THE GOVERNMENT'S MULTI-FACETED ROLE IN RESOLVING THE MAIN LEGAL ISSUES REGARDING CARBON CAPTURE AND SEQUESTRATION

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ABSTRACT

The legal issues that carbon capture and sequestration ("CCS") will bring are so wide and diverse that it makes the most sense to identify key issues that need to be addressed first. Specifically, permits, environmental impact assessments, liability, and property rights issues are of common importance and are priority areas to establish strong regulatory frameworks. It is important to ensure that each step requires a permit system with detailed standards in order for the government agency to be able to judge whether an authorization is appropriate. It is also necessary for the government to enforce environmental impact assessments while making evaluation items and evaluation methods as detailed and diverse as possible. With regard to the liability issue, it is desirable to clearly provide the relevant standards for liability and to have a liability system that effectively balances the interests of CCS operators and the government. Furthermore, a system for transferring liability to the government after a certain period of time needs to be adopted because it can contribute to public safety, both from the CCS operator and the government standpoint, and at the same time distribute the liability burden. In resolving the property rights issue, it is reasonable that the government's power of eminent domain be exercised at the federal level so that a unified institution can promote smooth CCS implementation. Therefore, the government will play a crucial role in many aspects of CCS implementation, such as through regulatory oversight and sharing liability associated with CCS.

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I. INTRODUCTION

This Article proposes to develop a thorough and well-designed legal and regulatory system in preparation for the introduction of carbon capture and sequestration ("CCS") technology, which is considered to be one of the key strategies in any greenhouse gas reduction portfolio.[1] Among a number of legal issues CCS may cause, this Article addresses four legal issues that are fundamentally important to individual countries and should be covered in any future systems: permit, environmental impact assessment, liability, and property rights issues. The legal issues regarding CCS are so wide and diverse that it is most effective to identify key priority issues that need to be addressed first. The four issues identified are also a suitable topic for comparing how the government should function efficiently in dealing with these main issues. This Article therefore explains what the four issues are and explores how to approach them in order to resolve various legal problems associated with each issue. The issue of permits and environmental impact assessments can be raised throughout the entire process of capture, transportation, and sequestration; and liability issues include compensation for leakage accidents and monitoring obligations for long-term storage. Regarding the property rights issue, this Article analyzes the strengths and weakness of each option on the issue of who will "own" the vast pore space required for CCS implementation. More importantly, CCS legislation which encompasses these legal issues should consider not only a smooth implementation of CCS projects for the timely introduction of this technology, but also the thorough preparation necessary for the potential risks of CCS technology. In other words, the precautionary principle and the polluter pays principle should be realized as firmly established principles in the area of international environmental law, but a flexible approach to these principles' interpretation and application is also needed in order for the implementation of CCS to be carried out safely and smoothly.

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1. Carbon dioxide is the most common cause of global warming and is produced most abundantly by power plants based on fossil fuels, accounting for about seventy percent of total emissions. Technology exists that directly captures and permanently isolates carbon dioxide from these emitting sources. This technology has attracted attention as a viable short-term strategy to combat the problem of climate change. This crucial strategy in the fight against global warming is termed carbon capture and sequestration ("CCS"). CCS technology is comprised of a series of processes in which CO_2 is captured from large-scale emitting sources, transported to a determined storage site, and then sequestered deep below the surface into pore space. *See* Stuart Haszeldine, *Geological Factors in Framing Legislation to Enable and Regulate Storage of Carbon Dioxide Deep in the Ground, in* THE CARBON CAPTURE AND STORAGE 7 (Ian Havercroft, Richard Macrory & Richard Stewart eds., 2011).

It is true that creating CCS legal and regulatory systems will be a difficult task because of the technology's unique features, such as interconnectedness between processes, technological complexity, long-term storage needs, and a wide range of impacts from the risk of leakage accidents. However, if this framework is well established and CCS technology is implemented on that basis, CCS technology will be able to fulfill its role as a bridge technology in the transitional period between the fossil fuel and renewable energy eras.[2]

II. FIRST ISSUE: THE GOVERNMENT'S ROLE IN PERMIT SYSTEMS

A relationship between the government and CCS business operators in which the government can play a diverse role with regard to CCS activities is important. For example, the government can conduct CCS-relevant activities, support CCS operators by providing a favorable business environment, and surveil operators' activities. Each government role is important, but it is essential for the government to play a strong role in regulating and surveilling CCS businesses.[3] In creating a legal and regulatory system, the government needs to establish strict permit systems encompassing each phase of the CCS process: capture, transportation, and sequestration.

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2. CCS opponents argue that the adoption of CCS technology, which acknowledges the dependence on fossil fuel energy sources, is not suited for the ideal goal for the development of renewable energy. They are concerned that CCS technology might be a barrier to the development of renewable energy. *See* Mark A. Latham, *The BP Deepwater Horizon*: *A Cautionary Tale for CCS, Hydrofracking, Geoengineering and Other Emerging Technologies with Environmental and Human Health Risks*, 36 WM. & MARY ENVTL. L. & POL'Y REV. 31, 77–79 (2011); EMILY ROCHON ET AL., FALSE HOPE: WHY CARBON CAPTURE AND STORAGE WON'T SAVE THE CLIMATE 37 (Jo Kuper ed., 2008); Philip J. Vergragt, Nils Markusson & Hanrik Karlsson, *Carbon Capture and Storage, Bio-energy with Carbon Capture and Storage, and the Escape from the Fossil-fuel Lock-in*, 21 GLOBAL ENVTL. CHANGE 2 (2011). However, CCS technology should not be used as a reason to justify the continuous use of fossil fuel energy sources alone. In other words, CCS technology has to be deployed along with renewable energy development and play an important role as a temporary solution connecting fossil fuel and renewable energy for the time being (likely the next few decades). *See* Schalk Cloete, *Why We Need CCS – Part 5: Bridge to a Sustainable Energy Future*, ENERGY CENT. (July 22, 2014), http://theenergycollective.com/schalk-cloete/437046/why-we-need-ccs-part-5-bridge-sustainable-energy-future; David Hone, *A Clear Explanation of Why We Need Carbon Capture and Storage*, ENERGY CENT. (Sept. 24, 2013), http://theenergycollective.com/davidhone/278546/clear-explanation-why-we-need-carbon-capture-and-storage.

3. Meanwhile, in South Korea, whether the government can function as a CCS operator is an important research question. *See* Sookyun Wang, *A Proposal for Regulating the Geological Sequestration of Carbon Dioxide*, 45 J. GEOLOGICAL SOC'Y KOR. 574 (2009). This situation calls for a careful approach in order to prevent the government from undermining its regulatory role.

A. PERMIT SYSTEMS IN THE CAPTURE PROCESS

First, in the capture process, there is a question of whether mandatory construction of a carbon dioxide capturing facility is reasonable or not. CCS technology will likely first be applied to fossil fuel electricity plants, steel companies, and cement manufacturers. However, these large carbon dioxide emitters are unlikely to voluntarily install carbon dioxide capture facilities because of the high costs.[4] When it comes to the importance of timely adoption and implementation of CCS technology as a bridge technology, there is a need for a mandatory installation to some degree.[5] Unlike the mandatory establishment applied to newly built power plants, the forced establishment for existing power plants can be problematic, which leads to potential violations of the principle of protection of confidence or the principle of estoppel.[6] Additionally, the mandatory system has its own disadvantage of preventing the regulated entity from exercising the right to choose carbon dioxide mitigation options.[7] Furthermore, there is a possibility that legal obligations may be a barrier in implementing CCS within the international Clean Development Mechanism ("CDM") framework.[8] For these reasons, the regulatory issue of mandatory installation of capture facilities needs to be addressed carefully while having these concerns in mind and also considering various technical and economic circumstances. The Clean Power Plan in the United States, for example, also takes this careful attitude in that it does not include provisions that mandate the application of CCS technology.[9]

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4. *See* JongYeong Lee, *Study on the EU CCS Directive*, 14 CHUNG-ANG L. REV. 11 (2012). In other words, without the obligation of mandatory installation of capture facilities, the concern of low participation in the CCS industry can arise.

5. For example, legislation and policies that mandate capture facility installation to new power plants over a certain scale have been proposed in some countries, such as the United States and Germany. German CCS legislation imposes the obligation to install facilities on new electricity generation plants larger than the scale of 300 megawatts. *See* JongYeong Lee et al., *German Act on the Capture and Storage of Carbon Dioxide*, 16 EUR. CONST. 339, 353 (2014).

6. *See* SoonJa Lee, *Legal Issues Related to Carbon Dioxide Capture and Storage – Focusing on Carbon Dioxide Capture*, 37 ENVTL. L. RES. 249, 279 (2015).

7. *See* Michael I. Jeffery, *Carbon Capture and Storage: Wishful Thinking or a Meaningful Part of the Climate Change Solution*, 27 PACE ENVTL. L. REV. 421, 466 (2010).

8. In order for a business to be approved as a CDM project, the business must have additional benefits. This concept is called additionality, which requires that a CDM project not fall within a particular set of legal obligations. *See* SEUNGHO HAN, CLEAN DEVELOPMENT MECHANISM, AN INNOVATIVE TOOL FOR COMBATING CLIMATE CHANGE UNDER THE UNFCCC 100 (2010).

