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Liability and Compensation for Damage Resulting from CO2 Storage Sites

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LIABILITY AND COMPENSATION FOR DAMAGE RESULTING FROM CO_2 STORAGE SITES

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INTRODUCTION

A. *Background*

There is a large interest in carbon capture and storage ("CCS") as an alternative to mitigating greenhouse gas emissions. It involves the capture and permanent storage of CO_2. Specifically for countries where further mitigation of greenhouse gases may be very costly, CCS is considered as an attractive alternative policy option.[1] To some extent it is held by some that CCS may be unavoidable, especially for those countries that still largely rely on fossil fuels for their energy supply.[2] There is an increasing interest among policy makers in CCS. However, questions arise concerning a regulatory framework that should accompany CCS.[3]

Some legal systems have now enacted regulations to stimulate the development of CCS. In the United States there are no rules at the federal level, but several states have developed CCS regulations[4] and on

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[1] *See, e.g.*, Alexandra B. Klass & Elizabeth J. Wilson, *Climate Change and Carbon Sequestration: Assessing a Liability Regime for Long-Term Storage of Carbon Dioxide*, 58 EMORY L. J. 103, 113–14 (2008) (qualifying carbon capture and sequestration ("CCS") as a promising technology).

[2] *See* David Hawkins, George Peridas & John Steelman, *Twelve Years after Sleipner: Moving CCS from Hype to Pipe*, 1 ENERGY PROCEDIA 4403, 4403 (2009).

[3] The International Energy Agency has already provided a model regulatory framework in November 2010. *See* INT'L ENERGY AGENCY, CARBON CAPTURE AND STORAGE: MODEL REGULATORY FRAMEWORK 9–10 (Nov. 2010).

[4] For an overview, *see* Arnold W. Reitze Jr. & Marie Bradshaw-Durant, *Control of*

April 2, 2009, Europe promulgated Directive 2009/31 dealing with the geological storage of carbon dioxide.[5] Article 19 of this Directive holds that "Member States shall ensure that proof that adequate provisions can be established, by way of financial security is presented by the potential operator as part of the application for a storage permit."[6] Article 20 also provides that "Member States shall ensure that the operator makes a financial contribution available to the competent authority before the transfer of responsibility has taken place."[7] However, the details of these liability and compensation mechanisms remain largely unclear.

There are several reasons to focus on the potential liability and compensation issues related to CO_2 storage. A first problem is that CCS could create so-called long-term risks. This entails that there could be negative effects and potential damage resulting from CO_2 in a distant future.[8] This long-term character always creates problems from a liability and compensation perspective. This raises *inter alia* the question how financing can be made available when damage would occur at the time when operators may no longer be in business. A related issue is that the risks emerging from CCS are not only potentially long-term, but also uncertain.[9] This uncertainty can relate to the probability of damage, but also to the potential magnitude of the damage when CO_2 would accidentally be released in the atmosphere. These uncertainties make an *ex ante* prediction of CCS-related risks difficult and that in turn endangers insurability.

B. Goal

It seems important to tackle these issues with an appropriate legal framework since the absence of such a framework dealing with liability for damages may jeopardize the development of this potentially important technology. Such a framework should both provide appropriate liability rules and allow for compensation of related damages. The goal of a liability and compensation scheme is to address how the long-term liability and compensation issues can be solved, and to indicate what

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Geological Carbon Sequestration in the Western United States, 14 ENVTL. L. REP., NEWS & ANALYSIS 10455, 10455 (2011).

[5] 2009 O.J. (L 140) 114, 119.

[6] *Id.* at 126.

[7] *Id.*

[8] JAAP SPIER, SHAPING THE LAW FOR GLOBAL CRISES: THOUGHTS ABOUT THE ROLE THE LAW COULD PLAY TO COME TO GRIPS WITH THE MAJOR CHALLENGES OF OUR TIME 24 (Elbert de Jong ed., 2012) ("This leaves untouched the most unfortunate given that, if something goes wrong, quite a few people may be affected (they may even lose their lives).").

[9] Klass & Wilson, *supra* note 1, at 118–19.

policymakers can do to stimulate market development. The goal of this Article is therefore to sketch how liability rules could be developed, and to present a compensation mechanism that takes into account the particular difficulties arising with CCS, especially the long-tail character of the potential damage.[10]

C. Methodology

This Article follows the economic analysis of law as the methodology for analyzing appropriate liability and compensation mechanisms with respect to damages resulting from CO_2 storage sites. There are various reasons for employing this approach. One reason is that many have already discussed the design of a liability and compensation scheme for CCS-related damages.[11] But these earlier studies have not yet approached the issue from the angle of an economic analysis of law. The advantage of this methodology is that attention is paid to the way in which various liability and compensation schemes affect the incentives for prevention of the various stakeholders involved.[12] After all, an important feature of any liability and compensation scheme should be that it provides appropriate incentives for prevention in the first place. Moreover, the law and economics methodology allows for both an assessment of liability rules from an efficiency perspective and an analysis of how the shape of particular liability rules can stimulate their insurability.

D. Structure

The structure of this Article will be as follows: first the nature of the risks posed by CCS and the relevant stakeholders will be sketched out (II). This is obviously necessary to have some idea as to whether there are potential long-term liabilities involved, the degree of uncertainty, and the potential magnitude of the damage. Next, this Article will address the question of what goals liability rules could fulfill in a CCS system, what parties could be held liable and how liability rules could be efficiently

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[10] This refers to the fact that CCS can lead to long-lasting damage that may appear years after the initial CO_2 storage. Damage in that sense can have a "long-tail."

[11] *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, 6–7 (2011); Klass & Wilson, *supra* note 1, at 108.

[12] *See generally* Michael G. Faure, *Regulatory Strategies in Environmental Liability, in* THE REGULATORY FUNCTION OF EUROPEAN PRIVATE LAW 129–87 (F. Cafaggi, F. Watt & H. Muir eds., 2011) (summarizing the literature on the economic analysis of liability rules).

structured (particularly the choice between strict liability and negligence) (II). We then turn logically to the options available to policymakers with respect to liability rules. This Article will show that policymakers are basically confronted with the dilemma of balancing a broad scope of liability (adding to the preventive effect of liability rules and stimulating the compensatory function of liability) against the danger that this may endanger the insurability of liability. Hence, particular features and limits of liability rules (such as available defences, applicability of liability rules in time and causation rules) need to be discussed since they can have an important bearing on the scope of liability (III).

Then we turn to compensation by first discussing general principles of fair and efficient compensation (IV). Next, this Article turns to criteria for insurability (V), such as the predictability of the risk, and the capacity and the need to remedy traditional problems such as moral hazard and adverse selection. Of course, the question that will have to be addressed is the extent to which these issues play an important role in cases of CCS. In addition to traditional insurance, alternative compensation mechanisms also need to be discussed (VI). Accordingly, attention will be paid *inter alia* to guarantees and deposits as well as the option of a risk-sharing agreement (pooling by operators). This study of insurance (V) and its alternatives (VI) merits the question of what role government (and policymakers in general) could play in facilitating compensation, particularly the insurability of CCS liability (VII).

This Article will end with a summary and formulation of policy recommendations (VIII). These will largely focus on the question of what policymakers can do to stimulate solutions for long-term liability issues related to CCS, combining the goal of preventing harm and making effective compensation available. This will be followed by concluding observations.

I. NATURE OF THE RISKS INVOLVED IN CCS

A. What Is CCS?

Carbon Capture and Storage ("CCS") was developed as an alternative to reducing greenhouse gases via changes in technology that would mitigate the emission of greenhouse gases.[13] CCS amounts to a technology whereby CO_2 is captured, transported and subsequently stored for a long period of time.[14] The principle is that CO_2 is captured from power plants

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[13] Klass & Wilson, *supra* note 1, at 107.
[14] *Id.*

since these are (especially when it is from coal-fired power plants) large emitters of greenhouse gases, or from other industrial sources.[15] After being captured, the CO_2 is transported to a sequestration site where it is injected at great depths underground;[16] storage usually takes place in geological formations such as depleted oil and gas reservoirs or unminable coal seams.[17] As injection can occur both onshore and offshore,[18] the cost of CCS depends on the cost of capturing, transporting, and storing the CO_2.[19] Finally, after storage, monitoring has to take place to conclude the full chain of CCS.[20] In principle, the CO_2 should remain in the underground storage site forever[21] and, as will be discussed, experts maintain that so long as sites are appropriately selected, the risks of CO_2 leakage diminish over time, and are considered small.[22] The Intergovernmental Panel on Climate Change ("IPCC") reports that for well-selected sites, over 99% of the injected CO_2 will very likely (this refers to a probability of 90 to 99%) remain underground for over 100 years.[23]

