# Digitizing the CCS value chain

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# $CO_2$ transport & storage at scale

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NORTHERN LIGHTS SCOPE

## $CO_2$ capture

Capture from industrial plants.
Liquefaction and temporary storage.

## Transport

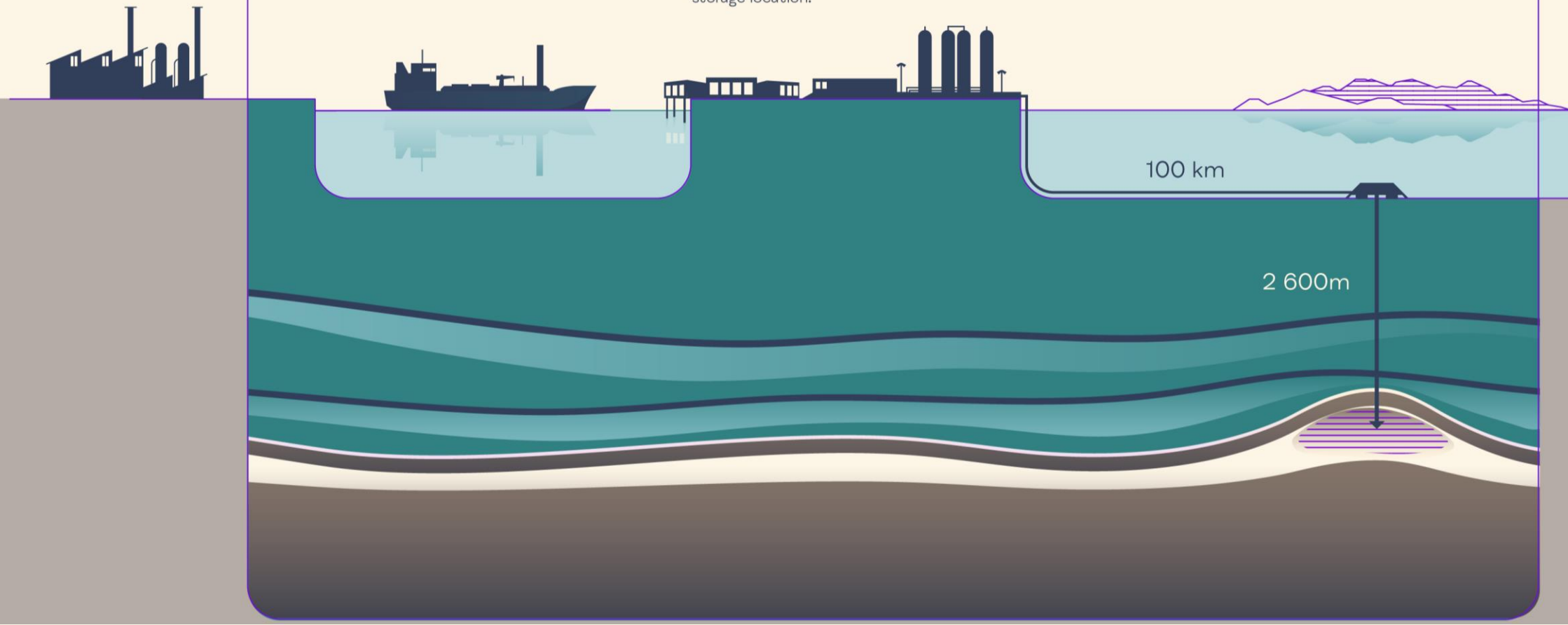
Liquid $CO_2$ transported by ship.

## Receiving terminal

Intermediate onshore storage.
Pipeline transport to offshore storage location.

## Permanent storage

$CO_2$ is injected into a saline aquifer.



# In operation by mid-2024

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# Northern European infrastructure

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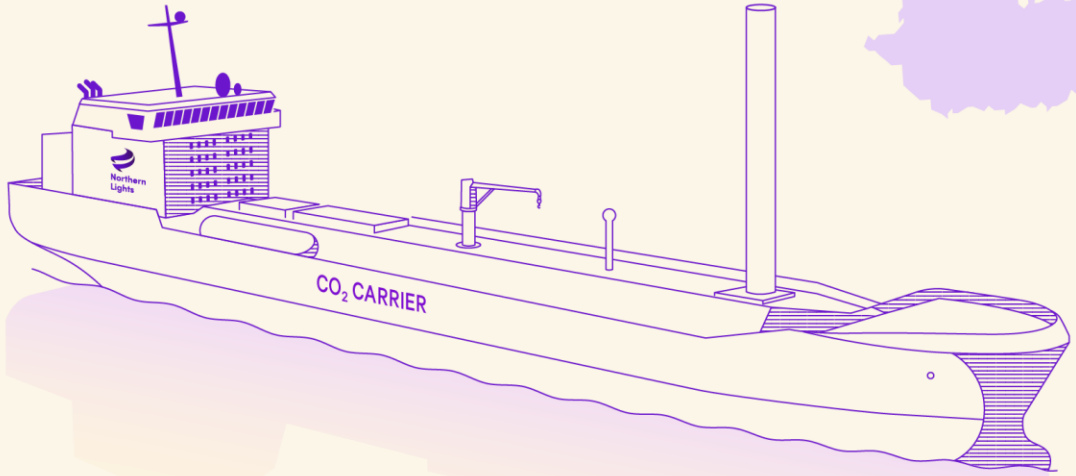


