WHEN TRUST MATTERS

CO_2 Safe&Sour JIP

General JIP presentation

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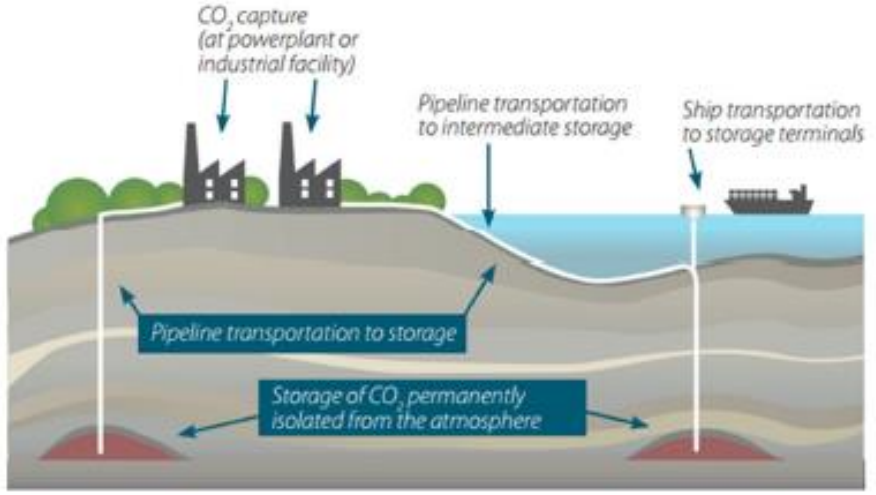
Background

- Carbon Capture and Storage (CCS) is being pursued as a means to reduce GHG emissions
- Currently there is a significant need coupled with incentive to facilitate CCS solutions.
- Capture/Transport of CO_2 from various sources will involve using the existing pipeline network as well as building new pipeline network.
- Injection/Storage of CO_2 in existing or new wells will also be a critical part of the CCS solution



Currently focus is on understanding the factors that influence performance of materials in the pipeline network

- Phase stability
- Effect of impurities
- Running Fracture
- Dispersion & Toxicity effects

DNV’s Joint Industry Projects for CCUS

CO2CAPTURE

CO2PIPETRANS

CO2WELLS

CO2QUALSTORE

CO2RISKMAN

Development of DNV-RP-F104

- First revision
  - DNV-RP-J202 (2010)
  - Based on JIP CO2PIPETRANS
- Second revision
  - Re-named from DNV-RP-J202 to DNVGL-RP-F104
  - Based on JIP CO2PIPETRANS (2017)
- Third revision
  - DNV-RP-F104 February 2021
  - Based on CO2SafeArrest JIP

