WHEN TRUST MATTERS

# CO2 Transportation – Presentation US DOE

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# DNV - An independent assurance and risk management company

**158** years

**~12,000** employees

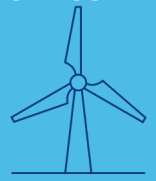
**100,000** customers

**100+** countries

**5% R&D** of annual revenue

**Ship and offshore classification and advisory**

**Energy advisory, certification, verification, inspection and monitoring**



**Management system certification, supply chain and product assurance**

**Certify, verify and test**

**Qualify and assure**

**Give expert advice**

**Co-create and share**



DNV

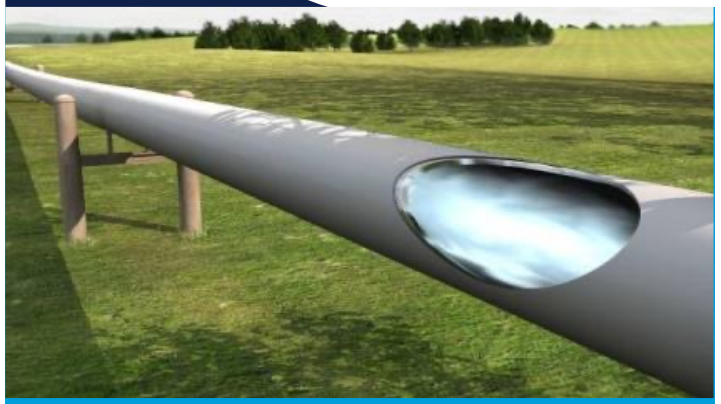
# Helping scale CCS – 200+ projects in past 10 years

## CAPTURE

- Fossil power plants
- Natural gas $CO_2$ reduction
- Other industrial processes

- Cost estimations
- Introduction of new technologies
- Technology review and benchmarking
- Up-scaling risk assessment
- HSE risk assessment
- Accidental release and dispersion
- Value of avoided $CO_2$

## TRANSPORT



- Pipelines
- Ships

- Corrosion
- Material selection and structural design
- Flow assurance and operational issues
- Accidental release and dispersion
- $CO_2$ shipping insights
- Classification of CO2 carriers
- Requalification of infrastructure

## STORAGE

- Depleted oil or gas reservoirs
- Saline aquifers
- Enhanced oil recovery (EOR)

- Verification of storage sites
- Permanence of storage
- Risk management
- Monitoring and verification
- Public concern
- Transfer of responsibility

# CO2 Shipping

# CO2 shipping
# - Three concepts for transportation

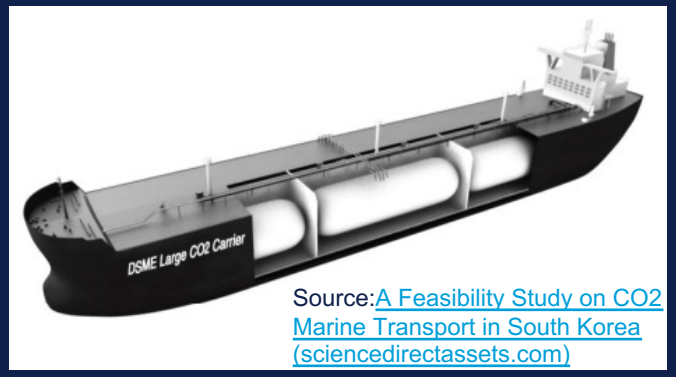
## Medium pressure (15-20 barg, -30C°)

- Mature technology - Decades of operational experience
- Limitations to cargo tank size
- Selected regime for northern light initial phases

Source: Yara International ASA

## Low pressure (7-10 barg, -50 C°):

- Novel operation
- Allow larger cargo tanks and reduced cost for shipping
- Increased cost for liquefaction and conditioning



Source:A Feasibility Study on CO2 Marine Transport in South Korea (sciencedirectassets.com)

## High pressure (40-50 barg, >0 C°):

- Novel design
- Scalable and flexible design
- Reduced cost for liquefaction and conditioning

