Bifrost, all offshore CO2 transport and storage project
Concept & Technology challenges

14/06/2022 - CCS and CO2 Management: From Capture to Offshore Storage
- a technology conference hosted by DTU Offshore -
Bifrost, CO₂ transportation and storage project leveraging on existing O&G assets

- 2-year pre-development study funded by EUDP
- 3 study partners: DUC, DTU, Ørsted
- 11 work-packages covering:
  - Project management and communication
  - Subsurface (both clastic and chalk reservoirs)
  - Store management and monitoring
  - Well design and performance, legacy wells integrity
  - Surface facility design
  - Alternate transportation via O&G pipeline conversion
  - Environmental and societal impact
  - Socioeconomic assessment

20/06/2022 – CCS and CO₂ Management: From Capture to Offshore Storage
Project vision summary

- All offshore concept with continuous injection from a floating CO₂ buffer-store & conditioning facility
- Leverage on:
  - DUC assets
  - Ørsted pipelines
  - DTU expertise
- to:
  1. Qualify Harald main Sandstone reservoir store
  2. Assess and mature Harald East Chalk reservoir to prepare for expansion
  3. Define a robust, safe and competitive development for transportation and storage
• Technology readiness efforts involving
  - Technology providers
  - Joint industrial projects
  - R&D
  - Development teams...
DSME (Apr 2022) South Korean shipbuilding Daewoo Shipbuilding & Marine Engineering has received basic design approval from classification society ABS for a large liquefied CO2 carrier.

www.shipinsight.com (Nov 2021) Mitsui O.S.K. Lines in cooperation with Mitsubishi Shipbuilding (of MHI) have completed their Concept Study of the multiple hull forms for a liquefied CO2 carrier.

Ship size selection: Mtpa x Distance
Factoring # emitters and possibility of milking
CO₂ Efficient Transportation via Ocean (Low pressure shipping)

**Objective**

- Provide evidence of the technical feasibility of a low-pressure CO₂ ship transportation concept, mitigating the risks and removing uncertainties related to design, construction and operation.
- Qualify 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.

**Technology Qualification Programme**

DNV-RP-A203

**Phase 1**

(completed Oct 2020)

Concept definition and functional requirements. Qualification activities and qualification plan

**Phase 2**

Ongoing

Execution of the qualification activities

7bar ; -49°C
Flexible Ship to ship transfer hose

Context

• Ship-to-ship liquid CO₂ transfer is done via a flexible hose

• The technology is not qualified for this product and at this condition

Key points of the development

• Flexibility at low temperature
• Limited diffusion of the gas through the structure
• Resistance to rapid gas decompression
• Qualification of the whole structure
3 Unbonded Flexible Pipe Technology for CO2 Transport

• Unbonded flexible pipe: Composite structure
  - Mechanical strength provided by steel wires, pressure vault and tensile wires (sensitive to corrosion)
  - CO2 will permeate through the Pressure Sheath (polymer layer)

• Main issues for flexible design remains the risk of
  - Combined presence of water in the annulus and high CO2 concentration and initiation of Stress corrosion cracking
  - Presence of O2/CO in contact with the inner carcass leading to potential high corrosion
  - Impact on polymer ageing
  - Impact of impurities on end-fittings

• Need for evaluation of
  - Annulus condition (CO2 concentration level)
  - Risk of water, coming from leak at subsea termination
  - Impact on material on presence of O2/CO

• Operating condition well within qualification range of flexible pipe
  - Pressure: 150 bar
  - Temperature: 4°C to 50°C
Flow Modeling: challenges for flow simulation in wells & pipes

**Challenges**

- Accurate modeling is particularly critical for well performance prediction and well design
  - Steady-state simulations
  - Pseudo steady states simulation (with IPR and near WB)
  - Transient simulations for well opening / closing

- Flow regimes and phenomena to be captured
  - Friction
  - Joules-Thompson effects
  - Hydrate formation predictions
  - Dual phase injection
  - Flow at saturation and differential velocity of fluids

**Axes for development**

- Well flow performance
  - Calibration and improvement of flow simulation tool: pilot for de-risking and prediction of all flow conditions

- De-risk injectivity impairment / CO₂ induced changes
  - Hydrate formation and impact on flow, characterization, modeling and remediation
  - Salt precipitation, impact on flow Modeling
  - Thermal Frac induced by CO₂ phase change

- Coupling Wells models
  - With Near Well Bore for transient well behavior
  - With Surface network for asset management
Well equipment qualification

Legacy wells integrity and safe conversion is of uttermost importance

- In spite of 30+ years of history, data set are sometimes limited
- Thematic of CO2 Storage in depleted reservoir is prone to experiencing severe cooling effects during startup phases
- Well conversion for CO₂ service needs to be scrutinized
- Ongoing qualification of two sizes of downhole safety valves undertaken by a JIP of 9 operators and 3 suppliers, piloted by Net-Zero Technology Center
- A protocol to qualify novel connections of injection tubing is under revision with pipe manufacturer (resistance with negative temperatures exposure)
- Evolution ongoing of cement sheath evaluation methods, both for post-job assessment and for potential new wells
FC-MAELSTROM research project – GEOSX at a glance
One of several internal initiatives

A strategic partnership that could develop to build a standard for CCS

**2020: GEOSX**
The Product of FC Maelstrom
R&D simulator
Fully coupled flow and geomechanics
Next-gen HPC-ready: Multi-GPU&Nodes
Open-source, free and transparent

GEOSX:
Develop a novel simulation tool for CCS designed for large scale simulations and coupled physics (flow & Geomeca)

**2022 ambitions**: Test solutions on real case studies. Embark additional partners. Add new physics for depleted reservoirs.

**Since 2017**
Ongoing applications to Northern-Lights and Middle Eastern aquifers
Collaboration “innomission project” with

A wide range of applications for CCS (and beyond)

Basin-scale simulation
Reservoir wellbore mechanics
Seismic imaging with INRIA
The Need for plume monitoring is inherent to a safe and permanent storage

- **Acquire** active & passive seismic data sets & **qualification** technologies & workflow
  - from existing injection pilot/site
  - from existing technology **low-cost network** (Fiber Optic)
  - by developing **new techno on TotalEnergies pilots**
  - though specific collaborations

- **Develop, test & improve** geophysical **interpretation** workflows
  - 4D Monitoring data acquired from surface & borehole
  - Setting passive detection of Induced Seismicity

- **Provide solution for the monitoring of the overburden**
  - Sensor & interpretation for pressure & saturation variations and strain monitoring
• TotalEnergies is investing in CO$_2$ storage services for its customers

• Our target is to develop ~10 Mtpa of storage capacity by 2030
  ✓ Bifrost is a promising contributor to this ambition

• Technology maturation axes
  ✓ Leveraging on R&D projects
  ✓ Involvement in JIPs
  ✓ Collaboration with Vendors, Academia and industrial partners