Exemplar storage permit applications to evaluate and test site characterisation methodologies.

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Abstract

The production of dry-run storage permit applications at two credible, if conceptual, CO₂ storage sites allowed development of effective approaches to site characterization and identified the necessary levels of evidence required to assess the safety, containment and storage capacity of putative sites. This paper describes an exemplar permitting process and conclusions drawn from this experience for developing successful storage permits.

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1. Introduction

The SiteChar project has undertaken site characterisation activities at five sites that may provide credible options for future CO₂ storage. The sites were selected to represent different geological and storage solutions across Europe. Two of the sites, the depleted hydrocarbon Blake Field Site in the UK northern North Sea and the Vedsted aquifer site in onshore Denmark, were selected for detailed site characterisation to enable development of dry-run storage permit applications. The northern North Sea site is described here. By developing dry-run permit applications, and undertaking independent reviews of these applications, the objective was to identify the best approaches to site characterisation to enable robust and defensible permit applications to be developed by storage operators in the future. It was also anticipated that the relevant regulatory authorities would find the process useful in identifying the necessary levels of evidence required to assess the safety, containment and capacity of putative storage sites. Several regulatory authorities responsible for granting storage permits in France and the UK, and assessing environmental
impact statements, contributed informally to discussions on the storage permitting process and the issues that the
dry-run application process raised.

To date, as far as the authors are aware, the ROAD project holds the only storage permit to have been granted in
Europe. ROAD plans to store CO2 captured from the new 1,100 MWe coal-fired power plant (Maasvlakte Power
Plant 3) in the Rotterdam port. Storage will be in the P18A depleted gas reservoir under the North Sea. This gas
reservoir is located 20 kilometres off the coast and is at a depth of 3,500 metres under the seabed. Development of
the storage permit took approximately two years1. Other industrial consortia are undertaking detailed site
characterisation in preparation for submitting permit applications. Two sites are being investigated in the UK North
Sea as part of the UK Government’s Commercialisation Programme: the Peterhead Project in Aberdeenshire in
Scotland and the White Rose project in the southern North Sea. Ongoing European demonstration projects, such as
Sleipner and Snohvit, are operating under petroleum regulations.

The permit reviews were carried out by the permit review team within SiteChar (Pearce and Delprat-Jannaud).
Whilst maintaining some degree of independence from the permit development teams (led by Akhurst and Nielsen),
the reviewers maintained a very close dialogue with each team during the development of their dry-run permit
applications. This was to support the permit development, ensuring it addressed, to the extent possible, the
requirements of the Storage Directive [1] and to provide advice on specific technical issues concerning the
development of the evidence base to support the storage applications. These specific issues included:

- The challenges in defining the storage complex and the need to have an agreed approach between the
  operator and the Competent Authority to defining the storage complex. This was especially relevant where
  storage is being considered in saline aquifers in which pressure responses might be expected far beyond the
  extent of the injected CO2 plume;
- The definition of the storage site performance and the benefits of using pre-defined permit performance
  conditions as qualitative and quantitative indicators of site performance;
- The potential for interactions to occur with other users of the subsurface;
- The need for pressure management through water production.

Our review has compared the dry-run applications against the requirements in the Storage Directive, and the
associated Guidance Documents. In addition, for the UK site, the UK-specific guidance documents [3] produced by
the UK Department of Energy and Climate Change [2] were also used to assess the completeness and relevance of
the evidence provided.

1.1. Scope

The submitted application includes the main elements expected to be included in a storage permit (Table 1).

<table>
<thead>
<tr>
<th>Storage Permit Application content</th>
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</thead>
<tbody>
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<td>1. Name and address of proposed operator</td>
<td>2. Appraisal term</td>
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<tr>
<td>3. Project description</td>
<td>4. Site description</td>
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<tr>
<td>i) Injection parameters and project concept</td>
<td>i. Boundaries</td>
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<td>ii) Storage development plan including:</td>
<td>ii. Site geology, hydrogeology…</td>
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<tr>
<td>Injection &amp; Operating Plan</td>
<td>iii. Past development history</td>
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<tr>
<td>Storage Performance Forecast</td>
<td>iv. Storage capacity estimate</td>
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5. Measures to prevent significant irregularities
   i. Risk register
   ii. Plan of risk mitigation
   iii. Dialogue with stakeholders