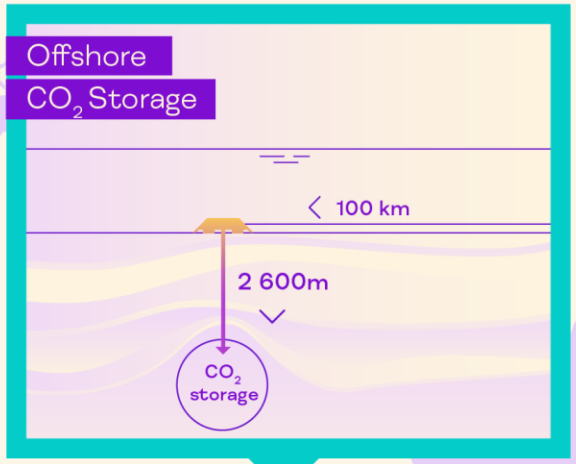


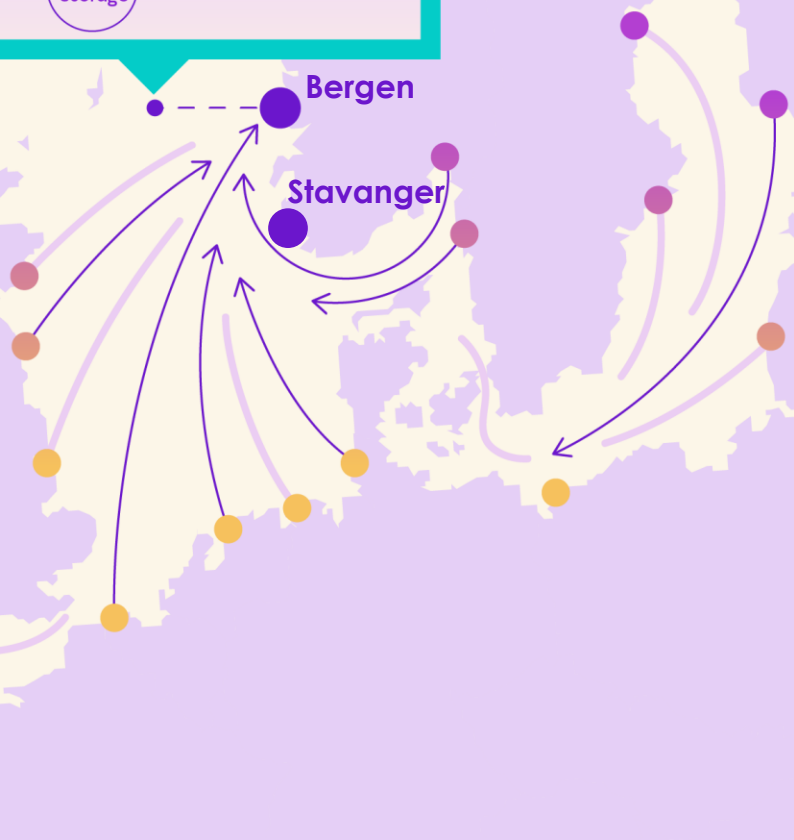

# Becoming a reality

## Receiving terminal at Øygarden

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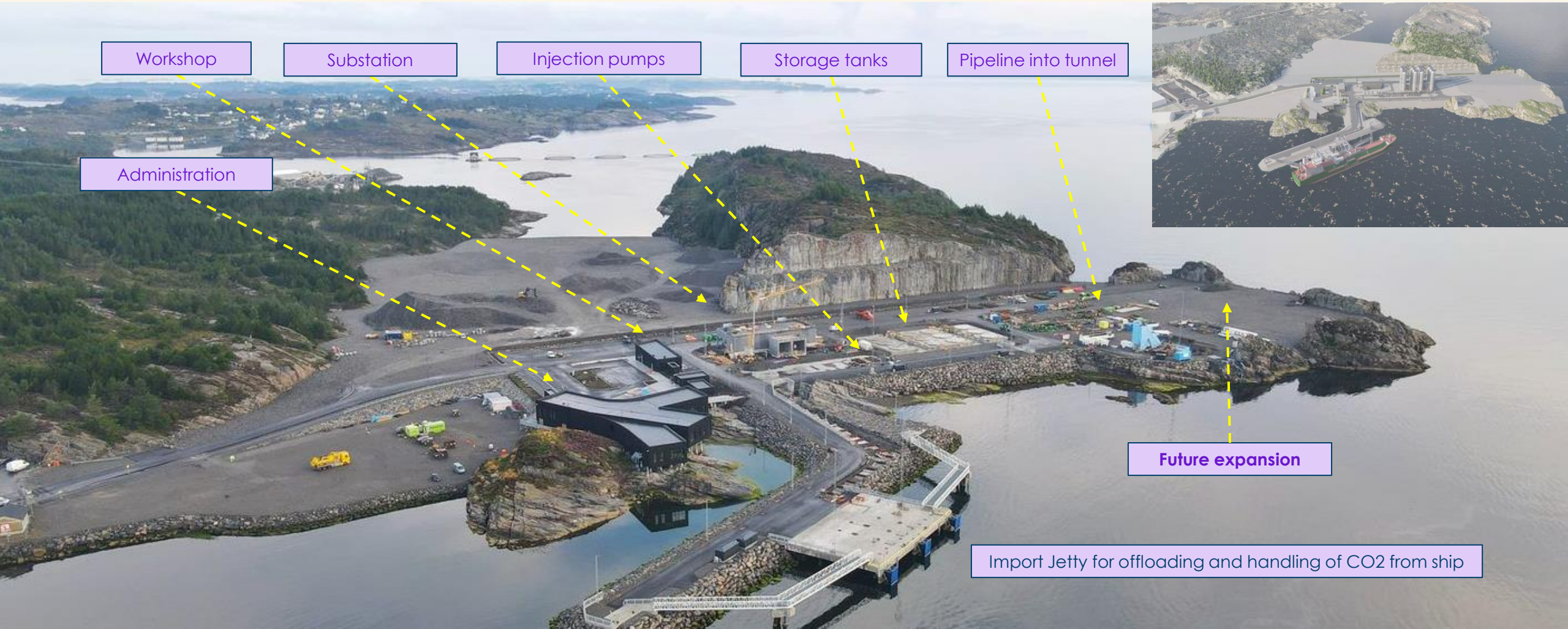