The IPCC quote referenced in the previous footnote shows two features of CCS that are crucial to the assessment of long-term liability risks: (1) properly stored CCS can provide an important contribution to the reduction of CO_2 emissions; and (2) these positive effects depend upon the selection, design, and management of the geological storage sites. In this respect, the risks of CCS are strongly related to appropriate site selection and monitoring of the storage conditions, which may require regulatory oversight.[24] Moreover, the most attractive sites (in terms of

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[15] *Id.*
[16] *Id.* at 115.
[17] *Id.*
[18] SVEN BODE & MARTINA JUNG, HAMBURGISCHES WELT-WIRTSCHAFTS-ARCHIV HAMBURG INST. OF INT'L ECON., CARBON DIOXIDE CAPTURE AND STORAGE—LIABILITY FOR NON-PERMANENCE UNDER THE UNFCCC 3 (July 14, 2005).
[19] *Id.* at 4.
[20] *Id.* at 3.
[21] Klass & Wilson, *supra* note 1, at 107.
[22] *See infra* Part I.D.2.
[23] *See* IPCC SPECIAL REPORT ON CARBONDIOXIDE CAPTURE AND STORAGE 14 (Bert Metz et al. eds. 2005), *available at* http://www.ipcc-wg3.de/special-reports/.files-images/SRCCS-WholeReport.pdf [http://perma.cc/NHR4-9J2M] ("Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1,000 years. For well-selected, designed and managed geological storage sites, the vaste majority of the CO_2 will gradually be immobilised by various trapping mechanisms and, in that case, could be retained for up to millions of years. Because of these mechanisms, storage could become more secure over longer timeframes").
[24] *See* Klass & Wilson, *supra* note 1, at 107.

geological conditions) are likely to be occupied by so-called "first movers."[25] Hence, the potential for damages may increase when the technology is implemented on a larger scale and storage takes place at riskier sequestration sites.

Enthusiasm for CCS is typically seen in countries that continue to use coal as a main energy source and think CCS could be used to create 'clean coal.'[26] This explains the interest for CCS in countries like the United States and Canada, but given large energy demands it may be a possibility for China and India as well.[27] Both the United States and Canada consider CCS to be a key technology in climate change policy.[28]

B. Advantages

The obvious advantage for countries like the United States and Canada is that CCS would, to a large extent, allow business as usual as far as energy policy is concerned.[29] In other words, these countries could continue their reliance on coal as their primary energy source and mitigate its negative consequences by capturing the CO_2 that results from coal-fired power plants and storing it via CCS technology.[30] The advantages of CCS are therefore especially apparent to those who consider CCS to be a mitigation technology for clean coal.[31] It has also mentioned in legal literature as "a promising technology that could enable the continued use of inexpensive fossil fuels while dramatically reducing accompanying greenhouse gas emissions,"[32] notwithstanding the potential risks.[33] CCS

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[25] *See id.* at 171.
[26] *See* Chiara Trabucchi & Lindene Patton, *Storing Carbon: Options for Liability Risk Management, Financial Responsibility*, WORLD CLIMATE CHANGE REPORT, THE BUREAU OF NAT'L AFFAIRS 5 (2008) (arguing that the adoption of CCS technology "is critical to the economic future of states that mine coal and depend heavily upon electricity from coal-fired powered [plants]." Given large coal reserves, they argue that countries like the United States will also in the future largely rely on coal as energy source (coal today providing approximately 50% of the electric supply in the United States).
[27] *Id.*
[28] *See* ZEN MAKUCH, SLAVINA GEORGIEVA & BEHDEEN ORAEE-MIRZAMANI, CARBON CAPTURE AND STORAGE: REGULATING LONG TERM LIABILITY 16 (Makuch & Pereira eds., 2011).
[29] *See* Trabucchi & Patton, *supra* note 26.
[30] These advantages constitute the reason why environmental non-governmental organizations ("NGOs") like Greenpeace are very critical of CCS and argue that it is more of a smoke screen than a sustainable solution. *See* GREENPEACE, FALSE HOPE—WHY CARBON CAPTURE AND STORAGE WON'T SAVE THE CLIMATE 37 (2008).
[31] *See* Trabucchi & Patton, *supra* note 26, at 4–6.
[32] Klass & Wilson, *supra* note 1, at 107.
[33] *See infra* Part II.E.

is hence promoted by a broad range of stakeholders "who assert that avoiding climate change will be impossible without it."[34] That is the opinion of the International Energy Agency ("IEA"), which argued that without CCS the annual costs of cutting global CO_2 emissions in half by 2050 would increase by 71% ($1.28 trillion per year).[35] Their conclusion is that "CCS is therefore essential to the achievement of deep emission cuts."[36] Also, prominent scholars have argued *inter alia* that states should act with fierce urgency to develop and implement CCS.[37] Scholars therefore generally conclude that "CCS holds great promise as an approach for preventing CO_2 emissions from entering the atmosphere"[38] but at the same time warn that "its success depends on the ability of a site to safely confine CO_2 in injection reservoirs, preventing it from migrating to the surface and causing harm or injury to public health or ecosystems."[39]

C. *Barriers and Limits*

Despite the potential advantages of CCS and the enthusiasm it has generated from leading scholars (and some policymakers),[40] CCS projects have seen very limited development so far. A 2008 article referred to four pilot projects that would soon be underway.[41] But until recently there were no commercialized CCS projects anywhere in the world.[42] A March 2013 communication from the European Commission on the future of carbon capture and storage in Europe mentioned that at that moment twenty demonstration-scale projects were in operation.[43]

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[34] Adelman & Duncan, *supra* note 11, at 1.
[35] INT'L ENERGY AGENCY ("IEA"), ENERGY TECHNOLOGY ANALYSIS: CO_2 CAPTURE AND STORAGE: A KEY-CARBON ABATEMENT OPTION 15 (2008), *available at* https://www.iea.org/publications/freepublications/publication/CCS_2008.pdf [http:/perma.cc/JT9Q-3VN9].
[36] *Id.* at 15.
[37] *See* Steven Chu, *Carbon Capture and Sequestration*, 325 SCIENCE 1599 (2009).
[38] Chiara Trabucchi, Michael Donlan & Sarah Wade, *A Multi-Disciplinary Framework to Monitize Financial Consequences Arising from CCS Projects and Motivate Effective Financial Responsibility*, 4 INT'L J. GREENHOUSE GAS CONTROL 388, 393 (2010).
[39] *Id.*
[40] *See infra* Part I.
[41] Klass & Wilson, *supra* note 1, at 117.
[42] Information provided by experts from the IEA.
[43] Eur. Comm'n, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions on the Future of Carbon Capture and Storage in Europe*, at 14, COM (2013) 180 final (Mar. 27, 2013) [hereinafter COM (2013) 180 final]. Information provided by Mr. Shaun McCoy of the IEA in a conversation with the author in March 2013.

There are also two full-scale projects located in Norway.[44] But besides these projects,[45] large scale development of CCS has not taken place.[46] This paradox is related to the fact that notwithstanding the apparent advantages of CCS there are still substantial barriers to its implementation. These barriers are well summarized in the provocative title of a study by Hawkins, Peridas, and Steelman: 'Twelve Years after Sleipner: Moving CCS from Hype to Pipe.'[47]

According to them, the first important barrier is based on the current carbon policies.[48] In simple terms: in legal systems such as the United States,[49] where a regulatory regime forcing greenhouse gas emitters to mitigate is largely lacking, the economic incentive to develop CCS will clearly be lacking as well.[50] This point is well-developed in a European Commission communication on the future of carbon capture and storage in Europe,[51] where it is argued that the current cost of CCS is in the order of €40 per ton of CO_2 for which emission was avoided. But prices under the European emission trading scheme are well below this price and (depending

[44] The reason for the location of two full-scale CCS projects in Norway is that oil and gas producers in that country face a tax of approximately € 25/ton of CO_2, which may lead to commercial development of CCS in Norway. *Id.* at 14–15.
[45] An overview of these projects is provided in the European Commission Communication on the future of carbon capture and storage in Europe. *Id.* at 24–26.
[46] *See* Hawkins, Peridas & Steelman, *supra* note 2, at 4404–05.
[47] *See* Klass & Wilson, *supra* note 1, at 117 (referring to an experiment to inject CO_2 from natural gas production in the North Sea); *see also* Hawkins, Peridas & Steelman, *supra* note 2.
[48] Hawkins, Peridas & Steelman, *supra* note 2, at 4405.
[49] At least at the U.S. federal level, at state level, many initiatives aimed at mitigation of greenhouse gas emissions do take place. *See, e.g.,* Erik B. Bluemel, *Regional Regulatory Initiatives addressing GHG Leakage in the USA*, *in* CLIMATE CHANGE AND EUROPEAN EMISSIONS TRADING: LESSONS FOR THEORY AND PRACTICE 225–56 (Michael Faure & Marjan Peeters eds., 2008).
[50] Hawkins, Peridas & Steelman, *supra* note 2, at 4405 ("The single biggest barrier standing in the way of CCS deployment is the absence of comprehensive climate policies that place a significant market value on avoiding emissions. Without such policies and legislation, economic drivers for CCS are simply lacking, as there is little other reason to capture and sequest the carbon"). This was also the opinion of Professor Michael Celia, information provided on February 27, 2013. *See also* Charles H. Haake & Karyn B. Marsh, *The Trouble with Angels: Carbon Capture and Storage Hurdles and Solutions*, WORLD CLIMATE CHANGE REPORT (May 8, 2009), *available at* http://www.gibsondunn.com/publications/Documents/Haake-Marsh-TroubleWithAngelsCarbonCaptureAndStorage.pdf [http://perma.cc/JS36-PM24] (holding that the private sector's inaction is likely due to the lack of legal framework defining the relative rights, responsibilities, and liabilities of stakeholders). Note, however, that they wrote this in 2009; a regulatory framework has meanwhile been provided in some legal systems such as the United States and EU.
[51] COM (2013) 180 final, *supra* note 43, at 14–16.

