

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

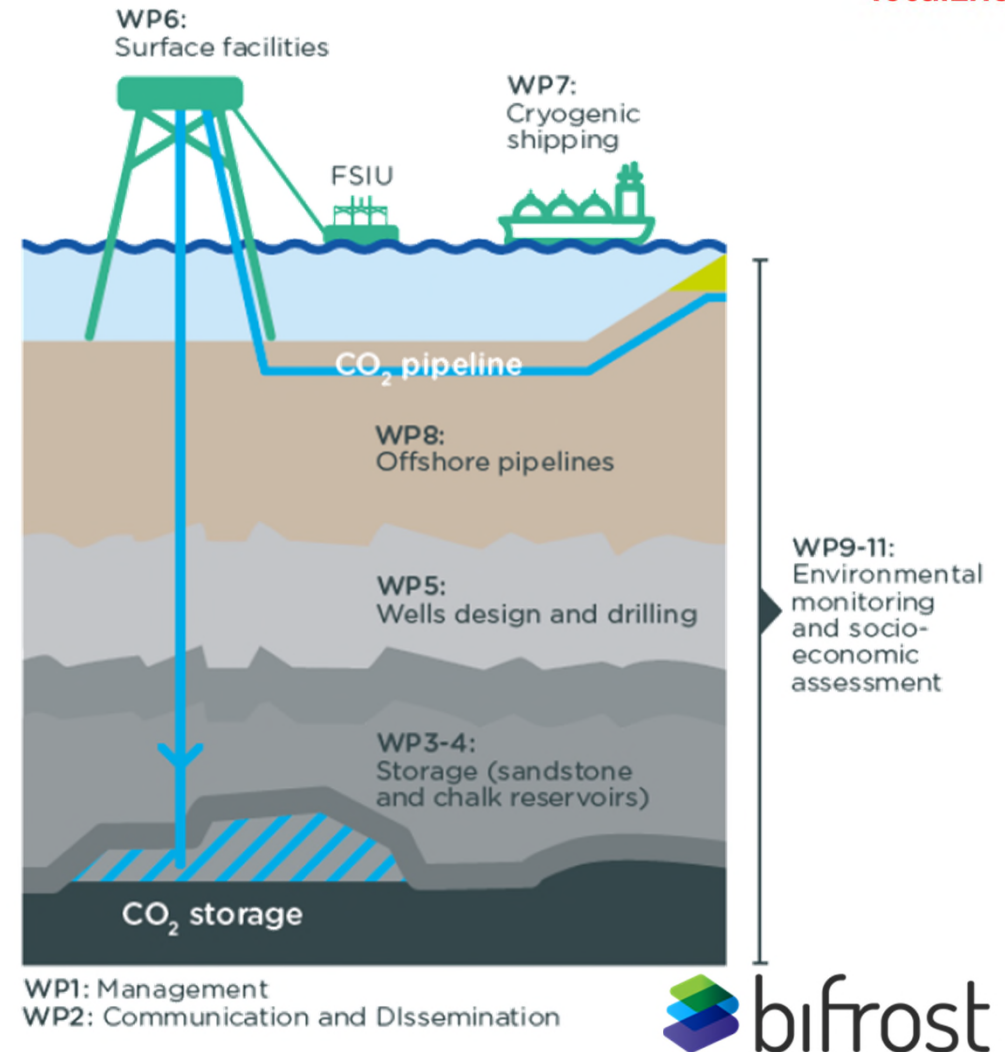
14/06/2022 – CCS and CO2 Management: From Capture to Offshore Storage
– a technology conference hosted by DTU Offshore –