# Building a market for $CO_2$ storage

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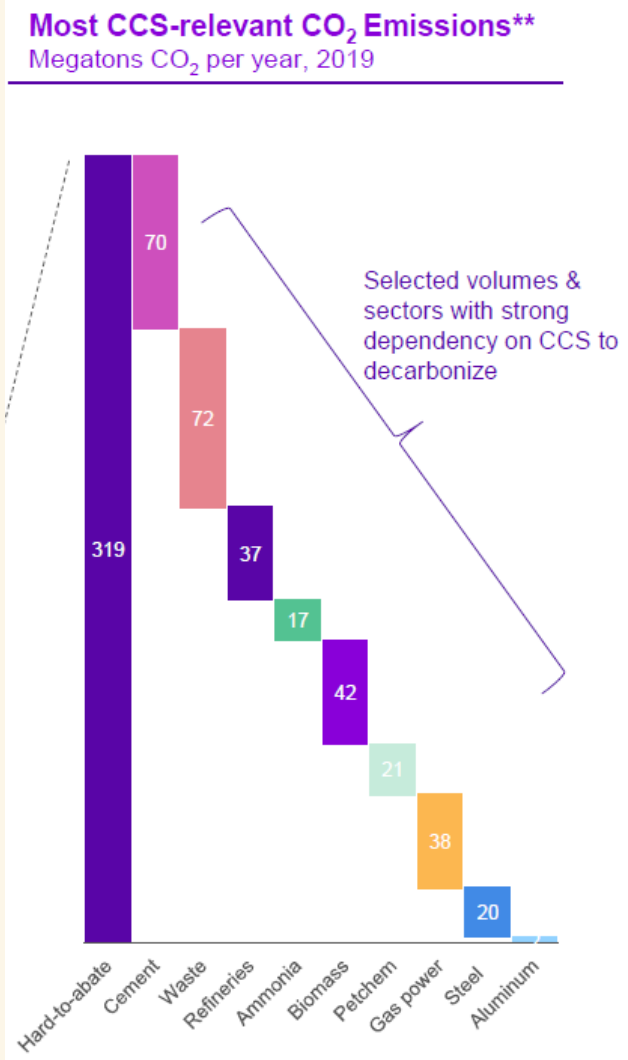


→ **Significant interest and demand for our services**

→ **Focus:**

- Deliver Phase 1, operational in 2024
- Building a commercial business

→ **Secure commercial contracts**

→ **Investment decision for capacity expansion**

→ **Hard to abate emissions from industry in Northern Europe**

- Process industry
- Cement
- Steel
- Waste incineration
- Negative emissions

→ **Market potential: 319 Mtpa**

# Value Chain

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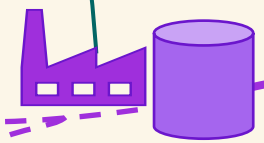
**Feed in of New Customers**

**$CO_2$ Source-Capture-Storage**

**Transport**



**Plant-Storage**
Øygarden

**Pipeline**

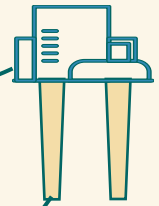
100 km

Umbilical

Umbilical

Umbilical

**Control room**
Sture

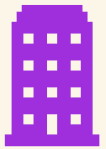


**Platform services**
Oseberg A

**Subsea Template**

**Wells** 2.6 km vertical depth

**$CO_2$ Storage**



**Authorities**
Norway, European Union

**Northern Lights Office**
Stavanger

# Interoperable digital CCS value chain

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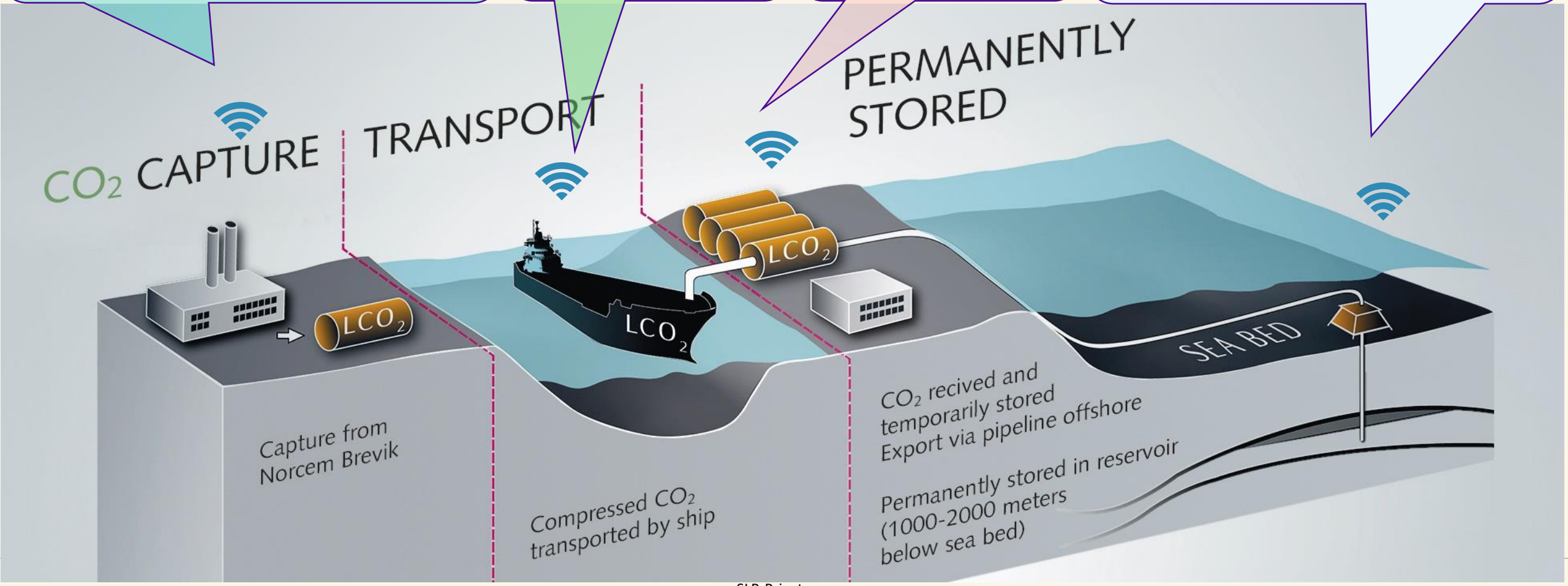
"Vessel 2, I am at 70% of max $CO_2$ capacity. Please, see my 5 days forecast. When do you pick up $CO_2$?"

"Plant 5, I will slow down to save fuel. Ready to load in 3 days, OK?"