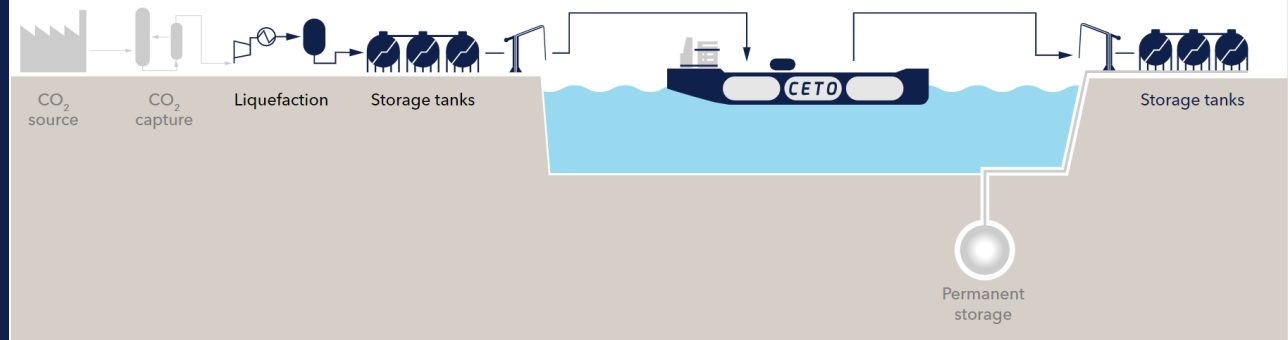

Source: KNCC (kn-cc.com)

# CETO – CO2 Efficient Transportation via Ocean (Low pressure shipping)

**Objective:**
Execute a full Technology Qualification process of a low-pressure CO2 solution for ship transport to enable larger ships for larger volume of CO2 and achieving a safe and cost-effective transportation chain. Web page with more details can be found here

**DNV Involvement:**

- Project Owner and Project manager
- Project tasks DNV:
  - Risk assessments
  - Definition of qualification basis and qualification plan
  - Large scale testing at Spade Adams
  - Approval in principle cargo tanks and cargo handling



# Knutsen – AIP and Technology Qualification (TQ) high pressure solution

**Objective AiP:**

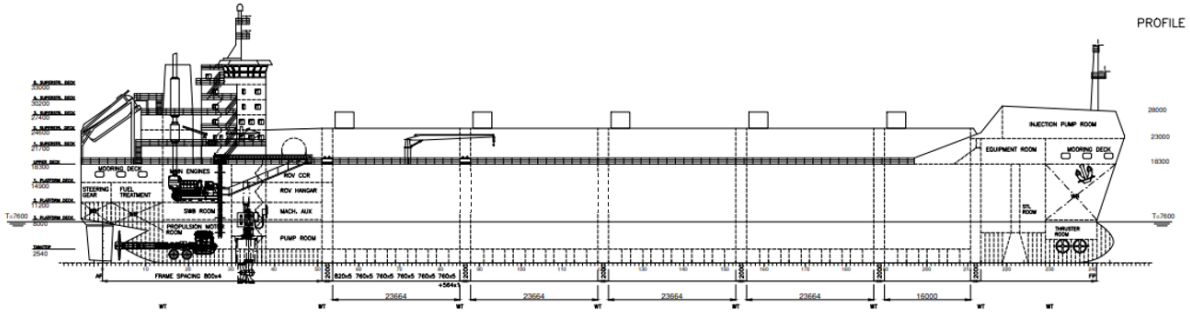
To "bridge" the IGC Code with the DNV CNG Rules to enable safe and secure transport of liquefied CO2 under high pressure.

**Objective TQ:**

Assist Client in establishing a qualification basis of the technology, to ensure that the functional requirements and technology elements are sufficiently and correctly described within specified limits for the technology and per guidance given in DNV-RP-A203.