6. Monitoring plan

7. Corrective measures plan
   i. Performance indicators
   ii. Corrective measures plan (provisional)

8. Post-closure plan
   i. Performance indicators
   ii. Post-closure plan (provisional)

9. Environmental Impact Assessment
   i. Description of relevant features

Some key aspects of the dry-run licence application were excluded as these were considered to be beyond the scope of the current study, notably:

- An evaluation of the stream composition which was assumed to be pure CO₂.
- A full Environmental Impact Statement
- A fully-developed Post-closure Plan.
- A full Storage Development Plan, especially the design and detailed locations of injection and production wells, together with any additional spare capacity or redundancy and the well completion strategy. Indicative dynamic simulations have been used assuming a single well for injection, though it is recognised this is unrealistic.
- The CO₂ transportation and injection facilities are also considered to be out of scope for this dry-run exercise.

2. Outer Moray Firth exemplar permit application

The project concept is for initial CO₂ storage in the Blake depleted hydrocarbon field, followed by further storage in the surrounding saline aquifer, principally the Captain Sandstone Member of the Wick Sandstone Formation. It is envisaged that CO₂ will be injected into the Blake Field, with pressure management via a water production well sited down-dip and beyond the extent of the field. Injection will continue to fill beyond the field allowing the CO₂ to migrate beyond the field boundaries and into the wider saline aquifer. Once injection ceases the CO₂ will be trapped structurally beneath the regional seal rocks and retained along its migration route by residual trapping and dissolution within pore spaces of the sandstone. This project concept was specifically chosen to be a credible scenario for CO₂ storage in a mature CCS ‘market’ where large-scale CO₂ storage in a saline aquifer, extending storage beyond the non-pressure-depleted field, is commercially viable. This concept was designed to test the site characterisation requirements and regulatory challenges in obtaining a permit for this more ambitious project in the relatively low risk environment of a research-based exercise.

The application proposes an injection rate of 5 Mt of CO₂ for 20 years to store 100 Mt in total. This will fill the Blake structure, which has been estimated as having a capacity of ~21-28 Mt and will then require around 72-79 Mt of storage in the underlying Captain Sandstone Aquifer. These provide credible volumes of storage with CO₂ being derived from onshore sources. However the total theoretical storage capacity of the Captain Sandstone is estimated at 360 Mt [3, 4]. A further 260 Mt of storage capacity might therefore be available for other storage projects into the Captain Sandstone. The owner of the pore space, the Crown Estate in the UK, might wish to understand how the currently proposed project might contribute to, or affect, utilisation of this estimated capacity. It may be beyond the
scope of an individual operator to undertake such an assessment, but regulators should encourage operators to provide sufficient evidence and data to enable this assessment to be carried out. This would include predictions of pressure evolution, which will be included in a permit application anyway, as well as commitments for reporting reservoir responses to injection, once operations start.

Dissolution of CO₂ into the formation brine is expected to be up to 2% in the field where water saturation is estimated to be ~70%. CO₂ also dissolves into the oil phase during injection. At the end of injection, reservoir pressures are expected to decrease rapidly, causing the CO₂-saturated oil to change to a gas phase. It is assumed this means that CO₂ initially saturated in the oil becomes a dense phase fluid which will begin to dissolve into the formation water, as the gas-water contact rises due to aquifer recharge into the Blake Field. This serves to further contain the CO₂ plume which is not predicted to migrate significantly once injection has ceased.

2.1. Size of permit area:

The complex boundary is a fundamental component of the storage permit application and approaches to its definition have been discussed in detail at Blake. The area enclosed within the storage complex boundary is here defined as the “Storage Permit Area”. Informal advice from a UK Competent Authority (CA) suggested that the storage complex boundary will be defined on the basis of the anticipated extent of the plume, achieved at its point of maximum extent, as determined by predictions of plume movement which in turn are based on pre-injection site characterisation. This maximum extent is taken to include both the supercritical CO₂ and that portion of the formation water in which CO₂ is dissolved at the point of transfer of responsibility. This raises a number of challenges for the operator and CA in defining the complex boundary. For some storage sites, such as Blake, the biggest challenge is the relative uncertainty associated with the static model parameters, and the consequent impact this might have on predicted plume movement. A number of simulations are therefore required to capture the range of uncertainty. The storage complex boundary would then be defined taking a conservative approach by including the plume extent based on selected credible scenarios.

The inclusion of the CO₂-saturated formation water, which extends beyond the dense phase CO₂, is included in the overall migration extent of the CO₂. This is an important consideration since it is the dissolved CO₂ that could lead to some of the leakage scenarios posited for this conceptual project being considered as relatively higher risk.

