Risk Assessment Regulations for the Geological Storage of CO$_2$

By: Jose Condor, PhD
5th Risk Assessment Network Meeting
Golden, Colorado, US
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1. Introduction: Risk Assessment

2. Regulations
   a. International
      - UNFCCC/IPCC
      - WRI
      - OSPAR
      - London Protocol
   b. EU Directives
      - CCS Directives
      - ETS Directives
   c. United States
      - EPA-VEF
      - EPA-UIC
      - IOGCC
      - ACES Act
      - States
   d. Canada
      - Federal
      - Provincial
   e. Australia
      - Commonwealth
      - States

3. Discussion
1) Introduction: Risk Assessment

Fields of Risk Assessment

- Public-health RA focus on the health effects of chronic exposures to chemicals, contaminants, and pollutants in the water, the air and the food.

- Engineered-systems RA, focus on immediate and delayed effects due to the failure of systems: Aerospace, vehicles, chemical process plants, and nuclear power plants.

- More recently:
  - Ecological: degradation of ecological systems due to nonnative invasive species, global warming, and genetically modified organisms;
  - Severe natural phenomena: hurricanes, earthquakes, fires, and floods;
  - Malicious human acts: terrorism.
1) Introduction: Risk Assessment

Risk Management

Risk Assessment

Risk Analysis (HAZID)
- Qualitative
  - FEP
  - VEF
- Semi
  - Fuzzy Logic
  - ESL
- Qualitative
  - DRA
  - PRA

Risk Evaluation
- Risk Matrix
  - Bow-tie
  - ALARP

Risk Treatment
- Risk Avoidance
- Risk Optimization
- Risk Transfer
- Risk Retention

Risk Acceptance
- Cost vs. benefit

Risk Communication

Source: after DNV 2009 – CO2QUALSTORE
1) Introduction: Risk Assessment

Risk analysis, risk assessment, and risk management

Source: DNV 2008
1) Introduction: Risk Assessment

CCS - Risks of What?

Reduction CO₂ credit
GHG cap integrity
Community hazards
Public perception
System integrity
Technology failure
Business loss
HES
Trust and confidence
Future liability

Would benefit from one common basic policy and consistent verification system with a holistic view

Capture
Transport
Injection
Storage
Post-closure

Can be dealt with under existing HES and RA frameworks
Technological challenges (reduce cost of systems)

Need fresh thinking and new frameworks. Probably best to use RA methods as basis
Challenges in many aspects (legal and regulatory; long-term effect and reliability, technology and economy)
1) Introduction: Risk Assessment

Risk Profile for CO₂ Storage

- Pressure recovery
- Secondary trapping mechanisms
- Confidence in predictive models

Source: Benson 2007
Illustration of risk and uncertainty management throughout the life of a GSC project. Reducing uncertainty shrinks the “risk box”, whereas reducing risk moves the “risk box” closer to the origin. This implies that reducing uncertainty will generally also reduce the assessed risk.

Source: after DNV 2009 – CO2QUALSTORE
2) Regulations – International

UNFCC - 2006 IPCC Guidelines

- Basis for other international and regional CCS regulatory frameworks (i.e. OSPAR & London Protocol, EU CCS Directive)

WRI

- A risk assessment should be required along with development and implementation of a risk management and risk communication plan for all storage projects
- Risk assessments should, at a minimum, examine potential for leakage of injected or displaced fluids via wells, faults, fractures and seismic events, and the fluid’s potential impacts to integrity of the confining zone and endangerment to human health and the environment (Storage Guideline 2a)

OSPAR
2) Regulations – International

OSPAR

- Prohibited some CCS configurations
  - Amendments (to Annexes II and III) for CO₂ storage adopted June 2007
  - Needs ratification by 7 Parties
- OSPAR Guidelines for Risk Assessment and Management of Storage of CO₂ in Geological Formations – includes the Framework for Risk Assessment and Management (FRAM)
  - Monitoring techniques from the IPCC Special Report on CCS (IPCC, 2005)

London Convention

- Protocol amendment came into force in Feb 2007 to allow disposal in geological formations
- CO₂ Specific Guidelines
- Prohibits trans-boundary transport of CO₂ for geological storage (migration is not export - Art 6)
  - Re-examination of CO₂ Specific Guidelines to trans-boundary migration
  - To come into force needs ratification by two thirds all Parties (>25)
- 2006 - Risk Assessment Framework for CO₂
2) Regulations – EU Directives

EU CCS Directive 2009/31/EC

- Projects with intended storage >100 ktonnes of CO₂
- Member States until 25 June 2011 to transpose it into their national laws
- Regulatory regime for permitting of exploration and storage
- Risk Assessment
  - No injection should be allowed unless risk assessment and mitigation strategies are undertaken
  - Risk analysis of CO₂ composition including corrosive substances of the streams must be undertaken
  - Risk assessment is a requirement for granting the storage permit
  - Must include details of the risks, their probability and mitigation procedures in case of occurrence