**DNV Involvement:**

- Risk assessment, HAZID/HAZOP
- Regulatory framework
- Independent review and support in cargo containment, material selection, tank arrangement and cargo handling

# Stella Maris – Large Scale Maritime Concept for Transport and Injection of $CO_2$

**Objective:**

Phase 1: **Feasibility study** "Large Scale Maritime Concept for Transport and Injection of $CO_2$ for Permanent Storage in Subsea Reservoirs"

Phase 2: **Concept selection** - Evaluate relevant concept solutions - identify the optimal concept for the logistic solution

Phase 3: **Concept definition –** Finalize technical concept for logistic solution

**DNV Involvement:**

- Regulatory framework
- Risk assessments and Independent review and support in cargo containment, material selection, tank arrangement and cargo handling
- Approval in principle selected concepts

altera

HÖEGH LNG


APL NOY mossmaritime

SEVAN marine

TGE

DNV

# ISO Technical Report CO2 shipping

- Regulatory regime for maritime CO2 transportation
- Description of shipping concepts for CO2
- Properties of CO2, CO2 streams and mixing of CO2 streams influencing ship transportation
- Ship Operations
- Technical gap assessment
  - Applicability/precision of existing requirements
  - Identification of additional relevant requirements such as practices onshore
  - Qualification and process for  new technology
  - Equipment, material, and systems for future development
- Health, safety and environment




# CO2 Pipelines

# Available standards and guidelines for $CO_2$ pipelines

| | | | |
|---|---|---|---|
| DNV | **DNV-RP-J201**<br>Qualification procedures for carbon dioxide capture technology | **DNV-RP-F104**<br>Design and operation of carbon dioxide pipelines<br>*First edition: 2010* | **DNV-RP-J203**<br>Geological storage of carbon dioxide |
| | ***First edition: 2010*** | ***First edition: 2010*** | ***First edition: 2017*** |
| **INTERNATIONAL STANDARD** | **ISO 27919-1**<br>Carbon dioxide capture – Performance evaluation methods for post-combustion $CO_2$ capture integrated with a power plant | **ISO 27913**<br>Carbon dioxide capture, transportation and geological storage – Pipeline transportation system | **ISO 27914**<br>Carbon dioxide capture, transportation and geological storage – Geological storage |
| | ***First edition: 2018*** | ***First edition: 2016*** | ***First edition: 2017*** |

# Re-stream – Study on the reuse of oil and gas infrastructure for hydrogen and CCS in Europe

- Assess the potential of existing European oil and gas infrastructure (in EU 27, UK and Norway) to transport H2 and/or CO2.
- Provide fact-based information to European policymakers and stakeholders in order to inform forthcoming debates on EU energy transition and climate policies.
- The study includes high level technical assessment of the infrastructure, identification of CO2 emitters and potential H2 users and producers that could benefit from the reuse of the infrastructure; and economic assessments of reuse compared to new build on specific cases.

**NOTE:** An initial technical screening was undertaken considering the data provided by the pipeline operators. This analysis does not replace a full pipeline re-qualification process that would require way more inputs for each pipeline

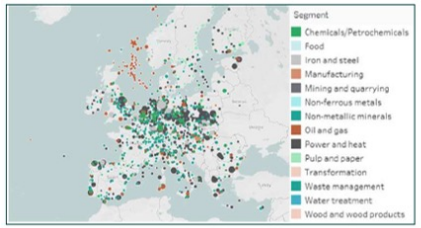
Contractors:

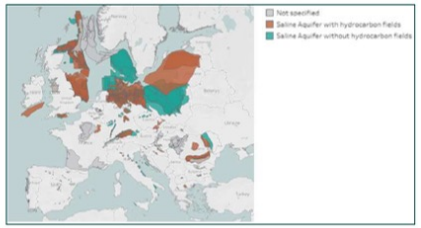
CARBON LIMITS

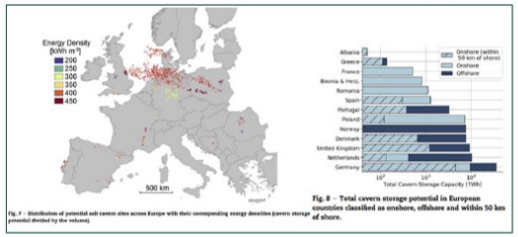
DNV·GL

Stakeholders:

| Offshore pipelines oil /gas | Onshore pipelines gas | Onshore pipelines oil/product | Underground Gas Storage / LNG plants |
|---|---|---|---|
| ~32,000 km - 335 pipelines- 73 operators - 30 IOGP members | ~225,000 km 44 TSO members, 3 Associated Partners and 9 Observers | ~34,000 km - 409 pipeline sections - 46 operators | |







**https://www.carbonlimits.no/project/re-stream-reuse-of-oil-and-gas-infrastructure-to-transport-hydrogen-and-co2-in-europe/**

# $CO_2$ Safe & Sour JIP

The Northern Lights pipeline is being developed with tight tolerances for impurities, including H2S.