Furthermore, site performance is predicated on the lack of leakage, which is defined in the Storage Directive as movement of CO₂ beyond the storage complex boundary. Whilst this is no doubt intended to prevent movement above the top boundary of the storage complex, this also means that operators are likely to take a conservative approach to defining the lateral extent of this boundary as well, to prevent uncertainties in static and dynamic modelling from creating unnecessary significant irregularities. For example, at Blake, the storage complex boundary is defined to enclose the updip area to the northeast of the predicted plume extent, to reflect uncertainty in the distribution of higher permeability channel facies which may allow higher than expected migration in this direction.

Another reason to extend the complex boundary beyond the plume limit is to provide a zone outside the plume in which some performance metrics can be monitored. These metrics might include pressure responses and the absence of CO₂ in key areas (e.g. reaching a fault with a relative permeability to CO₂ is uncertain and that may therefore pose a risk to longer-term containment; or poorly-completed wells). Such an approach may also provide storage operators with a protective zone within which other users would be forced to also consider and mitigate any activities that could impact on the storage operation.

The pressure footprint has not been considered in the complex boundary. The Storage Directive suggests such effects should be included but there is currently little consensus on the thresholds above which effects should be included, and since pressure responses have been shown to extend far beyond the field boundaries at Blake, this would require impractically large storage permit areas.

In summary, the storage permit area will therefore be defined on the basis of predictions from reservoir simulations which are in turn based on pre-injection static models (often greatly simplified models), plus a margin around that to allow monitoring outside the plume and possibly to ‘protect’ the operator from other users.
2.2. Interactions with other users

At Blake, the proposed Storage Permit Area encloses the boundaries of existing licence blocks for which agreement with licence holders would be sought. This implies that, although these interactions are not investigated in detail here, operators may need to include these in their permit area where such interactions are envisaged. The potential nature and extent of any interactions with other users is a key consideration for regulators. In the North Sea, these other users are many and include other storage site operators, hydrocarbon exploration and production with associated infrastructure owners and related activities (e.g. water extraction and disposal). They will also include, inter alia, the consideration of future production of reserves, sand and gravel extraction, fishing, wind farms, and military use.

It will be necessary to demonstrate that the proposed injection project does not have a detrimental effect on other legitimate users. Where such interactions occur, it is required that operators of proposed storage sites would enter into commercial agreements with affected users. However, it should be noted that it may be that an assessment of current and future risks may be challenging for operators (due to confidentiality issues and unfamiliarity with longer term strategic plans for all relevant users). In reality, it may be that the relevant ‘state owner of the resource’ (in the UK this would be the Crown Estate) is the only organisation able to take an overview of likely risks arising from multiple operations within a given area. The CA may therefore need to undertake its own risk assessment and supporting investigations, to provide guidance to operators during discussions prior to granting of storage permits.

The specific interactions that might arise from multiple uses, both at the seabed surface and in the underground, are numerous. Geologically, however, the most significant process is the potential for pressures rises associated with injection causing changes in the pressure regimes experienced by other users (specifically other storage sites and hydrocarbon producers). For example, at Blake pressure increases are predicted to not be experienced by adjacent oil fields in the Captain Sandstone though connection exists with Cromarty, in which pressure responses from water injection at Blake has been noted. Nearby fields are considered unlikely to be affected, as they produce from deeper Jurassic sandstones, or are likely to have ceased production.

Changes to pressure distributions by future injection of CO₂ into nearby depleted fields have not been discussed. This may be of more importance in discussions over initial lease terms but would be expected to be considered in permit applications in regions of significant CO₂ storage potential, such as the Captain Sandstone. Furthermore, the permit holder at Blake, for example, may wish to evaluate the consequences of additional future CO₂ storage in nearby fields, on their injectivity and overall storage capacity. The potential impacts of other uses, particularly hydrocarbon extraction, have not been assessed for the long-term evolution of the plume. This would be expected to be included in some scenarios to determine the potential effects, if any, of increased or decreased oil production in the wider connected sandstone. However, it is recognised that operators may find it challenging to undertake a detailed evaluation of this issue when working in isolation from other fields. Some responsibility for this should also lie with the regulators who may be able to take a more informed overview, at least of long-term strategy for resource development.