EU Directive 2008/1/EC

- Regulate risks of CO₂ capture to the environment and human health

EU Directive 85/337/EC

- Assess the effects of public and private projects on the environment

EU ETS Directive 2003/87/EC

- Scheme for GHG emission allowance trading
<table>
<thead>
<tr>
<th>Legislation</th>
<th>Description</th>
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</thead>
</table>
| American Clean Energy & Security Act            | • Passed by House of Representatives on 26 June 2009  
• Companion Bills currently at various stages in the Senate. (Act won’t be implemented until the US Senate approves it)                                      |
| CCS Early Deployment Act                        | • Introduced 24 March 2009, currently in committee  
• Provides for a referendum of relevant industries to incorporate a CCS Research Body to raise and distribute funds to CCS programmes.                                 |
| CCS Programme Amendments Act                    | • Introduced 7 May 2009  
• Would establish a demonstration programme for CCS.  
• Partly incorporated within the AC Energy Leadership Act so may not proceed.                                                                                  |
| American Clean Energy Leadership Act            | • Introduced 16 July 2009, awaiting consideration by Senate  
• Provides a regulatory framework for CCS as well as financial assistance for demonstration programmes.                                                  |
| Carbon Storage Stewardship Trust Fund           | • Introduced July 22, 2009  
• Provides for long-term Federal stewardship of storage sites accompanied by a trust fund to meet costs and liabilities.                                                                                       |
| EPA proposal                                    | • Federal requirements under the Underground Injection Control (UIC) Program for CO₂ Geological Storage                                                                                                          |
| Interstate Oil and Gas Compact Commission       | • Published September 2007  
• Detailed rules based on EOR, acid gas injection and natural gas storage  
• Includes ownership, permitting, verification, monitoring, and liability.  
• Legal and Regulatory Guide for States, which choose use them or not  
• H₂S, NOₓ and SO₂ impurities remain covered by existing regulation  
• The regulator is the “state” regulatory agency not the “federal” EPA                                                                                                                                 |

2) Regulations – United States

Vulnerability Evaluation Framework, EPA-VEF

<table>
<thead>
<tr>
<th>Geological Storage System &amp; Geologic Attributes</th>
<th>Spatial Area of Evaluation</th>
<th>Potential Impact Categories &amp; Receptors</th>
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<tbody>
<tr>
<td>Confining System</td>
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<td>Human Populations</td>
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<td>CO₂ Stream</td>
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<td>Populations covered by Executive Orders</td>
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<tr>
<td>Injection Zone</td>
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<td>Cultural/recreational resources</td>
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<td>Lateral extent</td>
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<td>Economic Resources</td>
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<td>Capillary pressure</td>
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<td>Permeability</td>
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<td>Sensitive species</td>
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<td>Travel time</td>
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<td>Legislatively protected species</td>
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<td>Wells</td>
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<td>Water quality</td>
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<td>Fault/fracture</td>
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<td>Regional groundwater flow</td>
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<tr>
<td>Geochemistry</td>
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<td>Protected/sensitive drinking water supply</td>
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<td>Tectonic</td>
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<td>Geomechanics</td>
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<td>Physical capacity</td>
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<td>Injectivity</td>
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<tr>
<td>Geochemistry &amp; Geomechanics</td>
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<td>Unanticipated Migration &amp; Leakage (CO₂ &amp; other fluids)</td>
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<td>Pressure changes</td>
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<td>Human health/welfare</td>
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<td>Atmosphere</td>
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<td>Ecosystems</td>
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<td>Groundwater &amp; Surface Water</td>
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<tr>
<td>Geosphere</td>
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Source: after EPA 2008 - VEF
2) Regulations – United States – EPA-UIC Programme

Guidelines were developed under EPA’s authority provided by the Safe Drinking Water Act (SDWA)

- To obtain permission from EPA, authorities must meet minimum federal requirements including construction, operation, monitoring, reporting, and closure requirements

The EPA’s proposal is to create a new category of well (Class VI) with new federal requirements

- Technical requirements for site characterisation, well construction and operating requirements, mechanical integrity, monitoring requirements, well plugging post-injection, site closure requirements, and financial responsibility
- Underground property rights and long-term liability for environmental impacts other than ground water contamination are not addressed

Risk Assessment

- Procedures required and must be submitted to Director before consideration of Storage permits
- Must be updated periodically
- Must include assessment of potential leakage pathways
2) Regulations – United States – IOGCC Guidelines

General
• Based on existing EOR, acid gas injection and natural gas storage
• After the permit is issued, authorisation must be obtained for each well
• Underground sources of drinking water must be identified and special drilling practices followed
• Standards for casing, tubing, corrosion, and cement must be followed to ensure isolation from underground water
• Downhole safety shut-off valves must be included
• Reporting requirements

Operational Standards
• Worker safety plans, leak detectors installed at all subsurface and injection wells, inspection records kept for five years
• Quarterly operational reporting of pressures, temperatures and volumes and corrosion monitoring

Closure phase
• A monitoring plan submitted for the State Agency for approval
• The operator remains liable after injection stops for ten years
• Responsibility for monitoring remediation is passed to state or federal agency and operator released from further liability
2) Regulations – United States – ACES Act

• Subtitle B: regulation related to the CO₂ capture and storage
  • The Administrator must establish a coordinated approach to certifying and permitting geologic sequestration of CCS
  • In achieving that, the Administrator must reduce redundancy with the requirements of the Drinking Water Act.
  • Less than two years of enacting this Act, the Administrator must introduce regulations to protect health and the environment by reducing the risk of leakage
  • Regulation should include
    • (i) a process to obtain certification
    • (ii) requirements for monitoring
    • (iii) requirements for record keeping and reporting
    • (iv) public participation in the certification process, and
    • (v) sharing of data between states, Indian tribes and the EPA
  • Requirements for maintaining evidence of ‘financial responsibility for remedial and emergency response, well plugging, site closure, and post injection site care’
  • The Administrator may establish financial responsibility using several options including insurance, guarantee, trust, standby trust, letter of credit, etc
American States with CCS Framework Legislation

- Kansas - HB 2419, 2007 Laws, Chapter 73
- Louisiana - HB 661, 2009 Laws, Chapter 517
- Montana - SB 498, 2009 Laws, Chapter 474
- North Dakota - S 2095, 2009 Laws, Chapter 318
- Oklahoma - SB 610, 2009 Laws
- Texas - SB 1387, 2009 Laws
- Utah – SB 202, 2008 Laws
- Washington - SB 6001, 2007 Laws, Chapter 307
- West Virginia - HB 2860, 2009 Laws, Chapter 97
- Wyoming - HB 90, 2008 Laws, Chapter 30
2) Regulations - Canada