upon fluctuations) are closer to €5.[52] Under those circumstances, rationales for economic operators to invest in CCS are largely lacking.[53]

Hawkins, Peridas, and Steelman also posit that a lacking regulatory framework and the potential for long-term liability could reduce incentives for investments in CCS.[54] Others point to the technological uncertainties with respect to capturing CO_2 that still persist. These opponents argue that it is important to tackle these technological uncertainties (e.g. via public-private partnerships) rather than focus on a liability cap that would not reduce those uncertainties.[55]

Many mention the fear of potential liability as an important barrier, which results in valuable CCS projects not emerging.[56] One of the most important political problems facing CCS (which could constitute a barrier to its implementation) is the appearance of risk. This has resulted in environmental NGOs like Greenpeace qualifying CCS as 'risky business,' merely providing 'false hope.'[57] Hence, it is important to address expert opinion concerning the nature of the long-term risk posed by CCS and the potential damage that could result from it.

D. *Potential Risks*

1. Nomenclature of Risks

First, it should be stressed that experts agree the risks involved in CCS projects depend very much on the project cycle (see Part F) of a CCS project. Too often, attention is paid merely to long-tail risks, despite the fact that risks can emerge at different stages of the CCS project.[58] The important question from a liability and insurance perspective, however, is to what extent it is possible to assess the long-term risks of a CCS project. This is particularly important since liability and insurance are often better suited for sudden and accidental events than for long-tail risks. Hence, a lot of the debate focuses on the nature of the potential long-tail risks related to CCS.[59]

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[52] *Id.*
[53] *Id.*
[54] Hawkins, Peridas & Steelman, *supra* note 2, at 4407.
[55] Adelman & Duncan, *supra* note 11, at 63–65.
[56] *See infra* Part III (focusing on liability rules).
[57] GREENPEACE, *supra* note 30, at 30.
[58] Elizabeth Aldrich, Cassandra Koener & David W. Keith, *Analysis of Liability Regimes for Carbon Capture and Sequestration: A Review for Policy Makers*, THE ENERGY POL'Y INST., Dec. 2011, at 9.
[59] *See* Elisabeth J. Wilson, Timothy L. Johnson & David W. Keith, *Regulating the Ultimate Sink: Managing the Risks of Geologic CO_2 Storage*, 35 ENVTL. SCI. TECH. 3476, 3477 (2003)

Generally, a distinction is made between risks related to the release of CO_2 in the atmosphere and other types of risks that could lead to different types of damage during the various phases of the project life cycle.[60] In CCS literature, a further distinction is made between risks of a global nature (particularly the release of CO_2 into the atmosphere) and risks of a more local nature.[61] Schematically, the following risks could be distinguished.

a. Global CO_2 Emissions

The mere leakage of CO_2 by itself would be a problem from the perspective that regulatory climate change goals (as they have been *inter alia* laid down in the United Nations Framework Convention on Climate Change ("UNFCCC") and the Kyoto Protocol) could not be reached.[62] Hence, leakage of CO_2 could potentially lead to liability for the non-permanence of CCS.[63] But while leakage could create a risk of climate change liability,[64] other risks could emerge as well. It is important to assess the nature of these risks, meaning the probability of their occurrence and the nature of the damage that could result if they materialized.

b. Affecting Water Aquifers

A second risk mentioned in CCS literature, not related to climate change liability and resulting from CCS, is that sequestration sites may have a negative impact on drinking water aquifers.[65] This could result from either CO_2 leakage or from the intrusion of native salt-laden waters, which are referred to as brines.[66] The brines could then be driven upward from sequestration reservoirs through the elevated pressures resulting from CO_2 injection.[67] However, the nature of these risks is different; CO_2 plumes in sequestration reservoirs can extend several kilometres from

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(for an overview of the potential risks coming from CCS); *see also* Aldrich, Koerner & Keith, *supra* note 58, at 4–5.

[60] *See, e.g.*, Trabucchi & Patton, *supra* note 26, at 8–10.

[61] *See, e.g.*, Wilson, Johnson & Keith, *supra* note 59, at 3477.

[62] *See* Bode & Jung, *supra* note 18, at 180.

[63] *Id.*

[64] *See* ADJUDICATING CLIMATE CHANGE: STATE, NATIONAL AND INTERNATIONAL APPROACHES (William C.G. Burns & Hari M. Osofsky eds., 2009); CLIMATE CHANGE LIABILITY (Michael Faure & Marjan Peeters eds., 2011); CLIMATE CHANGE REMEDIES INJUNCTIVE RELIEF AND CRIMINAL LAW RESPONSES (Jaap Spier & Ulrich Magnus eds., 2014).

[65] Adelman & Duncan, *supra* note 11, at 13.

[66] *Id.* at 4.

[67] *Id.*

a CO_2 injection well, but the area of elevated pressure in which brines could be forced into aquifers can extend across tens of kilometres.[68] The release of CO_2 and brine could potentially lead to contamination of drinking water through mobilization of toxic metals and increased salinity.[69] In their article, Adelman and Duncan stress that the risk of CO_2 leakage may to some extent be exaggerated since the risk of brine leakage and pressure changes is in fact more substantial.[70] They substantiate this claim with empirical data that establish that fifty years after the end of active CO_2 injections, the CO_2 plume would extend just three to five kilometres from the injection well, whereas the elevated pressure would be projected to extend many tens of kilometres from the well.[71]

c. Seismic Risks

The risk of brines being displaced within potable aquifers and the potential contamination of hydrocarbon resources have also been mentioned in CCS literature, as has the danger of pressure changes causing ground heave and possibly triggering seismic events.[72] However, Wilson, Klass and Bergan argue that "these risks likely will be small with properly-managed sites."[73]

d. Personal Injury

In addition to the impact to water resources and the potential atmospheric release of $CO_{2,}$ Wilson, Klass and Bergan also mention the fact that at very high concentrations (greater than 30%) CO_2 may cause immediate human death from asphyxiation.[74] An oft-quoted case involved a rapid CO_2 release from an underlining volcanic source from Lake Nyos in Cameroon, which would have led to the deaths of more than 1,700 people.[75] However, the IPCC clearly held that this CO_2 release is "not representative of the seepage through wells or fractures that may occur from underground geological storage sites."[76]

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[68] *Id.* at 5.
[69] *Id.* at 11.
[70] *Id.* at 4.
[71] Adelman & Duncan, *supra* note 11, at 15.
[72] Elisabeth J. Wilson, Alexandra B. Klass & Sara Bergan, *Assessing a Liability Regime for Carbon Capture and Storage*, 1 ENERGY PROCEDIA 4575, 4576 (2009).
[73] *Id.*
[74] Klass & Wilson, *supra* note 1, at 118.
[75] Adelman & Duncan, *supra* note 11, at 8.
[76] *Id.* at 8 (citing INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, IPCC SPECIAL REPORT ON CARBON CAPTURE AND STORAGE 211 (Bert Metz et al. eds., 2005)).

e. Environmental Risks

Finally, it should be mentioned that, in addition to the effects on the global atmosphere mentioned above, the emission of CO_2 can also cause negative local environmental effects leading, e.g., to the killing of trees.[77]