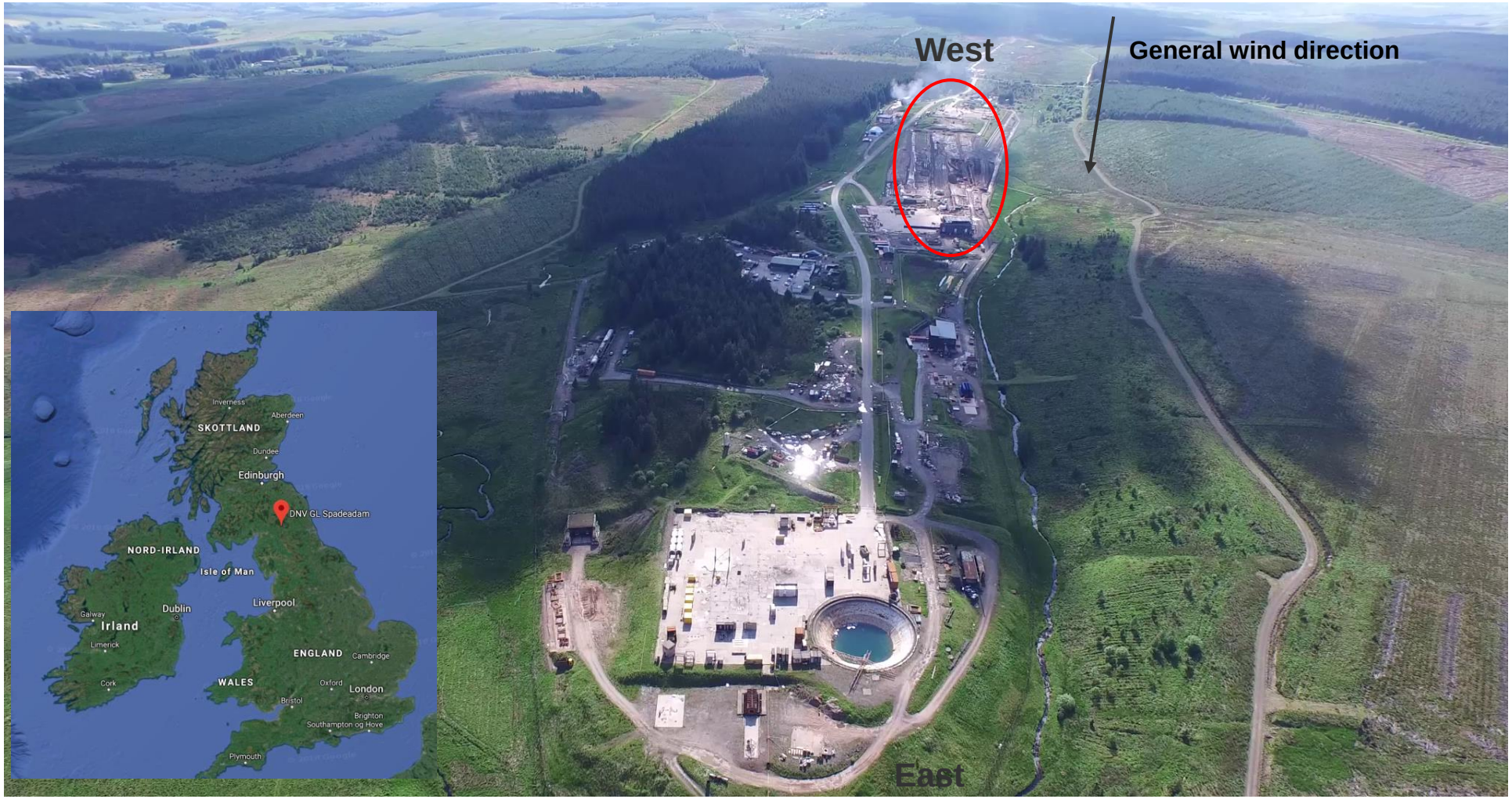
The world's 1st industry guideline

- provides guidance and sets out criteria for safe, reliable and cost efficient development, design, construction and operation of pipelines intended for CCS scale transmission of CO_2 in pipelines

- Experimental testing (phase I was desk top study)
  - CO_2 release (as input to dispersion modelling)
  - Corrosion testing
  - Fracture arrest testing
- Fracture arrest tests
  - 2 of 16” tests in Norway
  - 2 of 24” tests in Italy (SARCO2B JIP)

