

Offshore CO_2 Operations

Bridging the Gap Between CCS Project Development and Field Execution

Zachary Bruton | Noble

CCS Project Development Is Becoming Standardized. Operations Are Not.

Project Development

- Storage characterization
- Permitting and regulation
- Project design and economics
- Transport and injection infrastructure

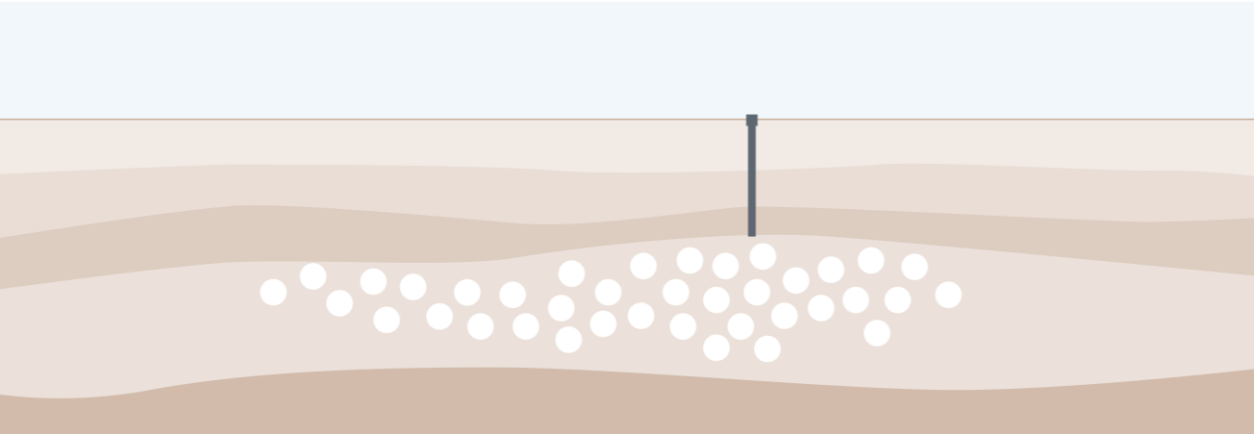
Increasingly repeatable

Field Operations

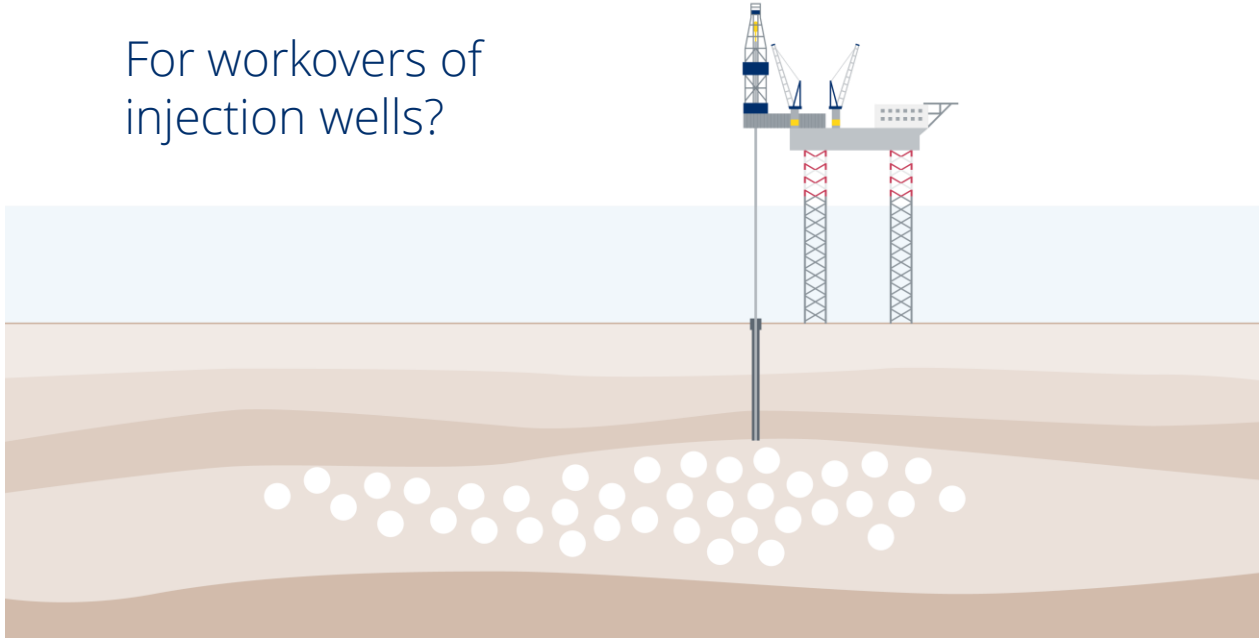
- Can we detect and control a CO_2 influx?
- Can existing equipment tolerate the exposure?
- Can crews respond safely at surface?
- Can we intervene throughout the storage lifecycle?

