Northern Lights – Risks and barriers

Nathalie RENZI, Northern Lights JV - HSEQ Director

Contents

→ **Presentation of Longship project and the Northern Lights concept**
- Longship
- Northern Lights

→ **CO_2 caracteristics**
- Properties and hazards
- Impacts for Northern Lights

→ **HSE Risks**
- Ships
- Onshore
- Offshore

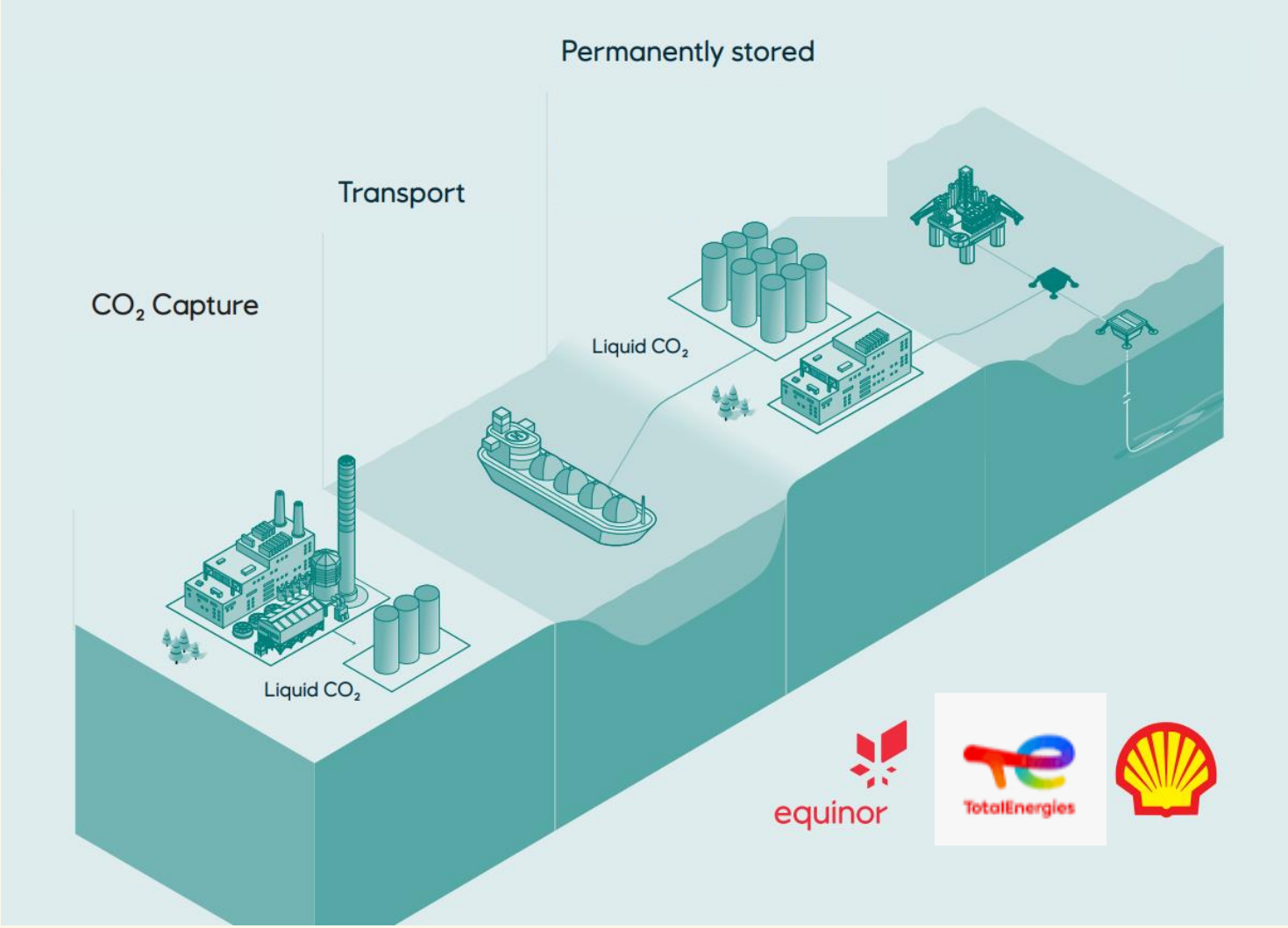
→ **HSE barriers in design and in operations**

Longship project

- **Longship** ("Langskip") is the name of the initiative from the Norwegian Government,
- The goal for Longship is to develop a **full-scale carbon capture and storage project (CCS)** as an effective cost to reach EU and Norway's CO2 reduction goals,
- The transportation and storage infrastructure, as well as knowledge sharing, **shall pave the way for further CCS projects in Europe.**