9. The Clean Power Plan is based on section 111(d) of the Clean Air Act and aims to reduce carbon dioxide emissions from the electricity sector. Although the EPA regulations do not mandate the introduction of CCS technology to comply with this standard, the EPA finds that CCS technology is the best system of emission reduction ("BSER") in the case of new coal-fired power plants. *See Fact Sheet: Overview of the Clean Power Plan*, ENVTL. PROTECTION AGENCY, https://archive.epa.gov/epa/cleanpowerplan/fact-sheet-overview-clean-power-plan html (last updated May

Another regulatory issue in a capture process is the elements that should be included under the capture permit system.[10] For example, whether the operators have enough sites for installation and whether the captured carbon dioxide stream includes any impurities can be important regulatory standards. Since capture facilities require a certain degree of space, the government needs to make sure that operators secure enough room when issuing a capture permit. Additionally, it is likely that a carbon dioxide stream has other chemical substances (SO_2, NO, H_2S, H_2, CO, CH_4, N_2, Ar, O_2, etc.) represented during the capturing process.[11] Since these impurities can be a cause of erosion of relevant facilities, which lead to a physical leakage of the carbon dioxide stream, the regulation of impurities or purities is necessary.[12] Requiring no impurities included in the process is ideal, but overly strict standards can create a cost burden on operators. Therefore, a careful approach in determining reasonable purity standards is also needed.

B. PERMIT SYSTEMS IN THE TRANSPORTATION PROCESS

When it comes to the transportation of carbon dioxide, a permit system which provides installation and operation-relevant standards is necessary.[13] In the case of newly established pipelines for carbon dioxide transportation,

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9, 2017). However, the EPA proposed to repeal the Clean Power Plan in 2017 and issued the proposed Affordable Clean Energy Rule in 2018. *See Electric Utility Generating Unites: Repealing the Clean Power Plan: Proposal*, ENVTL. PROTECTION AGENCY, https://www.epa.gov/stationary-sources-air-pollution/electric-utility-generating-units-repealing-clean-power-plan-0 (last updated Nov. 28, 2018).

10. This permit system enables the government to identify, regulate, and control carbon dioxide emitters and relevant facilities. *See* BARRY BARTON, KIMBERLEY JORDAN & GREG SEVERINSEN, CARBON CAPTURE AND STORAGE: DESIGNING THE LEGAL AND REGULATORY FRAMEWORK FOR NEW ZEALAND 110 (2013). Therefore, if it is necessary, the government can cancel the permit or impose administrative penalties.

11. Among impurities, H_2S is categorized among toxic and corrosive substances. *See* Filip Neele et al., *Toolbox of Effects of CO_2 Impurities on CO_2 Transport and Storage Systems*, 114 ENERGY PROCEDIA 6536, 6539 (2017).

12. For example, Japan has very strict standards on impurity regulations, which require more than ninety-nine percent purity of the carbon dioxide stream in CCS implementation. The kinds of purity- and impurity-relevant standards vary depending on the technical development. Therefore, there is an opinion that these technical elements need to be reflected in determining the level of purity and impurity regulations. Additionally, this possibility of variation and flexibility can also bring a legal and regulatory issue of delegation in which specific criteria are provided in subordinate legislation. *See* BARTON ET AL., *supra* note 10, at 111.

13. With regard to the need for pipeline permits, there exists an opposing view saying that they are unnecessary and that pipeline-relevant activities are allowed by the achievement of a sequestration-relevant permit, under the preference for a single permit. *See id.* Another example of the single-permit approach is that obtaining an injection permit even enables permit obtainers to do exploration-relevant activities. However, this concept has been criticized and the phased permit concept is preferable. *See id.* This is because each phase's characteristics and risks are different, and the difference brings the need for independent regulatory systems.

the transportation permit needs to propose specific criteria to ensure pipeline safety. For instance, the regulatory system can include standards regarding components used for installation, diameter, length, and depth of pipelines.[14] Due to the need for maintaining carbon dioxide stream purity, regulations on purity can be required in the transportation phase as well.[15] On the other hand, along with the facility and operation standards which fall under pipeline operators' obligations, it is also necessary for a regulatory regime to address pipeline operators' rights. For example, provisions or regulatory policies on rates and access need to be included under the transportation permit system.[16] A flexible and effective regulatory regime for addressing these issues can encourage the carbon dioxide pipeline industry and contribute to CCS facilitation.

Meanwhile, the interconnected nature of CCS systems requires a transportation phase, and this transportation system may need a long-distance pipeline network based on an analysis of geological or economic factors. For this reason, a careful approach is needed in creating a legal and regulatory system for the transportation phase. When installing carbon dioxide pipelines for CCS deployment, siting inevitably has to be conducted, and issues relevant to eminent domain can be associated with this pipeline siting. The siting can be a complicated problem, which involves many landowners and stakeholders, and it needs to be resolved in an effective way.[17] Additionally, unlike the capture process that happens in a limited area where carbon dioxide emitters are located, the transportation of carbon dioxide can be associated with many jurisdictions. Furthermore, if ocean sequestration is implicated, the applicable area is expanded to the ocean, which then even requires pipeline facilities linking land and the ocean. This complexity of applicable areas can lead to a difficult problem in determining the appropriate governmental unit to control the transportation phase of CCS.[18] Clarity regarding government

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14. *See* Joris Koornneef et al., *Quantitative Risk Assessment of CO_2 Transport by Pipelines – A Review of Uncertainties and Their Impacts*, 177 J. HAZARDOUS MATERIALS 12, 20–23 (2010).

15. *See* Jennifer Skougard Horne, *Getting from Here to There: Devising an Optimal Regulatory Model for CO_2 Transport in a New Carbon Capture and Sequestration Industry*, 30 J. LAND RESOURCES & ENVTL. L. 357, 372 (2010).

16. The rate issue is about determining transportation service price that pipeline operators can charge. Additionally, the access concept concerns pipeline owners' allowance of their transportation capacity to others. *See id.* at 371.

17. *See id*. at 373. For example, Germany has a regulatory regime in which transportation-relevant permit issuance entails the right of eminent domain. Under the article 4(5) of the Germen CCS legislation, the permit issuance of the pipeline installation plan empowers eminent domain of relevant estates for installing CCS pipelines. *See* JongYeong Lee et al., *supra* note 5, at 359.

18. *See* SooBin Bae, A Study on the Legislative System of Carbon Dioxide Capture and Storage (February 2012) (unpublished thesis, Korea Maritime and Ocean University) (on file with author).

jurisdiction is required, especially in the transportation system, and connection between relevant jurisdictions is also necessary if there are multiple jurisdictions.[19] Moreover, considering the nature of the transportation phase and involvement of various stakeholders (operators, landowners, regulators, etc.), the regulatory system needs to provide the stakeholders with procedural opportunities to voice concerns and provide input.[20]

C. PERMIT SYSTEMS IN THE SEQUESTRATION PROCESS

In the storage phase of carbon management, a more detailed and thorough legal and regulatory system has to be established since the permanent sequestration of carbon dioxide is a new, and still scientifically uncertain, concept. It is essential to propose a strong permitting system which helps regulate a series of processes within the sequestration process, such as exploration, injection, storage, and closure. The preferable regulatory approach shown from the developed countries or recommended by the International Energy Agency ("IEA") is a detailed and step-by-step permit system within the area of sequestration. This attitude can enable the government to look for the unique risk of each step and to control relevant activities with detailed regulations in order for CCS risks to be prevented.

The first permit required is the exploration permit or license.[21] This permit is necessary because exploring appropriate sites for storing carbon dioxide permanently needs to be conducted by experts with high technical skills since indiscriminate exploration causes a risk of underground contamination. Once an exploration permit is issued, permit holders have to act within the boundary of the permit authority, which defines the permit holders' rights and obligations.[22]

Second, a permit regarding injecting and storing carbon dioxide is required as a main regulatory regime in the sequestration phase. This injection

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19. Too many government agencies' involvement can slow CCS deployment. *See* Horne, *supra* note 15, at 373.

20. The German CCS legislation implemented this kind of system. *See* InSung Cho, *Legislative Measures to Improve the Social Acceptance of the Commercialization of Carbon Capture and Storage (CCS) – Focused on the Discussion in Japan, the USA, and Germany*, 17 EUR. CONST. 713, 740 (2015).

21. The task of exploring geologically appropriate sequestration sites is required for sequestering carbon dioxide permanently. This process is essential to guarantee CCS safety as a technical and scientific element. Sequestration of carbon dioxide in inappropriate sites due to erroneous exploration may lead to not only a waste of CCS costs but also environmental threats.

22. Additionally, in a legal and regulatory system that adopts an exploration permit system, exploration permit-holders should be granted priority for the right to achieve an injection permit. For example, the exploration permit retainer can be given the exclusive right to explore the possible sites in the allowed area, and the exploration activities have to be performed within a limited timeframe.

permit is necessary to regulate overall injection activities with stringent requirements, and risk assessment has to be conducted as a prerequisite to obtain this permit.[23] The strong and detailed requirements under injection permits need to provide technical standards associated with installation and operation of injection wells. For example, criteria regarding volume, pressure, and mobility of injected substances must be included with the injection permit; and the maximum and minimum requirements of each criterion as well as standards guaranteeing a sufficient geological storage site need to be included as well.[24] Additionally, for a thorough system of injection permits, permit requirements also need to include sufficient evidence of the applicant company's financial ability to satisfy these technical requirements and obligations of testing and monitoring.[25]

Third, for the step of closing storage sites after ceasing operation, a separate permit, called a closure permit, is required.[26] Significantly, the closure permit can be issued only when an operator proves that any risk of leakage is not detected or foreseen and that the government approves of the operator's proof. The main regulatory system at the closure phase is about operators' periodical monitoring obligations. When the government determines that the sequestration site is safe enough for closure through the results of periodical monitoring, the closure permit will finally be issued. Many countries require a certain monitoring period spanning ten to fifty years in order to apply for a closure permit.[27] The closure permit has meaning in that it can exempt operators from burdensome obligations, such as liability for damages caused by leakage accidents as well as future monitoring duties.[28]

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23. Sequestering carbon dioxide permanently deep underground is newly tried technology, and it is difficult to predict potential risks. For this reason, risk assessment is significant in CCS implementation. The risk assessment needs to be submitted in each phase: exploration, injection, and closure. Additionally, it is necessary to conduct risk assessment in the capture and transportation process as well as sequestration process.