"Port 1, here are your report for the $CO_2$ off-loading yesterday"

"Guys, based on AI, I predict the optical fiber switch will fail in 3 months. Suggest to replace while Plant 4 has turnaround, OK?"



# Digital CCS value chain

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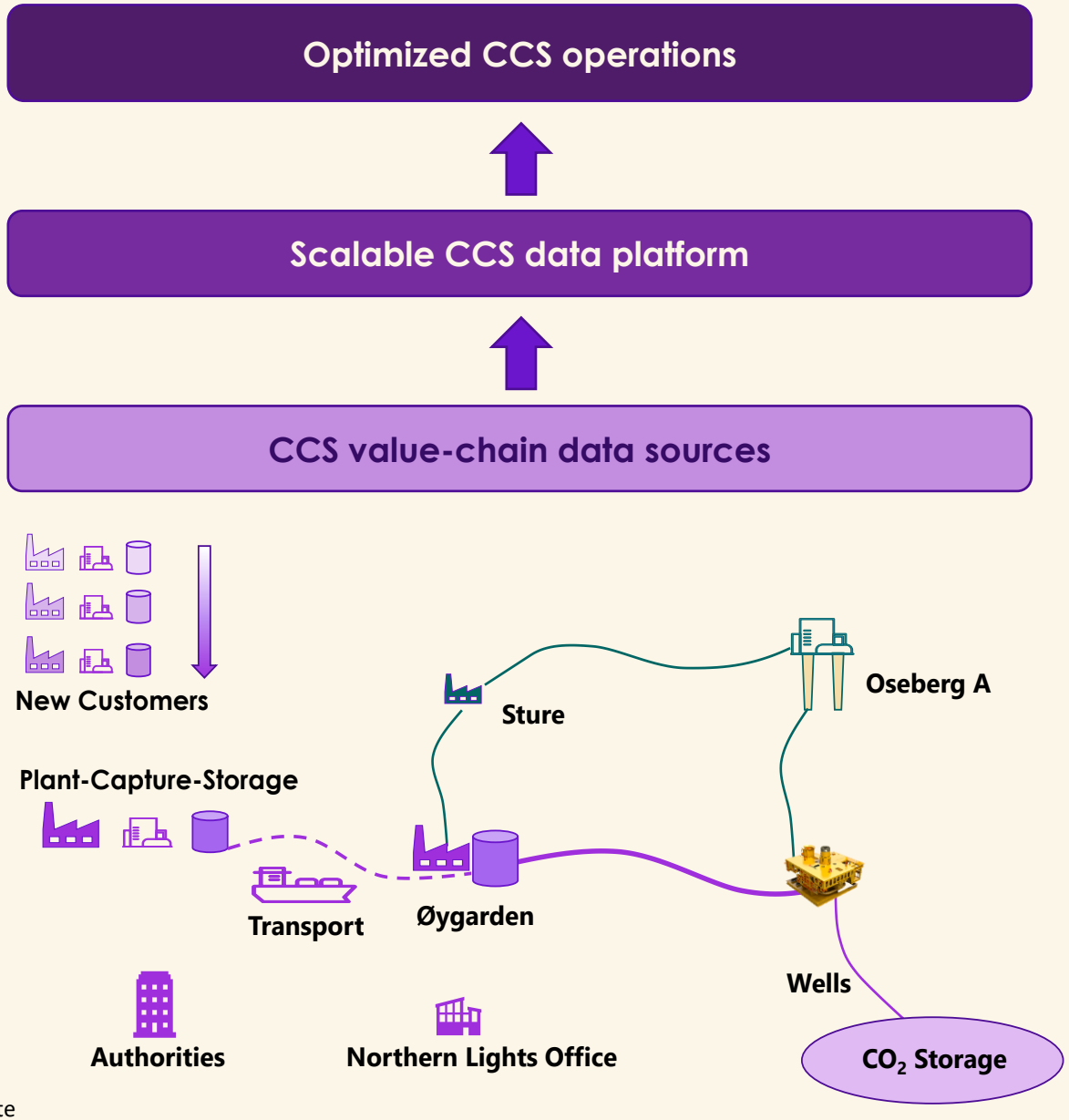
## → Use Case examples

- Automatic reporting
- Logistics simulation & optimization
- Subsurface simulation & optimization

## → Enablers for value-chain optimization

- Sharing data across value chain elements
- Scalable & secure solutions
- Open industry standards



# CCS digital ecosystem

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**Use Case Value Realization**

**Business Applications**
Independent Sofware Vendors (ISVs)
Global System Integrator (GSI)

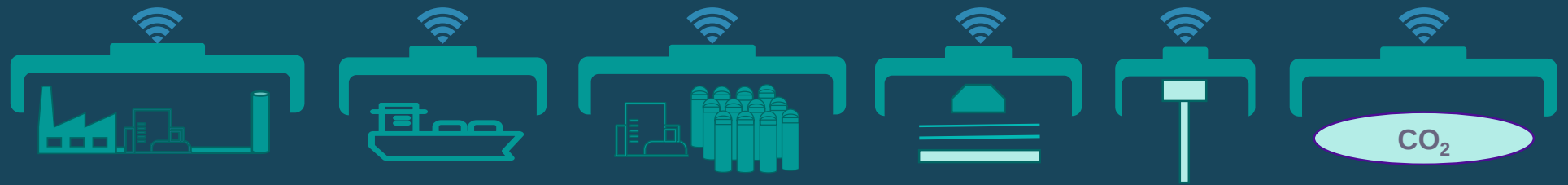
**Data Platform Based on Microsoft Azure**
Cloud solution