Longship project

→ **Full CCS value chain**



Northern Lights

→ Transport and Storage

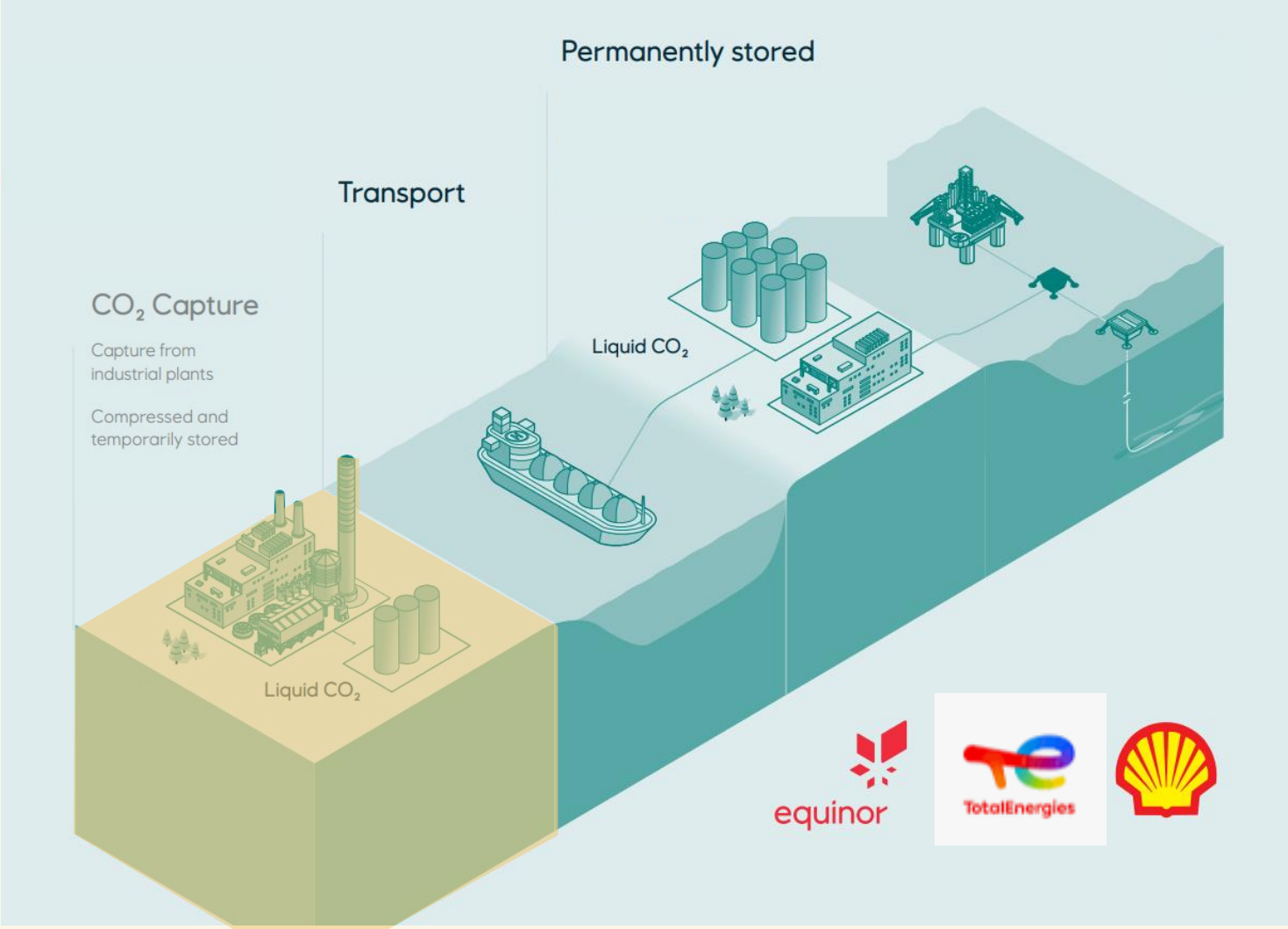
Interim storage onshore terminal

1,5 MT/y initial capacity

Pipeline sized for 5 MT/y

Exploitation license EL-001 in Norway

Start-up in 2024

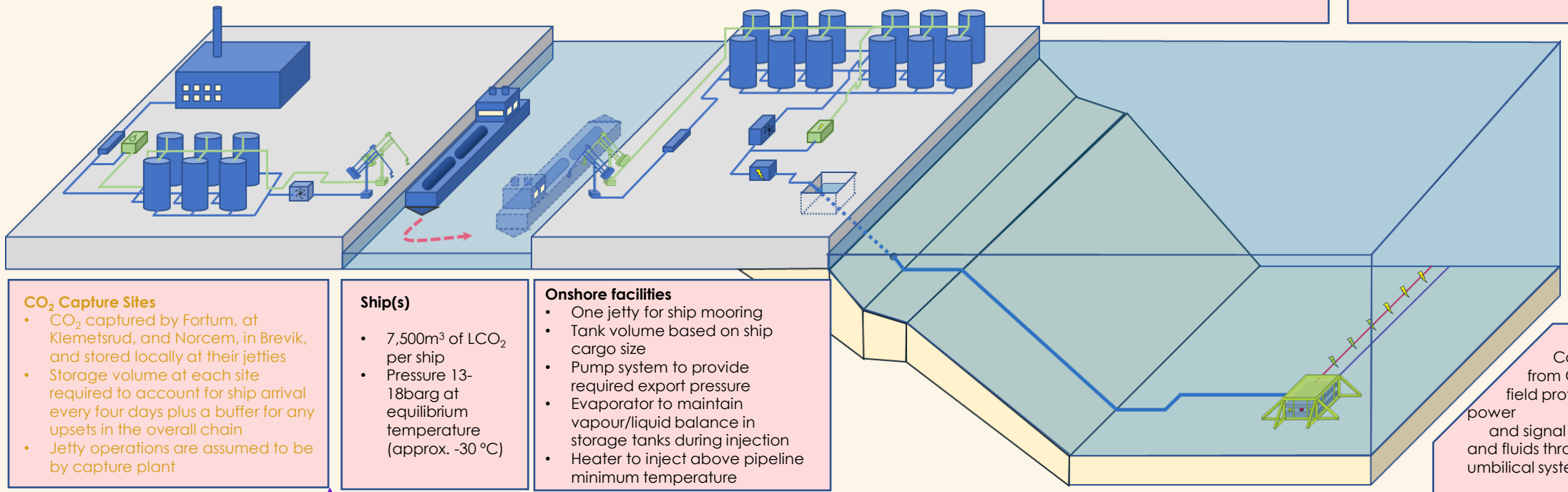


Northern Lights

Northern Lights concept

Pipeline
- 110km un-insulated pipeline
- 12 ¼ inch
- Single phase (liquid) CO_2

Subsea facilities
- Connecting pipeline, umbilical and well(s)
- Water depth ~300m
- Connection for future step-out



Subsea injection well
- Injection of CO_2 into reservoir at ~2-3000m depth
- Pressure in reservoir ~2-300bar
- Temperature in reservoir ~100 °C

CO_2 Capture Sites
- CO_2 captured by Fortum, at Klemetsrud, and Norcem, in Brevik, and stored locally at their jetties
- Storage volume at each site required to account for ship arrival every four days plus a buffer for any upsets in the overall chain
- Jetty operations are assumed to be by capture plant