2. Risks Limited

It is, however, important to stress that much of the CCS literature holds that, provided that the location site is correctly selected, the CCS risk profile is in fact rather limited, especially when the (often feared) long-tail risks are considered.[78] In this respect the earlier quote, oft-repeated in CCS literature, from the IPCC study showing that the risk of CO_2 leakage from a well-managed sequestration site is "likely to be small in magnitude and distant in time"[79] is important. For sites that are well-selected, designed, operated, and monitored it is very likely that more than 99% of the stored CO_2 will remain sequestered for more than 100 years.[80] Significant scientific research has been done concerning the risks associated with CCS.[81] The results show not only that the nature of these risks remains basically the same during the carbon dioxide injection/operation and after the closure of the site, but also that the risk of carbon leakage during the post injection phase is expected to diminish over time.[82] One study holds: "The good news is that the likelihood that the risk of some events occurring that result in an unexpected release of carbon dioxide more than 10 years after termination of injection will become increasingly remote due to geochemistry conditions."[83] Other studies mention that CO_2 storage has a potentially declining risk profile.[84]

In summary, CCS literature points to various potential risks, distinguishing between CO_2 releases and other types of risks.[85] The likelihood of CO_2 releases is considered small and even diminishing over time,[86] but that result is strongly dependent upon proper site selection

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[77] *See* Wilson, Johnson & Keith, *supra* note 59, at 3477.
[78] Adelman & Duncan, *supra* note 11.
[79] *See, e.g.*, *id.* at 18–19.
[80] Trabucchi & Patton, *supra* note 26, at 11.
[81] *See* Adelman & Duncan, *supra* note 11, at 5.
[82] Trabucchi & Patton, *supra* note 26, at 10.
[83] *Id.* at 12.
[84] James J. Dooley, Chiara Trabucchi & Lindene Patton, *Design Considerations for Financing a National Trust to Advance the Deployment of Geologic CO_2 Storage and Motivate Best Practices*, 4 INT'L J. GREENHOUSE GAS CONTROL 381, 381 (2009).
[85] *See* IPCC, *supra* note 23.
[86] *Id.*; *see generally* Dooley, Trabucchi & Patton, *supra* note 84.

and operation monitoring.[87] Finally, it should be mentioned that many studies have indicated that notwithstanding remaining uncertainties, it is possible to quantify the risks involved in CCS, since estimates can be made both of the probability of releases as well as the potential damage that could occur as a result.[88] Hence, monetization of the expected losses can be done in a site-specific manner.

Some scholars stress that there has already been direct evidence of CO_2 sequestration, which would confirm the low probability of the risk.[89] CO_2 has been used to facilitate oil extraction, which involves pumping large volumes of CO_2 underground.[90] The safety record of CO_2 in those cases was excellent.[91] Other studies refer to evidence of fluid injection, which suggests that long-term containment of CO_2 can be achieved in sites that are appropriately chosen, constructed, operated, and monitored.[92]

E. Potential Damage

The potential damage that could occur in the event potential CCS-related risks materialize logically follows from the previous discussion.[93] It should again be stressed that it is probably more important to focus on the probability that the risk will emerge, which according to scientific literature is small,[94] than on the potential damage. However, CCS literature also stresses that given the nature of the damage resulting from the primary risk of CCS (contamination of drinking water aquifers) it is unlikely that these costs would be huge.[95] Although CCS-related damage could undoubtedly trigger significant remediation costs, those would bear little resemblance to the large chemical releases to which Superfund applies.[96] The potential damage that could result from CO_2 storage largely

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[87] Dooley, Trabucchi & Patton, *supra* note 84, at 381.
[88] *See* Trabucchi, Donlan & Wade, *supra* note 38.
[89] *See* Ian J. Duncan, Jean-Philippe Nicot & Jong-Won Choi, *Assessment for Future CO_2 Sequestration Projects Based on CO_2 Enhanced Oil Recovery in the US*, 1 ENERGY PROCEDIA 2037, 2037 (2009).
[90] *Id.*
[91] *Id.*
[92] Trabucchi, Donlan & Wade, *supra* note 38, at 393.
[93] *See* Mark A. De Figueiredo, *The Liability of Carbon Dioxide Storage* (Ph.D. Thesis, Massachusettes Institute of Technology) 154–91 (2007), *available at* http://sequestration.mit.edu/pdf/Mark_de_Figueiredo_PhD_Dissertation.pdf [http://perma.cc/938K-357U] (discussing the types of damages that could result from CO_2 storage).
[94] IPCC, *supra* note 23, at 211; *see generally* Dooley, Trabucchi & Patton, *supra* note 84.
[95] Adelman & Duncan, *supra* note 11, at 4.
[96] *Id.* Superfund refers to the compensation mechanism for the costs of remediating soil pollution in the United States.

corresponds to the previously mentioned risk categories.[97] Hence, CCS literature recognizes the following potential damage categories:

- Atmospheric releases.[98] Already mentioned, these constitute the typical climate liability damages.[99] In legal systems that have a carbon cap, an economic valuation of the releases of CO_2 is possible; in other legal systems this could be more problematic.[100]
- Impacts on water resources.[101] These are the previously mentioned impacts on drinking water, groundwater, and/or surface water.[102] Again, water markets are established and provide a proxy for valuing the damage to water resources.[103]
- Geological impacts.[104] Following seismic events, substantial damage could obviously affect houses as well as urban infrastructure.
- Human health impacts (in the rare cases that very high concentrations of CO_2 result in morbidity or mortality).[105] There is extensive experience in valuing these human health impacts, which would make a loss valuation possible.[106]
- Ecological impacts.[107] These could lead to the type of natural resource damage that would make compensation for, e.g., replacement costs, necessary.[108]

In other words, most of the damaging effects of CCS can, according to prior studies, be estimated and valuated in monetary terms.[109] However, these studies also indicate that (even though the probability is small) CCS-created pressure changes could potentially cause ground

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[97] *See supra* Part I.D.1.
[98] Adelman & Duncan, *supra* note 11, at 31.
[99] *Id.* at 21.
[100] *See generally id.*
[101] Trabucchi & Patton, *supra* note 26, at 10.
[102] *Id.* at 11.
[103] *Id.*
[104] Wilson, Klass & Bergan, *supra* note 72, at 4576.
[105] Trabucchi & Patton, *supra* note 26, at 10.
[106] Trabucchi, Donlan & Wade, *supra* note 38, at 390.
[107] Trabucchi & Patton, *supra* note 26, at 10.
[108] Trabucchi, Donlan & Wade, *supra* note 38, at 390.
[109] Trabucchi & Patton, *supra* note 26, at 9–10.

heave and even trigger seismic events.[110] If this were the case, the damage could potentially be catastrophic in nature.

F. Project Life Cycle

As was already mentioned, the risks involved in a CCS project to some extent depend upon the life cycle of the CCS project.[111] From the outset it should be stated that in this study we strongly focus on the final phase of CCS, the geological storage of CO_2, since that is the most interesting phase from a liability and compensation perspective. However, as will be made clear, geological storage is only one, albeit essential, part of CCS.

Trabucchi and Patton distinguish between risks in different phases. First, they distinguish between capture, transport, and sequestration (storage), and within sequestration they distinguish between siting/design, operation (CO_2 injection), closure and post-closure, and long-term stewardship.[112] Risks can, of course, emerge at the first juncture, i.e., the point of capture where the CO_2 is generated,[113] as there could be an improper capture or leakage at the capture point.[114] In the second phase, the transport stage, risks could also emerge given the corrosive nature of carbon dioxide, especially when mixed with water.[115] However, in the first two phases the risks are not particularly difficult to handle from a liability and insurance perspective since those will usually be covered by the insurance policy of the operator or (in the case of liability) transporter.[116]

More interesting are the risks in the third phase of CO_2 sequestration. The first step here is site selection and regulatory review.[117] It is important to stress that all authors agree any long-term risk will, to a large extent, depend upon proper site selection and design.[118] The second

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[110] Wilson, Klass & Bergan, *supra* note 72, at 4576 (mentioning that those risks are likely to be small with properly managed sites).

[111] *See* Wilson, Johnson & Keith, *supra* note 59.

[112] Trabucchi & Patton, *supra* note 26, at 8; *see also* Ian Havercroft & Richard Macrory, LEGAL LIABILITY AND CARBON CAPTURE AND STORAGE: A COMPARATIVE PERSPECTIVE 11–12 (Oct. 2014), *available at* http://hub.globalccsinstitute.com/sites/default/files/publications/179798/legal-liability-carbon-capture-storage-comparative-perspective.pdf [http://perma.cc/R8W4-QFR2].

[113] Trabucchi & Patton, *supra* note 26, at 10.

[114] *Id.*

[115] *Id.* at 9.

[116] *See* Aldrich, Koerner & Keith, *supra* note 58, at 5–8 (discussing the different phases of the CCS project life cycle).

[117] Trabucchi & Patton, *supra* note 26, at 9; Klass & Wilson, *supra* note 1, at 115.