- Well-developed EOR/EGR regulations in AB and SK
- Regulations in place for gas disposal in deep saline aquifers and depleted hydrocarbon reservoir in AB and BC
  - Extensive experience with separation, capture, transport and injection
  - Regulatory framework for permitting, operation and abandonment may be expanded to cover the permanent storage and the post-abandonment stage of CO₂ storage operations, including monitoring and remediation
- Issues that need to be considered include financial issues, incentives, liability and ownership and access rights
- Regulation on disposal of acid gas (H₂S, SO₂) in geological aquifers
  - Acid gases have been stored in aquifers since 1989
  - Applicants must meet regulatory requirements, including selection of reservoir and reservoir property characterisation
  - Licensees are subject to continuing responsibility for the management and control of the well and they must report financial information
  - If the licensee’s liabilities exceed its assets, the licensee must place a security deposit for the difference
  - All licensees must pay into a general fund, which is used to fund the abandonment stage
2) Regulations - Australia

Framework to manage access and use of storage sites
- CommonWealth – Federal: offshore areas, extending from 3 nautical miles to the edge of Australia’s continental shelf
- States and Territories: onshore (Victoria, Queensland, South Australia)

Use ‘greenhouse gas’, instead of only CO₂ gives flexibility

Site closure and long-term liability
- The Minister will only grant permission if post injection monitoring shows that the stored substance is behaving as predicted and does not pose a significant risk to human health or the environment
- A closing certificate requires the pre-payment for an approved longer-term monitoring program
- Once the closing certificate is issued obligations cease, but common law liabilities will continue to a period of at least 15 years

Risk Assessment
- Risk assessment must prove that injection will be carried out in a manner that ensures that the site is secure
- Must outline location for storage of CO₂
- Must detail risks and remediation strategies
- Processes for identification, assessment and management of risks must be described in the site plan
3) Discussion

All the most important regulations have specific risk assessment sections.

The System Failing (deep leaks) would trigger regulatory actions.

IEA CCS roadmap recommendations

- Existing legal and regulatory frameworks should be reviewed and adapted for CCS demonstration by:
  - 2011 in OECD countries
  - 2015 in all countries
- All countries should have a legal and regulatory framework suitable for large-scale CCS deployment by 2020
- International legal issues need to be resolved by 2012
- Developing countries need to boost CCS regulatory frameworks (China, India, Brazil)

Great demand on CCS capacity building for different target groups: government officials, enterprise decision makers, researchers, etc.
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Backup slides
2) Regulations

IOGCC Guidelines
## 2) Regulations US IOGCC guidelines

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| Capture  | • CO2 is defined as direct emission stream with a purity of at least 95%  
          | • CO2 is not currently defined in federal air regulations as a pollutant. While SO2, NOx and contaminants should remain regulated as pollutants for public health, CO2 should not be defined as a pollutant  
          | • Existing state and federal regulations dealing with permitting, operating and emission standards can be easily modified to address CO2 capture technologies |
| Transport | • Well-established regulatory frameworks related to CO2 transport and so this will necessitate limited need for additional state regulation.  
            | • Federal agencies will ultimately need to address open access issues for CO2 pipeline. |
2) Regulations - US - ACES Act

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| Capture  | • A utility which is required to have a permit and which has initially been granted that permit on or after January 1, 2020, shall achieve an emission limit that is a 65% reduction in emissions of the CO2 produced by the unit, as measured on an annual basis.  
• In determining compliance with this subsection, the Administrator shall assume an energy penalty of the CO2 capture system of no greater than 15%.  
• If a utility is initially permitted after January 1, 2009, and before January 1, 2020, must, by the applicable compliance date established under the Act, achieve an emission limit that is a 50% reduction in emissions and assuming an energy penalty of no more than 15%.  
• The compliance date is the earliest of the following:  
  • January 1, 2025 or  
  • Four years after the date the Administrator issues a determination that there are in commercial operation in the United States electric generating units equipped with carbon capture and sequestration technology that, in the aggregate  
    • (i) have a total of at least 4 GW of nameplate generating capacity of which (a) at least 3 GW must be electric generating units; and (b) up to 1 GW may be industrial applications, for which capture and sequestration of 3 million tons of carbon dioxide per year on an aggregate annualized basis are considered equivalent to 1 GW;  
    • (ii) include at least 2 electric units, each with a nameplate generating capacity of 250 MW or greater, that inject carbon dioxide into geologic formations other than O&G fields; and  
    • (iii) are capturing and sequestering in the aggregate at least 12 million tons of carbon dioxide per year, calculated on an aggregate annualized basis  
• If the deadline for compliance is January 1, 2025, the Administrator may extend the date by 18 months. |
### Regulations - US – Transport general

<table>
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<tr>
<td>Transport</td>
<td>• CO2 pipeline is generally regulated by States, not Federal Government&lt;br&gt;• Jurisdiction over the “safety of CO2 pipeline” resides with the Office of Pipeline Safety (Department of Transportation)&lt;br&gt;• OPS sets minimum safety standards on the transportation of hazardous liquids including CO2&lt;br&gt;• OPS regulates interstate pipelines and certifies states to undertake intrastate pipeline regulation and enforcement activities&lt;br&gt;• Under OPS, there is no federal general certification of pipeline construction or rates (pricing) regulation and there is no protection from the entry of competing CO2 pipeline (unlike with natural gas pipeline)&lt;br&gt;• The Natural Gas Act 1938 vests in the Federal Energy Regulatory Commission (FERC) the authority to issue “certificates of public convenience and necessity” for the construction and operation of interstate natural gas pipeline&lt;br&gt;• FERC has explicitly rejected jurisdiction over CO2 pipeline siting and rates&lt;br&gt;• Jurisdiction over the regulation for pipelines other than gas, oil or water resides with the Surface Transportation Board (STB)&lt;br&gt;• According to WRI, under the Mining Leasing Act, CO2 pipelines may be subject to access and rate conditions imposed by the Bureau of Land Management when they cross Federally owned land (in addition to regulation by individual states)&lt;br&gt;• The Carbon Dioxide Pipeline Study Act of 2007 (S.2144), which would require the secretary of Energy to study the feasibility of, constructing and operating a network of CO2 pipelines for CCS, was not passed and did not become a law.</td>
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## 2) Regulations - US - UIC Programme