Ship(s)
- 7,500m³ of LCO_2 per ship
- Pressure 13-18barg at equilibrium temperature (approx. -30 °C)

Onshore facilities
- One jetty for ship mooring
- Tank volume based on ship cargo size
- Pump system to provide required export pressure
- Evaporator to maintain vapour/liquid balance in storage tanks during injection
- Heater to inject above pipeline minimum temperature

Connection from Oseberg-field providing power and signal from DC/FO and fluids through umbilical system

Storage complex
- Planned in the Johansen formation south of Troll ("Aurora") with an expected capacity of at least 100 Mt of CO_2
- Contingency storage in Heimdal (depleted field)

CO_2 caracteristics

CO_2 properties and hazards

Northern Lights

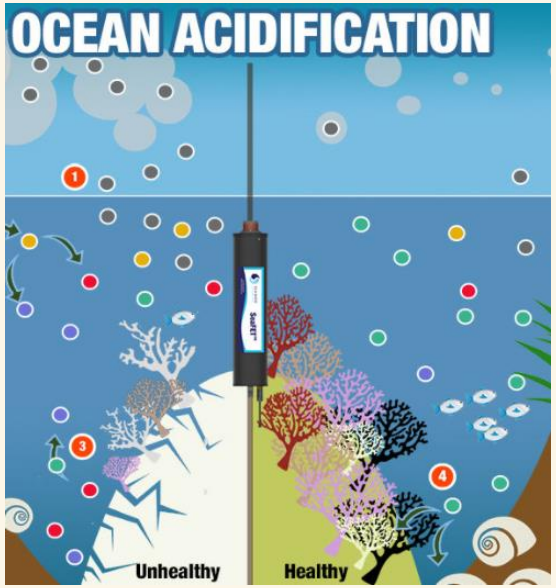
→ **Heavy gas. Can be invisible or a dense thick fog**

→ **Toxicity: Not classified as toxic but as an asphyxiant,**

- Oxygen displaceant,
- but suffocation happens at lower concentrations than for other inert gases as N_2, Ar and He.