**Context: $CO_2$ flow**

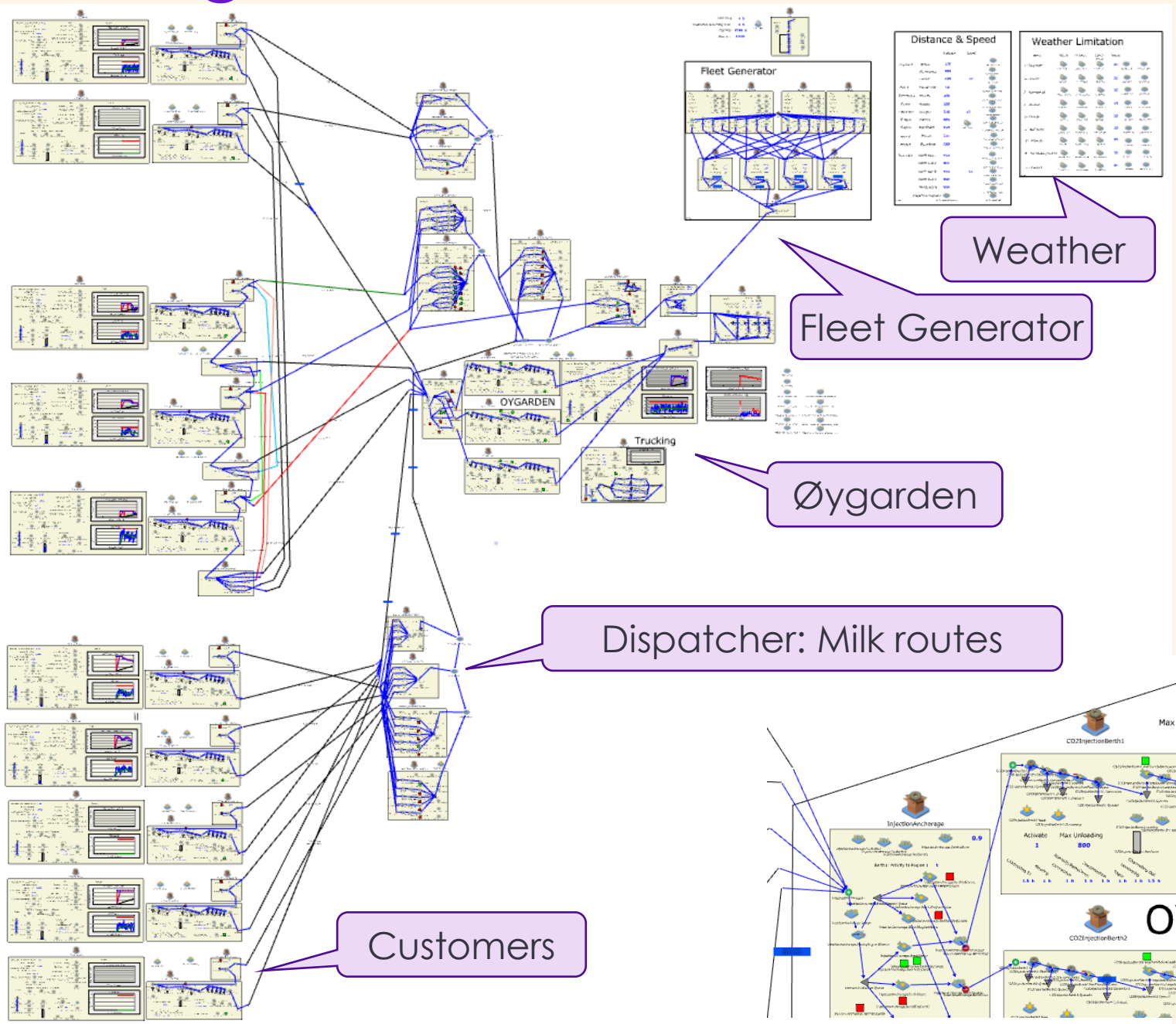
$CO_2$ Source → Capture → Port Storage → Vessel → Terminal Storage → Pipeline & Subsea → Well → Stored $CO_2$

