Long Term Stewardship: Releasing Residual Liability

By Brad Handler, Siddhant Kulkarni and Lindene Patton

In a carbon geological storage project, the final phase is referred to as Long Term Stewardship (LTS). It follows the Post Injection and Site Care (PISC) phase, i.e., after the injection well has been plugged, the developer has monitored the subsurface for any CO_2 leaks for the prescribed period, and the site has been "closed."

By the LTS phase, the risks of leakage of CO_2 are believed to be significantly lower than during or just after injection (this is discussed more thoroughly in the *Operational Risk Mitigation* paper). Yet, given that the CO_2 is supposed to remain stored for hundreds if not thousands of years, obligations remain. And in the very unlikely event of a CO_2 release, there needs to be a responsible party/body to handle remediation. With the project developer having been responsible for the CCS project for over fifty years, and with revenue streams associated with the project having ended decades earlier, it is reasonable to consider when the developer can "walk away" from the project. Said differently, it is plausible that developers would be deterred from engaging in CCS at all if their liability is indefinite[1].

Hence, a risk management framework that relieves the developer of liability during the LTS phase has been envisioned and, to varying degrees, enacted in eight U.S. states and in Europe. All such frameworks have as a prerequisite that the developer has performed its responsibilities throughout the preceding phases. In effect this means that the storage site will have behaved as expected for decades or else the operator will have remediated any operational shortcomings (leaks) to the satisfaction of regulators.

The frameworks also include that the developer will have funded a "Geological Storage Trust" (Trust) to be put toward the costs of ongoing monitoring as well as remediation and liability (if this is assumed by the jurisdiction's government) if there is environmental damage. This Trust is to provide a significant layer of protection against government (or taxpayers') exposure.

As opposed to the current patchwork of LTS solutions in the U.S., a nation-wide program can be considered. The benefits for developers of such a framework could include (1) broader geographic coverage; (2) more consistent and comprehensive assumption of liability; and (3) the presumed financial efficiency/risk diversification of having one larger Trust that can allow lower funding requirements vis-à-vis smaller ones.

The eight state risk management frameworks have coalesced around charging a "tipping fee" of $0.07-0.10 per ton of stored CO_2 to fund their respective Trusts. The rationale behind the

[1] One might imagine that this is true for various types of developers. For established, publicly traded companies with plans for multiple (perhaps network/hub) developments, the build-up of potential liability over time could potentially rise to a level of materiality in investor opinion. For new-to-the-world entities that are particularly dependent on project financing, having an eventual exit, including liability release, may be critical to obtain such financing.

funding requirements in state frameworks is not generally articulated. However, that tipping fee appears consistent with independent analysis of "residual" risks (i.e., those remaining at the LTS phase).

It is also worth noting that even a sub-$0.10/ton tipping fee would generate substantial funds in the Trust for government use once it assumes responsibility. To illustrate, the 154 projects at some stage of development in the U.S. (which admittedly are unlikely to all become operational) have nameplate CO_2 storage capacity of 330 million tons per year. A $0.07/ton tipping fee would generate $23 Million per year, or nearly $700 Million over 30 years of injection operations and over $900 Million over 30 years assuming the tipping fees are invested and earn a 2% compound interest rate.

This paper is organized as follows. First it describes key elements in a risk management framework, i.e. what needs to be included should government assume responsibility for management and liability of a geological storage site post site closure. It then considers the contention that such a transfer can create moral hazard for project developers. Next, it describes related individual state legislation, and then discusses adequate tipping fees. The paper closes with a brief review of previous national risk management framework legislation that helps inform consideration of a CCS LTS model.

This paper is an installment in a series that has thus far included separate papers on *Operational Risk Mitigation*, *Community Infrastructure Risk Mitigation*, and *Financial Risk Mitigation*. The next and final paper in the series will conclude and reflect on ways forward for CCS geological storage development.

THE CONTOURS OF A NATIONAL LTS RISK MANAGEMENT FRAMEWORK

Any framework that is to assume the responsibilities and liabilities of CCS projects in the LTS phase must have three elements.

First, creation of an entity. This entity is to accept title to and responsibilities of the site during the LTS phase[2]. This entity would be liable in the event of damages claimed due to leakage from any of the storage sites in its holdings (unless resulting from something that is legislatively excluded as is described in point 3 below).