→ **Cold (T < -78°C) if released from dense conditions**

- Freezing, dry ice formation (clogging), cryogenic burns, equipment integrity
- Cold BLEVEs have occurred several times in history leading to suffocation, flying debris, pressure waves.



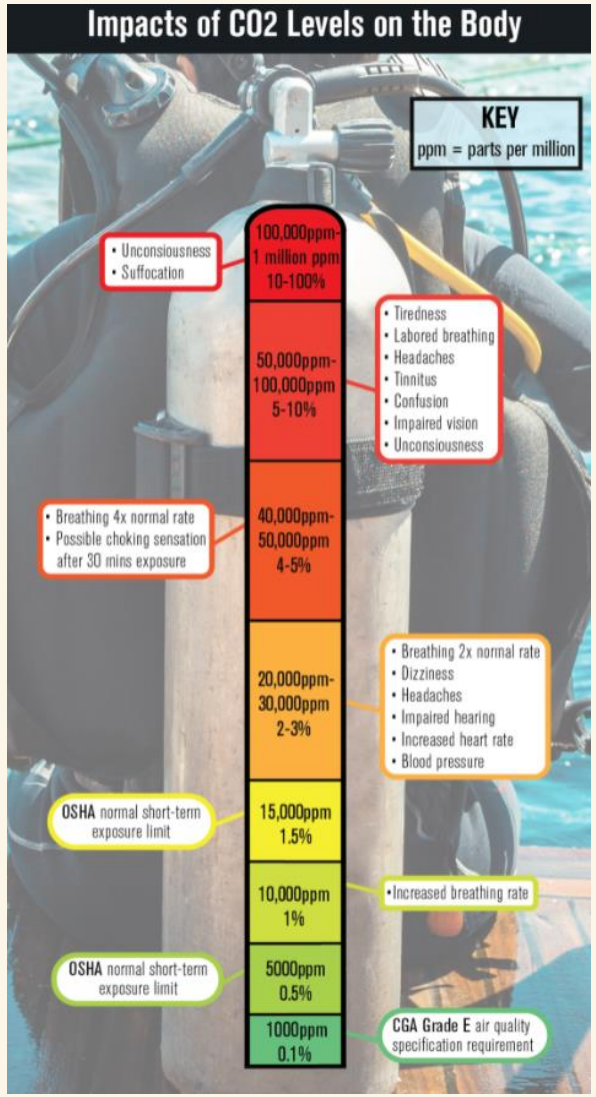
→ **Solvent properties – increases with temperature and pressure – gasket selection**

→ **Corrosive in combination with free water**

- Material selection and gas quality

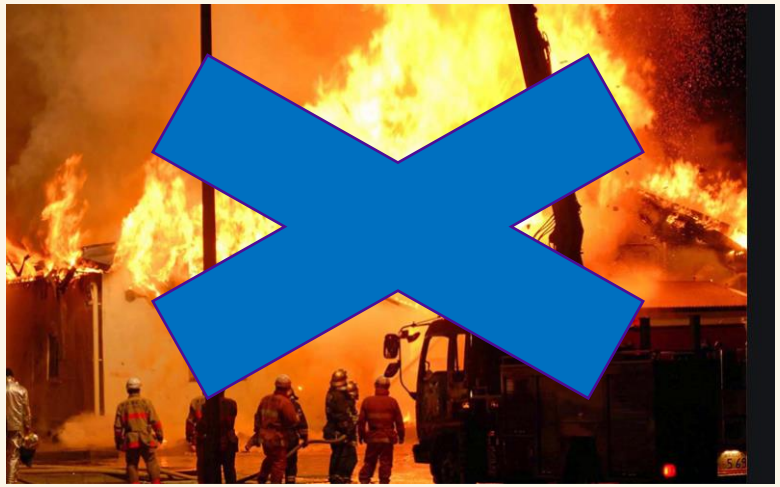
→ **Ocean acidification if released near or in the sea**

- Less calcium-based animals/fauna like shells and corals



Source: safety.co.uk

Impacts on Northern Lights design



→ **Fire and explosion risk at Northern Lights is low:**

- Risk of loss of critical safety functions less affected by fires and explosion
- Ignition source control, active and passive fire protection less critical

→ **The main risk is large CO_2 releases**

→ **Design loads based on natural loads -** wind, waves, snow, earthquake - **not fire and explosion loads**

→ **Rapid depressurization (emergency blowdown) avoided due to**

- Low risk of pressure increase due to fires exposure
- Risk of low temperature and dry ice formation/clogging

Conclusion

Even if carbon dioxide is neither classified as flammable, explosive or toxic, large releases represent significant hazards for life and health and general HSE principles apply.