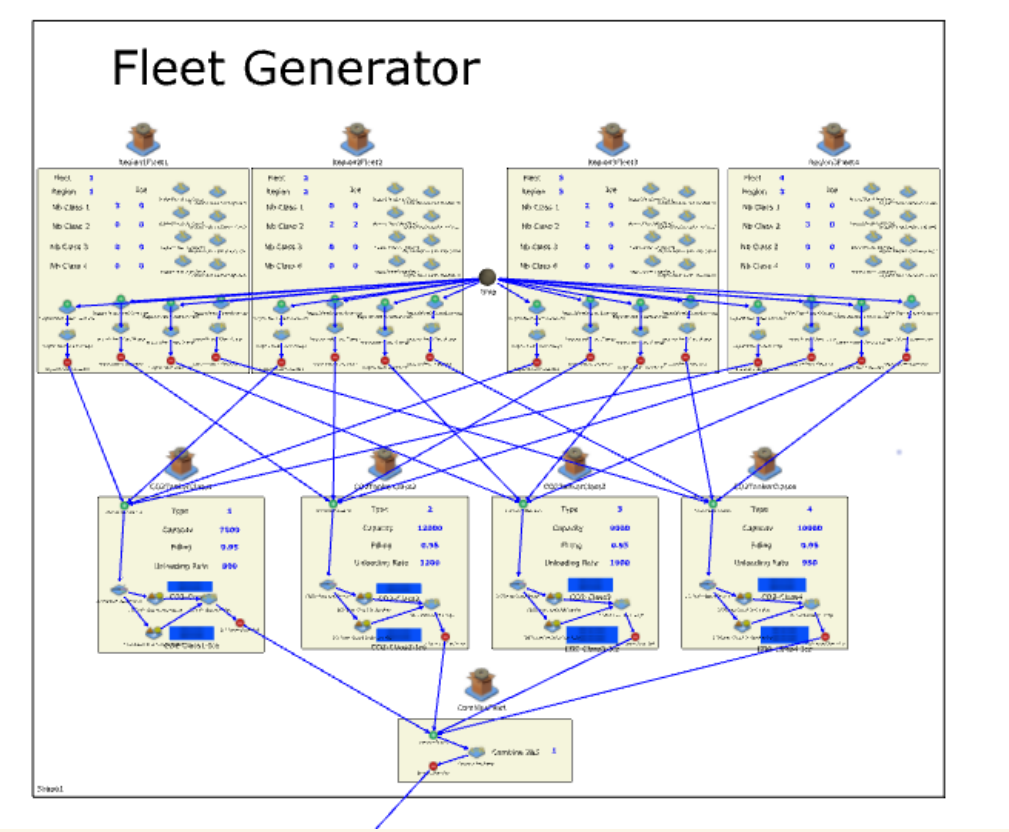
**Interoperability**

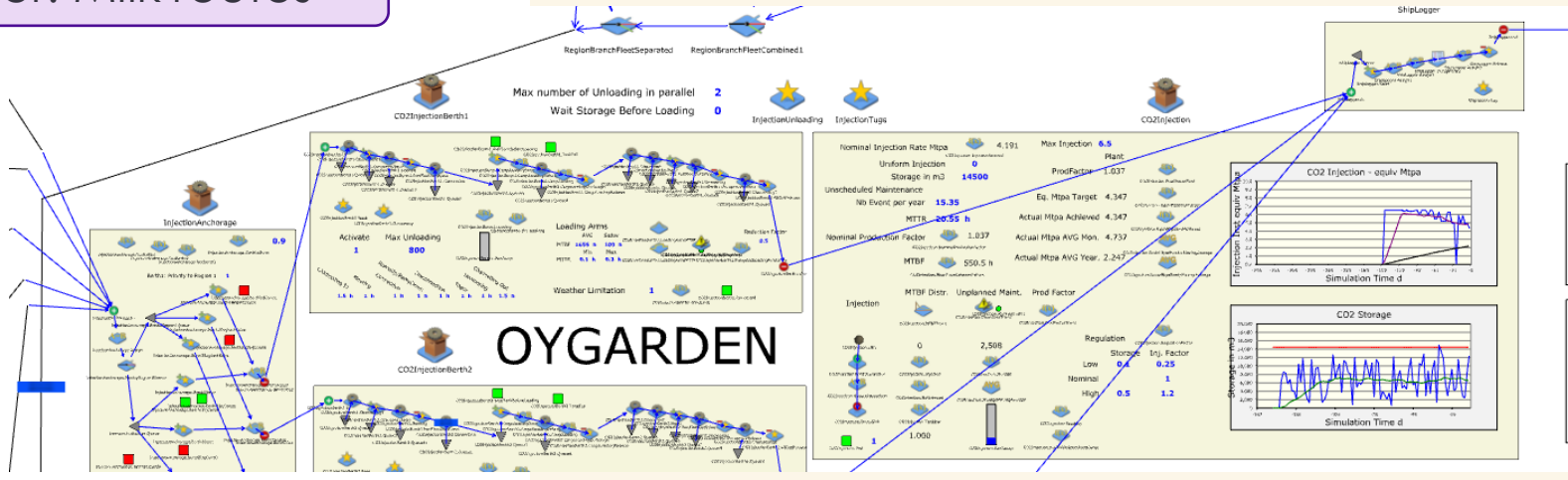
**Data Sources: Measured Data & Simulated Data**



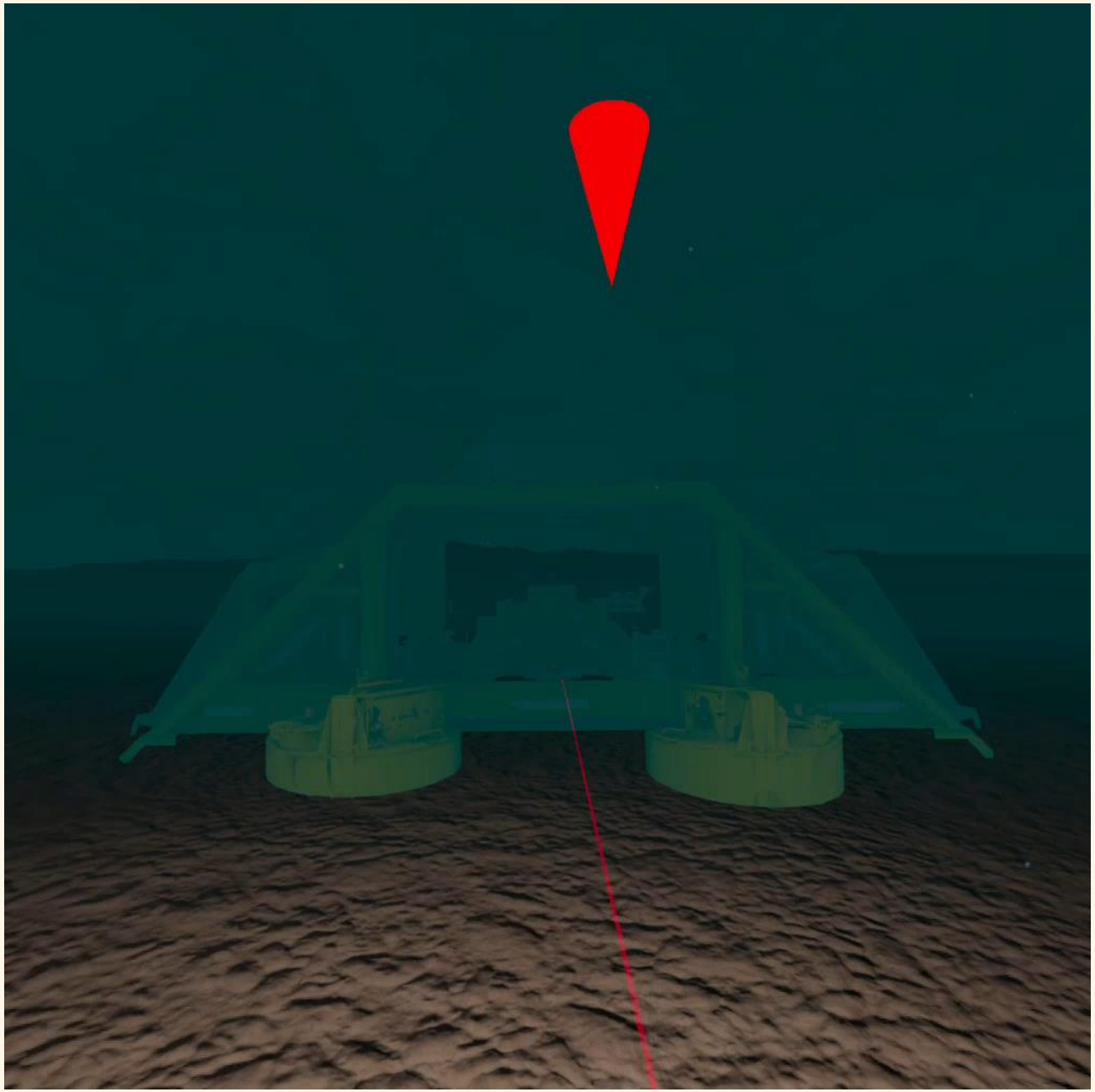
# Logistics Simulator: JaamSim



# Subsea Metaverse




**Metaverse**

- Gaming multiplayer environment
- Operational training
- HSE: Hazid & Hazop
- What if scenarios in digital twins