<table>
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<tr>
<th>Category</th>
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<tbody>
<tr>
<td>Exploration Permits</td>
<td>• Significant details are given on site characterisation and storage permits but not exploration permits as with the EU Directive</td>
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<tr>
<td>Site Characterisation</td>
<td>• While initial assessments indicate there are many geologic formations in the U.S. that can potentially receive injected CO2, not all can serve as adequate CO2 Geological Sequestration (GS) sites</td>
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<td>• Operators must submit maps and cross sections of the Underground Sources of Drinking Water (USDW) near the proposed injection well</td>
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<td>• Operators must submit data to demonstrate that the injection zone is sufficiently porous to receive the CO2 without fracturing and extensive enough to receive the anticipated total volumes of injected CO2</td>
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<td>• Operators must submit geologic core data, seismic survey data, cross sections, well logs, and data that demonstrate the lateral extent and thickness, strength, capacity, porosity, and permeability of subsurface formations</td>
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<td>• The following data must also be collected in order to characterise a site: porosity, geophysical, geochemical and geomechanical data including fracture, proximity to groundwater reservoirs, injection pressures and rates, reservoir pressures, seismicity data, CO2 composition, etc.</td>
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<td>• Mechanical integrity of injection well must be maintained</td>
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<td>• Automatic shut-off valves must be installed at surface and also down the injection hole</td>
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### 2) Regulations - US - UIC Programme

<table>
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<tr>
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<tbody>
<tr>
<td>Site Certification &amp; Storage Permits</td>
<td>• Information submitted for permit applications should include maps of the injection wells, the “Area of Review” (AoR) as determined through computational modeling, all artificial penetrations within the AoR, maps of the general vertical and lateral limits, maps of the geologic cross sections of the local area, the proposed operating data and injection procedures, proposed formation testing program, and stimulation program, well schematics and construction procedures, and contingency plans for shut-ins or well failures in addition to demonstration of financial responsibility to plug the well, and to provide for post-injection site care, and site closure</td>
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<td>• Plans that should be included in permit application:</td>
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<td>• Monitoring plan (site monitoring is site-specific and plans must be included up front to allow Director to undertake assessment of monitoring techniques proposed)</td>
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<td>• Corrective action plan</td>
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<td>• Post-injection site care and site closure plan</td>
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<td>Scale of Projects</td>
<td>• Pilot scale projects under new Class VI Program, also applicable for EOR and EGR under Class II Program</td>
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2) Regulations - US - UIC Programme

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</table>
| **Risk Assessment**              | • Risk assessment procedure required  
• Must be submitted to Director before consideration of Storage permits  
• Must be updated periodically  
• Must include assessment of potential leakage pathways (using simulations (potential magnitude of leakage, parameters affecting leakage (e.g. reservoir pressure, temperature, injection rate, etc.)) |
| **Classification of CO2**        | • Owners or operators will need to characterize their CO2 stream as part of their permit application to determine if the injected material is considered hazardous or not (this depends on coal type, composition, plant technology and operating conditions, pollution control technologies used, etc.) |
| **Access, Property Rights and Ownership** | • Not discussed in the EPA proposal. However, the IOGCC recommends that states should consider the potential need for legislation to clarify and address issues related to the ownership of the storage site (pore space) and payments for use of these storage sites |
| **EOR Experience**              | • Experience with CO2 injection for EOR includes the use of acid-resistant cements. Cements with a reduced Portland content are more resistant to acid because they contain less calcium carbonate (CaCO3)  
• There are technical challenges associated with geological storage in depleted oil and gas reservoirs. Injection volumes, operation conditions, and formation pressures for CO2 injection will differ from those of traditional EOR/EGR operations. |
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| Site Operation and Closure    | • Operators must limit CO2 injection pressures, except during well stimulation, so that injection does not initiate new fractures, propagate existing fractures in the injection zone, or cause movement of injection or formation fluids that endanger USDWs. During injection the pressure in the injection zone must not exceed 90 percent of the fracture pressure of the injection zone.  
• Hydraulic fracturing techniques used in EOR, EGR or ECBM would be acceptable provided integrity of confining systems is unaffected.  
• Once the operators provide documentation that demonstrates that the models predicting CO2 movement are consistent with monitoring results and that there are no longer risks of endangerment to USDWs, they could request that the Director authorize site closure.  
• Once closure approved by Director, operator must submit report within 90 days.  
• The report should provide documentation of injection and monitoring well plugging; copies of notifications to State and local authorities that may have authority over future drilling activities in the region; and records reflecting the nature, composition, and volume of the injected carbon dioxide stream. The report should provide information to potential users and authorities on the land surface and subsurface pore space regarding the operation.  
• No injection depth is specified in case some operators want to inject CO2 as gas. |
## 2) Regulations - US - UIC Programme

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| Post-closure, transfer of responsibility and Liability Issues           | • EPA considers three distinct options for determining post-injection period (1) establishing a fixed period, (2) allowing a performance-based approach based on pressure decay measurements, and (3) a combination of fixed period and performance-based standard  
• A default 50-year post-injection period before transfer of responsibility is suggested  
• During the 50-year period, the operator is required to submit periodic reports providing monitoring results and updated modelling results as appropriate until a demonstration of non-endangerment to USDWs can be made  
• The Director is allowed to increase or decrease the 50 years period  
• The Director would determine that the post-injection site care period has ended and authorize site closure when the following have occurred:  
  • All information required of post-injection and site closure plan received;  
  • Data demonstrate that there is no threat of endangerment to USDWs.                                               |
## 2) Regulations - US - UIC Programme