CO_2's specific properties needs to be taken into consideration in design and operation.

Main risks and precautions measures

Ships main hazards

- Collision
  - C02 tanks separated from hull allowing higher protection
  - High number of crew
  - Selection and Training of personnel coming from Gas tanker (LPG)

- Pollution
    - LNG tank (limited inventory - as it is used for the propulsion only),
    - CO2 release: acidification (fish farms within terminal vicinity) mitigated by the «double containment»

- Fire/Explosion
  - LPG carrier classification / notation allowing high standard of fire fighting system
  - Limited risks (LNG tanks used for propulsion only)

Northern Lights main hazards

Fire and explosion risk is low

→CO2

- Releases from:
  - jetty - collision risk and during unloading
  - process
  - storage area
  - landfall including ESDV
- Physical explosion (BLEVE)

→LNG

- From ship fuel tanks (500 m3)

→Transformer fire and explosion

Tolerance criteria for third party onshore facilities

- Based on acceptance criteria given in DCP's guideline for «safety around installations handling flammable, reactive, pressurised and explosive substances»
- Used as basis for land planning in Norwegian municipalities
- Important basis for the application of consent

Zone for area planning (hensynssone)	Zone for area planning related to hazardous substance reaches out to an annual frequency of	Rules within the zones (objects and activities accepted in the zones)
Inner zone	Risk contour 10^{-5}	Company's own area. In addition e.g. LNF area can be included within the inner zone. Only short-term passage for third party (e.g. hiking trails)
Mid zone	Risk contour 10^{-6}	Public roads, railways, jetties o.l. Permanent workplaces within industry and offices can also be located in mid zone. Within mid zone accommodation or residential areas are not permitted. Scattered residential housing can under certain conditions be accepted
Outer zone	Risk contour 10^{-7}	Areas regulated for housing purposes and additional use of the general population, including stores and public small accommodations/hotels
Outside outer zone	No limitations outside the outer zone	Schools, kindergartens, nursing homes, hospitals and similar institutions, shopping malls, hotels or large public arenas shall be located outside the outer zone

Risk contours – risk for third party (onshore plant)

- No residential buildings, public assembly areas, hospitals, schools within any of the contours – acceptable risk
- An unmanned pump house and multi-use storage hall at the neighbour facility is within the 10^{-5} contour
- Northern Lights has informed neighbour facilities about the results and warning/emergency procedures will be coordinated