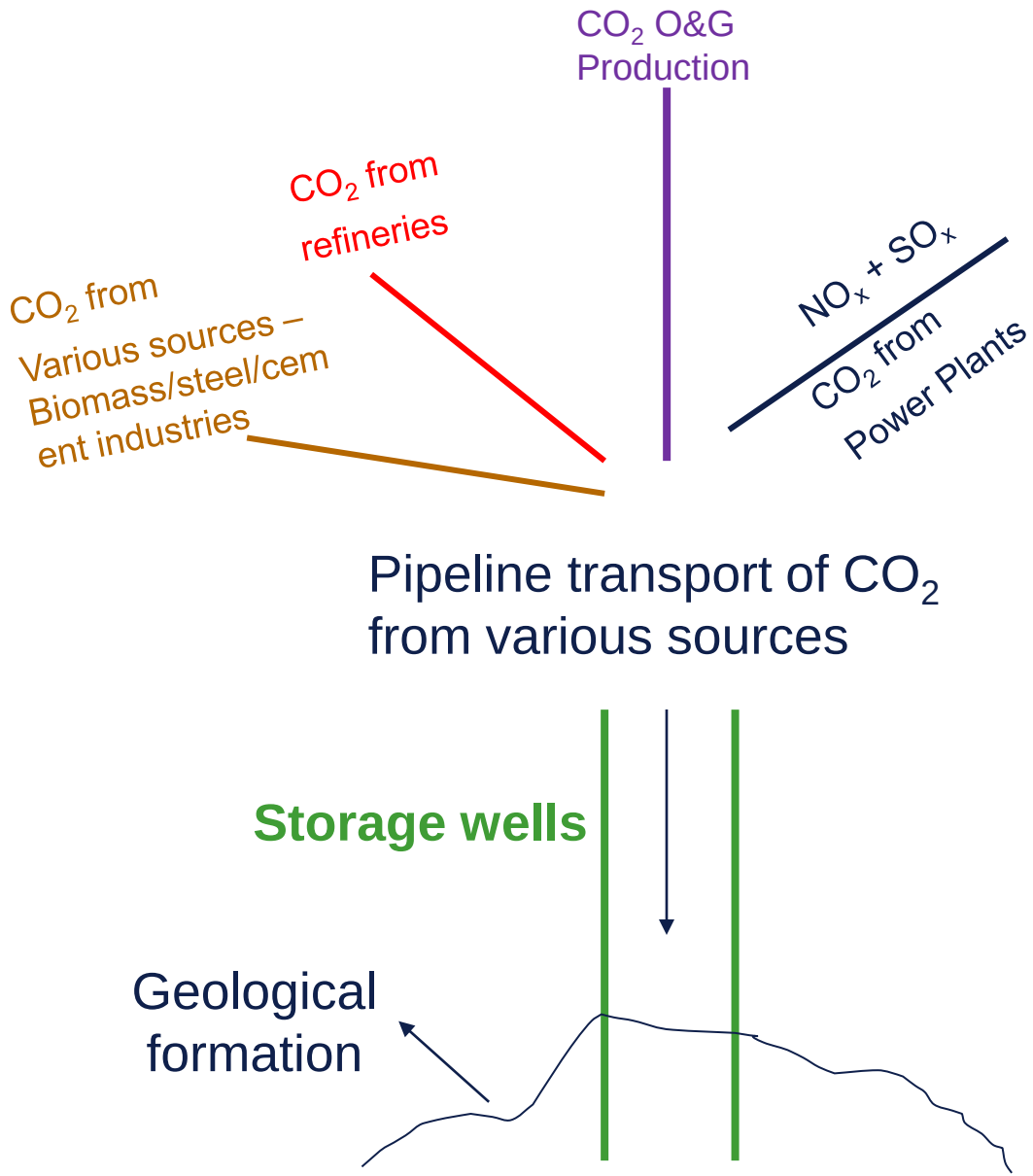
- Based on JIP CO2SafeArrest with objective:
  - Development of fracture arrest design requirements
  - Fracture arrest testing
    - 2 of 24” tests at Spadeadam

Spadeadam test site



Background

- CCS solutions will involve co-mingling and transport of CO_2 from various sources.
- Significant focus is being placed on capture and transportation → Need to understand the impact on materials in the transportation infrastructure.
- Understanding and defining the pipeline infrastructures ability to handle CO_2 with various impurities is important to ensure safety and feasibility of CCS solutions



CO_2 Safe & Sour JIP

The Northern Lights pipeline is being developed with tight tolerances for impurities, including H_2S.

Increased tolerance levels for impurities can give considerable value to CCS projects:

- Makes CCS more accessible for different sources/customers
- Limiting customers need for gas processing

Goal	• Increase tolerance levels for impurities resulting in sour service conditions. • Enable cost effective development of Northern Lights and other CCS Hub projects.
Objective	• Understand the implication of H_2S on the integrity of CO2 pipelines and quantify limits for safe operation.
End-state	• Knowledge basis for update of DNV-RP-F104 on allowable H_2S limits in operation.