Second, creation of a Trust. This Trust is to fund the activities of the entity, including ongoing monitoring of leaks, remediating any damages and paying for any associated liability in the

[2] Mindful of the moral hazard that such a liability "handoff" can create for other government actors, it was envisioned that this entity could be involved with the project as early as possible to give them stakes and more incentive to minimize risks. In other words, the entity could take on the role currently performed by the Environmental Protection Agency (EPA) or the state agencies (where states have been given primacy), including overseeing design and management, approving siting, mediating operational/permitting disputes, certifying certain completion milestones, etc. The entity would retain such oversight responsibilities through injection/operations and post site closure. With that said, the frameworks legislated by the states have not included that such entities be involved with CCS projects until the handoff at the end of the PISC phase.

event of a leak. Academics and others have recommended that the Trust amount be flexible and responsive to the latest assessments of (leakage) risk for the projects; it was assumed that operating experience would help inform such estimates. Consideration was given to the idea that maximum levels would be determined on a project-by-project basis.

Third, delineation (by the legislature) of conditions for and the extent of liability assumption. Legislation would allow the transfer of long-term liability to the regulatory entity. The legislation is to include conditions for that transfer, including defining under what circumstances the CCS operator remains accountable for damages and remediation costs. Those circumstances could include, for example:

- cases of negligence
- provision of erroneous information to regulators
- violation of law during the operating periods

Legislation would also establish what happens if expenses to remediate damages from leakage exceed those pooled in the Trust. As is noted above, the Trust's tipping fees collected across a significant number of storage projects would pool large sums, suggesting that any damages can likely be fully paid for out of the Trust. Having the developer remain responsible for costs in excess of the Trust's funds would therefore help address concerns (which we argue are exaggerated) regarding Moral hazard at very little risk to the developer (see below for more on this topic). Yet it would compromise the liability relief that can be helpful to catalyzing more project development.

A national LTS framework has the potential to improve upon the state frameworks that have emerged to date. As is described in detail below, state action thus far has yielded an inconsistent patchwork. The states are assuming monitoring responsibilities, and most (but not all) have also taken on liability, albeit to varying degrees. A national framework, however, offers the potential to significantly expand geographic coverage relative to what has been enacted thus far and create a comprehensive solution on liability coverage.

Further, there is a presumed financial efficiency to having one Trust rather than several. The theory of Risk Mutualization states that when risks are all combined into one large pool, they become more stable and predictable due to the diversification effect. The impact of any single risk incident is reduced, and they tend to converge toward an expected value or average. Moreover, the operating and administrative costs of managing a single pool should be lower than the cost of managing several smaller pools (although one can envision local administration of responsibilities, including monitoring).

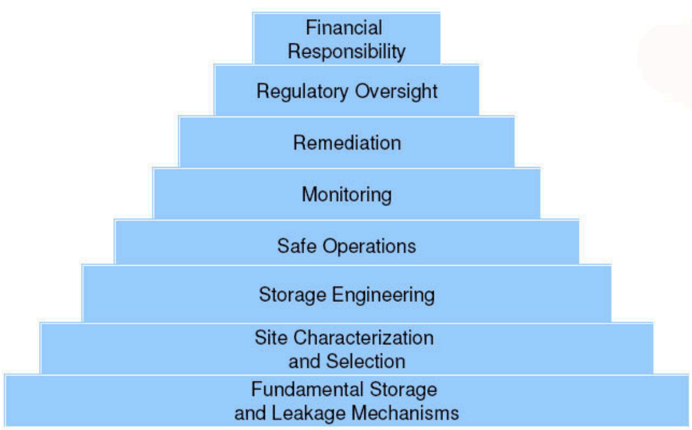
Notably, UK and EU CCS policy includes provisions for national-level liability assumption during the LTS phase of CCS projects, although the UK has not passed legislation (see Appendix II).

ADDRESSING MORAL HAZARD

Consideration of transferring liability raised concern regarding the moral hazard this can create for developers/operators. In other words, analysis of a LTS risk management framework included consideration that if a developer knows it will be relieved of liability at some point, it may do less to ensure it takes the steps through the operating phases of a CCS project to minimize the risks of leakage over the very long term.

Resolution of moral hazard concerns lies in making the requirements during the operating phases of a CCS project (which as noted last several decades) stringent enough to prevent any opportunity to "cut corners." The set of requirements is intended to combine to form a "storage security pyramid" (see Exhibit 1). The components of this pyramid have been incorporated into the EPA's Class VI well regulations (physical and financial). These regulations, as discussed in the *Operations Risk Management* and *Financial Risk Management* papers, include rigorous subsurface evaluation prior to approval, ongoing monitoring during and after injection, appropriate site closure practices, and financial assurance to fund site closure and remediation of environmental damage[3].