<table>
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<th>Category</th>
<th>Regulation</th>
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<tbody>
<tr>
<td>MMV Requirements</td>
<td>• MMV techniques are site-specific and must start before permits are granted</td>
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<td>• Owners or operators of Class VI wells must report semi-annually to the</td>
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<td>permitting authority, on the physical and chemical characteristics of</td>
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<td>injection fluids, injection pressure, flow rate, temperature, volume and</td>
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<td>annular pressure, annulus fluid volume added, and the results of plume</td>
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<td>tracking, and atmospheric/soil gas monitoring</td>
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<td>• “Area of Review” (AoR) modelling revisions; any updates on the type,</td>
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<td>number, and location of wells within the AoR; and information on</td>
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<td>additional corrective action performed or planned based on AoR re-</td>
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<td>evaluations must be submitted by operator to Director immediately as</td>
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<td>changes occur</td>
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<td></td>
<td>• Recordkeeping must be maintained throughout operation and for 3 years</td>
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<td>after closure</td>
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<td>• Automatic shut-off valves must be installed down-hole and at the surface</td>
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<td>• Corrosion must be monitored</td>
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<td>• Operators must monitor internal mechanical integrity of their injection</td>
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<td>wells by continuously monitoring injection pressure (not periodic testing),</td>
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<td>flow rate, and injected volumes, as well as the annular pressure and fluid</td>
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<td></td>
<td>volume</td>
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<td>• Any other additional tests can be requested by the Director</td>
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<td>• External mechanical integrity testing should be done at least once a year</td>
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<td>• For external mechanical integrity testing, current methods can be used</td>
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<td>such as a tracer survey or a temperature or noise log or any other method</td>
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<tr>
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<td>approved by the Director</td>
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</tbody>
</table>
## 2) Regulations - US - UIC Programme

<table>
<thead>
<tr>
<th>Category</th>
<th>Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Issues</td>
<td>• Operators must demonstrate and maintain financial responsibility, and have the resources for activities related to closing and remediation</td>
</tr>
<tr>
<td></td>
<td>• Proposal recommends that rule only specify a general duty to obtain financial responsibility acceptable to the Director</td>
</tr>
<tr>
<td></td>
<td>• Operators must demonstrate financial responsibility for corrective action including injection well plugging, post-injection site care and site closure, and emergency and remedial response using a financial mechanism acceptable to the Director</td>
</tr>
<tr>
<td></td>
<td>• The Director would determine if financing mechanisms are adequate to pay for well plugging, post-injection, site closure, and remediation activities</td>
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<tr>
<td></td>
<td>• After end of post-injection period, operators and owners do not need to provide proof financial assurance or security. This will be when the Director approves the post-injection site care and closure plan</td>
</tr>
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<td></td>
<td>• Operator should periodically update costs for post-closure activities based on corrective measures in the area</td>
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<td></td>
<td>• EPA will publish guidance for financial responsibility soon. Currently Financial assurance is typically demonstrated through two broad categories of financial instruments</td>
</tr>
<tr>
<td></td>
<td>• (1) Third party instruments, including surety bond, financial guarantee bond or performance bond, letters of credit</td>
</tr>
<tr>
<td></td>
<td>• (2) self-insurance instruments, including the corporate financial test and the corporate guarantee.</td>
</tr>
</tbody>
</table>
2) Regulations

United States
2) Regulations

- Wyoming
  - Wyoming passed legislation in 2008 (two bills) and 2009 (three bills) covering in total the general legislative framework, pore space ownership (including rights, limitations, protections) and unitization. Liability legislation covering “post closure” and “long term stewardship” are still in development and may be dealt with in 2010. Work is also under way to develop comprehensive rules anticipated to be completed in late 2009/early 2010.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Provisions:</td>
<td>Yes</td>
</tr>
<tr>
<td>Pore Space Ownership:</td>
<td>Yes</td>
</tr>
<tr>
<td>Aggregation of Storage Rights:</td>
<td>Yes</td>
</tr>
<tr>
<td>Long Term Liability:</td>
<td>No</td>
</tr>
</tbody>
</table>
2) Regulations

• North Dakota
  • At the request of the ND Industrial a task force drafted legislation. In advance of the 2009 legislative session, the Industrial Commission pre-filed the two bills created by the task force, one covering geologic storage and the other pore space. Both bills were passed and are were signed into law by Governor Hoeven on April 8, 2009. Rule development is in progress

  General Provisions: Yes
  Pore Space Ownership: Yes
  Aggregation of Storage Rights: Yes
  Long Term Liability: Yes
2) Regulations

- **Louisiana**
  - The Louisiana Legislature passed legislation in 2009 addressing the geologic storage of CO2 -- HB 661, Act 517. It is a comprehensive bill. A process for developing Rules has not yet begun.

<table>
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<tr>
<th>Provision</th>
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<tr>
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</tr>
<tr>
<td>Long Term Liability:</td>
<td>Yes</td>
</tr>
</tbody>
</table>
2) Regulations

• Kansas

  • The State of Kansas passed legislation in 2007 (HB 2419) that mandated development of regulations by July 1 of 2008. Although a public hearing was held in late March, and two open administrative meetings of the Kansas Corporation Commission over the summer, to my knowledge the commission has not yet finally approved the regulations. Proposed rule covers:

    General Provisions: Yes
    Pore Space Ownership: Yes
    Aggregation of Storage Rights: Yes
    Long Term Liability: Uncertain
2) Regulations

• Montana
  • Senate Bill 498 was signed by the Governor on May 6, 2009, becoming law. Most elements of the law will not be effective until the state is granted primacy authority by EPA under Rules currently being developed by EPA and not expected until 2011. Further development of rules in Montana is expected to await the grant of primacy authority by EPA.
2) Regulations