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

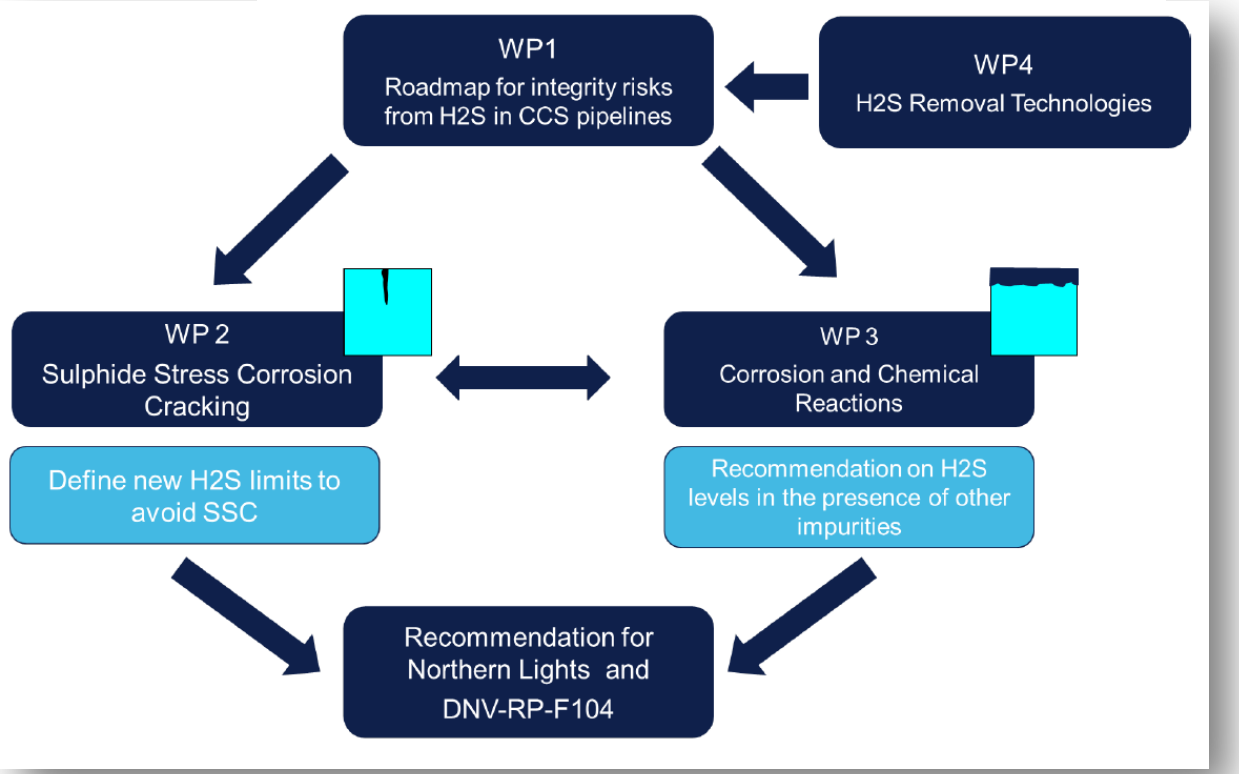
| | |
|---|---|
| Goal | • Increase tolerance levels for impurities resulting in sour service conditions.<br>• Enable cost effective development of Northern Lights and other CCS Hub projects. |
| Objective | • Understand the implication of H2S on the integrity of CO2 pipelines and quantify limits for safe operation. |
| End-state | • Knowledge basis for update of DNV-RP-F104 on allowable $H_2S$ limits in operation. |

equinor · TotalEnergies · GASSCO

H2S Challenge in CO2 pipelines JIP ← CLIMIT

Managed by DNV

DNV · IFE · wood.



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# CO2SafeArrest – Fracture propagation testing

Two full scale fracture arrest tests for validation of the numerical models at DNV's Spadeadam full scale test site during 2017/2018.