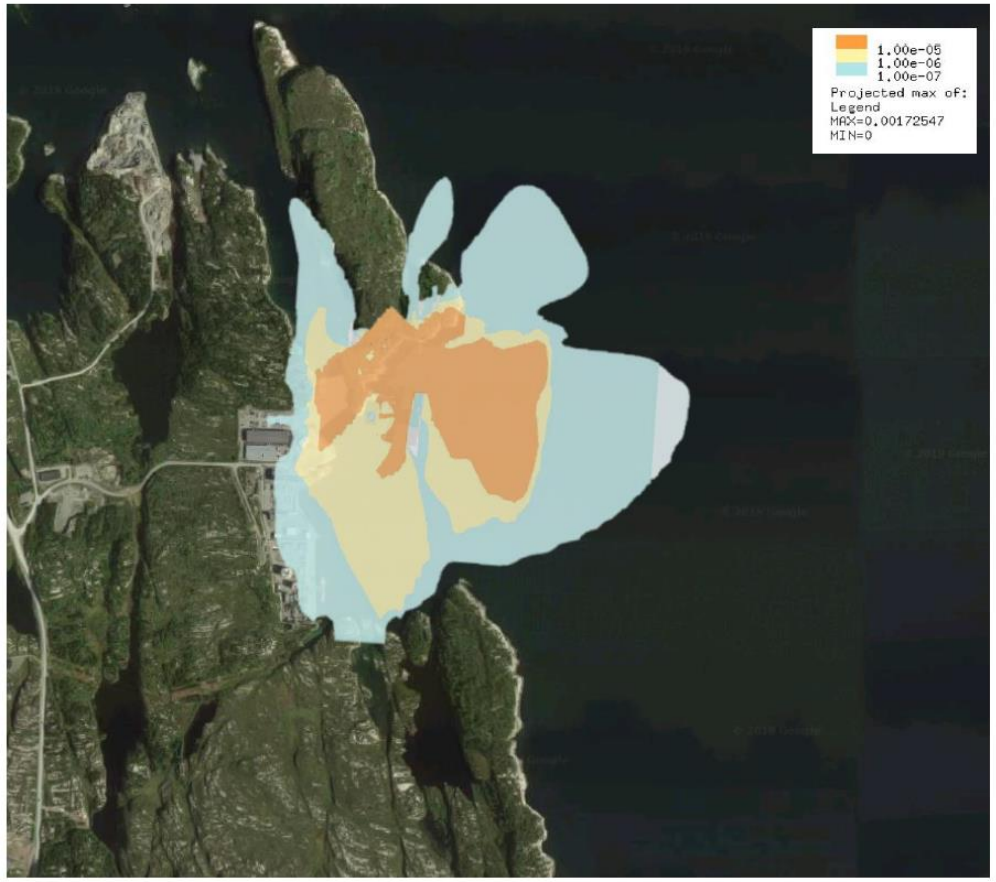
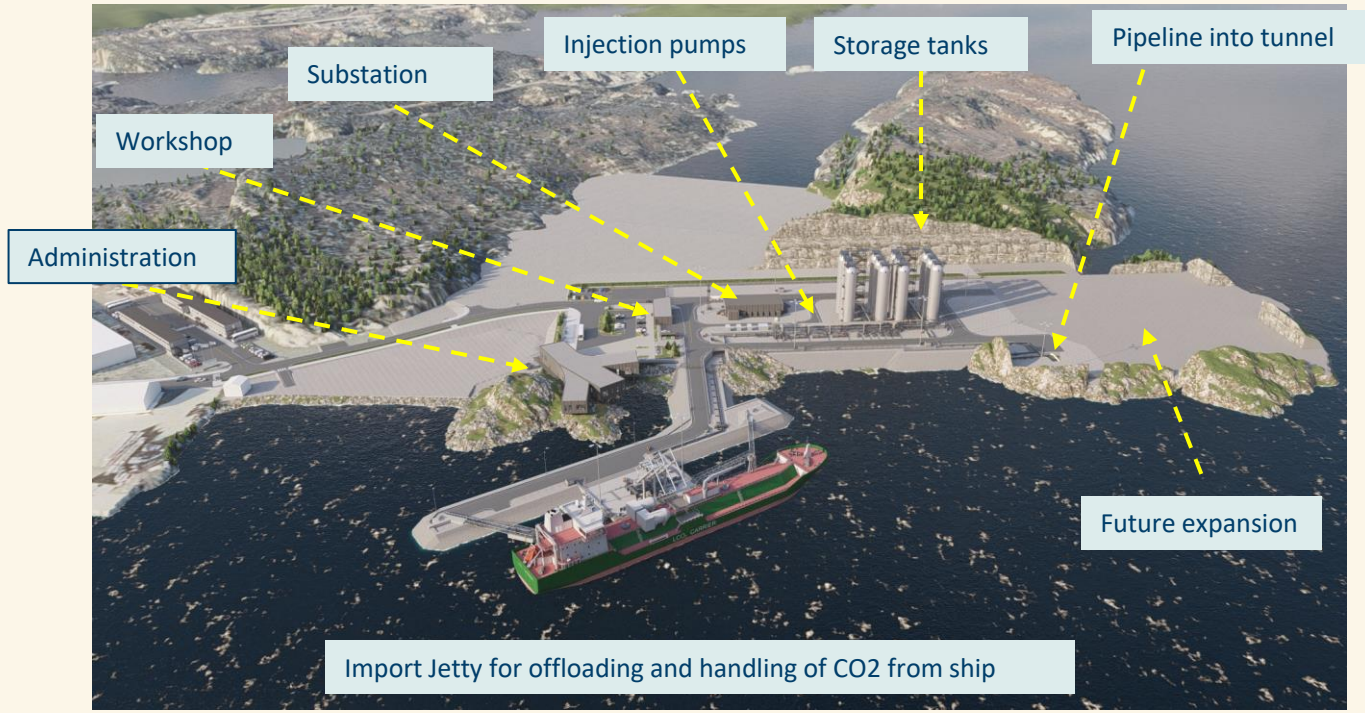


Figure 5.7 On the map, Risk contours for Potential Loss of Lives (PLL) based on duration of leakages, maximum 60 min, using probit function, over the Northern Lights receiving terminal and the surrounding areas

Design & Operations

- Operation and monitoring from Local Control Room in Naturgassparken or remotely from Sture control room.
- Automatic failsafe
- Well control will be from the Oseberg offshore platform.
- Utilise acknowledged recommendations for transport of liquefied gases and adapted to CO2:
  - OCIMF (Oil Companies International Marine Forum)
  - Sigtto (Society of International Gas Tanker and Terminal Operators
  - PIANC (Harbour).