Funded by EUDP C

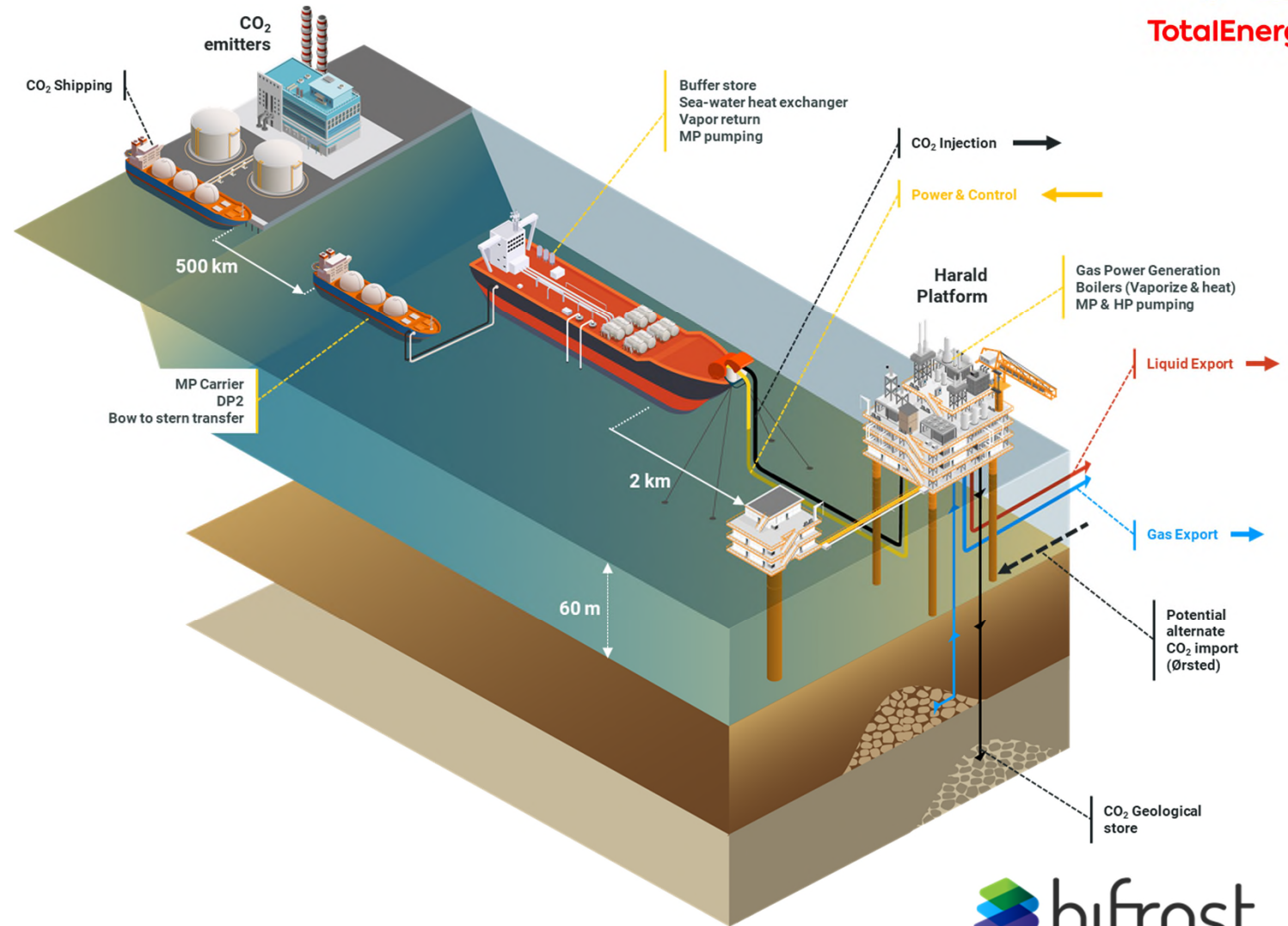
Bifrost, CO₂ transportation and storage project leveraging on existing O&G assets