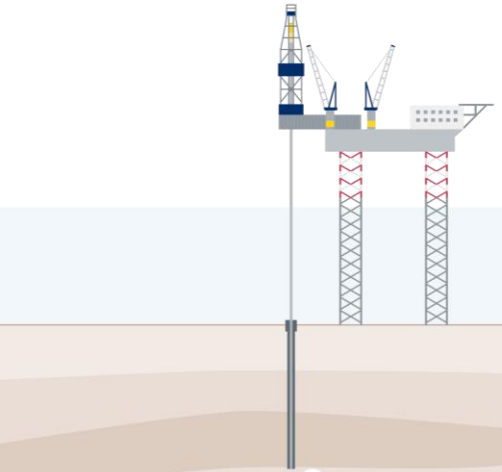
Still project-specific

How do we de-risk operations with pressurized CO_2 downhole?



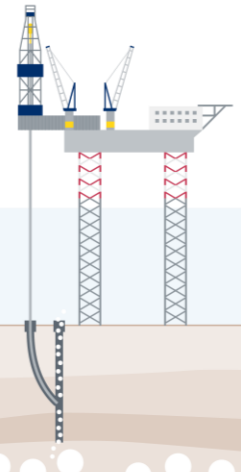
For workovers of injection wells?





For drilling new injection wells into charged reservoirs?

For drilling relief wells?



IOGP provides a framework for operational readiness.

Seven areas of consideration organized around three operational questions.

Can we understand it?

1. **Modelling**
2. **Kick detection & methods**

Can we control it?

3. **Well-control equipment**
4. **Personnel & training**

Can we manage the lifecycle?

5. **Relief well & kill**
6. **Well integrity**
7. **Well intervention**

IOGP White Paper | May 2026

Considerations: Well Control during CCS Operations | WHP001

What We Now Know

CO_2 well control exposure limits are bounded	• CO_2: ~90–100% • Temperature: ~–20 °C (BOP) → –40 °C (choke) • Duration: 1–6 hr dynamic, up to 48 hr static • Flow: multiphase, flashing across restrictions
Legacy equipment certification breaks at expected CO_2 levels	• Current rating: legacy systems ~10% CO_2 • Re-qualification can extend this, but **no credible OEM path to 80%+ CO_2**
Localized damage dominates over average corrosion	• Uniform corrosion (mean): < 0.2 mm over 72 hr • Localized hotspots: **~0.75 to > 5 mm** over 24–72 hr (**10–20× amplification** at inlets and cavities)
Inspection confidence is the limiter	• Critical BOP / connector features are internal and not fully inspectable offshore • NDE resolution: ~1–2% wall thickness so localized losses of ~0.3–1 mm are often not defensible