Phase 1

equinor, Shell, TotalEnergies, GASSCO, IFE, wood., CLIMIT

Phase 2 extension

ExxonMobil, Woodside, vallourec, COCAS, ArcelorMittal, subsea 7, Tenaris

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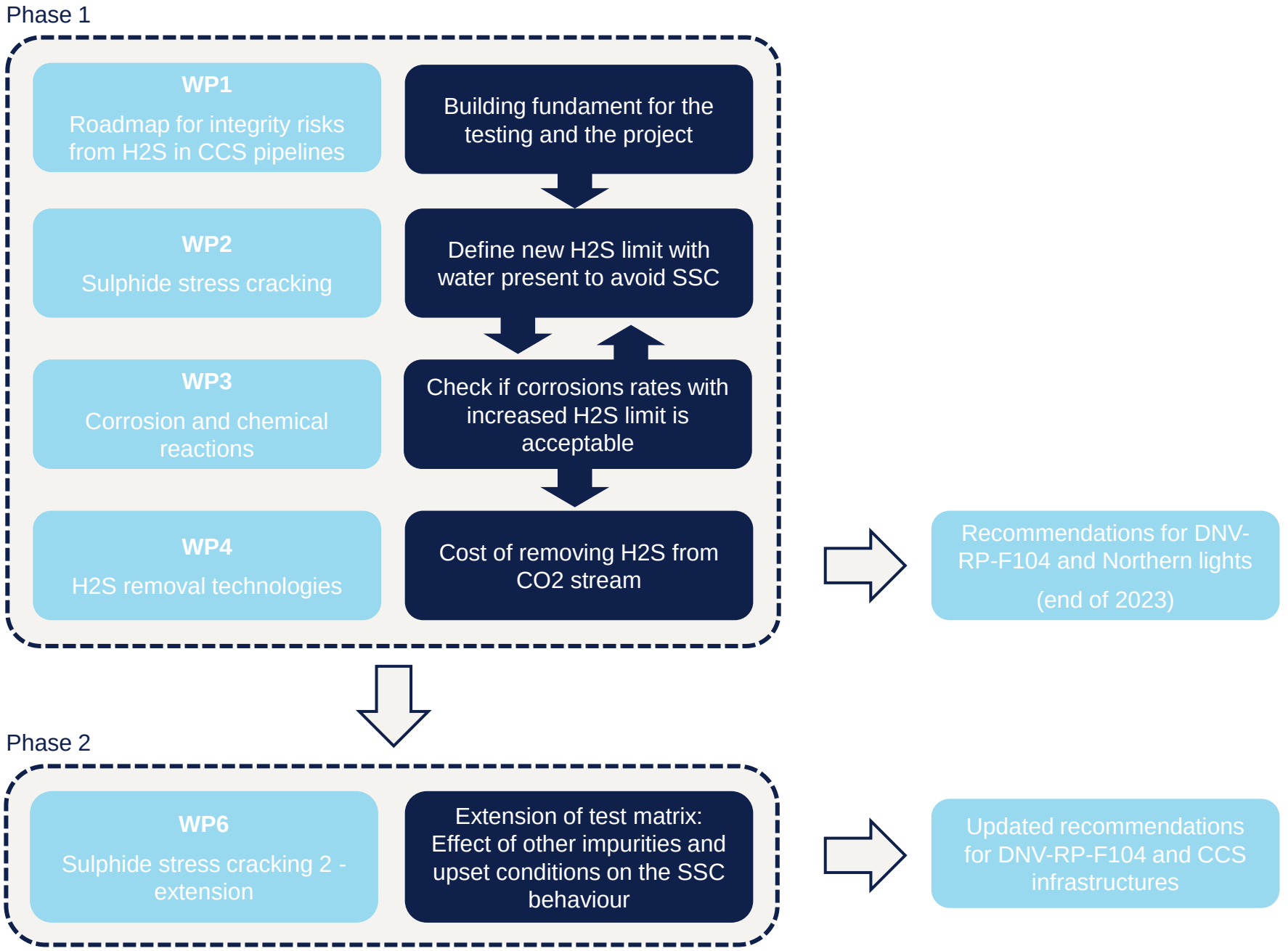
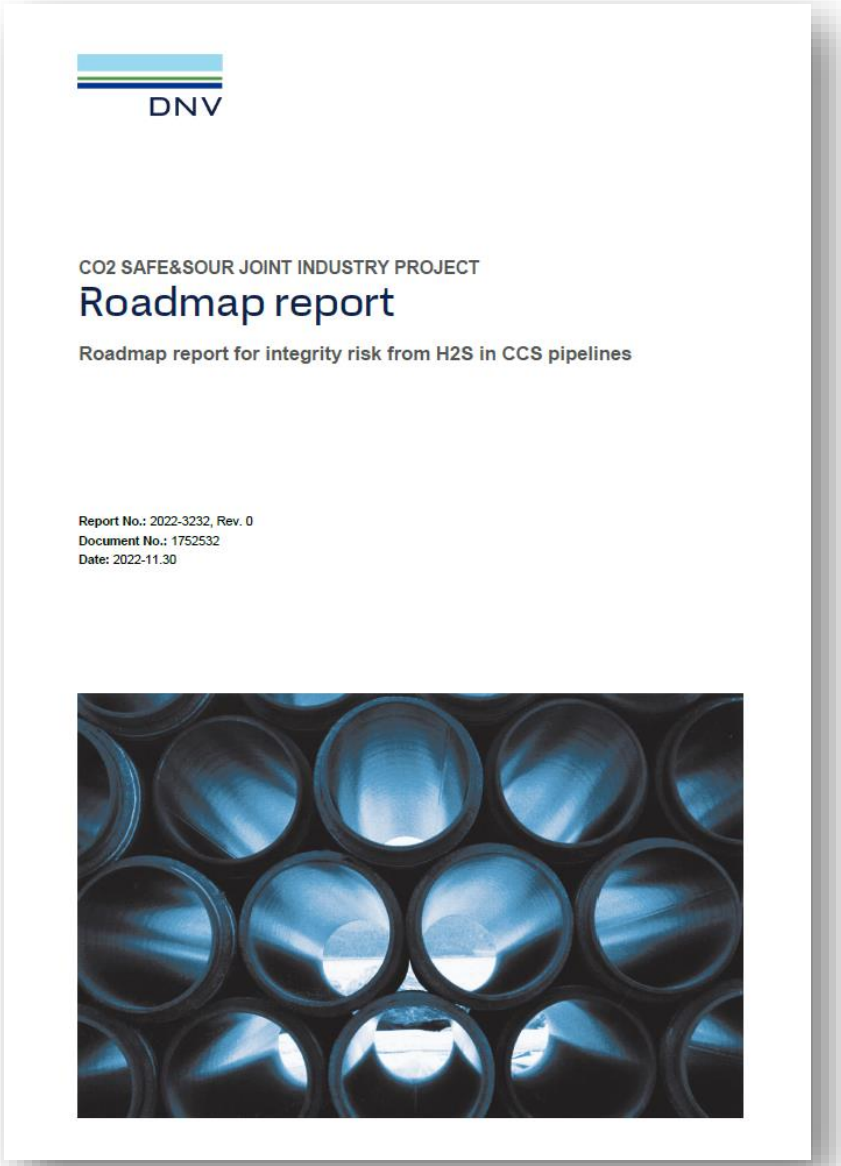