Water production was deemed necessary to maintain reservoir pressures below estimated caprock entry pressures. The production, treatment and disposal of produced waters have not been included in this permit application and would be a key component of the Environmental Impact Assessment in a more detailed application. It is our current understanding that such waters would be subject to the same environmental considerations as produced waters from oil fields and treated in the same way. Note that water is currently produced and discharged at Blake as part of hydrocarbon production under the Prevention of Oil Pollution Act (1971). Discussions with regulators during the permit application development have indicated that disposal of water is not considered particularly challenging from an environmental perspective, as it is widely practised in the hydrocarbon production industry and is expected to be regulated in the same way. Volumes of produced water necessary for pressure management in the North Sea have not been estimated. At the Vedsted aquifer, pressure management was not considered necessary at this stage. However it might be expected that disposal of produced waters may be significantly more challenging onshore than offshore, from a public-perception viewpoint and from an environmental viewpoint. The estimated volumes of produced water and their disposal would be expected to be a key topic in the storage and environmental permits for onshore sites.
2.3. Site performance: Permit Performance Conditions (PPCs)

The objective of defining Permit Performance Conditions (PPCs) is to develop a set of *a priori* agreed criteria which will demonstrate appropriate site performance. These criteria would form conditions of the storage permit allowing the operator and regulator to demonstrate adequate performance both during injection and, importantly at the point of transfer of responsibility following site closure.

PPCs include a range of metrics against which site performance can be measured, both during the operational and closure phases, providing a basis for the design of the geological monitoring program and the corrective measures plan. Whilst it might be relatively straightforward to define qualitative indicators, PPCs will need to be defined quantitatively for them to be the most effective.

PPCs are not explicitly required by the Directive but are considered as useful tools for discussion between the CA and operator, to agree acceptance criteria against which a storage operation can be assessed. Six PPCs were defined for the Blake site (Table 2) and define site performance in terms of absence of leakage, agreement between prediction and observed plume migration, limits on reservoir pressure, maintenance of geomechanical integrity and costs per tonne of CO₂. The latter is considered important to define an upper limit above which permit requirements would make the project uneconomic, thereby protecting the operator from impractical or too costly conditions. These PPCS were reviewed at a workshop between the permit development team within SiteChar, members of the SiteChar regulatory advisory board and invited regulators from the UK and France. These PPCs might be considered as high-level performance targets. They describe the evidence required to demonstrate that target has been met. In some storage scenarios, a PPC dealing with adverse environmental or health effects due to the operation would be necessary, primarily in onshore storage sites.

Table 2: Permit Performance Conditions as proposed in the Blake Field permit applications

<table>
<thead>
<tr>
<th>PPC</th>
<th>Description</th>
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<tbody>
<tr>
<td>PPC1</td>
<td>Environmental or human health will not be adversely affected by the storage operation</td>
</tr>
<tr>
<td>PPC2</td>
<td>CO₂ will not pass beyond the Storage Permit Area boundaries</td>
</tr>
<tr>
<td>PPC3</td>
<td>CO₂ plume shows migration within expected modelled behaviour</td>
</tr>
<tr>
<td>PPC4</td>
<td>Pressure changes will remain within predefined/predicted ranges</td>
</tr>
<tr>
<td>PPC5</td>
<td>Geomechanical integrity of site will be maintained</td>
</tr>
<tr>
<td>PPC6</td>
<td>Cost per tonne will remain within a set limit</td>
</tr>
</tbody>
</table>

2.4. Post-injection period

The permit must include a provisional post-closure plan. These were considered outside the scope of SiteChar and have therefore not been developed for either of the permit applications. However several points have been identified that will require addressing during site characterisation and permit development. It is worth noting that operators are likely to seek confirmation as part of the licence agreement that if the site performs as expected then both the operator and CA can have confidence that the responsibility of the site will be taken back by the CA. Although monitoring costs have been estimated as being approximately 5% of the total cost of the UK site and therefore costs associated with the pre-transfer period may be considered incremental, uncertainty in the duration of the pre-transfer period may be a barrier to final investment decisions. It will therefore be very important to establish, prior to injection, what evidence might be needed to demonstrate appropriate past, current and expected future performance, to enable site closure and abandonment and to give confidence to investors that transfer of responsibility will occur. Key metrics that would be used to demonstrate site performance have been proposed for the Blake Field and are listed in Table 2.