- Operational procedures
  - Based on relevant systems from gas facilities and industrial practice guidelines AND
  - Adapted for the operation of a facility storing, conditioning and transporting CO2
- Operators will be available during ship unloading, daily inspections, maintenance and during external visits to the plant/ tours in the facility

Safety barriers for onshore facilities

Barriers somewhat different than for hydrocarbon installations:

- Limited requirements related to fire and explosion hazards

→ **Barriers focused on:**

- Process safety
  - Measures to limit accidental releases (ESD valves)
  - Temperature and pressure control -> to avoid unacceptable conditions and risk of solid formation and clogging
  - Thermal safety valves in volumes that can be trapped
  - Redundant PSVs and short/no tailpipes downstream
- Protection against suffocating and cold gas
  - Gas detection (especially under vent locations and low lying areas)
  - Gas warning signals and alarms (general alarm and CO_2 alarm)
  - Visibility of evacuation routes - loss of sight because of condensed water/dry ice – "luminous painting" in escapeways and escape routes
  - Illuminated wind socks, visible at the whole plant
  - Gas protected mustering area in administration building
    - Confirmed detection of CO_2 in air inlets and outlets will close dampers
    - "Airlock" system in entrance

Safety barriers for onshore facilities: Operations

Barriers somewhat different than for hydrocarbon installations:

- Limited requirements related to fire and explosion hazards

→ **Operational Barriers will focus on:**

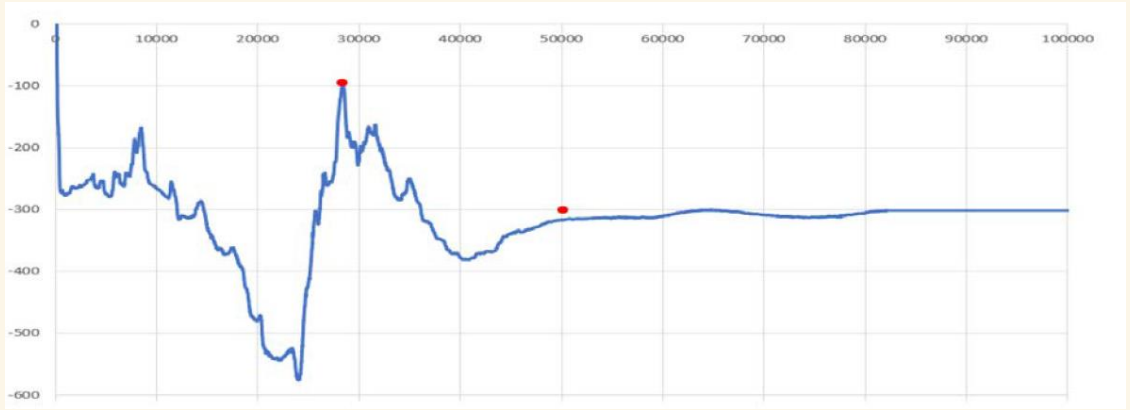
- Appropriate PPE to be available (breathing apparatus, clothing, cold burns protection),

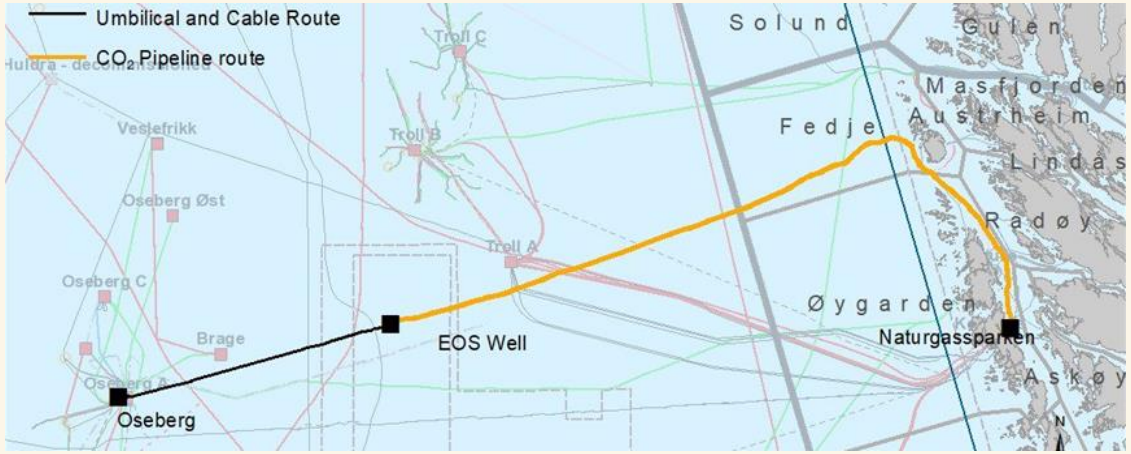
- Emergency procedures is being detailed in emergency plan and in cooperation with the municipal fire brigade. It will be tested regularly.

