Characterisation of European CO_2 storage

Dry-run storage permit applications

Lessons learned from the perspective of operators and regulators

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Motivation

- To date, one application has been made for a storage permit under the Storage Directive
- Demonstration projects are working towards submitting permits
  - But are not yet ready
  - Regulators may not able to receive applications in some MS
- Permit development needs to be tested at credible sites
  - ‘Low’ risk dry-run environment without the constraints of commercial projects
  - Allow testing of permitting in future storage situations (onshore and in saline aquifers)
  - Allow testing and refinement of the SiteChar workflow

Scope of licence applications

- Two teams have produced credible, if limited, licence applications with 'research-level' resources
  - Detailed permit applications are not produced
  - Includes most of key elements required by the Storage Directive
  - Key issues that should be addressed are identified.
- Based on existing data
  - No additional exploration, injections tests or core analysis has been undertaken
- Out of scope:
  - Full EIA
  - Provision relating to the acceptance and injection of CO_2
  - Details of financial security
  - A provisional post-closure plan
  - Provisions for reporting

Storage Permit Application content	Interim March 2012	Final June 2013
1. Name and address of proposed operator	✓	
2. Appraisal term	✓	
3. Project description		
i. Injection parameters and project concept	✓	
ii. Storage development plan incl.		✓
Injection & Operating plan		✓
Storage Performance Forecast		✓
4. Site description		
i. Boundaries	✓	
ii. Site geology, hydrogeology…	✓	
iii. Past development history	✓	
iv. Storage capacity estimate	Draft	✓
5. Measures to prevent significant irregularities		
i. Risk register	✓	✓
ii. Plan of risk mitigation	Draft	✓
iii. Dialogue with stakeholders	Draft	✓
6. Monitoring plan		✓
7. Corrective measures plan		
i. Key Performance Indicators	✓	
ii. Corrective measures plan (provisional)		✓
8. Post-closure plan		
i. Key Performance Indicators	✓	
ii. Post-closure plan (provisional)		✓
9. Environmental Impact Assessment		
i. Description of relevant features	✓	

Site Characterisation

Risk Assessment

Key Performance Indicators

Process

- Interim permit applications produced and reviewed
- Highlighted topics that formed the basis of discussions with:
  - Regulatory Advisory Board:
    - Owain Tucker, Shell
    - Franz May, BGR
    - Greg Leamon and Steve Tantala, RET, Australia Govt
    - Steve Cawley, BP
- Workshops were held with storage regulators from France, UK (& policy makers), Germany, Netherlands and Norway, with industry representatives including the RAB and others.
- Final permits submitted and reviewed internally and in detail by RAB.

Comparisons between Vedsted and Moray Firth – permitting perspective

Moray Firth

- Offshore
- Identified from previous regional reviews of UK northern North Sea storage targets
- 'Theoretical' study
  - Low risk – can try different permitting scenarios
  - No acquisition of new data
  - Range of injection scenarios
- Risks addressed in SiteChar:
  - Definition of storage complex
  - Caprock integrity
  - Potential for seismic monitoring

Vedsted

- Onshore
- Previously applied for licence prior to Directive to promote dialogue with Regulators
- Real project, now stopped
  - Application fits predefined concept & original licence application
  - Baseline monitoring data acquired
- Risks addressed in SiteChar :
  - Oil well integrity and abandonment status
  - Regional pressure responses and management

SiteChar: Dry-run permit development and review

CONCLUSIONS

Comparisons between Vedsted and Moray Firth – permitting perspective

Vedsted

- Risks being addressed in SiteChar:
  - Oil well integrity and abandonment status
  - Potential effects of regional pressure responses and the potential to manage these by water production

Moray Firth

- Risks being addressed in SiteChar:
  - Definition of site and complex boundaries
  - Well integrity
  - Caprock integrity
  - Potential for seismic monitoring and minimum detection limits

Site Characterisation

- Site characterisation should be driven by risk assessment process to:
  - Identify and reduce priority uncertainty,
  - Enable project design
  - Develop monitoring plans and performance metrics.

- Both projects consider an injection test would be needed.
  - To assess proof on injectivity, reservoir connectivity and pressure response.