• California
  • In 2006, California passed HB 1925 which mandated that the state produce a report containing recommendations identifying how the state can develop parameters to accelerate the adoption of GS strategies for the long-term management of industrial carbon dioxide. Finalization of the report is expected no sooner than 2010. Legislation is not expected to proceed until completion of the report.
2) Regulations

• Utah
  • In 2008, Utah passed SB 202 which mandated development of rules pertaining to CCGS by January 1, 2011. The law also requested recommendations as to the need for specific legislation. The state has created a working group in which responsibility for capture and transport issues has been assigned to the DEQ and storage issues to the Division of Oil, Gas and Mining. Rule development will likely await completion of EPA Rule development process.
2) Regulations

• New Mexico
  
  • In December of 2007 the State released a Blueprint for the Regulation of Geologic Sequestration of Carbon Dioxide in New Mexico. During the 2009 legislative session, a comprehensive bill to regulate CO2 sequestration died in House committee. Senate Bill 208, the pore space bill, was passed out of the Senate, but no action was taken by the House prior to adjournment and the bill died.
2) Regulations

- West Virginia
  - At the Governor’s request the legislature in 2009 took up the issue of CGS. The bill that passed (HB 2860) mandated creation of a CGS working group and the development of legislative rules that would implement the provisions of the statute. It also required that the working group prepare an interim report for the legislature by July 1, 2010 and a final report by July 1, 2011 that includes draft legislation addressing ownership of pore space. SB 507 also required that the West Virginia Clean Coal Technology Council prepare a study of carbon capture and control.
2) Regulations

• New York
  - Project specific legislation was introduced in June 2009 by Governor Paterson (Program Bill #45). It has been sponsored in the Assembly as A.8802 and in the Senate as S.53303. This legislation could still pass in 2009. The bill before the Assembly addresses pore space ownership, aggregation of storage rights and long term liability.
2) Regulations

EU Directives
2) Regulations - EU Directive 2009/31/EC

- Composition of CO2 stream (Art 12 EU Directive 2009/31/EC)
  - Draft as of April 2009 permitted injection of CO2 only, if stream consists overwhelmingly of CO2
  - CO2 as high as technically and economically feasible (BAT)
  - may contain substances that increase safety and improve monitoring, and that result from CCS processes
  - no adverse effects on people and environment, no impacts on long-term safety of the storage site, as well as safety of transport and injection
  - no waste or other matters for disposal
  - Operator: undertakes a RA, monitoring, reporting of composition of CO2 stream
  - Problem: lack of knowledge (experience with pipeline but not with storage / possible fluid-rock interactions)
2) Regulations - EU Directive 2009/31/EC

- Project boundary definition (Art 3(3), (6) EU Directive 2009/31/EC)
  - EU Directive: storage complex means the storage site and surrounding geological domain which can have an effect on overall storage integrity and security; that is, the secondary containment formations.
    - areal extent of CO2 distribution, and/or
    - areal of extent of pressure influence and/or
    - saline water displacement
  - Problem: boundary may change over time
  - Model to predict lateral (and vertical) spread of injected CO2 and pressure profile over time (until completion of injection operations and thereafter)
  - Monitoring to determine spread of injected CO2 and pressure built-up
  - Updating of monitoring plan, RA, and if necessary boundary where deviations from predictions occur (would probably need authority approval!)
2) Regulations - EU Directive 2009/31/EC

- Monitoring and verification requirements (Art 13 and Annex II EU Directive 2009/31/EC)
  - Annex defining criteria for preparation and updating monitoring concepts during and after injection
  - Principle: monitoring needs are determined from risk assessment
  - Obligatory monitoring of fugitive emissions of CO2 at injection point, volumetric CO2 stream at well head, P/T of CO2 at well head, chemical analysis of CO2 stream, P/T condition in reservoir
  - Operator delivers monitoring plans for entry into operation, regularly during injection period, for closure, and post-closure, state authorities approve / change
  - Monitoring plans improve / may change over time as include more and more data achieved over the life-time of the project and their modelling results
  - Responsible for monitoring: operator until at least 30 years after closure of storage site
  - Assess effects of corrective measures (Art. 16)
2) Regulations - EU Directive 2009/31/EC

- **Closure / post closure obligations (Art 17 Directive 2009/31/EC)**
  - requires a permit
  - requires a closure and post closure concept including an updated safety proof and monitoring concept
  - The safety concept i.a. includes a risk assessment, a remediation plan in case of leakages (or irregularities).
  - The operator needs to demonstrate that
    - the actual behaviour of injected CO2 coincides with the modelled behaviour
    - permanent integrity of the storage site is given
    - no leakages or significant irregularities occur
    - long-term stability of the storage site is given
  - Minimum post-closure period no shorter than 20 years unless CA decides otherwise based on all available evidence (Art 18)
- **Financial security (Art 19, 20):**
  - compulsory cover by operator (until transfer of responsibility)
  - follow-up cover by operator (at least 30 years after transfer of responsibility)
2) Regulations - EU Directive 2009/31/EC

• Competition with other resources
  • as early as the stage of exploration
    • interferences with underground resources,
    • interferences with other types of use (e.g. gas storage, waste disposal)
    • interferences with existing mining permits
  • Problem: large areas will be affected from CO2 storage
  • A possible way out: regional underground planning to settle conflicts of different forms of underground usage
### Regulations EU Directive 2009/31/EC