[118] Trabucchi & Patton, *supra* note 26, at 9 (mentioning that this first phase on the

step is active operation of the site, i.e., CO_2 injection.[119] This could, up to the point of closure, take one to thirty years.[120] The third step is closure and post-closure monitoring.[121] Different authors mention different time periods for post-closure monitoring,[122] however, the important point from the industry's perspective is that the third step of post-closure monitoring *has* a defined time period.[123] Only the long-term stewardship, the final phase, could potentially take hundreds of years[124] and is, in other words, indefinite.[125] That is why, especially as far as long-term stewardship is concerned, many consider the role of the state and believe that liability for long-term stewardship should be transferred to it.[126] This model is already incorporated in the EU Directive 2009/31/EC on the geological storage of carbon dioxide.[127] Article 17 of the Directive deals with the closure and aftercare of the storage site[128] and holds that once a site is deemed closed, liabilities shall pass to the state.[129] Of course, the question arises as to what the time limit would be. According to CCS-related literature, the time limit before such a passage could be long, even decades, unless needed legislative certainty is provided.[130] The CCS Directive also spells out the framework requirements to ensure the long-term stewardship of storage sites.[131]

The Directive thus provides for the possibility of sites being transferred to Member State control for the long-term.[132] A condition under the EU CCS Directive for the transfer of liabilities to the state is that a financial contribution be made for the post-transfer period covering the costs for monitoring for at least thirty years. Similar approaches concerning

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siting/design decision would normally take less than a year). *But see* Klass & Wilson, *supra* note 1, at 115 (mentioning, however, that this phase could take one to ten years).

[119] Trabucchi & Patton, *supra* note 26, at 8; Klass & Wilson, *supra* note 1, at 115.

[120] Trabucchi & Patton, *supra* note 26, at 8; Klass & Wilson, *supra* note 1, at 115 (mentioning a period of twenty to thirty years).

[121] Trabucchi & Patton, *supra* note 26, at 8; Klass & Wilson, *supra* note 1, at 115.

[122] Trabucchi & Patton, *supra* note 26, at 10 (mentioning ten, twenty, or fifty years). *But see* Klass & Wilson, *supra* note 1, at 115 (referring to fifteen to thirty years).

[123] Trabucchi & Patton, *supra* note 26, at 8; Klass & Wilson, *supra* note 1, at 115.

[124] *See* Klass & Wilson, *supra* note 1, at 115.

[125] *See* Trabucchi & Patton, *supra* note 26, at 8.

[126] MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 164.

[127] *Id.* at 171.

[128] *Id.* at 174.

[129] *Id.*

[130] *Id.* at 7.

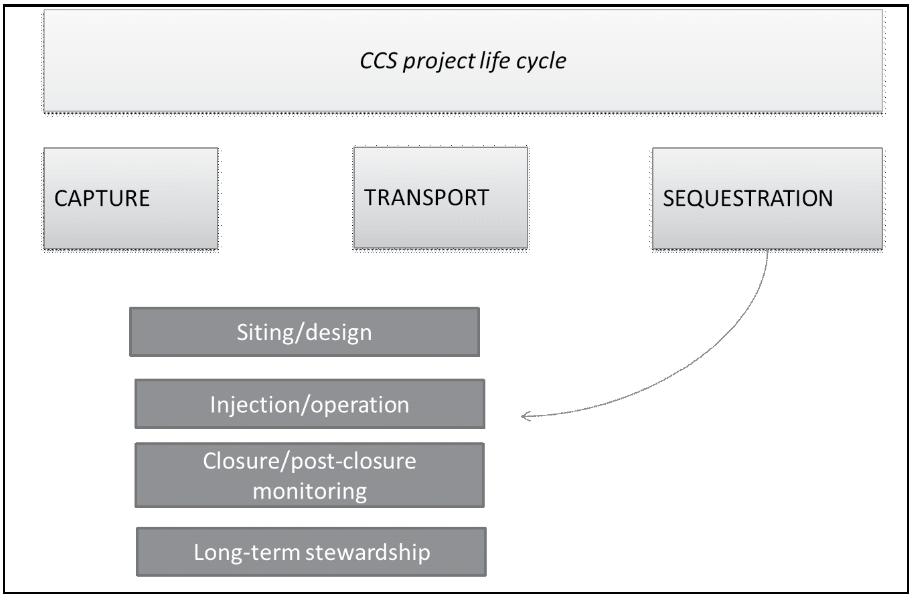
[131] *Id.*

[132] MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 9.

transfer of liability for long-term stewardship to the state have been proposed in other CCS literature.[133]

Graphically, the CCS project life cycle could be presented as follows:

TABLE 1. CCS PROJECT LIFE CYCLE[134]



G. Uncertainties

Although it has been said that the potential risks related to CCS can be managed, monitored, and valuated,[135] some believe there are still substantial uncertainties related to both legal issues and technological uncertainties, which could create major barriers to its deployment.[136]

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[133] *See, e.g.*, Trabucchi & Patton, *supra* note 26; *see also* M.A. de Figueiredo, D.M. Reiner & H.J. Herzog, *Framing the Long-Term in situ liability issue for geologic carbon storage in the United States*, 10 MITIGATION & ADAPTION STRATEGIES FOR GLOB. CHANGE 647, 648 (2005); Nathan R. Hoffman, *The Feasibility of Applying Strict-Liability Principles to Carbon Capture and Storage*, 49 WASHBURN L. J. 527, 528 (2010).
[134] *See* Klass & Wilson, *supra* note 1, at 115.
[135] *See supra* Part I.D.2.
[136] Adelman & Duncan, *supra* note 11, at 63–64.

Uncertainties would exist, especially with respect to capturing CO_2,[137] however, they should not preclude bounded estimates of risks since a reasonable risk assessment is very much possible.[138] Trabucchi and Patton stress that the nature of uncertainty may be different in the various phases of the CCS project life cycle.[139] Uncertainties are especially high in the post-closure phase of a CCS project since this may occur ten, twenty, or fifty years into the future.[140] Although the nature of the risks may largely be the same as during the period of CO_2 injection and operation of the site, what changes in the long-term is the added risk of changing science.[141] Also, society's understanding of what it means to store CO_2 in perpetuity may evolve, which adds uncertainty to the post-closure phase of a CCS project as compared to the previous phases.[142] Finally, in addition to these technical uncertainties, there may be legal uncertainties that could just as easily hamper the development of CCS technology.[143]

H. Summary

This brief introduction to the possibilities and challenges of CCS shows that there are many potential benefits to CCS projects. Those who stress the need for mitigating greenhouse gas emissions argue that the cost of reducing CO_2 emissions could be huge, especially for the power industry as it is very coal-reliant.[144] For them, CCS may be a cost-effective alternative. Opponents point to the potential risks and damage that could emerge from CCS projects, but technological evidence from independent sources seems to indicate that those risks can be reduced to reasonable levels so long as there is appropriate site selection, operation, and monitoring.[145] A particular feature of the risks involved in CCS is that long-term post-storage monitoring may be needed, which in some cases could potentially take hundreds of years and hence extend beyond the life span of the companies involved in the earlier phases of the project life

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[137] *See id.* at 64.
[138] *Id.* at 17.
[139] *See supra* Part II.F.
[140] *See* Trabucchi & Patton, *supra* note 26.
[141] *Id.*
[142] *See* Trabucchi & Patton, *supra* note 26, at 9–10.
[143] *See* Avelien Haan-Kamminga, Martha M. Roggenkamp & Edwin Woerdman, *Legal Uncertanties of Carbon Capture and Storage in the EU: The Netherlands as an Example*, 3 CARBON & CLIMATE L. REV. 240, 249 (2010) (analyzing those legal uncertainties).
[144] *See generally* Klass & Wilson, *supra* note 1, at 113.
[145] *Id.* at 109.

cycle.[146] This explains why applying traditional concepts of liability and insurance may not be easy for potential damages (which is also highly uncertain) that could theoretically manifest after fifty years. For that reason, many call for a governmental role in long-term stewardship.[147]

Government involvement could be an important incentive for the development of CCS projects. Indeed, notwithstanding the alleged advantages of CCS projects, it is striking that few projects have yet been developed on a commercial scale—in fact none at all.[148] To a large extent this may be related to technological barriers and uncertainties, but most importantly it is due to economic factors.[149] CCS may, understandably, only become an economically viable alternative in a legal environment where there is a legal duty to reduce greenhouse gas emissions and hence where carbon is appropriately priced. Moreover, the CCS literature also indicates that industries may be reluctant to step into the CCS adventure if it could potentially lead to liability expanding over long time periods.[150] This potential long-tail liability is considered even more of a problem in situations where the economic benefits of CCS are yet uncertain.[151] The remainder of this Article will address the extent to which a liability and compensation regime can provide an institutional background that adequately balances societal and operator interests, presents incentives for investment in CCS projects, and reasonably limits potential financial risks.