24. *See* Thomas A. Campbell, Robert A. James & Julie Hutchings, *Carbon Capture and Storage Project Development: An Overview of Property Rights Acquisition, Permitting, and Operational Liability Issues*, 38 TEX. ENVTL. L.J. 169, 179 (2008) (providing an overview of the requirements that the UIC Class VI regulation provides in detail).

25. Monitoring a sequestered carbon dioxide stream's movement and detecting possible leakages are important for securing CCS safety, and monitoring needs to be conducted continuously even after CCS operation. Therefore, a long-term monitoring plan and records of these operators' obligations are required.

26. Site closure for CCS means to close down filled space after injecting carbon dioxide, not to shut down an empty space after mining. Therefore, specific standards regarding sequestration site closure are necessary.

27. In the U.S., there is an obligation of Post-Injection Site Care ("PISC") monitoring, which lasts for fifty years. 40 C.F.R. §146.93 (2019).

28. In this context, sequestration site closure is related to the issues of CCS liability and liability transfer to the government. *See* BARTON ET AL., *supra* note 10, at 124. These liability-relevant issues will be addressed below.

III. SECOND ISSUE: THE GOVERNMENT'S ROLE IN RISK ASSESSMENT

Risk assessment is necessarily required under the legal and regulatory permit system, and thorough risk assessment conducted in each permit process can help predict and prepare for possible risks that CCS may cause.[29] In order to apply main international environmental principles to CCS deployment, the risk assessment, which is based on the approach of the precautionary principle, needs to be emphasized.[30] Additionally, the CDM's incorporation of CCS will enhance the importance of risk assessment in that authorization of CDM projects, which then allows for credit issuance, requires risk assessment enforcement.[31] In these contexts, risk assessment is a key element for creating a CCS legal and regulatory system, and it is necessary for the government to come up with strengthened regulatory systems for risk assessment.

A. PHASE-TO-PHASE RISK ASSESSMENT SYSTEM

First of all, it is important to make sure that the risk assessment is enforced in each phase of CCS implementation – capture, transportation, and sequestration. Each phase of CCS has its own characteristics and inherent risks, as shown in the approach for the permit system.[32] For example, in the capture process, chemical substances like amine-based materials can be used, and this necessitates environmental assessment of the chemical substances.[33] Additionally, economic elements need to be considered as factors in the risk

29. The term "Environmental Risk Assessment" can be expressed differently in each country, using instead terminology such as Environmental Impact Assessment. Meanwhile, continued monitoring and verification are required even after risk assessment. This area is called risk management. As for the term to indicate a long-term CCS risk management, this Article uses the term "long-term stewardship."

30. The main purpose of risk assessment is to prevent or minimize possible harms by assessing the degree of harms as precisely as possible in advance. In addition, subsequent risk management can be conducted. Additionally, the risk assessment can be a useful tool to build up information or materials, which can be utilized as evaluation standards. It also can effectively contribute to a greenhouse-gas-relevant accounting system by providing quantitative evaluations. *See* BARTON ET AL., *supra* note 10, at 144.

31. *See* TaeSeob Choi et al., *Scheme on Environmental Risk Assessment and Management for Carbon Dioxide Sequestration in Sub-seabed Geological Structures in Korea*, 12 J. KOREAN SOC'Y FOR MARINE ENVTL. ENGINEERING 307, 312 (2009).

32. *See* Joris Koornneef et al., *The Environmental Impact and Risk Assessment of CO_2 Capture, Transport and Storage – An Evaluation of the Knowledge Base*, 4 ENERGY PROCEDIA 2293, 2295 (2011).

33. *See* AIDAN WHITFIELD, AN ENVIRONMENTAL RISK ASSESSMENT FOR CARBON CAPTURE AND STORAGE 13 (2011).

assessment in the transportation phase. And for the sequestration phase specifically, the risk assessment should analyze and evaluate health and safety hazards along with environmental effects of long-term storage of carbon dioxide, which takes place deep underground. As this is a new and developing technology, some long-term impacts may be hard to assess.[34] For this reason, in order to combat this uncertainty, there is an increased need to establish a strong risk assessment regime with stringent and detailed standards and comprehensive evaluation. Since each country already has legislation relevant to environmental risk assessment, it is necessary to review whether CCS risk assessment can be conducted in each phase under the existing risk assessment system.[35] If legal and regulatory gaps regarding risk assessment are found in a phase in the series (capture, transportation, and sequestration) and a certain step within a sequestration phase (such as exploration, injection, and closure), legislative or administrative agency efforts to fill the gaps will be needed.[36]

B. RISK ASSESSMENT ITEMS, RISK ASSESSMENT METHODS, AND PUBLIC PARTICIPATION

Additionally, determining which assessment items and methods will be utilized to evaluate CCS risks is significant. Depending on the assessment objectives and methods, the usefulness and effectiveness of risk assessment can vary. First, assessment objectives—the targets or items listed for evaluation—need to be examined exhaustively. In other words, possible areas which may be affected by CCS implementation need to be described in detail. For example, potential risks can include toxicity for humans, atmosphere, groundwater, land, ecosystem, and biodiversity as well as acidification.[37] Additionally, there has been a recent effort to incorporate evaluation standards

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34. According to an analysis from the IEA, it is expected that existing risk assessment systems can work on CCS-relevant facilities that are located above the ground. However, risk assessment for CCS-relevant facilities under the ground may require a new and different approach in CCS risk assessment. *See* BARTON ET AL., *supra* note 10, at 142.

35. *See id*. at 143.

36. For example, in New Zealand, two laws can be applied to risk assessment of CCS: the Resource Management Act ("RMA") and CCS-specific legislation. *See* BARTON ET AL., *supra* note 10, at 142. With regard to New Zealand's CCS risk assessment regime, the contents and requirements under these two laws are closely aligned, although the RMA requirements are more general while the CCS legislation is more specific. *See id.*

37. For additional investigation into CCS risk factors, the Vulnerability Evaluation Framework ("VEF") of the United States can be a useful example to systematically figure out the circumstances or conditions under which negative effects increase. *See* ENVTL. PROT. AGENCY, TECHNICAL SUPPORT DOCUMENT, VULNERABILITY EVALUATION FRAMEWORK FOR GEOLOGIC SEQUESTRATION OF CARBON DIOXIDE 2 (2008).

which are relevant to social and economic factors.[38] The social and economic elements are not only related to CCS deployment but are also independently important. Therefore, expanding evaluation criteria to these factors will make the CCS risk assessment system more complete and efficient.[39] Second, evaluation methods have to be designed in the direction of proposing various and valuable scenarios, predicting behaviors based on the scenarios, and estimating effects of the behaviors.[40] When it comes to the risk assessment methods, there may be different attitudes of emphasizing a quantitative risk assessment[41] over a qualitative one.[42] However, rather than stressing one evaluation method, both need to be utilized for a more effective and realistic risk assessment. In other words, if quantitative risk assessment is available, the quantitative risk assessment has to be considered.[43] On the other hand, there are many possible CCS risks that are difficult to evaluate quantitatively. In those cases, qualitative risk assessment methods need to be used.[44] Third, an important element to consider in a risk assessment system is to incorporate and reflect the public's opinions and attitudes on CCS deployment near

38. In other words, multi-criteria decision analysis is recommended. Additionally, along with the inclusion of social and economic elements, tradeoffs between socioeconomic factors and environmental impacts need to be assessed and reflected in a CCS risk assessment system.

39. *See* Hun Kang et al., *Research About the Management of CCS Control with Specific Consideration of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC)*, 12 KOREAN J. LCA 50 (2011); KyungHee Shin et al., *A Study on the Improvement Scheme of Environmental Impact Assessment in Social Environment*, 21 ENVTL. IMPACT ASSESSMENT 24 (2012).

40. *See* ENV'T AGENCY, REPORT NO. GEHO0411BTSN-E-E, ENVIRONMENTAL RISK ASSESSMENT FOR CARBON CAPTURE AND STORAGE 2011 8–9 (2011).

41. *See* Behdeen Oraee-Mirzamani et al., *Risk Assessment and Management Associated with CCS*, 37 ENERGY PROCEDIA 4757, 4757 (2013) (examining the ways probability and criticality can be calculated). From this point of view, risk analysis statistics from other fields, such as natural gas or enhanced oil recovery risks, can be referred to for quantification. Additionally, quantified analysis issued by the Occupational Safety and Health Administration ("OSHA") can be relevant. Computer simulation models can also be useful for calculating the CCS risks. *See* SALLY M. BENSON, CARBON DIOXIDE CAPTURE AND STORAGE IN UNDERGROUND GEOLOGIC FORMATIONS 4 (2006).

42. *See* Jose Condor et al., *A Comparative Analysis of Risk Assessment Methodologies for the Geologic Storage of Carbon Dioxide*, 4 ENERGY PROCEDIA 4036, 4036 (2011).

43. For example, the possibility of corrosiveness increases according to the carbon dioxide concentration. *See* HEESANG GWAK, KOREAN INST. OF SCI. AND TECH. INFO., QUANTITATIVE RISK ASSESSMENT OF CO_2 PIPELINES 5 (2011).