- 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

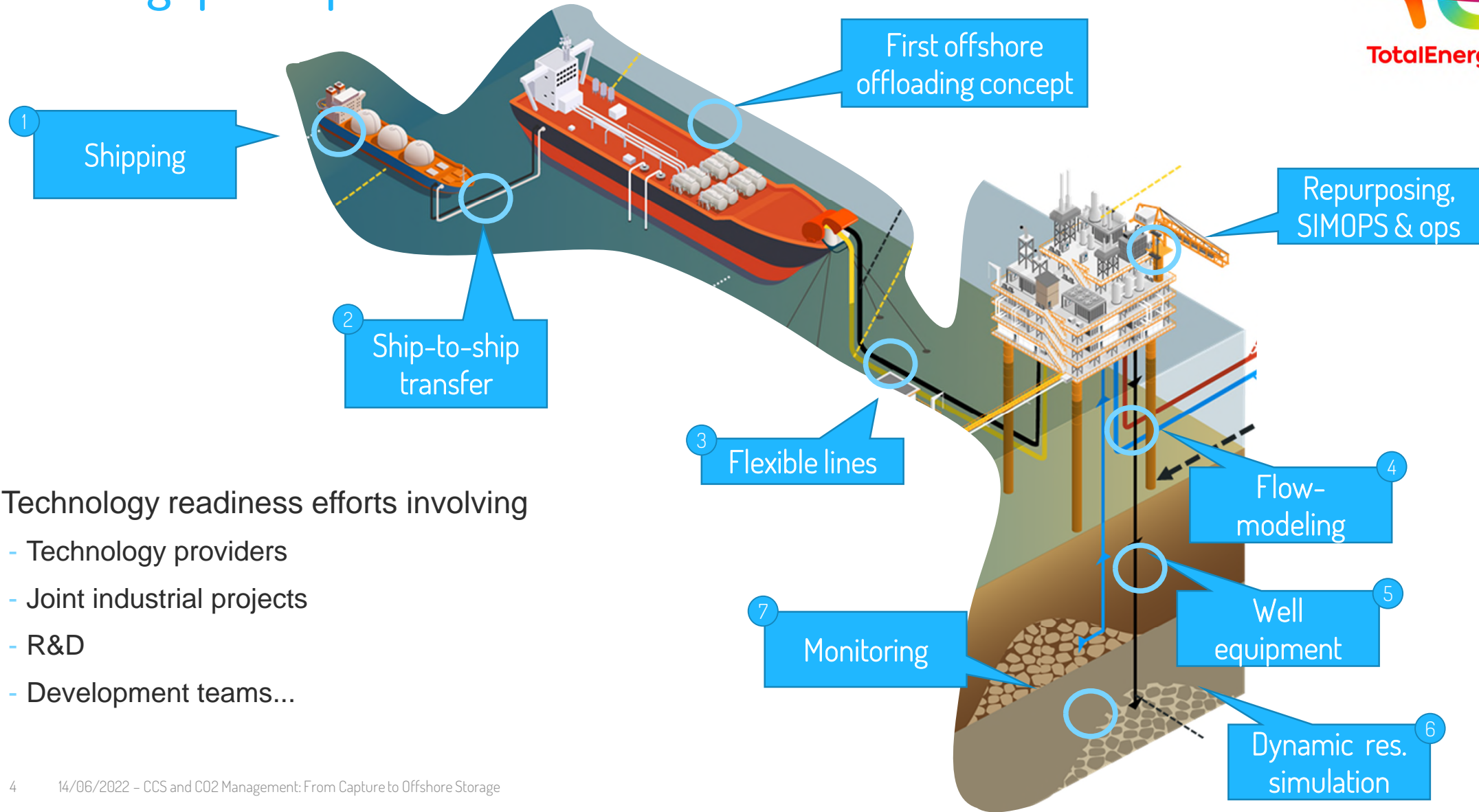


Project vision summary

- 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



Techno gaps map

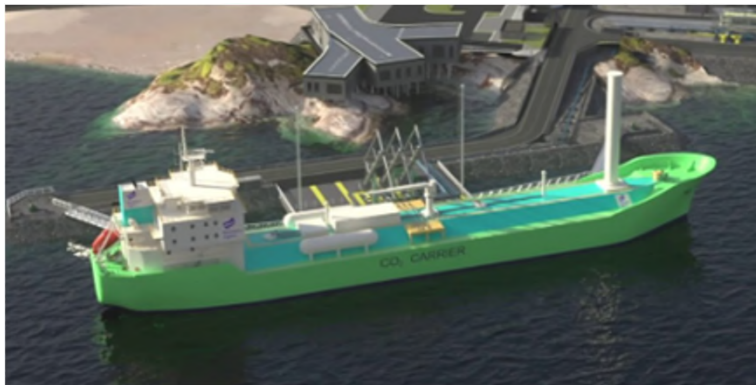


- Technology readiness efforts involving
 - Technology providers
 - Joint industrial projects
 - R&D
 - Development teams...

1 Ship size, long distance high capacity



7,500 m3



norlights.com (Oct 2021)

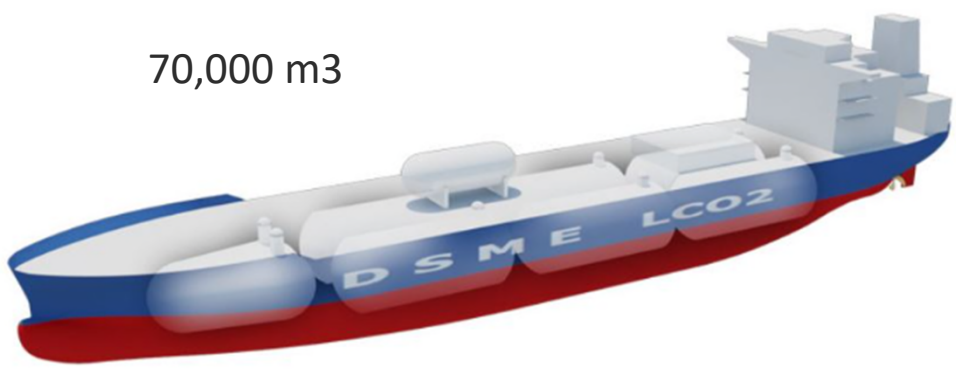
18bar ; -28°C

50,000 m3



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

70,000 m3



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

Ship size selection: Mtpa x Distance
Factoring # emitters and possibility
of milking