Exhibit 1: The "Storage Security Pyramid"



Source: Sally Benson, Stanford

U.S. STATE LEGISLATION TO DATE

Several U.S. states have taken it on themselves to assume CCS project responsibility and liability during the LTS phase. These states have also set up dedicated Trusts, funded by so-called

[3] Analysis of moral hazard in CCS included the supposition that if CCS were to scale enough to be a meaningful contributor to atmospheric CO2 reduction it would involve trade-offs in terms of site selection. In other words, eventually, the U.S. would consider sites for geological storage that were less good than those chosen in earlier projects.

"tipping fees" charged on a $/ton stored basis, to help manage and monitor the storage sites. Each state's actions are described below and are summarized in Exhibit 2.

- **Illinois**: The legislation in Illinois is very narrow. It states that long-term liability can only be transferred to the state if the project is part of the FutureGen initiative; FutureGen aimed to demonstrate the feasibility of clean coal technology through CCS. However, with the termination of FutureGen in 2015, this legislation is now outdated. Recent legislation, passed in June 2024, does not include any provisions for transferring long-term liability to the state, but has set up a CO_2 Administrative Fund to help all CCS operators with post injection monitoring and management. It is funded by operators at $0.31/ton if they have a Project Labor Agreement, which covers all terms and conditions of employment on a specific project and includes provisions that establish the minimum wage and other benefits of the laborers and provisions that prevent them from engaging in strikes. Operators without a Project Labor Agreement are assessed a fee of $0.62/ton.
- **Indiana**: The state can take on liability 10 years after documentation of cessation of injection and project completion has been provided. It has also set up a Trust to help the government undertake long-term management and monitoring of the site using a tipping fee of $0.08/ton of CO_2 sequestered.
- **Kansas**: The state is not responsible for any liability. Its framework does include a CO_2 Injection Well and Underground Storage Trust, funded by the operators at $0.05/ton, to aid with long-term monitoring and post injection activities.
- **Louisiana:** Liability can be transferred over to the state 10 years after injection has ceased, but the extent of the liability is capped at the amount available in the state's Geologic Storage Trust Fund. This Trust is funded by developers (amount not specified) and also covers the state's expenses to carry out long-term management and monitoring activities.
- **Montana**: The state will assume long-term liability of the stored CO_2 30 years after injection operations have ceased, but this is a two-step process. First, the operator must obtain a certificate of completion by demonstrating no CO_2 leakage for 15 years. Then, after an additional 15-year period, the liability can be officially transferred to the state. The state has set up a geologic storage Trust, funded through tipping fees (the fee varies by project), to be used for carrying out the state's responsibility to monitor and manage storage reservoirs. However, MT also requires the CCS operator to provide financial assurances to cover the anticipated monitoring costs for the storage site for at least 30 years after the transfer of liability to the state. The legislation notes that the state can enter into cooperative agreements with other government entities to regulate CCS projects that extend beyond MT's regulatory authority.
- **North Dakota**: ND can assume liability from the developer/operator 10 years after cessation of injection but requires the operator to provide documentation of project completion and proof of well integrity. If the operator cannot demonstrate the CO_2 reservoir has mechanical integrity, the state can still assume ownership of the storage facility but not the liability. The state will charge operators a $0.07/ton tipping fee, for at least 10 years during injection, to fund a Storage Trust, which the state can then use for long-term management and monitoring of the sites.

- **Texas Onshore**: TX can assume full liability of the project immediately after injection has ceased. The state has also set up the Anthropogenic CO_2 Storage Trust Fund to help with the long-term management and monitoring of the site. The Trust Fund is to be funded by the operator at $0.1/ton of CO_2 sequestered.
- **Wyoming**: Long-term liability can be transferred to WY 20 years after injection has ceased. State liability, however, is capped at the balance of the geologic sequestration Trust set up by the state. This Trust is funded by the operators using a tipping fee of $0.07/ton; the Trust also covers the expenses of the management and monitoring of the site.