Subsea facilities

- **Sintef SURE code (CFD tool) used for dispersion in the water column**
  - tailored to take into account the properties of CO_2
- **Pipeline rupture (worstcase) calculated at 2 leak locations**
  - At sea depth 300 m CO_2 does not reach the sea surface
  - At sea depth 100 m significant gas volumes can reach the surface
  - The results indicate that the risk is very low along most of the pipeline
- **A full quantitative risk analysis is being done to assess the risk for ship traffic, and any exposure of coastal areas from the subsea facilities**
- **Tools and validation under further development – R&D**

Sea depth along pipeline route, leak location indicated

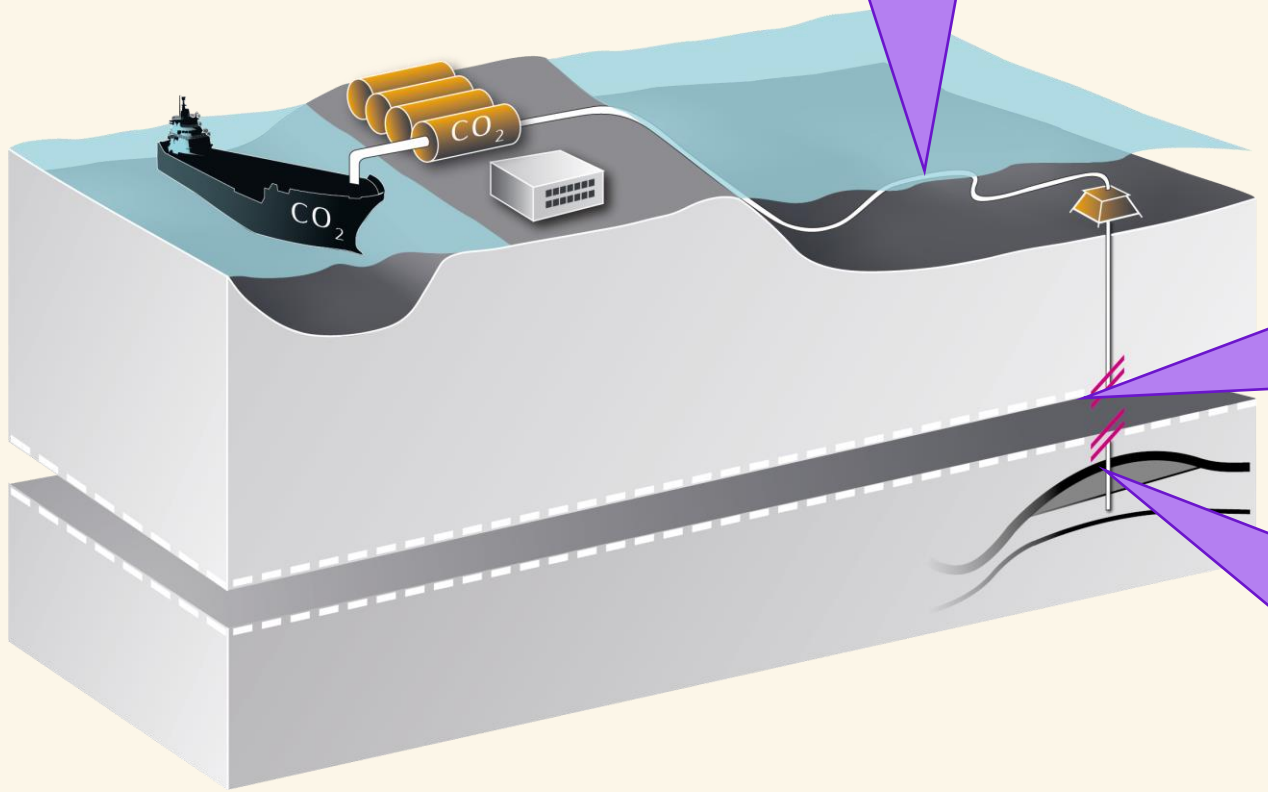




Offshore and Sub-Surface Monitoring plan

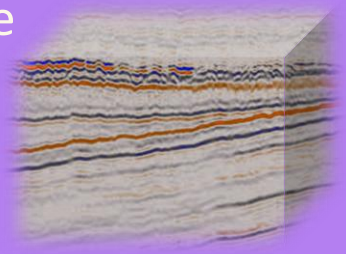
Northern Lights

Regular inspection of pipeline and subsea installation: leakage detection system



Subsea and well injection monitoring: injection rate, pressure and temperature

Subsurface monitoring: active and passive seismic monitoring by regular 3D seismic repeats and in-well instrumentation



Northern Lights

norlights.com