Current regulations assume that when a permit is relinquished the site would be closed and infrastructure removed. However, for sites with large storage capacities such as the Captain Sandstone, the lesar (i.e., the Crown Estate in the UK) may wish to extend the field life beyond the current permit term and encourage transfer or extension of the permit to other operators. In these circumstances, the CA might wish to consider how best to approach the post-closure plan to ensure future costs for storage at the site can be reduced without compromising
short or long-term safety and containment. Mothballing of infrastructure, for short periods at least, might be considered, although costs of platform and pipeline maintenance in the offshore would need to be included in the assessment.

As part of the discussions between operator and CA, the degree of flexibility that might be envisaged in the permit might be discussed. The Blake permit describes a single project that has been clearly defined. However, there might be legitimate circumstances when the operation must be altered. There are numerous credible scenarios which may result in a requirement to alter the permit conditions and these should be fully explored between operator and CA. These might include changes resulting from the actions of others: for example, additional hydrocarbon production or CO$_2$ storage might change pressures resulting in changes to storage capacities); experience from the initial injection may require updates to static models, and hence changes to predictions of longer-term performance; changes to commercial arrangements requiring changes to injection rates (up or down) or even changes in target storage reservoirs.

3. Conclusions

A preliminary assessment of risks has defined the site characterisation activities on which the permit application is founded. It should be noted that there remain some key gaps in the applications due to lack of resources and limited scope of the research project. Important limitations have included a lack of data on CO$_2$ relative permeabilities, detailed correlations between well logs and seismic data and an understanding of fault properties.

The permit application, as part of the dry-run exercise, has identified further characterisation that would be needed to ensure a full application could be made for each site, which would be carried out under the terms of an exploration licence. This reveals a slight limitation in the dry-run process undertaken in SiteChar, relative to the expected process undertaken during a full site investigation. In SiteChar, it is assumed that the dry-runs develop storage permit applications for the injection of CO$_2$, rather than a preceding exploration licence.

It is anticipated that an injection test would be needed, which would be expected in a full permit application to include a detailed plan of the injection tests to be carried out, their objectives and anticipated proof of injectivity, reservoir connectivity and pressure response. However, it is not clear if operators would be willing to drill and core new appraisal wells in order to secure a storage permit, possibly preferring to undertake indirect assessment of existing or newly acquired seismic, assumed to be less costly, before a permit is obtained. Currently at least, indications suggest that final investment decisions seem to require that permits are in place first.

Site characterisation at the Blake Field took approximately 27 months within SiteChar, though this benefited from previous studies undertaken prior to the start of this study. From the two dry-run permit applications undertaken here we can estimate that characterisation might take up to 200 person-months of effort and could take 2-5 years to complete. The time taken would depend on the extent and quality of data already available to the operator.

The Blake permit application considered the need to actively manage the reservoir pressure by producing water from a production well. At the Blake Field, geomechanical analysis was used to provide evidence that without formation water production, injection would lead to pressures exceeding fracture pressures and, importantly, that with water production, fracture pressures would not be exceeded. A consistent approach to defining acceptable reservoir pressures should be developed and should take into account site-specific risks. Acceptable reservoir pressures might be defined according to different criteria in onshore and offshore sites. For example, ground movement may be a higher risk onshore due to possible greater consequences than offshore and may therefore play a more important role in limiting reservoir pressures.

Assessments of plume migration and reservoir pressure responses following the end of injection were undertaken. At Blake, simulations were extended for 1000 years. However the absolute durations are less relevant than the criteria for determining the duration of the simulations. In both cases simulations were extended until the predictions indicated that the plume and reservoir pressures were either reaching equilibrium or that their continued evolution demonstrates that a steady state of permanent storage was likely to be achieved.

Both permits assumed that the post-injection period will be for 20 years, although the predictions of performance undertaken here indicate that both sites, injecting relatively small volumes into large-capacity stores, will rapidly achieve a steady-state, with limited further plume movement, after a few tens of years. For the UK, regulations
suggest that the pre-transfer period might be reviewed for each case and it may be interesting to see if UK regulators would be willing to accept a shorter post-injection monitoring period for the Blake Field.

At Blake no assessment was made of other potential storage in the area. Whilst an operator is not required to undertake further appraisal in such cases, there may be good reasons why commercial arrangements might be made between operators and authorities to extend site characterization to deeper (or shallower) horizons for the benefit of encouraging further storage in these areas. Furthermore, regulators might also wish to consider the impacts of storage projects at shallower depths that may make deeper storage more challenging in the future (through increased drilling costs and additional leakage liabilities for the second operator from storage by the first would need to be included in feasibility assessments).

