Rigid Line Pipe**
**ILI Pigs** (*size dependent*)
**Onshore Pig Traps**

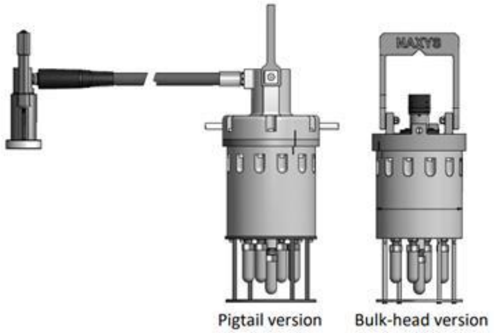
# Subsea Leak Detection Methods

- **Gap in Subsea CCS TRL**: Lowest TRL-3 is leak detection.
  - Limited projects operating with subsea CO2 injection leak detection.
- **Qualification ongoing**
- Methods available include:
  - Internal Methods (Real-time Transient Modelling)
  - Passive Acoustic Leak Detection
  - Active Acoustic Leak Detection
  - Underwater Intervention Drones




**Internal Methods (Real-time Transient Modelling)**

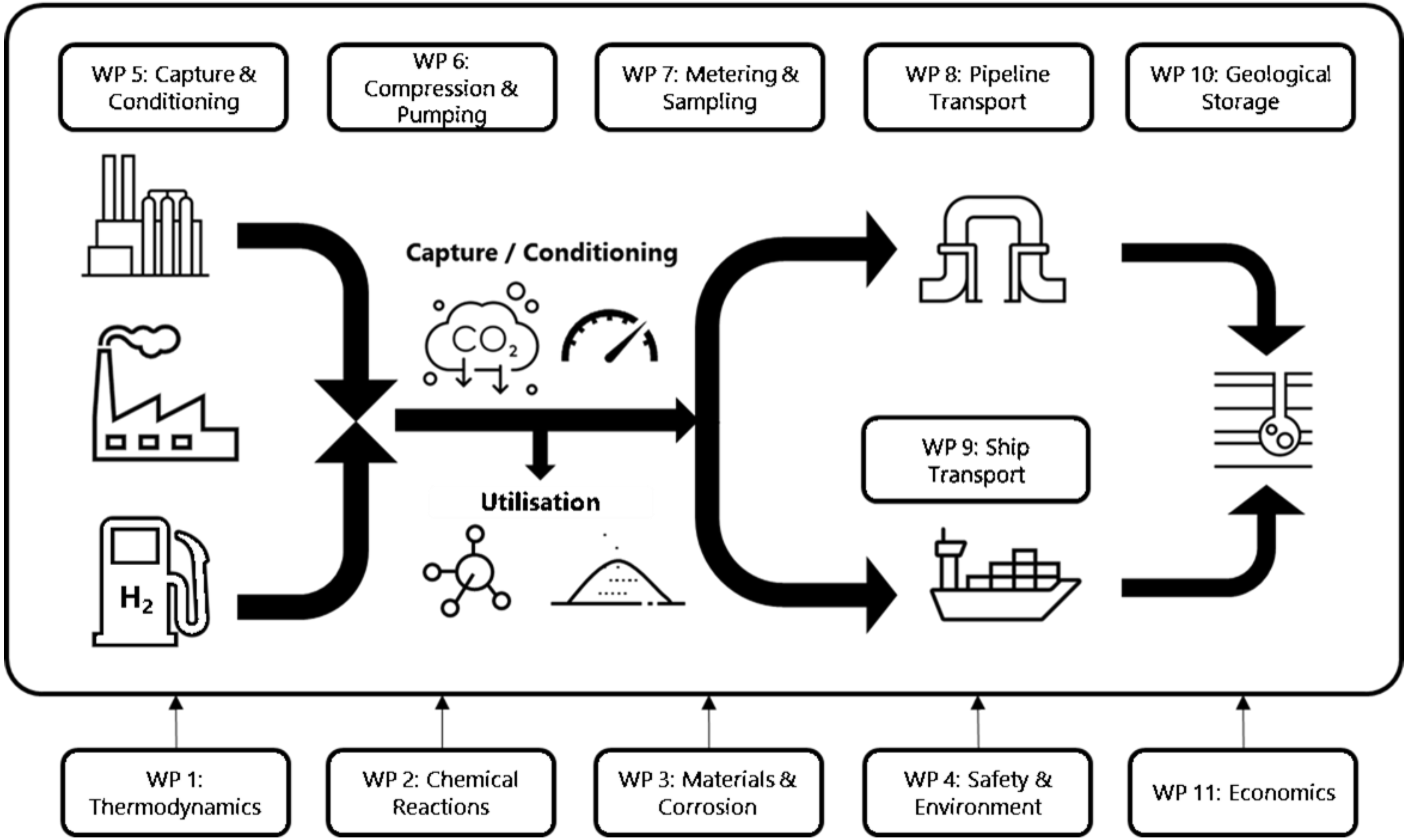

**Active Acoustic**




**Passive Acoustic**

# Scope of the CCS Value Chain Impurity JIP

- Full CCUS chain from capture through to geological storage.
- Address interdependence between each part of the chain and between the emitters and transport & storage operators.
- Reviews the required CO2 conditioning to meet safety, environmental, technical and operational requirements.
- Collaboration with research and industry experts to provide a comprehensive and holistic understanding of the impact of impurities across the chain.

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# WP8 - Pipeline Transport

- **Gaps in pipeline design** codes identified.
- Impurity within the stream have impact on Thermodynamic Behaviour, Material Selection, Requalification and Pipeline Design. Different to traditional hydrocarbon design.
- Even at 1 mol% hydrogen may have a detrimental effect on fatigue performance of pipeline steels and welded joints.
- Impurities impact minimum pipeline fracture toughness requirements to resist running ductile fracture.
- Pipeline are the component with the largest $CO_2$ inventory. Consideration required for isolation to minimize inventory (e.g. block valve spacing.)
- Further testing ongoing within industry into **fracture toughness requirements, crack arrestor types, as well as spacing.**




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# Key Gaps

- **Codes and Standards**: ISO 13623 and DNV-ST-F101 are suitable pipeline design, but gaps remain in materials, leak detection, and commissioning standards requiring further R&D.
- **Corrosion Risks:** Acidic corrosion can form from impurity reactions (NOx, SOx) even below water solubility limits; Further work on limits of NOx, Sox to reduces risk.
- **Technical Readiness:** Subsea leak detection is least mature technology with ongoing qualification; other subsea equipment are system installed to field proven.
- **CO2 Specification:** Setting a CO2 specifications is crucial for safe transportation and injection across the value chain.
- **Pipeline Challenges:** CO2 pipelines face unique failure mechanisms such as running ductile fracture, corrosion and embrittlement which are effected by the presence of impurities.

**What's next?**

DNV CO2SafePipe
Closing knowledge gaps in CO2 pipeline transportation

***Collaboration and knowledge sharing is needed to move the industry and its projects forward efficiently.***

# Thank You – Questions?

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Lead Pipeline Engineer

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**Scope of the Impurity JIP**

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