44. When it comes to assessing and analyzing CCS risks, arguments for a comprehensive risk assessment system are becoming more persuasive. This option emphasizes a full range of environmental impact assessments, including consumption of energy, and requires inclusion of indirect impacts as well as direct impacts. *See* SARAH M. FORBES & MICAH S. ZIEGLER, WORLD RES. INST., CARBON DIOXIDE CAPTURE AND STORAGE AND THE UNFCCC: RECOMMENDATIONS FOR ADDRESSING TECHNICAL ISSUES 13 (2010). For example, the European Union shows an improved system with various methods of assessment, such as comparative analysis between scenarios and alternative analysis between risk mitigation options, as well as an indirect environmental impact analysis. *Id.*

homes and other businesses.[45] This public participation is called risk communication, which makes the risk assessment regime of CCS more robust, while enhancing social acceptability of CCS technology.

A few experiences on risk assessment regarding CCS projects, such as FutureGen in the United States, Det Norske Veritas ("DNV") in Norway, and Gorgon in Australia, are useful comparison points since they show improved risk assessment systems with various and comprehensive tools for evaluating environmental effects from CCS implementation.[46] Under the precautionary principle, the government has to play a key role in making sure evaluation objectives and methods are appropriate for CCS risk assessment and in responding to the need for additional evaluation tools.

C. STRATEGIC RISK ASSESSMENT AND LONG-TERM MONITORING

Even in the times prior to and after CCS operation, the government can play a positive role in risk governance regarding CCS. For example, when the government establishes an overall national strategy for CCS and delineates the scope of CCS implementation, strategic risk assessment can be utilized.[47] Since the strategic risk assessment regarding CCS features an overall evaluation of the applicability of CCS technology, it can be helpful in site selection for CCS projects. On the other hand, more importantly, the government needs to provide long-term surveillance of safe sequestration of carbon dioxide even after a site closes as a part of risk management. This is also called long-term stewardship of CCS, which is primarily comprised of (1) continued monitoring of CCS-relevant risks, (2) verification, and (3) reporting of the monitoring results. The long-term monitoring is essential for CCS implementation since possible risks of leakage cannot be completely ruled out due to a change of geological strata or earthquakes, even though no problem is detected for a few decades. Specifically, in enforcing monitoring for

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45. *See* John S. Applegate, *A Beginning and Not an End in Itself: The Role of Risk Assessment in Environmental Decision-Making*, 63 U. CIN. L. REV. 1643, 1652 (1995).

46. In the United States, the National Energy Technology Laboratory ("NETL") has produced an Environmental Impact Statement ("EIS") regarding the FutureGen project. *See generally* U.S. DEP'T OF ENERGY, DOE/EIS-0460, FUTUREGEN 2.0 PROJECT: FINAL ENVIRONMENTAL IMPACT STATEMENT (2013). For more information on DNV reports, see *Carbon Capture, Utilization and Storage (CCUS): Enabling Enhanced Performance with Carbon Management Technologies*, DNVGL, https://www.dnvgl.com/services/carbon-capture-utilization-and-storage-ccus—5196 (last visited Feb. 26, 2019).

47. *See* STRACTO, SUPPORT TO REGULATORY ACTIVITIES FOR CARBON CAPTURE AND STORAGE: SYNTHESIS REPORT 118 (2009) [hereinafter STRACTO SYNTHESIS REPORT]; Koornneef et al., *supra* note 32, at 2297–98. The European Union has adopted the Strategic Environmental Assessment ("SEA"). STRACTO SYNTHESIS REPORT, *supra*. There are positive evaluations on the SEA because it contributes to the sustainable development concept by being carried out in the early stage of businesses prior to risk assessment from a careful and precautionary approach.

detecting long-term CCS risks, more technical development is important. Additionally, monitoring techniques need to be used flexibly because the technique that is applied to a CCS project can vary depending on the site characteristics and monitoring targets.[48] Furthermore, the question of how often the monitoring has to be enforced is also an important regulatory issue, which can be determined based on the regulatory scheme's flexibility.[49] The government needs to make sure that periodic monitoring is enforced. Additionally, the government needs to review the outcomes of the monitoring results and incorporate technical improvements into regulatory systems. Moreover, periodical disclosure of monitoring results is significant not only in risk assessment but also in risk management. Therefore, the government needs to make the monitoring consequences easily accessible to other CCS operators and the public. Along with public participation in risk assessment, information disclosure in risk assessment can also play a positive role for social acceptability of CCS.

IV. THIRD ISSUE: LIABILITY SYSTEMS FOR CCS

A. BACKGROUND AND REASONABLE DIRECTIONS

It is necessary to prevent and reduce the possibility of CCS risks, but CCS technology inevitably has a potential risk of leakage accidents as a new technology.[50] Therefore, a long-term liability and compensation regime is needed which would make the CCS legal framework more complete and induce operators or investors into participation in the CCS industry.[51] Currently, ambiguous and conflicting CCS liability systems still exist. This

48. In other words, determining monitoring methods needs to be flexible. BARTON ET AL., *supra* note 10, at 143. Geological formations are various and a monitoring tool which is suitable for one project may not be pertinent to another project. *See id.* Additionally, according to the criteria measured (e.g., measurable leakage, well integrity, injection pressure, and injection volume), different monitoring techniques can be applied to individual CCS projects. *See* FORBES & ZIEGLER, *supra* note 44, at 12.

49. For now, there is a lack of consensus on the proper period for monitoring. *See id.* at 11. The countries or states that provide CCS-relevant legislation show a wide variation on monitoring periods, starting at ten years and reaching to fifty years.

50. Specifically, there is a risk of leakage accidents in the long term, which comes with great liability. *See* Allan Ingelson et al., *Long-Term Liability for Carbon Capture and Storage in Depleted North American Oil and Gas Reservoirs – A Comparative Analysis*, 31 ENERGY L.J. 431, 467 (2010). When a leakage risk is perceived or a leakage accident happens, CCS operators have to take immediate measures to prevent the accident and minimize the negative effects. In case of an urgent situation of a carbon dioxide leakage accident, the government's role can be imperative by directing operators to take measures or taking responsive action itself.

51. *See* CCSREG PROJECT, CARBON CAPTURE AND SEQUESTRATION: FRAMING THE ISSUES FOR REGULATION 103 (2009) [hereinafter CCSREG REPORT].

means that a clearer interpretation and approach is required in the CCS liability context.[52] More importantly, the CCS liability issue is not a simple matter but a complicated task. In the event of a CCS leakage accident, many issues, such as who will be liable, who will actually be compensated, and how to determine the scope and extent of the damage will be raised in various ways. When it comes to making a decision regarding liability issues, alternative and complementary measures for a certain decision need to be taken together while having a multi-faceted and balanced approach.[53] It is true that operators have to be liable for leakage accidents, which is consistent with the polluter pays principle, one of the key principles of international environmental law.[54] However, considering the nature of long-term sequestration of carbon dioxide, it is necessary to transfer the liability to the government after a certain period of time.[55] This approach can be justified from the need for a somewhat loose interpretation on the polluter pays principle in the case of CCS technology and the importance of the government's role in responding to the climate change crisis.[56]

B. THE NEED FOR STRICT LIABILITY ADOPTION FOR CCS

First of all, it is necessary to review the liability regime itself before discussing the liability transfer. A variety of civil lawsuits, which are associated with operators' CCS activities in the processes of capture, transport, and sequestration, can be raised. For example, a trespass lawsuit can arise while building CCS pipelines. Additionally, when CCS operators cause physical or property damage, such as noise and vibration, persons who are damaged from the operators' activities during the installation and operation of CCS facilities can raise negligence or nuisance lawsuits.[57] There is no doubt that these kinds of lawsuits will be resolved through existing statutory and common-law

52. *See* FORBES & ZIEGLER, *supra* note 44, at 15.

53. For example, in the view that the operator is liable for compensating for the damage in case of a leakage accident, there are possible issues that arise: whether it is desirable to introduce an insurance system which is unique for CCS, whether this insurance should be compulsory for operators, how to determine the coverage scope, and so on. *See Zurich Unveils Carbon Capture and Storage Insurance*, ECOLOGIST (Mar. 1, 2009), https://theecologist.org/2009/mar/01/zurich-unveils-carbon-capture-and-storage-insurance. Moreover, there is a need for further discussion as to whether a more robust insurance structure in the form of reinsurance is necessary for CCS. *See* MARK ANTHONY DE FIGUEIREDO, THE LIABILITY OF CARBON DIOXIDE STORAGE 4 (2007).

54. *See* Jason Unger, *Time to Apply 'Polluter Pays' Principle*, ENVTL. LAW CENTRE (Nov. 8, 2010), http://elc.ab.ca/time-to-apply-polluter-pays-principle/.

55. *See* Paul Bailey et al., *Can Governments Ensure Adherence to the Polluter Pays Principle in the Long-Term CCS Liability Context?*, 12 SUSTAINABLE DEV. L. & POL'Y 46, 47 (2012).

56. *See id.* at 51.

57. *See* RICHARD MACRORY ET AL., UCL CARBON CAPTURE LEGAL PROGRAMME, LEGAL STATUS OF CO_2 – ENHANCED OIL RECOVERY 28–31 (2013).

rules.[58] However, damages may be difficult to prove, as well as the causal links between operators' breaches of care and leakage accidents in certain circumstances. For instance, when leakage accidents and damages from those accidents happen long after injection and operation, or when the plaintiff does not recognize harm due to a gradual leakage and brings a lawsuit very late, obtaining compensation will be difficult.[59] In order to prepare for these situations, there is a need for strict liability. However, there are also still opposing views on the adoption of strict liability for CCS liability regimes.[60]

The opponents of strict liability say that it is important to encourage development in the CCS industry and protect operators when creating a CCS liability regime. The opponents' concern is that adoption of strict liability may be a huge burden on CCS operators due to substantial liability costs.[61] Additionally, they argue sequestering carbon dioxide in depleted oil reservoirs or saline aquifers cannot fall under the abnormally dangerous activity standard required for a strict liability regime.[62] On the other hand, proponents for strict liability argue that the quantity and quality of risks that CCS implementation may cause can constitute an abnormally dangerous activity.[63] In addition, one opinion for strict liability points out that strict liability can relieve a court's burden or shortcomings.[64] From that perspective, strict liability is necessary because a fact finder's decision on whether operators exercise due diligence is no easy task and may differ depending on the characteristics of the sequestration sites.[65] There are no actual lawsuits yet regarding CCS leakage accidents, and the issue of strict liability adoption in a CCS liability

58. *See* BARTON ET AL., *supra* note 10, at 217–22.