1 CO₂ Efficient Transportation via Ocean (Low pressure shipping)



CETO JIP

7bar ; -49°C

- 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



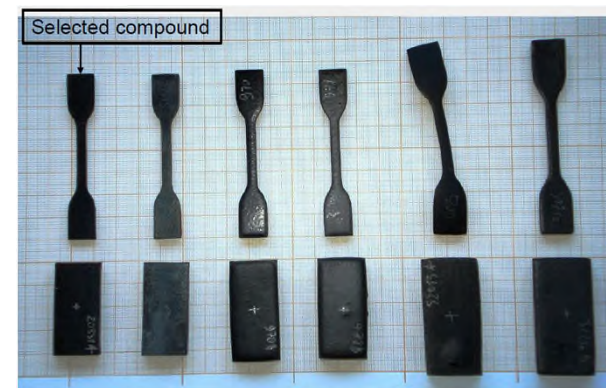
2 Flexible Ship to ship transfer hose

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

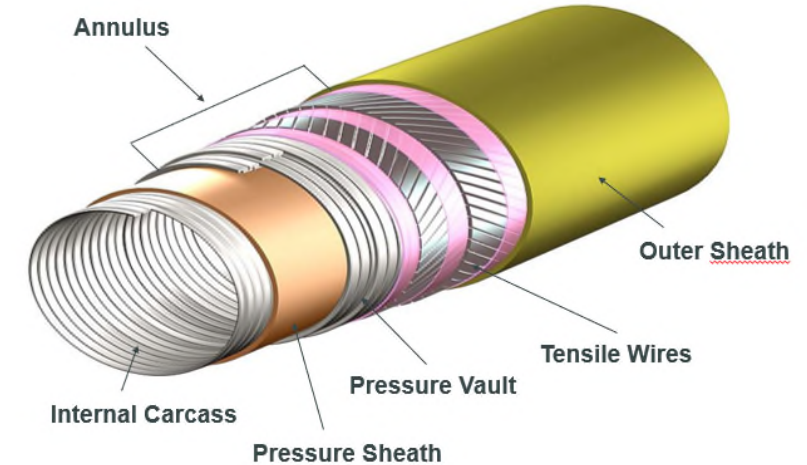
Key points of the development

- 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

4 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

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

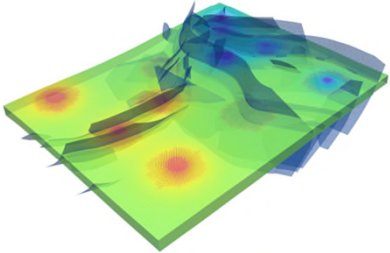
FC-MAELSTROM research project – GEOSX at a glance

One of several internal initiatives



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

Since 2017



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 news physics for depleted reservoirs.

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

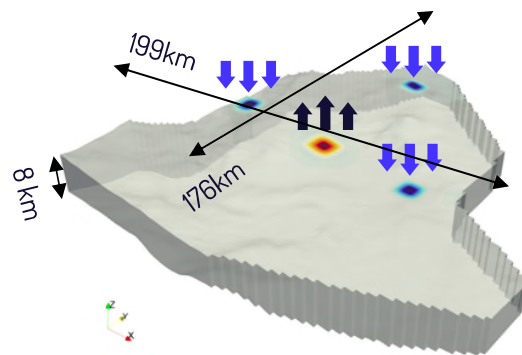


Ongoing applications to Northern-Lights and Middle Eastern aquifers
Collaboration "innomission project" with

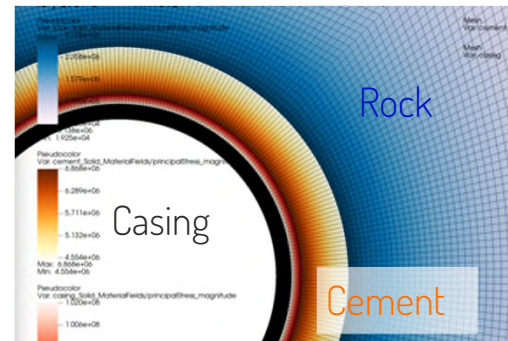


A wide range of application for CCS (and beyond)

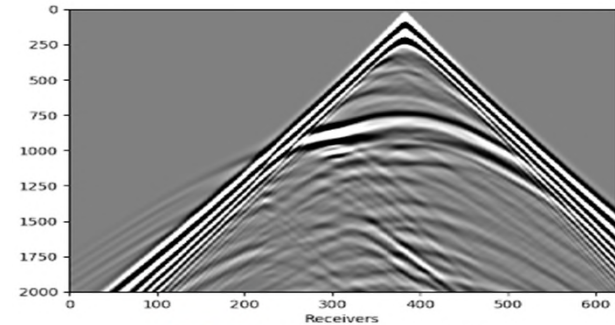
Basin-scale simulation



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

Conclusions

- TotalEnergies is investing in CO₂ 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