Full-scale fracture propagation testing to understand ductile fracture propagation/arrest behaviour of pipelines.

Improving safety and efficiency of $CO_2$ pipelines by developing and validating predictive models for $CO_2$ pipeline design.

## SOLUTION

DNV's validation of fracture arrest models and design requirements will:

- Eliminate project-specific full scale fracture arrest tests
- Remove excessive conservatism (sufficient wall thickness and material properties identified)
- Reduce costs for new $CO_2$ pipeline projects
- Input to definition of safety class and selection of pipeline safety factors.

## PROJECT DETAILS

**Customer:** Energy Pipelines CRC (Australia)
**Funding:** CCLIMIT program by Gassnov

**Location**
UK + Norway

**Date**
2017-2020

# Full scale testing of Submerged $CO_2$ pipelines

**DNV** supports **Wintershall DEA** and the **OTH Regensburg University of Applied Sciences** to explore how existing natural gas pipelines in the southern North Sea can be used for future $CO_2$ transport.

A key activity is performing large-scale $CO_2$ pipeline testing of running fracture in air and in submerged (water) condition at DNV's Testing and Research Facility at Spadeadam in the UK

**SOLUTION**

Quantify the effect of the water surrounding the pipeline on the crack arrest behavior for a specific pipeline, and thus better define the model parameters used for different backfill types.

https://www.dnv.com/news/dnv-supports-world-first-large-scale-testing-of-submerged-co2-pipelines

**PROJECT DETAILS**

**Customer**
Wintershall Dea (Germany)

**Location**
Germany + UK + Norway

OSTBAYERISCHE TECHNISCHE HOCHSCHULE REGENSBURG

# Summary

# Summary

## Pipeline vs shipping

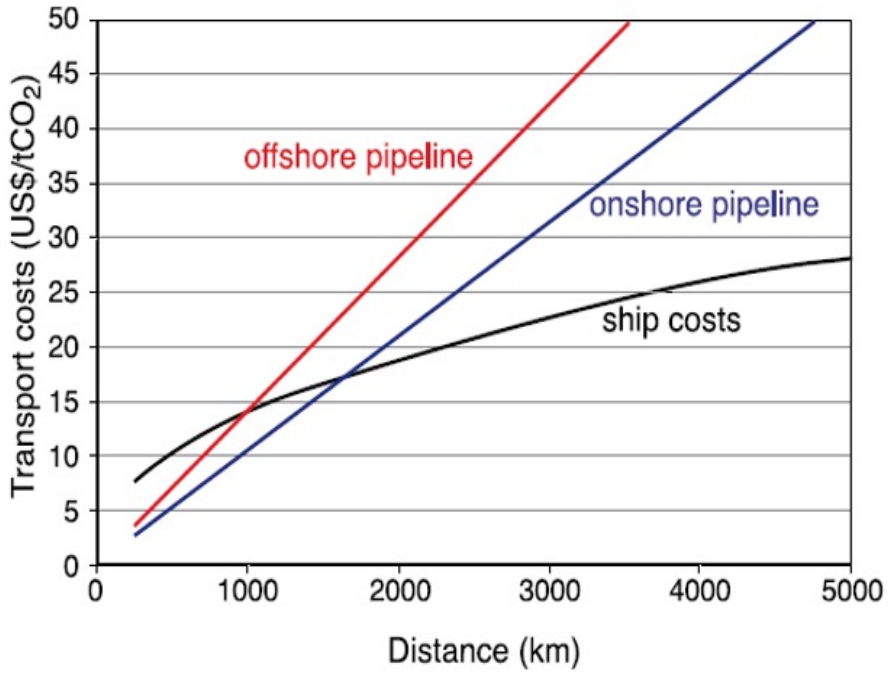
- Shipping and pipeline constitutes the two main options for transportation of large volumes of CO2
- The two options have different cost structure and technical challenges

## Shipping

- Shipping of Liquid CO2 has been done in small quantities for many years
- Development are ongoing to scale up cargo tank volumes enabling larger vessels and lower transportation cost.

## Pipeline

- Pipeline standards and guidelines already exists.
- Experience from US (onshore) and Norway (Snøhvit, Northern light) and recent requalification projects and concept studies.



# Q&A

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