Technology (courtesy Equinor, Echo):

- Digital twins
- Unreal Engine 4
- Meta Quest 2

# Subsurface CCS focus

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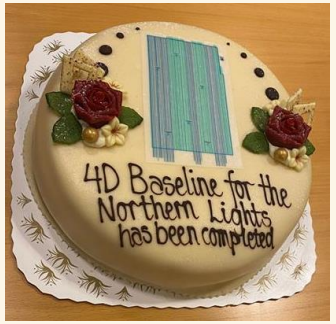
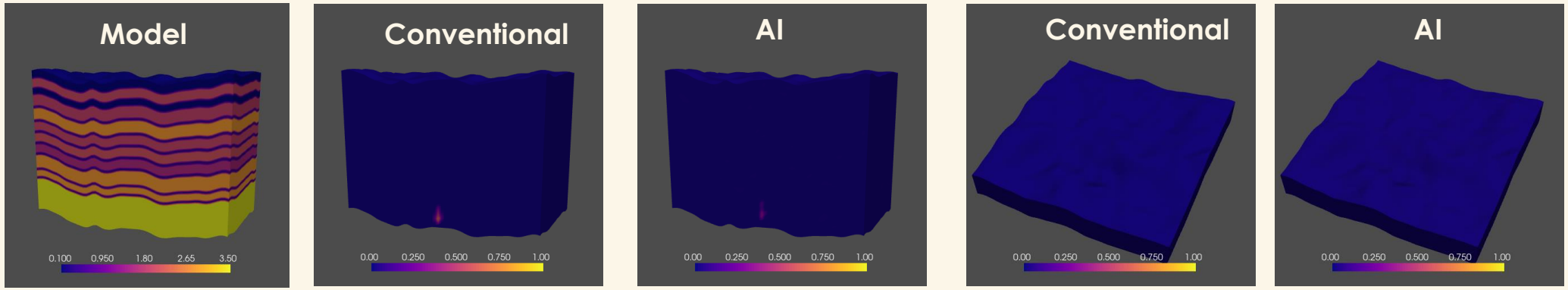
- → Safe $CO_2$ storage by geological seal of storage complex: Rock mechanics & large models
- → Commitment of future $CO_2$ injection volume: Injectivity & storage capacity, uncertainty
- → Monitoring $CO_2$ for safe storage in saline acquifer

- → Digital collaboration with Schlumberger and Microsoft:
  - Data platform
  - Uncertainty modeling: Agile Reservoir Modeling
  - Optimize subsurface tools for CCS
  - Super-fast $CO_2$ flow simulation: 30 000X speedup by Artificial Intelligence




Courtesy: Philipp Witte, Microsoft Research for Industry

# DELFI Agile Reservoir Modeling (ARM): Stochastic modeling

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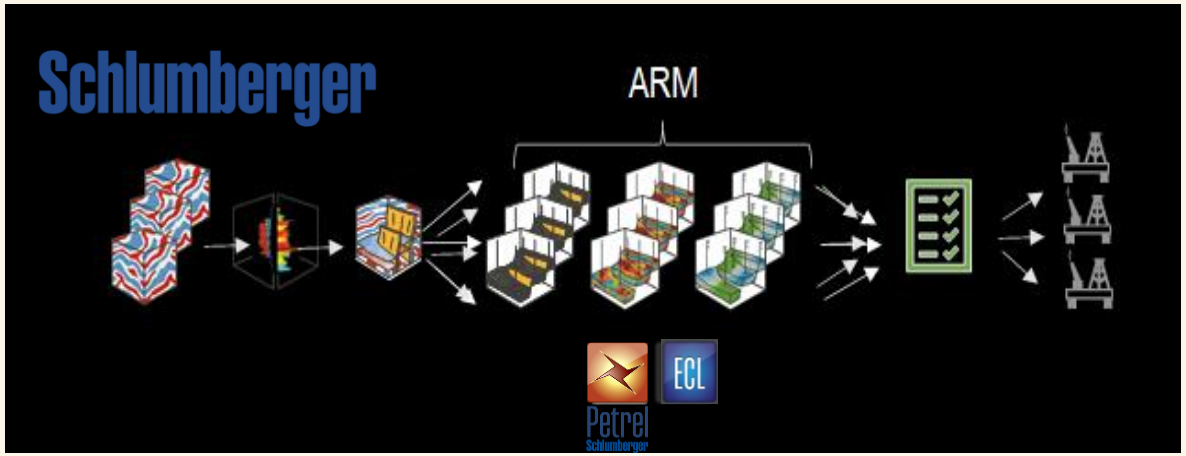