Exhibit 2: Summary of State Liability Assumption Legislation

State	Liability and When State Will Assume	Storage Fund	Storage Fund Tipping Fee ($/ metric ton)	CO_2 Ownership	Pore Space[4]	Class VI Primacy*
IL	No provision for transfer of liability	Carbon Dioxide Storage Administrative Fund	Project Labor Agreement- $0.62 W/o PLA- $0.31		Granted to the owner of surface land	No
IN	Unlimited liability can be transferred to state 10 years after injection cessation and certificate		$0.08			No
KS	State not responsible for any liability	Carbon Dioxide Injection Well and Underground Storage Fund	$0.05			No
LA	Liability transferred to the state 10 years after injection cessation but capped at the state's carbon dioxide geologic trust fund balance. Operator liable for remaining	Geologic Storage Trust Fund		Some cases state some cases operator		Yes
MT	Unlimited liability can be transferred to state 30 years after injection has ceased and certificate	Geologic Storage Reservoir Program Account	Project-specific	Operator	Granted to the owner of the surface land	No
ND	Unlimited liability can be transferred to state 10 years after injection has ceased and certificate	Long term monitoring fund + fund for admin expenses	$0.07	Operator	Granted to the owner of the surface land	Yes
TX Onshore	Liability transferred to state after injection has ceased	Anthropogenic Carbon Dioxide Storage Trust Fund	$0.10	Operator		No
WY	Liability transferred to state 20 years after injection has ceased but is capped at balance of geologic sequestration special revenue account	Geologic Sequestration Special Revenue Account	$0.07	Operator	Granted to the owner of the surface land	Yes

Source: State Government reports

**Class VI Primacy: State's authority granted by the EPA to issue Class VI well permits*

DETERMINING THE TIPPING FEE

Each state's rationale for their tipping fee is not clear to the authors of this paper. Yet a more general assessment of storage project risk during LTS appears to support the "consensus" choice of a sub-$0.10/ton tipping fee.

That conclusion is based on risk assessments undertaken to establish Financial Assurance (FA) requirements (see the *Financial Risk Mitigation* paper for more on FA). Such assessments consider risks throughout the operating lifecycle of the storage project, i.e. the Injection and Post Injection Site Care (PISC) phases, identifying specific events that would result in leakage. The assessments then estimate probability of occurrence of each event and cost to remediate. A Monte Carlo simulation analysis then derives an expected value (i.e., cost) of remediating leakage at each project, as well as a distribution of probability and resulting cost outcomes.

Many of the risks that are assessed in this process would no longer be present during LTS (i.e., the risks related to leakage through "active" injection or monitoring wells), while some of the remaining risks are believed to be lower during LTS than they were during operations (for more on this see the *Operational Risk Mitigation* paper). With these caveats, a review of such a FA assessment can prove instructive in considering LTS risk and Trust requirements.

As an illustration, the [FA analysis for ADM's Class VI permit application, Wells #5-7], can be considered. The analysis identified 13 risks, along with annual probability of occurrence (see Exhibit 3) and cost to remediate (see Exhibit 4)[4]. Through a Monte Carlo simulation (100,000 runs), the expected value on this risk-weighted basis over the operational phases for these wells was determined to be $5.5 Million, or $0.14/ton of expected stored CO_2. This per ton expected value happens to be consistent with other studies[5].

Exhibit 3: ADM CCS Wells 5-7, Estimated Probability of Risk Events

Risk Event	**Annual Frequency of Failure (Single Item)**	
	Low Estimate	**High Estimate**
Pipeline Rupture	0.004700%	0.590000%
Pipeline Puncture	0.009400%	1.200000%
Wellhead Equipment Failure	0.001000%	0.003000%
Upward rapid leakage through Installed well	0.000100%	0.001000%
Upward slow leakage through Installed well	0.000100%	0.001000%
Upward rapid leakage through deep transecting wells	0.000100%	0.100000%
Upward slow leakage through deep transecting wells	0.000100%	0.100000%
Leaks due to undocumented deep wells, high rate	0.001000%	0.100000%
Leaks due to undocumented deep wells, low rate	0.001000%	0.100000%
Upward rapid leakage through caprock	0.000000%	0.000000%
Upward slow leakage through caprock	0.0030%	0.005000%
Release through existing faults	0.0000%	0.000003%
Release through induced faults	0.0000%	0.000003%

Source: EPA (Petrotek analysis)

[4] Where cost data/estimates were believed to be unreliable because of lack of occurrence historically, a 100x multiplier was assumed between the low and high cost estimates for conservatism.