<table>
<thead>
<tr>
<th>Category</th>
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</table>
| Capture  | Capture will be regulated by inclusion in the Integrated Pollution Prevention and Control Directive  
• According to this Directive, all capture plant operators will need to get a permit.  
• According to this Directive, public consultation will be required and operators will be required to use best available techniques for capture  
• An Environmental Impact Assessment will be required and an Environmental Statement must be prepared. An environmental Impact Assessment has to be undertaken in the capture permit process in order to investigate the level of impurities in the CO2 stream in addition to other environmental impacts. The composition of the CO2 stream should be verified before injection.  
• Carbon Capture Readiness (CCR) requirements are defined. Installations must be able to fit capture technology at a later date. It must be ensured that there is suitable space set aside for capture plant, that there are suitable storage sites, that transport infrastructure is available and that the process is economically feasible.  
• CCR provisions will be reviewed in 2015 by the Commission, which may lead to replacing CCR with new schemes that require CCS from the beginning.  
• Directive 2008/1/EC of the European Parliament (January 2008) is suitable for regulating the risks of CO2 capture to the environment and to human health |
## 2) Regulations EU Directive 2009/31/EC

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</table>
• No permit is required but EIA must be undertaken according to national procedures and requirements.  
• Third party access to pipeline networks: Operators will only be permitted to refuse access to transport networks on the ground of lack of capacity. They may wish to add capacity if third party is willing to pay.  
• Member States will resolve disputes  
• The Directive lays down conditions for resolving cross-border disputes |
| Exploration Permits | • Member States should ensure that exploration permits are provided before exploration commences.  
• Monitoring tests may be included in the exploration permits  
• Period for exploration should not exceed period necessary to undertake the exploration it is granted for. However, extension may be granted if exploration has been done according to permit.  
• The holder of a permit is the only party allowed to explore the potential storage area.  
• Holder of exploration permit has preference over other applicants when it comes to granting of storage permits |
## 2) Regulations EU Directive 2009/31/EC

<table>
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</table>
| Site Characterisation     | • States retain the right to determine areas from which sites may be selected.  
                              • States shall undertake an assessment of the storage capacity available in parts or the whole of their territory.  
                              • Suitability will be determined through characterisation and assessment of site.  
                              • Characterisation and assessment of sites should be taken in three steps:  
                                • Data collection: Sufficient data must be collected to construct a volumetric and 3-D-earth model of storage site. These data should be collected at least: geology and geophysics, hydrogeology (especially presence of groundwater), reservoir engineering (pore volume calculation and ultimate storage capacity), geochemistry (dissolution rates, mineralization rates), geomechanics (fracture pressure, permeability), seismicity, presence and conditions of man-made pathways such as wells and boreholes. These should be documented: domains surrounding site which may be affected by CO2 storage, population distribution in region, proximity to natural resources, activities around storage area (e.g. oil or gas exploration or groundwater extraction), and proximity to potential CO2 sources and adequate transport networks.  
                                • Building 3-D static geological earth model: Using data collected above, a single or several 3-D models should be developed using computer reservoir simulators. Models should characterise geological structure, flow properties, fracture system characterisation, area and vertical extent of storage site, pore space volume amongst other parameters. Uncertainty of the models should also be included.  
                                • Characterisation of storage dynamic behaviour: Based on dynamic modeling using time-step simulations of CO2 injection into storage site using the static model developed above. These should be considered: possible injection rates and CO2 properties, short and long-term simulations, pressure and temperature of the storage formation, a real and vertical extent of CO2 vs. time, CO2 trapping mechanisms, etc. |
### 2) Regulations EU Directive 2009/31/EC

<table>
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</table>
| Site Certification and Storage Permits | • A geological site should only be selected if under the proposed conditions no risk of leakage and no health and environmental risks exist. Conditions:  
  • No storage site is operated without permit  
  • Only one operator per site  
  • Procedure for granting of permits should be open to all entities with the necessary capacities and are based on transparent, published and objective criteria  
  • Priority should be given to the holder of the exploration permit.  
  • Priority in granting the storage permit should be given to the holder of the exploration permit.  
  • In early stages of implementing the Directive, all storage permits should be made available to the EC in order to ensure consistency amongst all EU Members. This is thought to ‘enhance public confidence’.  
  • Permits should be withdrawn if leakage or irregularities are detected. The responsible authority should either issue a new permit or close the storage site. During this process, the responsible authority will be legally responsible for the site and any costs incurred should be recovered from the previous operator.  
  • Operational, closure and post-closure obligations should be defined at the certification stage. This includes monitoring and reporting requirements as well as remediation following any leakage. |
2) Regulations EU Directive 2009/31/EC

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Site Certification and Storage Permits (2)</td>
<td>• Operators must provide financial provision to ensure that all terms of the Directive and the issued permit are adhered to.</td>
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<td>• Application to Storage Permit: Storage permits should give information on</td>
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<td>• Name and address of operator and Precise location of storage site,</td>
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<td></td>
<td>• Requirements for storage operation and total quantity authorised,</td>
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<tr>
<td></td>
<td>• Reservoir pressure limits and Maximum injection rates and pressures,</td>
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<td></td>
<td>• Requirements for composition of CO2 stream,</td>
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<td></td>
<td>• If necessary, further requirements for injection and storage to prevent irregularities</td>
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<td>• Approved monitoring plan in addition to obligation to implement the plan and requirements for updating the plan</td>
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<td>• Requirement to notify authority in case of leakage and the corrective measures plan that will be undertaken in case of leakage</td>
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<td>• The conditions for closure</td>
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<td>• The approved provisional post-closure plan</td>
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<td>• Provisions on changes, review, updating and withdrawal of the storage permit</td>
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<td>• Requirement to establish and maintain financial security</td>
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## 2) Regulations EU Directive 2009/31/EC