59. *See id.* at 215; Jan Glazewski, *Legal and Regulatory Aspects of Carbon Capture and Storage: A Developed and Developing Country Perspective*, *in* CLIMATE CHANGE: INTERNATIONAL LAW AND GLOBAL GOVERNANCE 948 (Oliver C. Ruppel et al. eds., 2013); NKAEPE ETTEH, CARBON CAPTURE AND STORAGE: LIABILITY IMPLICATIONS 13 (2009).

60. Meanwhile, the liability transfer to the government needs to be distinguished from the concept of administrative liability. Administrative liability applies to government officers' own breaches of duty. *See* IAN HAVERCROFT & RICHARD MACRORY, GLOB. CARBON CAPTURE & STORAGE INST., LEGAL LIABILITY AND CARBON CAPTURE AND STORAGE: A COMPARATIVE PERSPECTIVE 25 (2014). On the other hand, the liability transfer to the government shifts the liability, which is supposed to be burdened on operators, to the government.

61. *See* Victor B. Flatt, *Paving the Legal Path for Carbon Sequestration from Coal*, 19 DUKE ENVTL. L. & POL'Y F. 211, 220, 224 (2009).

62. *See* Christopher Bidlack, *Regulating the Inevitable: Understanding the Legal Consequences of and Providing for the Regulation of the Geologic Sequestration of Carbon Dioxide*, 30 J. LAND RESOURCES & ENVTL. L. 199, 210 (2010).

63. *See* Nathan R. Hoffman, *The Feasibility of Applying Strict-Liability Principles to Carbon Capture and Storage*, 49 WASHBURN L.J. 527, 547 (2010).

64. *See id.* at 560–61.

65. *See* David E. Adelman & Ian J. Duncan, *The Limits of Liability in Promoting Safe Geologic Sequestration of CO_2*, 22 DUKE ENVTL. L. & POL'Y F. 1, 50 (2011); Hoffman, *supra* note 63, at 560–61.

framework will be determined according to each country's legal and regulatory circumstances. However, in the early stage of CCS implementation, which has fewer scientific certainties, a strict liability regime needs to be established, and it has been accepted in some countries, such as Germany.[66] Meanwhile, a liability cap under strict liability needs to be considered because too great of a cost burden on CCS operators and the negative effect on the industry are inconsistent with encouraging the industry to grow.[67]

C. THE NEED FOR LIABILITY TRANSFER TO THE GOVERNMENT

This subpart will discuss liability transfer to the government. It is a controversial issue, and there are differing opinions among countries and states within countries.[68] Critics who argue against the liability transfer to the government say that it is reasonable for CCS operators to assume the full liability and costs that they have caused under the polluter pays principle.[69] They also argue that the government's internalization of long-term liability or indemnification of the potential hazards associated with the CCS storage process provides less incentive to minimize risk.[70] Additionally, they point out that the government's assumption of liability may be an undue burden on the public.[71] On the other hand, supporting opinions for the liability transfer to the government say that because of the long-term nature of CCS, there is a high possibility that the operators will not be available to sue by the time liability arises, creating an unreasonable situation of not being able to receive compensation from operators.[72] In other words, they say that a liability shift to the government can fill this potential compensation gap. Additionally, they argue that the opponents' concerns can diminish when a reasonable time for

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66. *See German CCS legislation*, GLOB. CCS INST., https://hub.globalccsinstitute.com/publications/dedicated-ccs-legislation-current-and-proposed/german-ccs-legislation (last visited Mar. 31, 2019).

67. *See* Adam Gardner Rankin, *Geologic Sequestration of CO_2: How EPA's Proposal Falls Short*, 49 NAT. RESOURCES J. 883, 920 (2009). The CCS liability framework can have a broad spectrum. *See* CCSREG REPORT, *supra* note 51, at 105.

68. For example, the EU CCS Directive provides liability transfer to the government. *See* Directive 2009/31/EC of the European Parliament and of the Council 2009 O.J. (L 140/114) 56. On the other hand, Wyoming in the United States provides that liability transfer is not allowed. *See* MEGAN CLEVELAND, CARBON CAPTURE AND SEQUESTRATION, NATIONAL CONFERENCE OF STATE LEGISLATURES 5 (2017). Meanwhile, Montana provides that the liability is transferred to the government under some conditions. *See* HOLLY JAVEDAN, REGULATION FOR UNDERGROUND STORAGE OF CO_2 PASSED BY U.S. STATES 5 (2013).

69. *See* Bailey et al., *supra* note 55, at 51.

70. *See* Flatt, *supra* note 61, at 220.

71. *See* Larry Nettles & Mary Conner, *Carbon Dioxide Sequestration – Transportation, Storage, and Other Infrastructure Issues*, 4 TEX. J. OIL GAS & ENERGY L. 27, 48 (2008).

72. *See* BARTON ET AL., *supra* note 10, at 223.

liability transfer is established.[73] Finally, they assert that CCS implementation can be included in the concept of public use, similar to an eminent domain theory, rebutting the opponents' arguments.[74]

The liability transfer to the government is necessary for CCS legal and regulatory systems because the liability under CCS implementation will likely manifest after a far longer period of time than is expected in current environmental law regimes. The government's assumption of liability has more room to be justified since overcoming the climate change crisis is an important national-level task, which undoubtedly will affect future generations.[75] Therefore, the liability transfer to the government would be consistent with the polluter pays principle. Additionally, the government's liability under a CCS liability regime needs to be emphasized with regard to the CDM's incorporation of CCS.[76] According to the IEA's recommendations, CCS operators from the developed Annex I countries are obligated to assume the compensation liability from leakage accidents and monitoring obligations, and then all liabilities are transferred to the host country after the end of the monitoring period.[77] When the requirements of liability and the framework for liability transfer to the government are clearly defined in a domestic CCS liability system, they can also help prepare for transboundary liability problems, which can arise within the CDM.[78] Meanwhile, the timing of the liability shift to the government can vary. Generally, the liability of damage compensation can be transferred to the government, along with the monitoring obligation, after the monitoring period of ten to fifty years.[79] It is also

73. *See* INT'L ENERGY AGENCY, CARBON CAPTURE AND STORAGE: MODEL REGULATORY FRAMEWORK 100 (2010).

74. *See* Alexandra B. Klass & Elizabeth J. Wilson, *Climate Change, Carbon Sequestration, and Property Rights*, 2010 U. ILL. L. REV. 363, 428 (2010).

75. *See* EDITH BROWN WEISS, IN FAIRNESS TO FUTURE GENERATIONS: INTERNATIONAL LAW, COMMON PATRIMONY, AND INTERGENERATIONAL EQUITY 47 (Richard Falk ed., 1989); BUNWOONG KIM ET AL., ENVIRONMENTAL ADMINISTRATION 55 (2014).

76. *See* HyonJeong Noh et al., *Analysis of Modality and Procedures for CCS as CDM Projects and its Countermeasures*, 15 J. KOREAN SOC'Y FOR MARINE ENVTL. ENGINEERING 270 (2012).

77. *See* CÉDRIC PHILIBERT, JANE ELLIS & JACEK PODKANSKI, OECD/IEA, CARBON CAPTURE AND STORAGE IN THE CDM 26 (2007).

78. *Id.*

79. According to the World Resource Institute's recommendations, the contents of liability, which is transferred to the government, include compensation liability for damaged persons or entities from unexpected leakage accidents and monitoring liability as a part of long-term stewardship. Furthermore, the climate liability under the international trading scheme, such as credit issuance liability, is transferred to the government as well according to the recommendations. *See* FORBES & ZIEGLER, *supra* note 44, at 15. However, it is possible to take an approach or interpretation that these kinds of liabilities are not necessarily transferred together at the same time. Currently, it seems that liability provisions created at a domestic level do not clearly explain the contents or scope of the liability which is transferred to the government. Therefore, clear definition or interpretations

important to establish reasonable standards regarding the timeline for the liability transfer, which are calibrated to balance the interests of both CCS operators and the government. Additionally, when it comes to the methods of compensation under government liability, some alternatives should also be considered.[80] For example, industry-level funding is one option.[81] This schema would raise funds from CCS industry operators in advance in order to cover costs for compensating damages and for monitoring facilities installation.[82] This option can be more consistent with the polluter pays principle. Another option is government indemnification, which compensates CCS operators' liability using government funds.[83] Additionally, both options can be utilized together. Each country needs to adopt an appropriate method of liability implementation reflecting its own circumstances.

In conclusion, the government's role in setting up a CCS liability regime is important. The liability transfer to the government along with operators' strict liability provides a reasonable solution. By holding CCS operators stringently liable for the damages caused by CCS leakage accidents and transferring liability to the government after a certain period of time, the liability regime can be helpful and persuasive for both parties – CCS operators and the government.[84] Additionally, through this liability system, CCS operators can focus on preventing CCS risks due to the diminished liability burden within the ten- to fifty-year period, and the government would simultaneously have a strong interest in implementing a thorough regulatory regime due to potential liability in the future.[85]

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associated with the liability transfer are needed. *See* BARTON ET AL., *supra* note 10, at 226. Additionally, the government's role needs to be prescribed more in detail, which will make the CCS liability regime more complete.