II. LIABILITY RULES FOR CCS

Now that we have outlined the nature of CCS and the potential risks involved during the different phases of the CCS life cycle, it is possible to address potential liability regimes for CCS, taking into account principles of the economic analysis of law. This will be done in different steps: first the general goals of a liability system for CCS will be sketched out. A crucial question within the economic analysis of accident law is whether such a liability regime should be based on strict liability or negligence.[152]

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[146] *Id.* at 132.
[147] *Id.* at 159.
[148] *Id.* at 109, 171.
[149] *Id.* at 109.
[150] *See* Adelman & Duncan, *supra* note 11, at 122.
[151] Klass & Wilson, *supra* note 1, at 109–10 (citing examples of other issues affecting the certainty of the economic benefits of CCS).
[152] *Id.* at 135–43.

Also, many have stressed the limits of liability rules in addressing risks of an ultrahazardous nature, to which CCS could belong.[153] They claim the primary instrument aimed at the prevention of CCS-induced harm should be regulation rather than liability.[154] That raises the question of how such a regulatory framework should be shaped and what the added value of liability rules would be compared to regulation. After the general principles of applying liability rules to CCS have been established, a few policy options regarding the shape of liability rules will be discussed in more detail.

A. *Goals of a Liability System for CCS*

From an economic perspective, a liability system has an important social function in remedying market failures. The market failure at stake in the case of CCS would be an externality, more particularly a negative externality.[155] Such an externality (also referred to as a negative external effect) relates to the idea that actors can engage in socially beneficial activities (like reducing greenhouse gas emissions through CCS) but at the same time create effects that are not taken into account by the operator (and thus external).[156] If such an externality remains external, it effectively means that an operator (such as in the case of CCS) could throw the costs of his activity onto others (i.e., onto society) and only reap the benefits.[157] This behavior would constitute a market failure since it would mean that operators would not have to take into account the social costs of their activity (like CCS) in their prices.[158] The result would be that prices would not reflect true social costs; as a result, consumers could have an excessively high demand for a relatively risky product (since it did not correctly reflect social costs). Moreover, if CCS operators were not forced to internalize externalities but competitors in other branches were, the result would be relatively low prices for producers engaged in CCS. In other words, liability rules play an important role in curing the market failure caused by externalities.[159]

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[153] *Id.* at 127, 130, 132.
[154] *Id.* at 178–79.
[155] Israel Gilead, *Tort Law and Internalisation: The Gap between Private Loss and Social Cost*, 17 INT'L REV. L. & ECON. 589, 589 (1997).
[156] Adelman & Duncan, *supra* note 11, at 2.
[157] Gilead, *supra* note 155, at 589.
[158] *Id.*
[159] *See infra* Part III.D (arguing that there are obviously many other instruments that could cure externalities other than liability rules, e.g., *ex ante* regulation by government,

At the end of the last century there were fierce debates between economists and lawyers on the goals of tort law, and some attempts were made to reconcile the legal (corrective justice-based) approach with the economic (deterrence) based approach.[160] Now the legal community and policymakers have become more and more convinced of the importance of liability rules as an instrument of prevention, especially in the environmental arena.[161] One of the reasons for this change is the increasing empirical evidence showing that industrial operators (like those in the environmental field) respond to financial incentives provided through liability regimes.[162]

Before addressing whether this efficient level of care can be found through a strict liability or negligence rule, we will discuss how the function of liability rules is viewed in CCS literature.

In a study, Adelman and Duncan mention that common law liability is likely to play a modest role in promoting safe sequestration of CO_2.[163] The reason they argue this is that, as was previously mentioned,[164] CCS creates a potential mix of short-term and long-term risks that are difficult to handle in a liability regime. They refer to articles whose authors are strongly opposed to transferring long-term stewardship to the government since this would essentially remove liability from operators. This could present a risk of moral hazard (e.g., location choice) if operators knew that the government would pay the costs of long-term liability.[165] The moral hazard risk is stressed *inter alia* by Trabucchi and Patton, who state that if the operator has little or no financial risk this could lead to poor site selection and management decisions.[166] They are therefore opposed to financial solutions where the risk would be transferred

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and market-based instruments such as emission trading, which has become popular as an instrument to mitigate climate change).

[160] *See, e.g.*, Gary T. Schwartz, *Mixed Theories of Tort Law: Affirming both Deterrence and Corrective Justice*, 95 TEX. L. REV. 1801, 1801 (1997).

[161] The preventive effect of liability rules was explicitly mentioned in the EU White Paper on Environmental Liability, which preceded the European Environmental Liability Directive. *See* Eur. Comm'n, *White Paper on Environmental Liability*, COM (2000) 66 final (Feb. 9, 2000).

[162] *See generally Empirics of Tort*, *in* TORT LAW AND ECONOMICS 453–98 (Michael Faure ed., 2010); Michael G. Faure, *Effectiveness of Environmental Law: What Does the Evidence Tell Us?*, 36 WM. & MARY ENVTL. L. & POL'Y REV. 293, 301–05 (2012) (stating an overview of empirical evidence with respect to the deterrent effect of liability rules).

[163] Adelman & Duncan, *supra* note 11, at 5.

[164] *See supra* Parts I.D–F.

[165] Adelman & Duncan, *supra* note 11, at 22.

[166] Trabucchi & Patton, *supra* note 26, at 9.

to the public since this would remove incentives for proper site selection.[167] Trabucchi and Patton instead rely on the deterrent effect of exposure to liability, arguing that when CCS operators bear the costs of safely operating and closing their facilities the companies will have a financial incentive to site, design, and operate facilities in a risk-reducing manner.[168]

The literature hence provides a mixed picture on the role of liability rules for CCS. This may have to do with the fact that liability for risks emerging in the different phases of the CCS life cycle are sometimes insufficiently distinguished.[169] Generally authors seem to agree that as far as proper site selection, injection, operation, and closure of the site are concerned, liability rules can play an important role in providing incentives.[170] However, many argue that the role of tort liability is much more limited with regard to long-term stewardship (long-tail risk).[171] Expectations seem to be overstated for the role that the liability system can play both with the operators and with the public at large. As has already been mentioned,[172] many consider the creation of a proper and clear liability regime important for providing certainty to the industry. Concerns about potential liability would hence be an important barrier to developing CCS projects.[173]

According to some, there is a demand for a clear liability regime not only from the industry but also from the public at large.[174] Wilson, Klass and Bergan stress that a clear and transparent liability regime may help the public have confidence that risks will be actively managed and, in the event of an accident, effectively remediated and compensated.[175] The way in which long-term liability is addressed may therefore have an impact on public perceptions of CCS.[176] This shows that the demand for a liability regime is not based solely on objective valuations of the risk but may also have a symbolic function for industries—as reinsurance concerning the limits on their long-term liability exposure—and

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[167] *See id.* at 11 (arguing that if the risk were to be transferred to the public this would place environmentally superior operations at a competitive disadvantage).
[168] *Id.* at 13.
[169] *Id.*
[170] *See* Adelman & Duncan, *supra* note 11, at 31 (arguing that traditional tort liability may provide meaningful deterrence against poor site selection and operation).
[171] Adelman & Duncan, *supra* note 11, at 30–31.
[172] *See supra* Part I.C.
[173] *See, e.g.*, Trabucchi, Donlan & Wade, *supra* note 38, at 388.
[174] Wilson, Klass & Bergan, *supra* note 72, at 4575.
[175] *Id.*
[176] *See* De Figueiredo, Reiner & Herzog, *supra* note 133, at 655.

for the public.[177] The latter is, however, a double-edged sword. For example, transferring liability for long-term stewardship to the government could signal to the public that the industry may not be liable for (remaining) long-tail risks, but could also provide reinsurance that, in the event of damage, compensation (via government) would be available.[178]

Adelman and Duncan rightly plead for a realistic approach concerning the possibilities and limits of liability rules for CCS.[179] They distinguish between the different functions of liability rules (prevention/deterrence and compensation), address how these functions can play different roles in the various phases of the CCS life cycle, and mention alternative regulatory instruments to liability rules that could fulfill this role.[180] For example, they argue that as a starting point liability rules could provide meaningful deterrence against poor site selection and operation.[181] However, this deterrence function will mostly play a role in the phases of the CCS project prior to long-term stewardship. Given the fact that long-tail risks are relatively limited, liability for long-tail risks would only offer nominal deterrence.[182] From that perspective a transfer of financial risk for the long-term stewardship should not necessarily create a moral hazard risk for operators.[183] Moreover, as we will subsequently argue,[184] to the extent that liability rules do not provide perfect incentives for deterrence, incentives could be provided through regulatory standards aimed at rigorous site selection, diligent project management, and monitoring.[185]

Finally, as far as the goal of victim compensation is concerned, other instruments than liability rules[186] could be employed to provide victim compensation.[187] Using liability rules not for prevention but rather for compensation often leads to a dilution of policy goals and may thus create inefficiencies.[188] Both operators and the public at large have therefore probably overstated the importance of liability rules[189] with respect

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[177] *Id.*
[178] *Id.*
[179] Adelman & Duncan, *supra* note 11, at 19.
[180] *Id.*
[181] *Id.* at 31.
[182] *Id.* at 6.
[183] *Id.*
[184] *See supra* Part II.D.
[185] *See* Klass & Wilson, *supra* note 1, at 109.
[186] *See infra* Parts IV–V.
[187] *See* Adelman & Duncan, *supra* note 11, at 29.
[188] *Id.*
[189] *See id.* at 53.

to prevention and compensation. This preventive role may be quite important until the phase of long-term stewardship; after that liability could only provide nominal deterrence and would for that reason have very little added value.