Phase 1
WP1
Roadmap for integrity risks from H2S in CCS pipelines
Building fundament for the testing and the project
WP2
Sulphide stress cracking
Define new H2S limit with water present to avoid SSC
WP3
Corrosion and chemical reactions
Check if corrosions rates with increased H2S limit is acceptable
WP4
H2S removal technologies
Cost of removing H2S from CO2 stream
Recommendations for DNV-RP-F104 and Northern lights
(end of 2023)
Phase 2
WP6
Sulphide stress cracking 2 - extension
Extension of test matrix: Effect of other impurities and upset conditions on the SSC behaviour
Updated recommendations for DNV-RP-F104 and CCS infrastructures

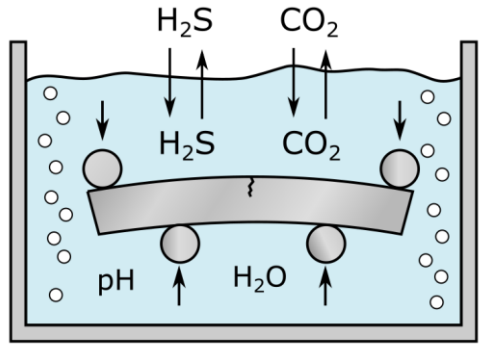
WP1 Roadmap for integrity risks from H_2S in CCS pipelines

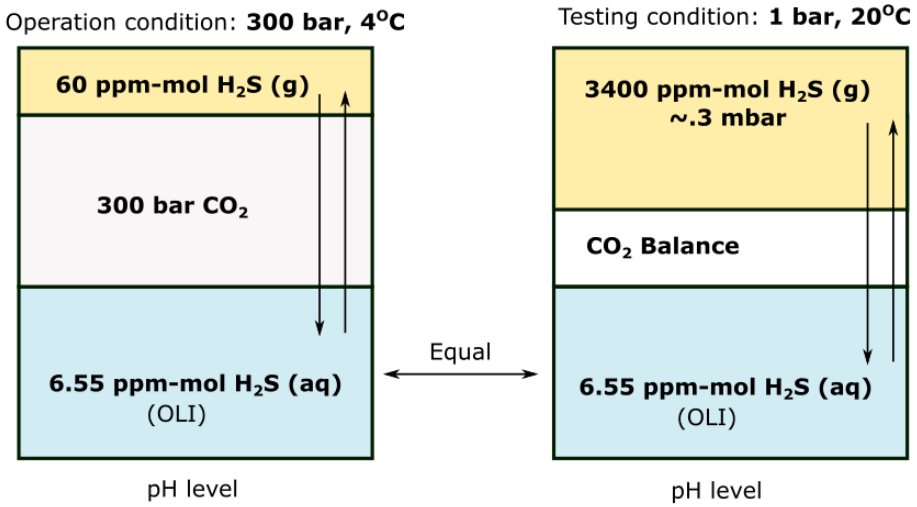
- Report reflecting the discussions leading to the experimental work to be performed in the project
- Rev 0 issued November 2022
- Addresses:
  - Integrity risk
  - Relevant standards
  - Pipeline environment
  - Pipeline design
  - Basis for SSC testing
  - Basis for corrosion and chemical reactions testing



WP2 Sulphide stress cracking

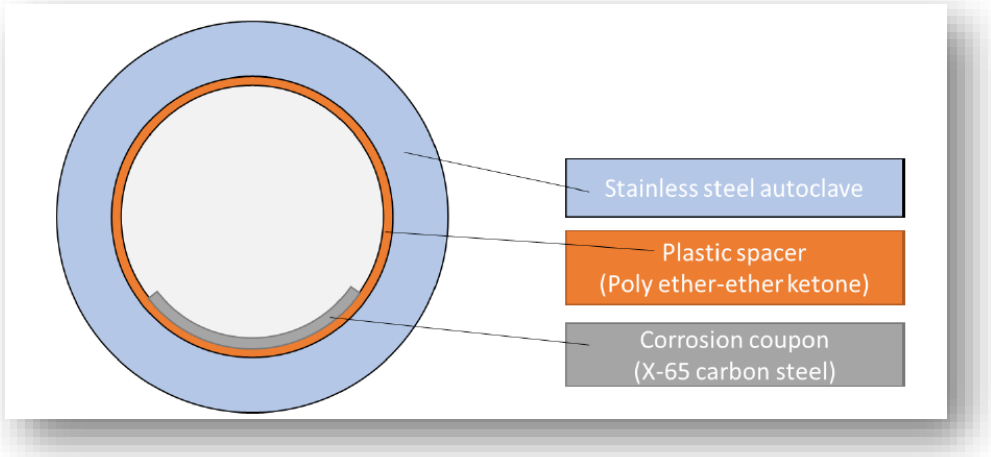
- Quantifying H_2S limit in CO_2 streams in the presence of water
- Defining “simplified” test setups representing the key factors leading to SSC in pipelines
  - Modelling as input
  - Focus on representing the pH and the H_2S level in the aqueous phase
- Screening testing at simplified test setups
  - Four-point bending
  - H_2S level in aqueous phase, controlled pH
- Validating tests at conditions close to real operation
  - Four-point bending
  - H_2S level in gas, pH controlled by gas composition