80. *See* ENERGY POLICY INST., ANALYSIS OF LIABILITY REGIMES FOR CARBON CAPTURE AND SEQUESTRATION: A REVIEW FOR POLICYMAKERS 13 (2011).

81. Considering the possibility of any leakage or damage resulting from the CCS process in the long term, special funds or insurance schemes can be considered. However, insurers' decisions not to insure may reduce the willingness of some to invest in CCS technology. *See* KATE ROBERTSON ET AL., NAT'L ENERGY TECH. LAB., DOE/NETL-2006/1236, INTERNATIONAL CARBON CAPTURE AND STORAGE PROJECTS OVERCOMING LEGAL BARRIERS 14 (2006).

82. The Price Anderson Act provides an industry-level funding scheme in preparation for the complex liability issues that can arise in the phase of post operation. *See* Campbell et al., *supra* note 24, at 185.

83. For example, Germany requires CCS operators to deposit three percent of the allowances they obtain every year. *See* Moon Ji Rhee, *Legal and Regulatory Issues of CCS projects*, 36 ANAM L. REV. 696, 729 (2011).

84. In other words, harmonization is needed. Furthermore, consistent and concerted agreement regarding liability schemes across national jurisdictions will be more effective when preparing for worldwide operation and implementation of CCS. *See* HAVERCROFT & MACRORY, *supra* note 60, at 6.

85. A liability system needs to consider various factors, and a CCS liability system should be created on the basis of considering both the relationship between the injurer and victim, and the

V. FOURTH ISSUE: PORE SPACE OWNERSHIP REGARDING CCS

A. BASIC CONCEPT AND IMPORTANCE OF THE PORE SPACE OWNERSHIP

To achieve successful CCS implementation, including exploration for appropriate sites, pipeline construction, and injection facilities installation, it may be necessary to use or expropriate landowners' property and/or subsurface rights. Specifically, the long-term sequestration of carbon dioxide in areas of depleted oil and gas reservoirs or saline aquifer formations inevitably raises the questions of who the owner of the storage volume is in these reservoirs (referred to as "pore space") and how CCS operators can obtain the right to use that pore space from the potential owner.[86] This legal issue of large-volume pore space ownership is a new and controversial topic brought about by the novel aspects of CCS technology, and it needs to be resolved in the early stages of CCS activities.[87] Early resolution for this issue is essential because CCS operators can only make significant progress in their activities after the owner of the pore space is determined and the right to use the area is obtained from the landowners. Additionally, the pore space ownership issue is significant since successful and efficient CCS implementation often rests on how to deal with this issue.[88] Despite its importance, there is a lack

characteristics of CCS. Additionally, social and economic factors must be taken into account. *See* GUIDO CALABRESI, THE COSTS OF ACCIDENTS: A LEGAL AND ECONOMIC ANALYSIS 301–08 (1970) ("The fault system may have arisen in a world where one injurer and one victim were the most that society could handle adequately, and in such a world it probably was a fairly good mixed system. It did a good job of meeting our combination of goals: general and specific deterrence, spreading, justice, and even efficiency. But even assuming that such was the world in which the fault system grew, it is not today's world. Today accidents must be viewed not as incidental events linking one victim with one injurer, but as a more general societal problem.").

86. In other words, this Part is about property rights regarding pore space ownership. Meanwhile, as for the discussions which are associated with property in CCS legal and regulatory systems, other issues may exist, such as the ownership of carbon dioxide itself and on-land facilities during CCS implementation. These issues are not as contentious, and in such cases the property rights of carbon dioxide or infrastructures falls within the ownership of the operators concerned. This Part also does not address CCS intellectual property rights issues.

87. The legal issue of pore space is raised in onshore sequestration only. Offshore sequestration does not involve this issue since the pore space beneath the ocean is under state ownership or no ownership. Additionally, the use and expropriation of the pore space for the phase of long-term sequestration of carbon dioxide under the ground may cause complicated problems because the process requires an enormous pore space based on density and sweep efficiency. *See* Klass & Wilson, *supra* note 74, at 363.

88. Considering the importance of economic and social factors which were mentioned before, the establishment of a legal system, which includes methods to facilitate CCS implementation by reducing transaction costs and to enhance public acceptance of CCS by protecting private owners' interests, is needed. The legal regime for property rights has advanced along with the change of society and technological improvement. In this context, CCS technology requires a new perspective

of clear delineation regarding property rights of pore space at a state level as well as at a federal level. Moreover, the fact that each country or each state in a country is likely to take a different approach makes addressing this legal issue more difficult. The various options show that the pore space ownership can be granted to the surface owner, mineral owners, or the government. These options derive from each country's circumstances based on legislation or case law. Therefore, the next subpart will analyze the advantages and disadvantages of these options in order to find the most appropriate direction.

B. HISTORIC AND PRESENT CIRCUMSTANCES OF THE PORE SPACE OWNERSHIP ISSUE INCLUDING PRINCIPLES, CASES, AND LEGISLATION

In the United States, Wyoming, Montana, and North Dakota have state legislation regarding pore space ownership for carbon dioxide storage.[89] The state legislation provides that the surface landowners have the ownership of the pore space, which is the subsurface area below their land for this purpose.[90] No other states have any provisions which are relevant to subsurface ownership (even though they recognize this legal issue and a need for legislation).[91] The stance that subsurface ownership is granted to the surface owner is based on the Latin maxim *cujus est solum ejus est usque ad coelum et ad inferos* ("*ad coelum* doctrine"), and the common-law principle of "from heaven to hell," which is drawn from that maxim.[92] These concepts say that the landowner owns the space above and below the surface without limitation.[93] On the other hand, due to the recognition that the *ad coelum* doctrine

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and approach on an area which is considered useless from a property-law perspective. *See* Troy A. Rule, *Property Rights and Modern Energy*, 20 GEO. MASON L. REV. 803, 804, 831 (2013).

89. *See* JAVEDAN, *supra* note 68, at 8.

90. *See* Kenneth R. Richards et al., *Pouring Out Our Soils: Facing the Challenge of Poorly Defined Property Rights in Subsurface Pore Space for Carbon Capture and Storage*, J. ENERGY & ENVTL. L., Winter 2012, at 33, 33. The trend which supports a surface owner's ownership of the subsurface is gaining uniformity in the United States. *See* Mark A. Imbrogno, *Pipedream to Pipeline: Ownership of Kentucky's Subterranean Pore Space for Use in Carbon Capture and Sequestration*, 49 U. LOUISVILLE L. REV. 291, 309 (2010).

91. The CCS Review Panel of California also states that it is recommended to follow the stance shown in the three states that have adopted legislation. Richards et al., *supra* note 90, at 34.

92. *See* Barry Barton, *The Common Law of Subsurface Activity: General Principle and Current Problems*, *in* THE LAW OF ENERGY UNDERGROUND: UNDERSTANDING NEW DEVELOPMENTS IN SUBSURFACE PRODUCTION, TRANSMISSION, AND STORAGE 21, 22–23 (Donald N. Zillman et al. eds., 2014).

93. This maxim was first introduced by an Italian lawyer, Franciscus Accursius, in the thirteenth century and was later quoted by Lord Chief Justice Coke in the sixteenth century, but after that it virtually disappeared. In the eighteenth century, William Blackstone quoted this maxim again in his *Commentaries on the Laws of England*, and it subsequently influenced the common law in the United States. *See* Daniel H. Cole, *Property Creation by Regulation: Rights to Clean Air and Rights to Pollute*, *in* PROPERTY IN LAND AND OTHER RESOURCES 125, 132–33 (Daniel H. Cole &

is not an appropriate principle to apply to some underground resources, such as oil and gas, the rule of capture was adopted for oil and gas recovery. The rule of capture means that neighboring surface landowners generally cannot file a trespass lawsuit against operators for depleting an oil or gas reservoir.[94] Put another way, oil and gas operators have no liability to neighboring landowners as long as the physical equipment they use to extract the oil or gas does not intrude onto the neighbor's property, even though the developed resources flowed from the subsurface owned by those neighbors.[95]

Additionally, in the states with no provisions regarding pore space ownership, courts' decisions will be an important standard until legislative actions are taken. First, looking at the cases that have addressed ownership above the ground can be a useful analogy when dealing with the underground ownership associated with CCS. When it came to the ownership above the ground, the *ad coelum* doctrine originally applied. However, this changed with a 1946 U.S. Supreme Court decision.[96] In *Causby*, the Court held that the rights of the landowner could be restricted by analogizing the airspace to a public highway, which is discerned from the landowner's protectable property interest above the surface.[97] Second, cases associated with oil and gas development, including rights of the surface owner and developer, can give more direct insight into the ownership of pore space issues because CCS tech-

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Elinor Ostrom eds., 2012). It is noteworthy, however, that this was only a maxim of the Roman period, not actually Roman law. Rather, according to Roman law, a landowner did not necessarily control the space above and below the surface, and the atmosphere was regarded as an open-access commons or common property of all. Similarly, the maxim has never been the law in the United Kingdom. *See id.* at 134; STUART BANNER, WHO OWNS THE SKY?: THE STRUGGLE TO CONTROL AIRSPACE FROM THE WRIGHT BROTHERS ON 85 (2008).

94. *See* NIGEL BANKES, LEGAL ISSUES ASSOCIATED WITH THE ADOPTION OF COMMERCIAL SCALE CCS PROJECTS 8 (2008). At the time of early development of oil and gas in the U.S., neighboring landowners filed trespass lawsuits based on the *ad coelum* doctrine, since there was an ambiguity on where the oil and gas was extracted from and whose subsurface held these resources. In this context, the rule of capture principle is designed for a social need of encouraging oil and gas development and it is also a convenience principle.