Furthermore, it is interesting to note that potentially good storage capacity might not to be exploited in the proposed storage solution, as it is considered necessary to use this for secondary containment, as indicated in the Guidance Documents published in support of the Storage Directive. This indirect consequence of the regulatory requirements may have a possible impact by reducing storage capacity in the area. Again, in areas of high demand for storage, it may be more efficient and less costly to exploit all storage reservoirs in a stacked sequence in an optimum way. Regulators might wish to consider the feasibility of this when assessing storage permit applications.

Reasonably detailed risk assessments have been undertaken. However each risk was treated in isolation. In reality there are often strong interdependencies between risks. Scenario development within the risk assessment could be further utilised to identify when and where safeguarding and corrective measures, including targeted monitoring, could be applied. This would greatly help to strengthen the corrective measures plan since a workflow for each significant irregularity could be developed, with appropriate trigger events (parameter thresholds or incidents) along the scenario to reduce the risks and correct appropriately. The ‘bow-tie’ approach is one conceptual approach to this.

The definition of Permit Performance Conditions (PPCs) allows development of a set of a priori agreed criteria which will demonstrate appropriate site performance. PPCs are not explicitly required by the Directive but are considered as useful tools for discussion between the CA and operator. PPCs should include a range of metrics against which site performance can be measured, both during the operational and closure phases, providing a basis for the design of the geological monitoring program and the corrective measures plan. Whilst it might be relatively straightforward to define qualitative indicators, PPCs will need to be defined quantitatively for them to be the most effective.

The monitoring plan includes the need for a monitoring well. The monitoring well is placed at an appropriate distance from the injection well, on the path of likely plume migration to allow monitoring of pressure response, plume migration and fluid chemistry, microseismic monitoring and detailed reservoir imaging.

Risks to the operations of other users were included in the Blake Field assessment although the conditions under which the permit might need to be reviewed should also be included in a full permit application. An additional Permit Performance Condition, or at least a qualifier to relevant PPCs, might be needed to take into account the risk that external actions, beyond the storage operators’ control, may require the permit conditions to be reviewed and if necessary changed. Conditions under which permits might need to be reviewed include:

- Third party access
- New operations or interactions with other users which lead to a change in the pressure response within the permit holder’s storage complex.

4. Recommendations for storage permit development

Focused and risk-based site characterisation. Storage operations require site characterisation activities that are fit for purpose and focused on reducing uncertainty and risk for the specific storage project. Site characterisation should be driven by risk and uncertainty assessment, aiming to anticipate, reduce and mitigate risks and identify objectives for subsequent storage performance monitoring.

Storage complex definition. In our experience, the definition of the storage complex can be quite challenging. It is an important element of the storage permit since its boundaries define the leased volume for exploration and will ultimately also define CO₂ leakage, considered to be migration of CO₂ beyond the storage complex. Its definition
will require consideration of plume migration, pressure response and management, as well as the locations of necessary monitoring. In some cases, including the pressure footprint would require impractically large storage permit areas, since pressure responses can extend far beyond the injected CO₂ plume. In addition there is little consensus on the thresholds or consequences above which effects should be included. In this context we recommend, at least for offshore sites, to define the complex storage by the maximum extent of plume, including CO₂-saturated formation water, plus a margin to enable monitoring to reflect inherent uncertainty in predictions.

Demonstrating permanent safe storage. Establishing agreement during the permit process of the level of evidence required to demonstrate permanent safe containment will be a significant aspect of site characterisation. In addition to successfully obtaining a permit to store, this agreement will also enable the transfer of the site to the State at the end of the project. Both operators and Competent Authorities will need certainty on the metrics by which site performance will be assessed and by which safe, permanent containment will be demonstrated. Definition of acceptance criteria is key to determine the level of required evidence to gain a storage permit, allowing both operator and regulator to demonstrate safe performance, and providing a basis for the design of the geological monitoring program. Behaviour outside these conditions may be considered as significant irregularities and are likely to trigger corrective measures. A number of metrics were developed for both permit applications that enabled acceptable site performance to be defined and monitored. These “Permit Performance Conditions” (PPCs) are likely to be a combination of qualitative and quantitative metrics and could be a useful basis for discussion between the Competent Authority and operator. Importantly however, where performance has been demonstrated to be acceptable (as defined by such PPCs), there should be greater confidence between applicant and Competent Authority that transfer of responsibility for the site will be granted.

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