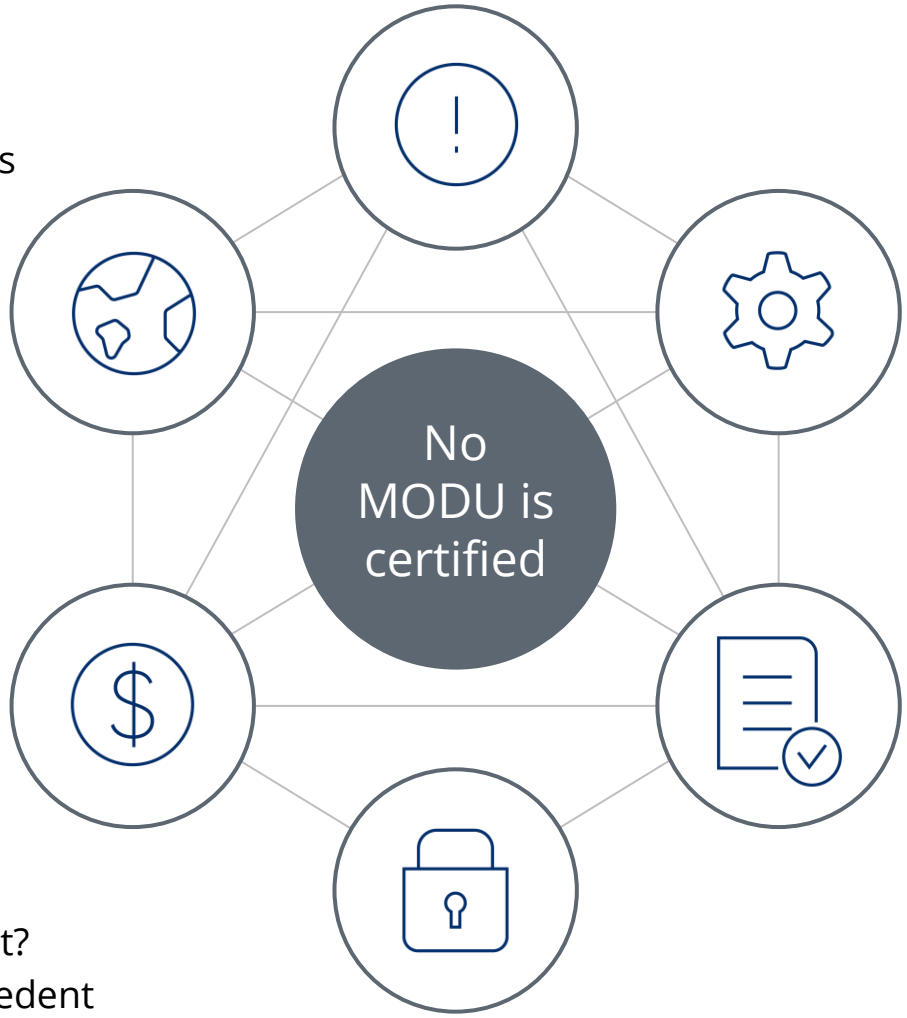
The Offshore CO_2 Risk Stack

HSE

- CO_2 toxicity and dispersion introduce new safety risks
- Emergency response differs from conventional operations

Regulatory

- No standardized pathway for CO_2 ops
- EU regulations requiring storage capacity



Technical

- New well control failure modes
- Material degradation and temperature effects

Commercial

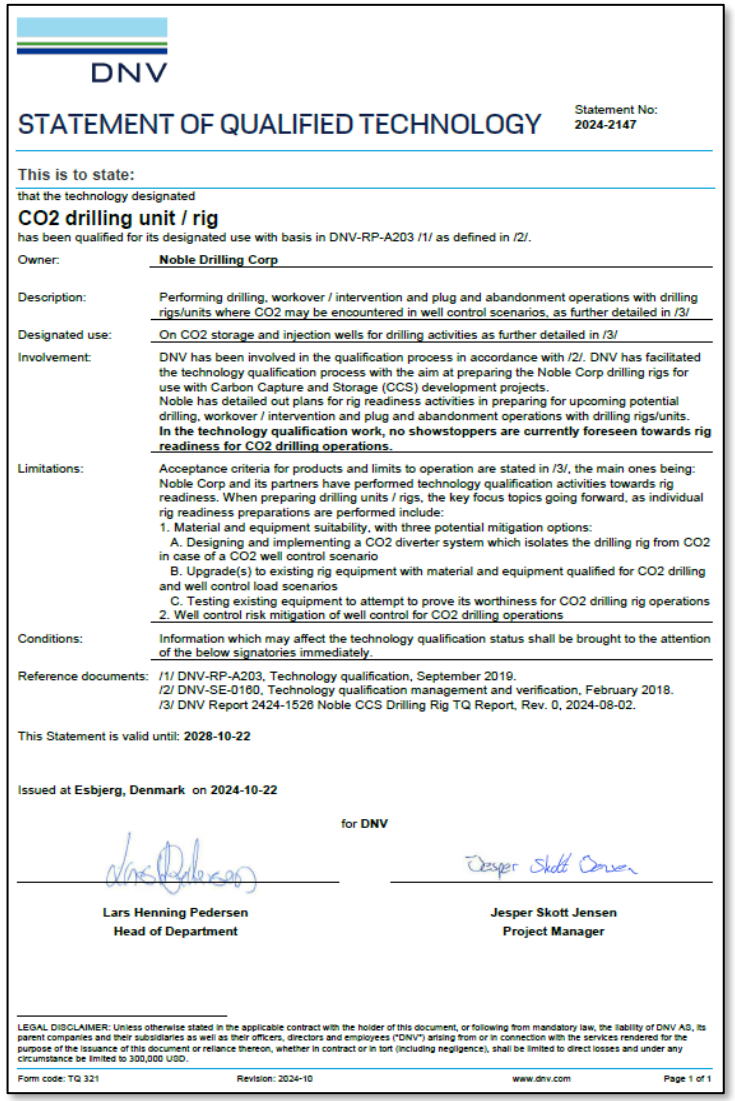
- Project-based vs ecosystem funding models?
- Internal ownership unclear (R&D, CCS teams, or central functions)

Legal

- Liability and indemnity structure will be novel, extensive and require project-specific negotiation
- No established contracting precedent

Insurance

- What will they accept?
- No established precedent



DNV

STATEMENT OF QUALIFIED TECHNOLOGY

Statement No:
2024-2147

This is to state:

that the technology designated

CO2 drilling unit / rig

has been qualified for its designated use with basis in DNV-RP-A203 /1/ as defined in /2/.