95. This is expressed as a reverse rule of capture principle. *See id.* There is an opinion that when the reverse rule of capture principle is applied to CCS implementation, it will be a more efficient way of enabling CCS operators to obtain the right to use only from surface owners in whose land injection wells are constructed without the necessity of obtaining the right from all surface owners who have potential areas of carbon dioxide movement. *See id.* at 10; Christopher J. Miller, *Carbon Capture and Sequestration in Texas: Navigating the Legal Challenges Related to Pore Space Ownership*, 6 TEX. J. OIL GAS & ENERGY L. 399, 418 (2011).

96. United States v. Causby, 328 U.S. 256 (1946); *see* Klass & Wilson, *supra* note 74, at 387.

97. *See generally Causby*, 328 U.S. 256.

nology will be utilized most often in the area of depleted oil and gas reservoirs after development.[98] For example, Texas is a state that has many representative cases. Illustrative is *Getty Oil Co. v. Jones*,[99] where the Texas Supreme Court stated that the oil and gas developer could use the subsurface within the reasonable scope of a user, not as an owner, and the developer therefore could not unreasonably violate the rights of the surface owner. Similarly, in *Emeny v. United States*,[100] a federal court applying Texas law explicitly expressed that the ownership of pore space falls within the surface owner's right. Furthermore, the Texas Supreme Court later held in *Ball v. Dillard*[101] that while the surface owner is the owner of the subsurface, the owner should guarantee the developer's right to use the subsurface area within a necessary scope for oil and gas development, stating that the relation between the surface owner's rights and developer's rights is different but reciprocal.[102] To sum up, the main approach in Texas is that the ownership of the subsurface is granted to the surface owner, which is similar to the stance in other states.[103]

Meanwhile, the Civil Act of South Korea, including property law, has no explicit provision to grant subsurface ownership to any entity. Instead, article 212 of the Civil Act provides that "[w]ithin the scope, where a justifiable profit exists, the ownership of land extends both above and below its surface."[104] Therefore, depending on the interpretation of the word "justifiable profit," the pore space ownership can be determined.[105] In other words,

98. Specifically, in a case where both surface owners and developers exist, it is necessary to address the issue of pore space ownership carefully since both can claim the right. In Texas, there are court decisions which deal with the relation between landowners and developers in their disputes. Furthermore, some cases in Texas provide direct decisions on the ownership of pore space. *See infra* notes 99–101.

99. 470 S.W.2d 618 (Tex. 1971).

100. 412 F.2d 1319 (Ct. Cl. 1969).

101. 602 S.W.2d 521 (Tex. 1980).

102. *See* Miller, *supra* note 95, at 407. One view is that it is reasonable for a CCS operator to get an allowance from a developer as a user, as well as a surface owner, as owner of the subsurface when inferred from these Texas cases. *See* Campbell et al., *supra* note 24, at 174–75. However, another opinion argues that allowance only from the owner, regardless of the existence of land users, is enough for CCS operators since the first approach may cause a legal complexity, which could lead to a delay of CCS activities. *See* Will Reisinger et al., *Reconciling King Coal and Climate Change: A Regulatory Framework for Carbon Capture and Storage*, 11 VT. J. ENVTL. L. 1, 7, 35 (2009).

103. On the other hand, Canada takes a different attitude than the United States. In Canada, the ownership of pore space after the end of development is granted to the developer, not the surface owner. *See* BANKES, *supra* note 94, at 6.

104. Minbeob [Civil Act], Act No. 14965, Oct. 31, 2017, art. 212 (S. Kor.).

105. In South Korea, different interpretations are possible with regards to this article 212. One opinion says that the surface owner's ownership extends above and below the land unlimitedly, but exercising the right can be limited if necessary. *See* PanKi Kim, *A Study on Legal Policy About Use*

through the interpretation of this article, the surface owner's right either will or will not extend to the depth of the pore space.[106] The general attitude shared by scholars is that the standard of interpretation should be based on an ordinary person's best available use of the land,[107] and it is within this standard that the surface landowner's rights will be determined.[108] In South Korea, under the need for rapid underground development, there is a discussion that some areas, which would otherwise be assessed as valueless to the surface owner's interest in using the subsurface, can be exempted from the surface owner's private property right and be considered as part of the public domain.[109] Similar to the debates in legislative interpretation, the Supreme Court of South Korea has yet to provide a clear and uniform standard for determining pore space ownership. Additionally, regional courts' cases differ regarding the depth to which a surface owner's property right can extend below the surface.[110]

In sum, with regard to subsurface ownership, the existing legislative actions and cases at a state level in the United States say that the surface owner owns the subsurface. On the other hand, a clear attitude is not yet found in South Korea. Meanwhile, Australia resolves this legal issue of pore space ownership by granting it to the Crown, which is consistent with the approach recommended by the International Energy Agency. China also grants pore space ownership to the state.[111] However, even in the United States and South Korea, there is still a possibility of limiting private property rights of surface owners and acknowledging government ownership.

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and Ownership of Underground Space, 14 RES. L. & POL'Y 1789, 1801 (2014). On the other hand, another opinion says that this article 212 implies a limited ownership for the surface owner within a reasonable scope above and below the surface. *See* CHANGHO RYU, KOREA LEGISLATION RESEARCH INST., A LEGISLATIVE STUDY ON PERPENDICULAR SCOPE ON LANDOWNERSHIP 35 (2005).

106. *See* KwonHong Ryu, *Ownership of Underground Pore Hole – Focused on CCS Cases in America*, 67 DONG-A U. L. REV. 247, 265 (2015).

107. This concept means that "justifiable profit" must be objectively judged and that it does not take into account subjective circumstances, such as whether the landowner has the intention and ability to use that area. *See* RYU, *supra* note 105, at 42.

108. Therefore, it is more likely that the approach of dividing the ownership of subsurface area with a one-size-fits-all depth has less support and is not as consistent with legislative intent in South Korea. *See* Kim, *supra* note 105, at 1799.

109. However, there also exists criticism of the public concept of land ownership. *See* Young-Min Cha & YuJeong Kim, *The Scope of Effect of Landownership of Underground Space*, 20 RES. L. & POL'Y 521, 539 (2014).

110. *See id.* at 536.

111. Specifically, the Chinese constitution and the mineral resources law of China explicitly provide that the "mineral resources are owned by the State." *See* GLOB. ENERGY ASSESSMENT TOWARD A SUSTAINABLE FUTURE 1044 (2012). Moreover, in China, all natural resources, such as forests, mountains, and grassland, fall within state ownership. *See* DEBORAH SELIGSOHN ET AL., WORLD RES. INST., CCS IN CHINA: TOWARD AN ENVIRONMENTAL, HEALTH, AND SAFETY REGULATORY FRAMEWORK 17 (2010).

C. POSSIBLE OPTIONS FOR PORE SPACE OWNERSHIP AND ITS CONTENTS, EVALUATIONS, AND IMPLICATIONS

In order to implement CCS, underground areas for pipeline construction or enormous amounts of deep pore space for permanent sequestration are necessary, which requires CCS operators to obtain rights from the owners of these areas. CCS legal and regulatory systems not only serve to regulate CCS operators for preventing risks but also to facilitate the technology's implementation. Therefore, situations in which CCS operators' activities are delayed or disturbed from legal, regulatory, and economic barriers should be avoided when possible. From an alternate perspective, the value of a surface owner's property rights also needs to be protected, and if these rights are limited excessively, then CCS is less likely to gain broad social acceptance. So far, each of the three pore space ownership options has both advantages and disadvantages. Therefore, with the current circumstances, a reasonable direction will be to first analyze both sides of each option and, through the analysis, explore ways to minimize disadvantages. In this context, the important principle to keep in mind is that an effort should be made in order to strike a balance between conflicting interests from CCS operators and private landowners while considering economic and social factors.

The first option is the surface owner retaining ownership of the pore space. Under this approach, the *ad coelum* doctrine is maintained, and the private owner's property rights are protected.[112] However, this approach has a great shortcoming entailing high transaction costs, as a CCS operator must negotiate with all of the surface owners and achieve the right to use the subsurface from each of them.[113] This would make the CCS process very delayed and inefficient. Additionally, surface ownership of the pore space could cause a problem of holdouts, which means that CCS projects may have difficulty in progressing due to private owners' opposition or suspension of the negotiations with CCS operators.[114] For these reasons, it is necessary to suggest alternatives for overcoming such shortcomings.

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112. *See* JERRY R. FISH & ERIC L. MARTIN, CAL. CARBON CAPTURE & STORAGE REVIEW PANEL, TECHNICAL ADVISORY COMMITTEE REPORT: APPROACHES TO PORE SPACE RIGHTS 1–2 (2010).

113. *See id.* at 4. This inefficiency problem of requiring allowances from all potential landowners can be expressed as the "tragedy of the anticommons." *See* Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621, 670 (1998). The tragedy of the anticommons is the inverse of the tragedy of the commons explained by Hardin. While the tragedy of the commons points out the problem of environmental damages due to the excessive use of public resources, the tragedy of anticommons states that too many private rights may slow down resource development and cause valuable resources to go unused. *See* Richards et al., *supra* note 90, at 54; Rule, *supra* note 88, at 815.

114. *See* CCSREG REPORT, *supra* note 51, at 58.