Storage Complex Boundary

- Informal discussion with regulators indicate that the pressure footprint might receive lower emphasis in defining the complex boundary.
- Including the pressure footprint would require impractically large storage permit areas, since pressure responses can extend far beyond the plume.
- There is little consensus on the thresholds or consequences above which effects should be included.
- A clear and prior agreement with CA will be needed on definition of storage complex
- In SiteChar we propose that the complex defined by maximum extent of plume
  - including CO_2-saturated formation water
  - plus a margin to enable monitoring
  - to reflect inherent uncertainty in predictions

Interactions with other users

- The nature and extent of interactions with other users is a key consideration for regulators.
- Operators are expected to establish potential impacts on pre-existing users of surface and subsurface
- Assessing future interactions may be challenging for operators
  - E.g. future operations (HC production and/or other storage) may impact on the risk profile of a project.
  - The ‘state owner of the resource’ may be best placed to take an overview

Pressure management & water disposal

- Disposal of water offshore is not considered particularly challenging, as it is widely practised in HC production.
- Volumes of produced water for pressure management in the North Sea have not been estimated.
  - For comparison, 175 million m^3 of produced water were discharged in UK waters in 2011
  - Moray Firth estimated similar volumes produced as CO_2 injected
- At Vedsted, pressure management was considered, since pressures were limited to 85% of lithostatic.
- Disposal of produced waters may be significantly more challenging onshore than offshore,
  - A key topic in the storage and environmental permits for onshore sites.

Permit performance conditions (PPCs)

- Define limits to site behaviour which, if exceeded, indicate that a significant irregularity or leakage has occurred.
  - Identified through Risk Assessment
  - Inform the Monitoring Plan
  - Trigger Corrective Measures if exceeded
  - Indicators will be in the Corrective Measures and Post-Closure plans
  - Enable site closure

Blake Field	
PPC1	**Environmental or human health will not be adversely affected by the storage operation**
PPC2	**CO_2 will not pass beyond the Storage Permit Area boundaries**
PPC3	**CO_2 plume shows migration within expected modelled behaviour**
PPC4	**Pressure changes will remain within predefined/predicted ranges**
PPC5	**Geomechanical integrity of site will be maintained**
PPC6	**Cost per tonne will remain within a set limit**

Recommendations on PPCs

- PPCs should be linked to the specific risks they address
  - To demonstrate that the risk register, PPCs, corrective measures plan and monitoring plan are closely integrated.
- PPCs should be written with positive phrasing as the permits will be public documents.

Flexibility in the storage permit

- Conditions under which permits should be changed (to reflect changes in operation) should be agreed.
  - This would not be predictions of alternative scenarios and open permits but rather the circumstances under which permits might need to be changed.
  - Provide a ‘master’ storage permit with additional permits for specific activities such as drilling wells

Post-injection period

- SiteChar permits have 20-year post-injection periods
- If sites are performing as expected, operators likely to wish to transfer responsibility as soon as possible.
  - Both sites predict (albeit with limited simulations) reaching safe steady-states quickly.
- Any uncertainty in conditions for site closure may delay FID.
- Crucial to agree, during permit negotiations, exact evidence required to enable site closure and transfer of responsibility.
  - Challenging due to multiple CAs involved.

Communication and management of uncertainty

- Uncertainty and hazard should be distinguished
- Site characterisation will always be associated with a degree of uncertainty.
  - How much is acceptable?
- Assessment by scenario development
- Focus on assessing uncertainty related to parameters which significantly impact capacity and containment.
- Reducing uncertainty will be iterative, requiring a focus on reducing areas of most significance incrementally.

Communication and management of uncertainty

- Site characterisation may indicate that one geological model interpretation is more likely than others
  - This will form the basis of the permit application.
- However other interpretations might be possible and should be discussed.
- Contingencies should be included in the application.
- The operator and the CA will need to agree on acceptable levels of uncertainty and the evidence needed to support the permit application

Competent authorities

- Reviews of history matching between observation and predictions should be undertaken throughout the project.
  - May require specialist technical advice to support this.
- It is currently assumed all sites will be closed and infrastructure removed.
  - It may be beneficial for some sites to be kept open. CA may wish to extend storage life.
- Data archiving requirements should be applied to hydrocarbon licence holders for benefit of storage site characterisation.
- The CA(s) may need to undertake its own risk assessment and supporting investigations, to provide guidance to operators, including around third party access.

Competent authorities - questions

- Over what periods should predictions of post-closure performance be undertaken?
  - 500-1000 years in SiteChar
- Under what conditions could other users challenge a storage permit application?
- Definition of storage complex
- How storage should be managed in areas of multiple storage operations

Feedback for Storage Directive

- Detailed guidance on defining complex boundaries
- The extent to which impacts from pressure should be included
- PPCs are useful tools for discussion between the CA and operator
  - to define and agree acceptance criteria against which a storage operation can be assessed.
  - Likely to be a combination of qualitative and quantitative metrics.
- Conditions under which permits might need to be changed

Summary

- Site characterisation undertaken at varying levels on credible storage sites.
- Estimated 2-5 years with up to 200 person months of effort for storage permit applications
  - CAs will need significant resources and expertise to assess applications and during operation.
  - Several CAs likely to be involved.
- Dry-run permitting process has identified approaches to demonstrating safe and permanent CO_2 storage.
- Recommendations arising from the dry-run process provide guidance to operators and regulators on site characterisation and the SiteChar workflow.

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