Owner:	**Noble Drilling Corp**
Description:	Performing drilling, workover / intervention and plug and abandonment operations with drilling rigs/units where CO2 may be encountered in well control scenarios, as further detailed in /3/
Designated use:	On CO2 storage and injection wells for drilling activities as further detailed in /3/
Involvement:	DNV has been involved in the qualification process in accordance with /2/. DNV has facilitated the technology qualification process with the aim at preparing the Noble Corp drilling rigs for use with Carbon Capture and Storage (CCS) development projects. Noble has detailed out plans for rig readiness activities in preparing for upcoming potential drilling, workover / intervention and plug and abandonment operations with drilling rigs/units. **In the technology qualification work, no showstoppers are currently foreseen towards rig readiness for CO2 drilling operations.**
Limitations:	Acceptance criteria for products and limits to operation are stated in /3/, the main ones being: Noble Corp and its partners have performed technology qualification activities towards rig readiness. When preparing drilling units / rigs, the key focus topics going forward, as individual rig readiness preparations are performed include: 1. Material and equipment suitability, with three potential mitigation options: A. Designing and implementing a CO2 diverter system which isolates the drilling rig from CO2 in case of a CO2 well control scenario B. Upgrade(s) to existing rig equipment with material and equipment qualified for CO2 drilling and well control load scenarios C. Testing existing equipment to attempt to prove its worthiness for CO2 drilling rig operations 2. Well control risk mitigation of well control for CO2 drilling operations
Conditions:	Information which may affect the technology qualification status shall be brought to the attention of the below signatories immediately.
Reference documents:	/1/ DNV-RP-A203, Technology qualification, September 2019. /2/ DNV-SE-0160, Technology qualification management and verification, February 2018. /3/ DNV Report 2424-1526 Noble CCS Drilling Rig TQ Report, Rev. 0, 2024-08-02.

This Statement is valid until: **2028-10-22**

Issued at **Esbjerg, Denmark** on **2024-10-22**

for **DNV**

Lars Henning Pedersen
Head of Department

Jesper Skott Jensen
Project Manager

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Industry Response Pathways

Only 3 ways to certify well control equipment for a CO_2 environment:

1. Fully Upgrade the Whole System Including the BOP

+ **Pros:** Integrity, Reliability, Compatibility

÷ **Cons:** Cost, Lead times, Downtime

2. Conduct Materials Testing and Research to Certify the Legacy Package

+ **Pros:** Targeted upgrade, Preservation, Custom solution

÷ **Cons:** Uncertainty, Time-consuming, Research costs, Approvals

3. Install a CO_2 Grade Bypass System to Circumvent the Legacy Package

+ **Pros:** Cost-effective, Faster, Lower risk

÷ **Cons:** Integration, Logistics, Limited redundancy

NOBLE

Operational readiness is more than equipment.

CO_2 changes how crews detect, respond, shelter and recover.

DETECT CO_2 detectors in manned and vulnerable areas

PROTECT Breathing support and protection of occupied spaces

RESPOND CO_2-specific alarms, dispersion and venting decisions

TRAIN Simulator drills, alternative methods and CCS-specific contingency plans

Closing the gaps requires shared evidence

Define Operating Reality

- Exposure Envelope
- Operating Conditions
- Acceptance Criteria
- Risk Basis

DEFINE

Test Physical Reality

- Modelling
- Simulation
- Materials Testing
- Equipment Qualification

VALIDATE

Prove Operational Reality

- Procedures
- Training
- Assurance
- Operational Readiness

DEPLOY

Three Takeaways

01 **CCS is entering an operational phase**

Storage development is advancing rapidly. The next challenge is operating CO_2 wells safely and reliably throughout their lifecycle.

02 **Operational readiness extends beyond equipment**

Success requires aligned modelling, equipment, procedures, training, contingency planning, and lifecycle management.

03 **Shared evidence accelerates deployment**

The industry must define common operating assumptions, validate them through testing, and convert them into repeatable operating practices.