The first method to curb transaction costs is for the government to exercise the power of eminent domain, which would enable CCS operators to obtain the subsurface rights for necessary sites for CCS implementation.[115] With regard to eminent domain, the Fifth Amendment to the U.S. Constitution would be applied, and CCS activities likely fall within the public use doctrine. CCS technology is a significant technology for combatting the climate change crisis, and this fact alone could allow governmental units to exercise eminent domain power. However, even though eminent domain can likely be rightfully exercised, the procedure of eminent domain and the process of setting standards for just compensation are convoluted, and the process may be accompanied with potential claims. In this context, the discussion on the need for proximity payment methods can be considered to reduce the time and cost, which enables efficient calculation of compensation.[116]

Another example to relieve the transaction cost problem is compulsory unitization, which enables unitization despite the objection of some surface owners.[117] Through this process, a quick negotiation that achieves results can be reached, even though each surface owner's interest can be restricted to some extent. To sum up, in a country which grants subsurface ownership to surface owners under the *ad coelum* doctrine, these alternatives to overcome the main drawback of high transaction costs need to be considered.

The second subsurface ownership option is public or government ownership, as opposed to the first option.[118] This option takes a similar approach

115. *See* Richards et al., *supra* note 90, at 56. Currently, eminent domain power is applied to the natural gas industry in the U.S. *See* Reisinger et al., *supra* note 102, at 35.

116. *See* Richards et al., *supra* note 90, at 60. For example, if the proximity payment is implemented at a state level, the state will require a CCS operator to submit expected areas to use and have the CCS operator make a dollar-per-acre payment to the surface owners. *See* COMM'N ON ENERGY & THE ENV'T, IND. UNIV. PUB. POL'Y INST., 11-C40, REPORT ON POLICY CHOICES AND OPTIONS 31 (2012).

117. *See* Bill Jeffery, *Carbon Capture and Storage: Promising Technology, but Many Legal Questions Remain*, *in* 29 ENERGY & MINERAL LAW INSTITUTE 1, 24 (2008). This compulsory unitization method is utilized in the oil and gas industry in the U.S. In most states producing oil and natural gas (except Texas), compulsory unitization laws have been adopted. According to these laws, if other potential unit members consent to constitute the unit with a sufficient percentage, it forces unwilling landowners to join the unit. The percentage can vary from state to state, ranging from fifty-one percent to eighty percent. *See* PAUL W. PARFOMAK, CONG. RESEARCH SERV., RL34601, COMMUNITY ACCEPTANCE OF CARBON CAPTURE AND SEQUESTRATION INFRASTRUCTURE: SITING CHALLENGES 15 (2008). There is an opinion that this method can be applied to CCS implementation as it is used for enhanced oil recovery. *See* MARIANNE HORINKO, AM. PUB. POWER ASS'N, CARBON CAPTURE AND SEQUESTRATION LEGAL AND ENVIRONMENTAL CHALLENGES AHEAD 3 (2007); PARFOMAK, *supra*, at 15 (stating that the "[o]il and gas industry experience with compulsory unitization is important in the CCS context because a similar unitization process will need to be developed").

118. *See* James Robert Zadick, Note, *The Public Pore Space: Enabling Carbon Capture and Sequestration by Reconceptualizing Subsurface Property Rights*, 36 WM. & MARY ENVTL. L. & POL'Y REV. 257, 260 (2011).

to the *Causby* case, in which the ownership of high-altitude airspace is regarded as part of the public realm.[119] The main advantage of this option is the facilitation of CCS development without the necessity of operators negotiating for contracts with all private landowners concerned.[120] However, some disadvantages also exist with this option. The first concern is that if the government declares that pore space for carbon dioxide sequestration is part of the public domain, and therefore may be utilized without compensation to the surface owner, it may bring out a claim that this violates the takings clause of the Fifth Amendment.[121] Another critique is that this option comes from purely administrative convenience. However, this public or government ownership option has an increasingly persuasive rationale, particularly if the property value for private landowners is less valuable than the public value of CCS as a key climate change mitigation option.[122]

The third approach represents a middle ground to find a compromise between both a surface owner's property rights and a CCS operator's business.[123] In other words, along with private pore space ownership for surface owners, this approach provides that the rights of surface owners can be limited when certain standards are met. The first standard relates to a qualitative element. For example, a CCS operator would be obliged to compensate surface owners who are also the owners of pore space only when surface owners' property value in the subsurface suffers from actual and substantial harm or the property is damaged from its ongoing economic use.[124] Another example under this standard is to limit surface owners' property rights only in cases when they have a reasonable and predictable interest regarding the use of the subsurface.[125] The second standard is to limit surface owners' rights with

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119. *See* Thomas R. Decesar, *An Evaluation of Eminent Domain and a National Carbon Capture and Geologic Sequestration Program: Redefining the Space Below*, 45 WAKE FOREST L. REV. 261, 282–83 (2010).

120. *See* Zadick, *supra* note 118, at 268, 291.

121. *See id.* at 277–78.

122. The proponents for public ownership of pore space state that CCS business can be facilitated by putting the management of pore space under the government. *See id.* at 260. Furthermore, under this approach, the specific discussion on which government has jurisdiction over the pore space (e.g., federal, state, or regional government) is necessary.

123. *See* FISH & MARTIN, *supra* note 112, at 5.

124. *See* Owen L. Anderson, *Subsurface "Trespass": A Man's Subsurface Is Not His Castle*, 49 WASHBURN L.J. 247, 251 (2010); Klass & Wilson, *supra* note 74, at 404–05.

125. *See* John G. Sprankling, *Owning the Center of the Earth*, 55 UCLA L. REV. 979, 1036 (2008).

quantitative criteria, such as limiting rights to 500 feet or some other predetermined depth.[126] Under this approach, the pore space ownership is granted to surface owners, ranging from the surface to a certain depth, and the ownership of the rest of the area below that depth is granted to the government. These standards have the merit of a balanced approach that can effectively determine whether the surface owners' property rights regarding pore space require compensation for use.[127] However, these standards are not complete and also have shortcomings. As for the qualitative approach, there is a lack of clarity, and the quantitative standard for applying uniform depth limitations lacks the flexibility to consider case-specific circumstances.[128]

Consequently, each country will be forced to choose a variation of these three options. Since each option has both positive and negative characteristics, countries and individual states will have to address this property-rights issue associated with CCS implementation according to their legal and regulatory foundations and circumstances. Therefore, a legal and regulatory system for CCS regarding pore space ownership needs to focus not just on one side's interest between the conflicting interests of surface owners and CCS operators, but also on the fundamental legal background of the state or country.[129]

VI. CONCLUSION

The issues of permits, environmental impact assessments, liability, and property rights are of common importance to the development of CCS technology. In resolving each of these key legal issues, the precautionary principle and the polluter pays principle should be realized when possible. Furthermore, a flexible approach to these principles' interpretation and application

126. This is called zone model. *See id.* at 1036–38 (stating that one thousand feet seems appropriate as a specific depth for subsurface ownership, which draws on four standards that Sprankling has suggested: (1) expectations, (2) lack of possession, (3) enforcement difficulty, and (4) environmental concerns).

127. In other words, this opinion has the advantage of both reducing too many transaction costs by limiting the scope to be negotiated and compensated and relieving the public's backlash by not directly granting the ownership to the government.

128. As for qualitative standards, there is a critical view that it is difficult to decide the subsurface ownership with this standard. *See* Sprankling, *supra* note 125, at 1036. Additionally, under these standards, it is questionable that surface owners' property interests are adequately protected and compensated. This is because pore space is likely to be considered as the area which is not substantially harmed or expected to be harmed. The qualitative standard of depth is also likely to be estimated, making it hard to adopt since it does not consider specific circumstances.

129. In case of a federal system, if each state shows a different attitude on pore space ownership, it may also cause problems and the need for a uniform law may arise. For example, in the United States, some issues that are inevitably associated with various jurisdictions, such as aviation, require the unification of relevant laws and regulations, and that interstate uniformity is particularly needed in a commercial area like aviation. *See* BANNER, *supra* note 93, at 102–03, 110. This uniformity argument also has implications for pore space ownership associated with CCS.

is also needed in order for the implementation of CCS to be carried out safely and seamlessly.

First, for permit systems, it is important to ensure that each step (site exploration, capture, transport, storage, and post-closure management) requires detailed standards in order for the government agency to be able to judge whether an authorization is appropriate. Second, it is necessary for the government to enforce environmental impact assessments while making evaluation items and evaluation methods as detailed and diverse as possible. It is also significant to emphasize the enforcement of monitoring, especially in the long term, to ensure that the potential risks of carbon leakage are managed on a continuous basis. In this regard, clear criteria for monitoring are needed. Monitoring movements of the carbon dioxide stream and associated conditions are particularly significant in CCS, which need to be meticulously addressed using both laws and enforcement decrees. Third, with regard to the liability issue, different opinions can be raised as to who will be liable for damages by carbon leakage accidents, what standard to use, and the extent of liability. It is desirable to clearly provide the relevant standards for operator predictability and to have a liability system that effectively balances the interests of CCS operators and the government. Specifically, it is reasonable for the CCS operator to assume compensation liability for leakage accidents.

Regarding the standard for judging liability, strict liability is necessary because the damage from a leak incident could be significant and proving operator negligence will be difficult. On the other hand, a system for transferring liability to the government after a certain period of time, thirty years, for example, also needs to be adopted because it can contribute to the duty of securing safety for both the CCS operators and the government and at the same time distribute the liability burden.

Finally, in resolving the property rights issue, the government should exercise its power of eminent domain at a federal level so that a unified institution can promote the smooth implementation of CCS. In addition, if a country's relevant property laws and citizens permit it, government ownership of the pore space should be considered. As shown from approaching and addressing these four key issues, the world's governments will play a crucial role in facilitating CCS implementation and sharing liability associated with CCS.