[5] An example of another such study is the FutureGen 1.0 CCS project in Jewett, TX., performed by Industrial Economics in 2012, which yielded an expected value of $0.15/ton.

Exhibit 4: ADM CCS Wells 5-7, Estimated Costs to Remediate Risk Events

Risk Event	Event Event Description Cost Estimates		
	Low	Most Likely	High
Pipeline Rupture	$1,000	$515,000	$3,950,000
Pipeline Puncture	$0	$4,500	$302,000
Wellhead Equipment Failure	$2,000	$25,000	$725,000
Upward rapid leakage through Installed well	$150,000	$1,253,000	$11,750,000
Upward slow leakage through Installed well	$150,000	$260,000	$1,828,000
Upward rapid leakage through deep transecting wells	$150,000	$1,220,000	$12,200,000
Upward slow leakage through deep transecting wells	$150,000	$228,000	$2,280,000
Leaks due to undocumented deep wells, high rate	$865,000	$2,120,000	$14,700,000
Leaks due to undocumented deep wells, low rate	$766,000	$1,130,000	$4,780,000
Upward rapid leakage through caprock	$3,310,000	$7,940,000	$49,600,000
Upward slow leakage through caprock	$333,000	$799,000	$4,990,000
Release through existing faults	$331,000	$3,310,000	$33,100,000
Release through induced faults	$331,000	$3,310,000	$33,100,000

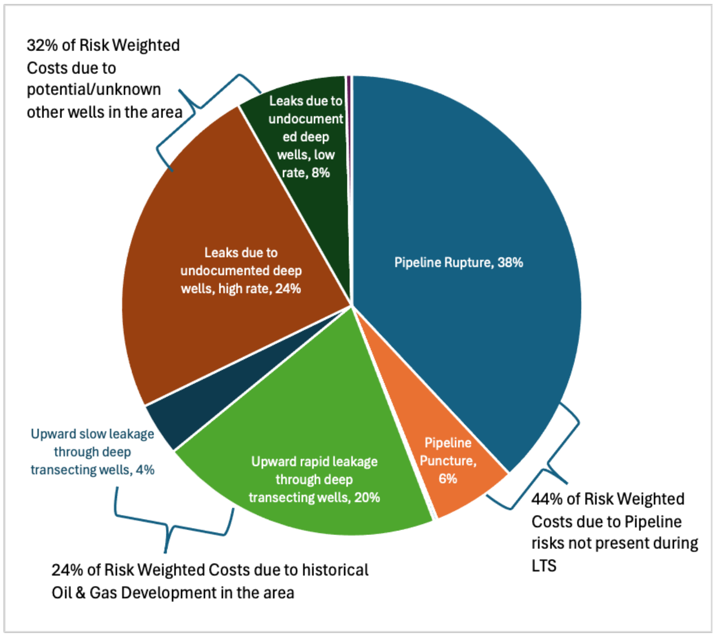
Source: EPA (Petrotek analysis)

Yet, again, this reflects an expected value of cost through the operational phases and some of these sources of risk would be expected to no longer be relevant during LTS; most prominently, 44% of the probability-weighted annual cost (using the high-cost estimates) were the result of pipeline-related events (see Exhibit 5)[6].

Replicating the Monte Carlo analysis for the risks that are still present during the LTS phase, as well as considering how those risks will have declined given the decline in pressure in the storage area through the years following injection, is outside the scope of this paper. Nevertheless, this example appears to support that the expected value of remediating a risk event for this project during LTS phase is (well) below $0.10/ton. Therefore, it is supportive of the tipping fees stipulated by most of the state legislatures, even when such fees are also intended to fund ongoing monitoring.

[6] Also noteworthy is that a further 32% of risk-weighted annual cost is derived from allowanced for undocumented wells in the area, a function of legacy oil & gas activity. This risk would not be expected to be present in this form across projects generally.

