North Sea Transition Authority

Well-Based Technologies for Measurement, Monitoring and Verification (MMV) in Carbon Storage.

1. Role of Wells in MMV

Wells serve three interlinked MMV objectives:

Containment Verification
Demonstrate no unintended CO_2 migration

Conformance Assessment
Validate observed behaviour against predictive models

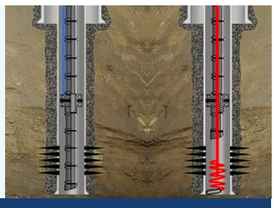
Assurance
Provide regulators and stakeholders with evidence of safe long-term storage

Wells are both the highest-risk leakage pathway and the highest-fidelity monitoring access point, making well-based MMV indispensable.

2. Key MMV Well-Based Technologies

Near-Wellbore Formation & CO_2 Plume Monitoring

Directly images plume migration and geomechanical response near the well.



Core Technologies
- Time-lapse Pulsed Neutron Logging (PNL)
- Fibre-optic Distributed Acoustic and Temperature Sensing (DAS/DTS)
- Vertical Seismic Profiling (VSP)
- Microseismic monitoring

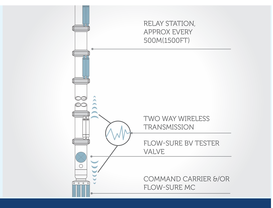
Example Technologies
- Fibre-optic DAS VSP for time-lapse plume tracking
- Pulsed neutron tools (SLB Pulsar, Weatherford Raptor)

MMV Contribution
- Detect CO_2 breakthrough and saturation change
- Validate plume extent and caprock integrity
- Identify injection-induced deformation or fault activation

Technology Maturity
- Mature (PNL, VSP) with emerging fibre-based systems

In-Well and Bottom-Hole Monitoring

Provides continuous surveillance of well integrity and reservoir response.



Core Technologies
- Permanent Downhole Pressure & Temperature Gauges (PDHG)
- Electromagnetic and acoustic wireless telemetry
- Cement bond and ultrasonic logging (CBL/USIT)

Example Technologies
- Permanent quartz gauges (SLB Metris, Halliburton DataSphere)
- Wireless annulus monitoring (Emerson Roxar, Metrol Paragon EM)
- High-resolution ultrasonic imaging (Nusonix)

MMV Contribution
- Early detection of annular pressurisation
- Barrier degradation and casing corrosion
- Compliance with Class VI/ISO 27914 requirements

Technology Maturity
- Mature to emerging (wireless systems rapidly advancing)

Tracers and Leak Detection

High-sensitivity early warning of migration and containment loss.

Core Technologies
- Chemical and nanoparticle tracers
- Ultra-low detection soil gas/seabed sampling

Example Technologies
- FloTrac nanoparticle tracers (QuantumPro)
- High Integrity Detection Systems (Resman)

MMV Contribution
- Detect migration at parts-per-trillion levels
- Independent verification pathway complementing seismic and pressure data

Technology Maturity
- Emerging but field-proven at pilot scale

Injection Monitoring

Ensures mass balance, injectivity control and operational compliance.

Core Technologies
- Subsea and topside Venturi/Coriolis flowmeters
- Wellhead pressure and temperature gauges

Example Technologies
- Carbonstream Subsea CO_2 Flow Meter for multiphase and supercritical CO_2 injection (Solartron ISA/Ametek)

Technology Maturity
- Mature – deployment ongoing at Northern Lights and UKCS pilots

3. Technology Gaps and Challenges

Long-term durability of sensors in corrosive CO_2 environments

Balancing monitoring resolution vs economic viability

Distributed pressure sensing (DPS) maturity

Legacy well monitoring and remediation strategies

4. Conclusions

Well-based MMV technologies are central to CCS containment assurance. The CCS Wells Technology Roadmap, published by NZTC and NSTA, indicates that:

Most required MMV technologies already exist from the oil and gas sector.

Adaptation, qualification, and integration are key challenges.

A layered MMV approach, combining mature and emerging tools, provides the highest confidence.

Continued supply chain collaboration and field deployment will be essential to enable safe, cost-effective, and scalable CO_2 storage.

CCS Wells Technology Roadmap NZTC © 2025