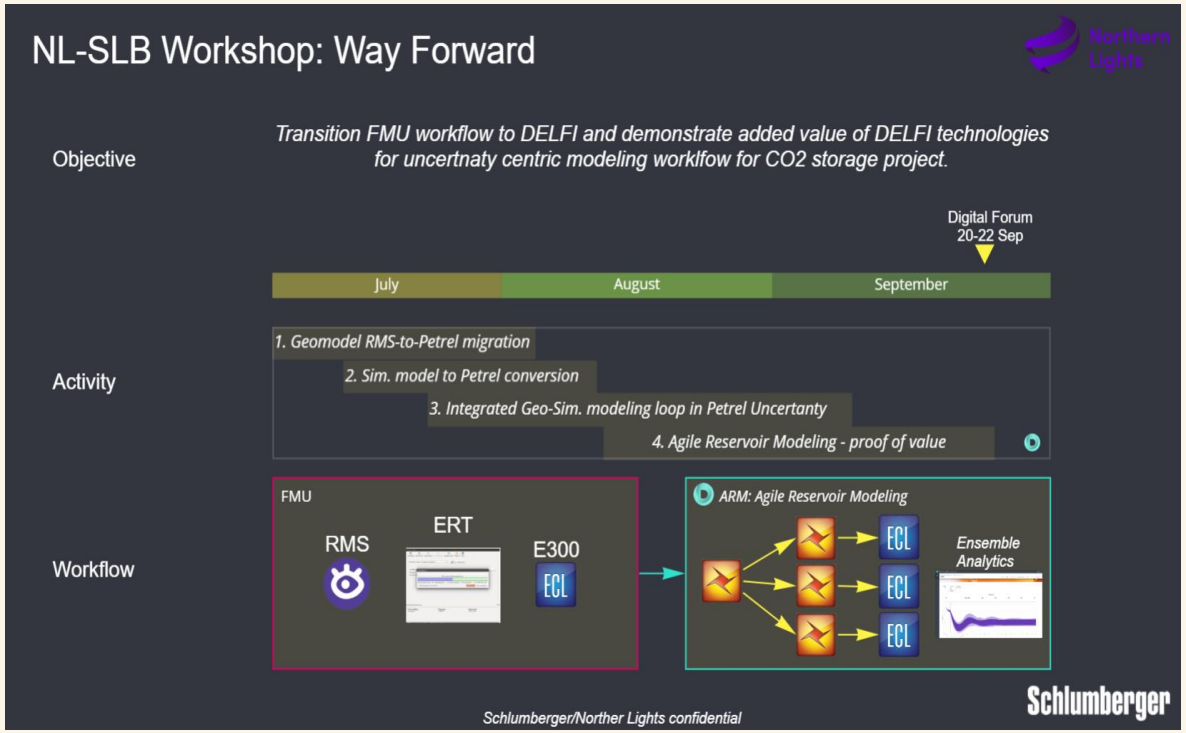


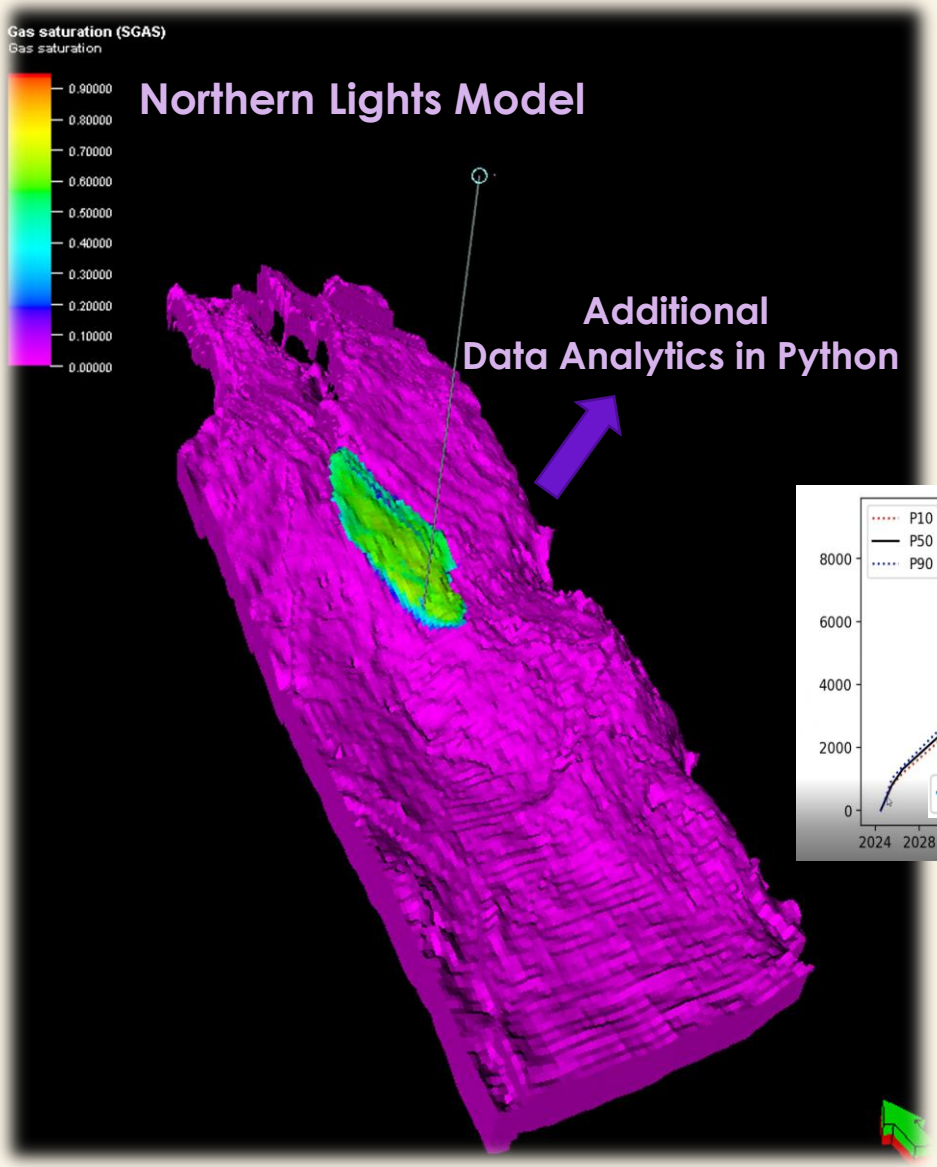


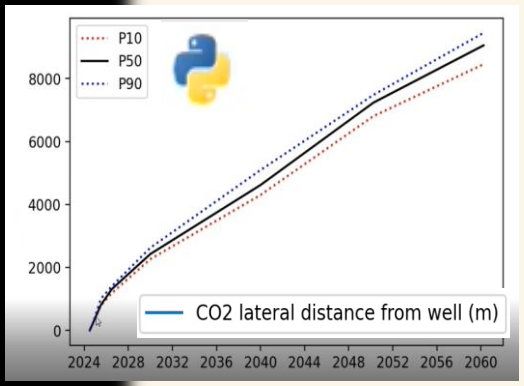

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