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<tr>
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<tbody>
<tr>
<td>Scale of Projects</td>
<td>• Applies to any project with more than 100 kilo tonnes of CO2</td>
</tr>
</tbody>
</table>
| Risk Assessment               | • No injection should be allowed unless risk assessment and mitigation strategies is undertaken  
• Risk analysis of CO2 composition including corrosive substances of the streams must be undertaken.  
• Risk assessment is a requirement for granting the storage permit  
• Must include details of the risks, their probability and mitigation procedures in case of occurrence                                                                                                                                                                                                 |
| Classification and Composition of CO2 | • The composition of the CO2 stream should be verified before injection.  
• A CO2 stream should consist mainly of carbon dioxide. No waste or other matter may be added. Incidental impurities from the source capture or injection processes and substances used for MMV should be below levels, which will adversely affect the integrity of the storage site or transport infrastructure. Impurity levels should not pose risk to environmental or human health or breach existing legislation.  
• No injection should be allowed unless risk assessment is undertaken regarding the composition of CO2 streams.  
• A register must be kept of properties and quantities of CO2 streams delivered and injected including composition of these streams.                                                                                           |
## 2) Regulations EU Directive 2009/31/EC

<table>
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<tbody>
<tr>
<td>Access, Property Rights and Ownership</td>
<td>• Member States must ensure potential users have access to storage site.</td>
</tr>
<tr>
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<td>• Access rights criteria should be transparent, published and clear.</td>
</tr>
<tr>
<td>Site Operation and Closure</td>
<td>• The operator should accept and inject CO2 only if an analysis of the streams including corrosive substances has been undertaken and that the analysis shows that contamination levels within the criteria in the Directive.</td>
</tr>
<tr>
<td></td>
<td>• Member States should ensure that site operators monitor CO2 injection and storage according to a monitoring plan based on specific requirements.</td>
</tr>
<tr>
<td></td>
<td>• This monitoring plan should be submitted to and approved by the authority in place before injection starts.</td>
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<tr>
<td></td>
<td>• For offshore storage under the seabed, the monitoring plan should also consider the specific conditions in the marine environment.</td>
</tr>
<tr>
<td></td>
<td>• Obligation on the operator of the storage site to take corrective measures in case of leakage. If the operator does not take these corrective measures, they should be undertaken by the authority and costs recovered from the operator.</td>
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<tr>
<td></td>
<td>• Storage site should be closed upon request from operator if all conditions in the permit were complied with.</td>
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<tr>
<td></td>
<td>• After closure, operator should remain responsible for site maintenance, monitoring and control according to a closure plan submitted to and approved by the responsible authority. This should remain the case until responsibility is transferred to authority.</td>
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</table>
## 2) Regulations EU Directive 2009/31/EC

<table>
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</table>
- Liability is dealt with by including storage site in Directive 2003/87/EC, which requires surrender of emission trading allowances for any leaked emissions.  
- Responsibility will be transferred from operator to authority when evidence is shown that all CO2 will permanently and completely remain contained. Operator should submit report to authority for approval of the transfer. All reports must be available to the EC after receipt by the responsible authority.  
- Liabilities other than those related to the phases of injection, closure and the period after transfer of responsibility should be dealt with at national levels.  
- After transfer of liability, monitoring should be reduced but should include leakage detection and should be intensified if leakage is detected. In this case no recovery of cost from the previous operator can be obtained.  
- Financial provisions should be made to allow for closure and post-closure obligations and to deal with corrective measure due to leakage or other irregularities.  
- States should ensure operators provide financial security before injection starts  
- After transfer of responsibility, national authorities may have to bear monitoring costs associated with CO2 storage. In this case, operators need to provide financial contributions before transfer takes place.  
- This financial contribution should cover monitoring costs for a period of 30 years. It is the responsibility of States to determine the level of this contribution |
<table>
<thead>
<tr>
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</thead>
</table>
| MMV      | • Monitoring plan for operation and post-closure phases must be submitted with permit application.  
• Monitoring plan must include: parameters to be monitored, monitoring technology to be used and rationale, frequency of application, monitoring locations and rationale for spatial sampling.  
• Operator must carry monitoring of injection facilities and surrounding environment  
• This must be observed by Member States  
• Comparison between observed and modelled behaviour should be undertaken  
• Monitoring should detect CO2 migration, leakage and any significant irregularities.  
• Monitoring should provide information on adverse effects on surrounding environment in particular ground water or human populations.  
• Assessment of whether stored CO2 will be permanently contained must be included in monitoring  
• Monitoring networks should be updated in the short and long-term  
• All monitoring information should be reported in the reporting period to the authority.  
• Reports should include information on composition of streams and quantities injected.  
• Member States should ensure the organisation of routine and non-routine inspections of all storage sites. |
### 2) Regulations EU Directive 2009/31/EC

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<tr>
<td>MMV (2)</td>
<td>• Inspections should include visits, assessing MMV operations and checking all records.</td>
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<td></td>
<td>• Continuous monitoring should be undertaken of the following: (1) fugitive CO2 emissions at the injection facility, (2) CO2 volumetric flow rate, temperature and pressure at injection well heads, (3) chemical analysis of injected material, (4) reservoir temperature and pressure (to determine phase behaviour)</td>
</tr>
<tr>
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<td>• Data collected must be collated and interpreted and the observed results must be compared to behaviour predicted from dynamic simulations. If significant deviation is observed, the simulation model should be re-calibrated based on data from the monitoring plan.</td>
</tr>
<tr>
<td></td>
<td>• Post-closure monitoring must be based on information collected and modelled during implementation of monitoring plan above.</td>
</tr>
<tr>
<td>Financial Issues</td>
<td>• Member States should ensure that proof that adequate provisions can be established by way of financial security.</td>
</tr>
<tr>
<td></td>
<td>• This should include closure and post-closure requirements and must be valid and in place before injection starts.</td>
</tr>
<tr>
<td></td>
<td>• Financial security should be periodically adjusted to take account of changes in risk of leakage and estimated costs of all obligations arising under the permit.</td>
</tr>
<tr>
<td></td>
<td>• Proof of financial security and maintenance should be reported periodically.</td>
</tr>
<tr>
<td></td>
<td>• Financial security must remain valid after site closure.</td>
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</tbody>
</table>