Exhibit 5: ADM CCS Wells 5-7, Breakdown of Probability-Weighted Costs to Remediate Risk Events



Source: EPA (Petrotek analysis), Payne Institute

HISTORICAL MODELS & LEARNINGS

Risk management frameworks, in which the government assumes financial liability, have had a long history in the U.S. and frameworks for LTS risk management drew on lessons learned from past legislation. Several of these frameworks include some commonalities, including pooling funds into a Trust from participating operators/projects and use of a tipping fee to fund that Trust. Further, the frameworks include that the government will assume liabilities that exceed the funds in the Trust if necessary. Any one example of past legislation is imperfect, in terms of its fit and scalability to geological storage LTS, but portions are instructive. Lessons to be learned from past programs include (and see Appendix I for more detail on specific legislation):

- Avoiding moral hazard requires operators to have meaningful financial liability throughout periods in which they are operating facilities (Price Andersen Act).
- The interests of actors involved with permitting must be aligned with those responsible for managing long-term liabilities. Policies that are too lenient/forgiving, or in the CCS case are insufficiently stringent in terms of site selection or operations management, can lead to excessive liability/underfunded Trusts (National Flood Insurance Act).
- It is important to regularly review estimates of loss potential and probability of loss. This allows for updating of funding requirements (e.g., adjustment of tipping fees on active projects) to avoid under- (or over-) funding the Trust. In the same vein, funding requirements for the Trust cannot be allowed to end, or "sunset", independently of the evaluation that the Trust is adequately funded (Oil Pollution Act).

Appendix I – Historical Risk Management Frameworks and Lessons for CCS

Models	Description	Experience/ Relevance to CCS Model
Price Anderson Act	Tiered risk program to limit nuclear operators' liability. The tiers: operator <$450 million; industry pooled funds $450MM to $13.6 Billion; federal government >$13.6B Industry pool funds raised through a "tipping fee"	Tipping fee can be applied to CCS -- operators fund pool through tipping fee per ton of CO2 sequestered. Federal Government to provide support in case expenses exceed fund balance
National Flood Insurance Act	Creates a pool for insurers to provide flood coverage to property owners & assume a portion of liability for claims. Funded through premiums paid by insurers. NFI Board has authority to borrow from Treasury to cover shortfalls.	Pool has proven to be underfunded; shows the importance of reviewing requirements regularly and being able to adjust tipping fees as necessary
Oil Pollution Act	Pool of funds to cover oil removal and oil spill damages. Funded through per barrel tax, cost recoveries from liable parties. Requires tank vessel owners/operators to establish and maintain evidence of financial responsibility sufficient to meet maximum probable discharge liabilities.	Requires operators to meet certain pre-requisites before government can take over liability (Financial responsibility, Closure obligations) Liability Provisions: Federal government has the power to adjust liability limits for responsible parties depending on vessel size and negligence. Artificial sunset provisions that render risk management tools underfunded show the importance of continuation of funding (especially for covering losses & liabilities)
Trans-Alaska Pipeline Authorization Act	Non-profit risk pool to facilitate delivery of North Slope oil to domestic markets via pipeline. Funded by a per-barrel fee on transported oil, to pay claims up to a statutory maximum cap. Government steps in for amounts exceeding the cap. Set a liability cap but allowed it to be waived if the operator was proven negligent, allowing injured parties to pursue full damages.	Operator to remain liable for damages, if caused due to negligence To combat artificial funding/liability caps like during the Exxon Valdez spill, loss estimations should be frequently updated as and when new data comes in.

Appendix II - LTS Solution Considerations in UK And EU

Long term stewardship consideration in the UK has been contemplated for over a decade, with groundwork laid through the [Storage of Carbon Dioxide Regulations 2010 and 2011] laws. During the active injection phase, CO_2 liability lies with the project operator who holds the storage license and permit. Operator responsibilities include monitoring, reporting, corrective measures, and obligations relating to purchasing allowances in case of leakages. The operator is also responsible for sealing the storage site and removing injection facilities.

Regulations require this liability to eventually transfer to the state after site closure. That said, there is no current law that specifically addresses the liability transfer process. The Energy Act 2023 lays the groundwork for CCS storage networks but does not address long-term liability transfer.

UK regulation does include provisions that allow the state/entity to recover costs from the operator in case of some negligence or if there is a leakage after the site is transferred. The Storage of Carbon Dioxide Regulations state that the transfer of liabilities (including leakage liability) will not take place at least 20 years after the operations conclude.

In Europe, the EU CCS Directive has established a legal framework for the responsible development and operation of CCS projects, including governing the long-term liability transfer from operator to the government, which is mandatory. The Directive requires that after a storage site has been closed in accordance with the terms of its operating permit, a minimum period of years determined by each member state must elapse before the transfer of liability can take place. Generally, this period must be at least 20 years, unless the operator convinces the state otherwise. After the transfer of liability, this member state is responsible for all long-term monitoring and corrective measures of the project site.

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