Finally, it should be stressed that models have been developed that enable valuation and monetization of the risks involved with CCS.[190] This is important since it shows that, notwithstanding uncertainties,[191] there is sufficient scientific expertise available to determine the potential damage resulting from CCS and develop optimal prevention standards.

B. Strict Liability or Negligence?

The economic approach to liability holds that in a so-called unilateral accident model (where only the injurer can influence the accident risk) both a strict liability and negligence rule provide incentives to follow an optimal care level.[192] In a bilateral care situation (where the victim can also influence the accident risk) a contributory negligence defense should be added to the strict liability rule to provide the victim with incentives to take care as well.[193] Additionally, the economic approach holds that it is important to provide incentives to parties to adopt efficient activity levels.[194]

The activity level can be interpreted as any control variable not taken into account in setting the optimal level of care.[195] Under a negligence rule an injurer has no incentive to adopt an optimal level of activity.[196] This cannot be remedied because judges cannot easily incorporate the optimal activity level into the due care standard.[197]

Since activity level changes are not included in the due care standard, strict liability (with a defence of contributory negligence) will encourage activity level changes for the injurer, while a negligence rule

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[190] *See, e.g.*, Trabucchi, Donlan & Wade, *supra* note 38.
[191] *See supra* Part I.G.
[192] *See* STEVEN SHAVELL, ECONOMIC ANALYSIS OF ACCIDENT LAW 14 (1987); Steven Shavell, *Strict Liability versus Negligence*, J. LEGAL STUD. (1980); William Landes & Richard Posner, *The Positive Economic Theory of Tort Law*, GA. L. REV. 851 (1981).
[193] *See* SHAVELL, *supra* note 192, at 14.
[194] Peter A. Diamond, *Single Activity Accidents*, 3 J. LEGAL STUD. 107 (1974); A. Mitchell Polinsky, *Strict Liability versus Negligence in a Market Setting*, NAT'L BUREAU OF ECON. RES. 44 (1980); Shavell, *supra* note 192.
[195] Diamond, *supra* note 194, at 109.
[196] *Id.* at 120.
[197] It is difficult to determine both the optimal and the actual activity level. *See, e.g.*, Polinsky, *supra* note 194, at 47; Shavell, *supra* note 192, at 2.

will encourage activity level changes for the victim. Several authors suggest that in bilateral cases strict liability would be a superior device if it is more important to give injurers an incentive to change their activity level than it is to incentivize the victims.[198] This implies that if the injurer's activity is very dangerous and creates a high accident risk, even if optimal care is taken, e.g., if through use of explosives an injurer caused an old house to collapse in the middle of a densely populated area, it would be more desirable to control the injurer's activity. Conversely, the advantage of a strict liability rule disappears if the injurer's activity is not important enough to be controlled. For instance, if the injurer ran to catch a train and collided with another pedestrian a negligence rule would be superior because it is just as important to control the victim's activity as it is to control the injurer's. If the activity of the injurer is not very dangerous, if exercised with reasonable care, it is desirable to give the victim an incentive to adopt an optimal activity level as well.

Even though a clear-cut test is difficult to give, Landes and Posner describe several factors that may lead to a preference for a strict liability rule.[199] These elements are: (1) high expected accident costs; (2) the impossibility that more care by the injurer would reduce the accident risk; (3) the impracticability of constraining the victim's activity in favor of the injurer's; and (4) the desirability to reduce the risk by changing the injurer's activity level.[200]

In sum, how do these economic arguments in favor of strict liability apply to CCS? To some extent the analysis of liability for CCS-related damage resembles the analysis of liability for environmental risks.[201] The risks created by CCS can in most cases be considered a unilateral accident, i.e., an accident whereby only the injurer can influence the accident risk. In that case economic analysis predicts that the advantage of the strict liability rule is that it will give the injurer an incentive both to adopt an optimal activity level and to take efficient care.[202] Since the

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[198] Landes & Posner, *supra* note 192, at 877; Shavell, *supra* note 192, at 7, 19.

[199] Landes & Posner, *supra* note 192, at 907.

[200] *Id.*

[201] *See, e.g.*, LUCAS BERGKAMP & BARBARA GOLDSMITH (EDS.), THE EU ENVIRONMENTAL LIABILITY DIRECTIVE: A COMMENTARY 32–33, 37–38 (2013); KRISTEL DE SMEDT, ENVIRONMENTAL LIABILITY IN A FEDERAL SYSTEM: A LAW AND ECONOMICS ANALYSIS (2007); Michael G. Faure & Jing Liu, *New Morals for the Compensation of Natural Resources Damage*, 4 KY. J. EQUINE, AGRIC. & NAT. RES. L. 261, 274 (2011–12); JING LIU, COMPENSATING ECOLOGICAL DAMAGE: COMPARATIVE AND ECONOMIC OBSERVATIONS 45 (2013); Barbara Pozzo, *The Liability Problem in Modern Environmental Statutes*, 4 EUR. REV. PRIV. L. 111 (1996).

[202] BENJAMIN J. RICHARDSON, ENVIRONMENTAL REGULATION THROUGH FINANCIAL ORGANISATIONS: COMPARATIVE PERSPECTIVES ON THE INDUSTRIALIZED NATION 166–67 (2002).

victim can, in most cases, not influence the accident risk,[203] strict liability seems to be the best solution to give the potential injurer optimal incentives for accident reduction in those cases. It is, however, important to add that in bilateral cases, even when strict liability remains preferred because the injurer has the largest influence on the accident risk, it is important to add a defense to take into account the victim's behavior as well.[204] These arguments also justify the introduction of strict liability for environmental harm,[205] which many countries have proceeded to do.[206]

The arguments in favor of strict liability can, to a large extent, also be found in theoretical literature on liability for CCS and also in some legal systems.[207] Adelman and Duncan mention that under American law, strict liability is favored when an activity is deemed to be "abnormally dangerous."[208] Even though they argue that CCS is in fact not an abnormally hazardous activity, the unilateral nature of the activity, also stressed in economic analysis, favors strict liability for CCS-related damage.[209] This would lead to strict liability for releases of CO_2, as well as for releases of brine.[210] Several authors have analyzed the way in which damage related to CCS is treated under particular legal systems and found that, while different legal bases may constitute CCS-related liability depending on the country, strict liability is the most common standard.[211] This seems to not only be the standard in the United States[212] but in many European countries as well.[213] In the EU the operation of storage

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[203] *Id.* at 166.

[204] The operation of storage sites pursuant to the directive on the geological storage of carbon dioxide has now been added to Annex III of Directive 2004/35/EC dealing with environmental liability.

[205] *See* LUCAS BERGKAMP, LIABILITY AND ENVIRONMENT: PRIVATE AND PUBLIC LAW ASPECTS OF CIVIL LIABILITY FOR ENVIRONMENTAL HARM IN AN INTERNATIONAL CONTEXT 119–50 (2001) (providing an overview of the justifications for strict liability).

[206] *See* RICHARDSON, *supra* note 202, at 165.

[207] *Id.*

[208] Adelman & Duncan, *supra* note 11, at 41.

[209] *Id.* at 43–44.

[210] *Id.* at 51–52 (arguing that there may be an argument for a negligence rule as far as the liability for *ex ante* site selection is concerned). However, since harm is often indevisable it may be more appropriate to use one generalised strict liability rule.

[211] *See* De Figueiredo, Reiner & Herzog, *supra* note 133, at 649–52 (concerning American law); Hoffman, *supra* note 133, at 539–44.

[212] Hoffman, *supra* note 133, at 539.