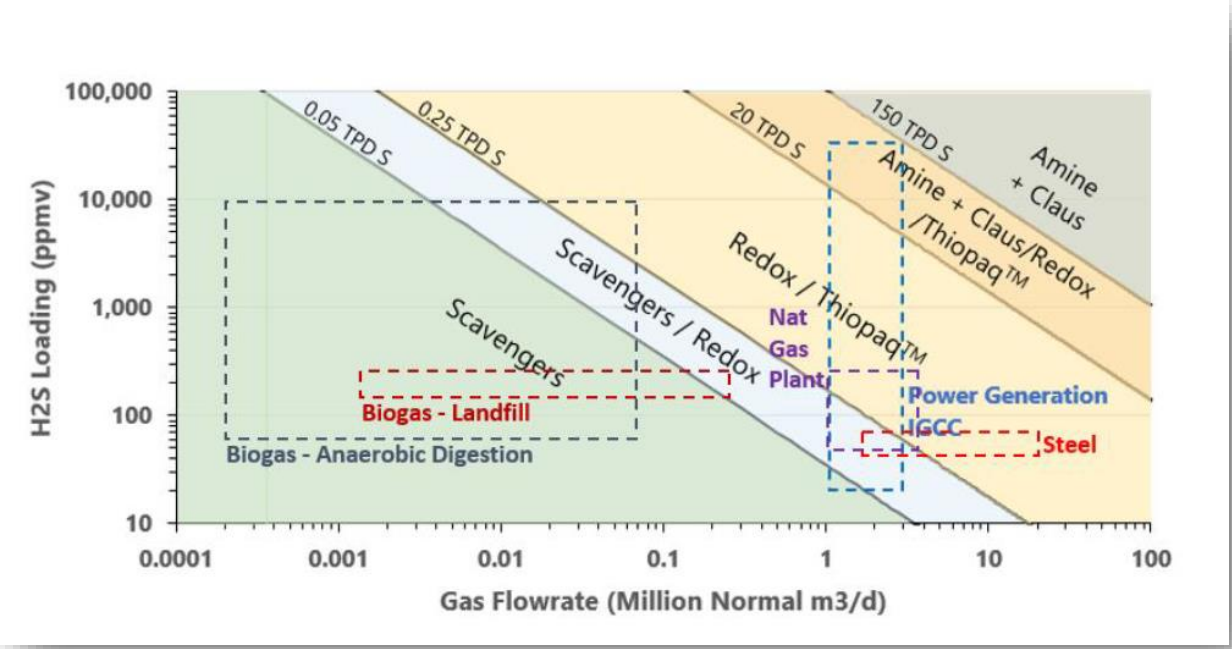
WP3 Corrosion and chemical reactions

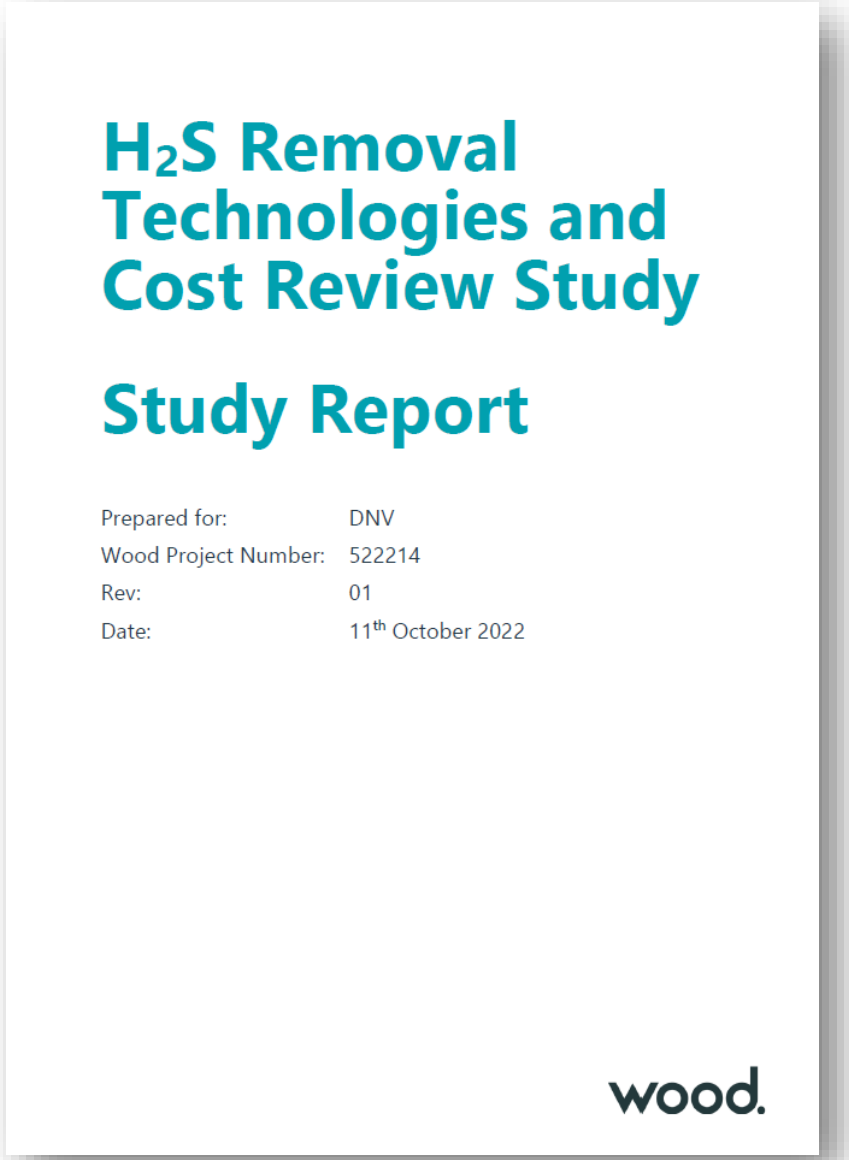
- Acceptable corrosion rates with increased H_2S content in the gas specification?
- Risk of drop-out of acid with increased H_2S level in the gas specification?
- Testing in dense phase CO_2 with selected gas components from the Northern Light gas specification and H_2S
- The initial experimental work will be based on:
  - The Northern Lights CO_2 specification
  - Modified NL specification with increased H_2S content



WP4 H_2S removal technologies

- Extensive review of H_2S removal technologies applicable to captured CO_2 streams
- CO_2 streams from different sectors
- Different removal technologies and related cost





WP6 Sulphide stress cracking 2 - extension phase 2

- Extending the test matrix based on experimental results in WP2 and WP3
- **Scope to be detailed**, likely focus areas:
  - The risk for SSC in upset conditions related to other gas compositions – the risk of acid dropout (Effect of lower pH and transient behaviours)
  - Hydrogen permeation
  - Fracture mechanics based testing
  - Additional materials

Key Takeaways & Next Steps

- Comingling of CO_2 streams from various sources can result in significantly different gas compositions from what has been used in EOR
- Understanding the role of impurities on CO_2 pipelines is critical
- Key Questions to consider
  - Role of Impurities on Phase Stability
  - Role of Impurities on damage accumulation
    - Some work is in progress on corrosion but very little on *cracking behavior*
  - Impact of impurities on running fracture
  - Technologies for removal of impurities

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