[213] *See* INT'L ENERGY AGENCY ("IEA"), CARBON CAPTURE AND STORAGE: LEGAL AND REGULATORY REVIEW (2nd ed., 2011) (summarizing the liability regime for long-term liability for stored CO_2 in various Organization for Economic Co-operation and Development ("OECD") countries).

sites pursuant to the CCS Directive has now been brought under the framework of the Environmental Liability Directive.[214] CCS storage has been brought under Annex III of the European Liability Directive; as a result, a strict liability regime applies to it as well.[215]

C. *Liability or Regulation?*

1. Regulation for CCS-Related Damage?[216]

The choice between regulation and liability rules was thoroughly examined by Steven Shavell in a 1984 paper in which he advanced several influential criteria.[217] Shavell argues that when the government has better information or can acquire information at a lower cost than private parties; when there is a risk that the damage will be higher than the wealth of an individual operator (and hence an insolvency risk may arise); and when there is a danger that a liability suit will never be brought (e.g., because of problems of causation, proof, or latency) there may be a strong preference for safety regulation.[218]

If one looks at the first criterion, that of information costs, it must be stressed that assessing the risks of a certain activity often requires expert knowledge and judgment.[219] Small organizations might lack the incentive or resources to invest in research to find out what the optimal care level would be. Also, there would be little incentive to carry out intensive research if the results were automatically available to competitors in the market: this is the well-known "free rider" problem.[220] This problem can be partially countered by legal instruments granting an intellectual property right to the results of the research. However, it may not be possible for small companies to undertake studies on the optimal technology for preventing environmental damage. Therefore, it is often more efficient to allow the government itself to do the research (e.g., in a governmental research institute).[221] The results of this research can then

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[214] *See* 2009 O.J. (L 140) 114.
[215] *Id.*
[216] *See also* Adelman & Duncan, *supra* note 11, at 24–27.
[217] *See generally* Steven Shavell, *Liability for Harm versus Regulation of Safety*, 13 J. LEGAL STUD. 357 (1984); Shavell, *supra* note 192, at 277–90.
[218] Shavell, *supra* note 217, at 357.
[219] *Id.* at 358.
[220] *Id.* at 374.
[221] *Id.* at 369.

be passed on to the parties through regulation.[222] Hence, setting standards in regulation can be seen as a means of passing on information with the minimal technology required. Obviously, it is more efficient for the government to acquire information on the optimal standard than it would be for an individual firm to find out what additional reduction in a particular CCS-related risk would produce the greatest reduction in expected damages. There are undeniable "economies of scale" advantages in regulation.[223]

The insolvency argument also points in the direction of regulation. CCS-related risks can be caused by individuals or firms with fewer assets than the damages that result from them.[224] It should not be forgotten that even a small firm could cause harm to a large number of individuals and result in damages largely exceeding the firm's assets.[225] Moreover, most firms have been incorporated as a legal entity and therefore benefit from limited liability with respect to creditors,[226] as individual shareholders are not liable to the extent of their personal assets.[227]

Also, the chances of a liability suit being brought for damage caused as a result of CCS-related risks is normally very low. Whether there are victims with an incentive to sue may greatly depend upon the potential damage that could be caused by a CCS project. Especially with human health impacts there is a danger that the damage may be spread over a large number of people, who will have difficulty organizing themselves to bring a lawsuit. Additionally, the damage may only become apparent years after the wrongful act took place. This is, as was previously mentioned,[228] the essence of CCS-related risks, i.e., long-tail risks, which bring proof of causation and latency problems and only make it more difficult to bring suit against whoever caused the risk.

The importance of regulation as a primary tool in preventing risks emerging from CCS is also stressed in literature dealing with CCS-related liability.[229] An important reason why CCS literature hold that traditional liability rules will not provide efficient incentives for prevention relates to the potentially long-term nature of liability. Liability for risks that may occur more than fifty years into the future may not have

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[222] *Id.*
[223] *Id.*
[224] Shavell, *supra* note 217, at 369.
[225] *Id.*
[226] *Id.* at 362.
[227] *Id.*
[228] *See supra* Part I.F.
[229] Adelman & Duncan, *supra* note 11.

a strong deterrent effect on decisions that have to be made *ex ante*.[230] This has important consequences: (1) little would be lost as far as deterrence is concerned if operators were relieved from this long-term liability; and (2) the fact that liability rules are weak, especially as far as long-tail damage is concerned, is a strong argument in favor of *ex ante* safety regulation.[231] Shavell's criteria, especially the risk of spinning off parts of the business into small low capital companies and thus creating a judgment proof problem, is considered a serious issue.[232] The same goes for the likelihood that a lawsuit would be brought as a result of damage caused by CCS. Latency may substantially reduce the effectiveness of a liability suit and, moreover, damage may be spread over a large number of victims.[233] It is well-known that in these types of situations the incentives for a victim to file a liability suit are very small[234]: any personal benefits from a lawsuit would be low, and given free rider problems, individuals would have no incentive to bring suits that could benefit everyone.[235] The only argument that may favor a liability framework would be information asymmetry.[236] But that would only favor liability rules if it could be argued that operators would be better placed than the government to assess the potential risks emerging from CCS.[237]

Other authors argue that liability rules alone are not able to sufficiently control the risks posed by CCS[238] and that a tailored regulatory structure is an important component of risk management.[239] Direct regulation of the conditions under which the various phases in the CCS project life cycle are executed is crucial in reducing the residual risk-tail for a particular CCS site.[240] Many are hence in favor of installing a

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[230] *Id.* at 22.
[231] *Id.*
[232] *Id.* at 25.
[233] *Id.*
[234] This is referred to as the rational apathy problem. *See* Hans-Bernd Schäfer, *The Bundling of Similar Interests in Litigation. The Incentives for Class Actions and Legal Actions taken by Associations*, 9 EUR. J. L. & ECON. 183, 183–213 (2000).
[235] *See* Steven Shavell, *The Social versus the Private Incentive to Sue in a Costly Legal System*, 11 J. LEGAL STUD. 333 (1982); *see generally* Susan Rose-Ackerman & Mark Geisteld, *The Diversions between Social and Private Incentives to Sue: A Comment on Shavell, Menell and Kaplow*, 16 J. LEGAL STUD. 483 (1987).
[236] Shavell, *supra* note 217, at 359.
[237] Adelman & Duncan, *supra* note 11, at 61.
[238] Klass & Wilson, *supra* note 1, at 159 (arguing that tort liability (1) fails to detect and assign blame for harm; (2) may lead to operator insolvency; and (3) is unable to provide a remedy for long-tail risks).
[239] *Id.*
[240] *See* Trabucchi & Patton, *supra* note 26, at 8–9.

private/public board that controls the elements influencing risk such as proper siting, immediate corrective action, and early shutdown of highly risky facilities.[241] All authors agree that, notwithstanding the virtues of a liability system, it cannot be the primary system of prevention. *Ex ante* safety regulation will necessarily be the preferred instrument for drafting and enforcing tailor-made safety regulations aimed at the reduction of CCS-related risks.[242] Moreover, given that research also indicates that the preventive measures to be taken largely depend upon the specific location and are hence site-specific,[243] regulation should not be of a general nature. The administrative instrument for enabling such an adaptation of regulatory conditions to the specific site is obviously the permit or license, through which regulatory authorities can lay down particular safety standards.

2. Supplementary Role of Liability Rules

Although there are strong arguments for making safety regulation the primary instrument for preventing CCS-related harm, there may still be an important, although supplementary, role to be played by liability rules. There are many reasons for this.[244]

The first point that is often stressed is that just because there are many arguments in favor of *ex ante* regulation of CCS-related risks, it does not mean the tort system should no longer be used for its deterring and compensating functions.[245] One reason to still rely on the tort system is that the effectiveness of regulation is dependent upon enforcement, which may be weak. Additionally, the influence of lobby groups on regulation, which public choice theory has rightly highlighted, can to some extent be overcome by combining safety regulation and liability rules. Moreover, safety regulation, e.g., licences, can be quickly outdated and often lack flexibility, which merits utilization of tort rules.[246]

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[241] *Id.* at 14–16.
[242] Adelman & Duncan, *supra* note 11, at 29 ("The failure of common law regimes to deter latent harms also places a high premium on effective ex ante regulation").
[243] *Liability*, GLOBAL CCS INST., http://hub.globalccsinstitute.com/publications/carbon-dioxide-capture-and-storage-and-unfccc-recommendations-addressing-technical-18 [http://perma.cc/BK65-R2X8] (last visited Jan. 22, 2016).
[244] *See also* BERGKAMP, *supra* note 205, at 233–36 (describing the interdependencies between regulation and liability).
[245] Adelman & Duncan, *supra* note 11, at 29.
[246] The literature generally concludes, also with respect to environmental risks, that liability and regulation should be combined in order to reach optimal deterrence. *See inter alia* Patrick W. Schmitz, *On the Joint Use of Liability and Safety Regulation*, INT'L

CCS-related risks also stress the importance of liability rules in providing backup for regulatory failure.[247] Especially where liability is targeted not at long-term stewardship but at the near-term risks, it is considered a useful complement to regulatory requirements.[248] Given the fact that regulation can be vulnerable to information gaps (in a situation where operators possess better information on preventive measures than regulators), liability rules could have an important deterrent effect.[249] In fact, the most important reason for liability's supplementary role is related to the informational advantage of operators and to the rather static nature of regulation.[250] Since CCS is a new technology involving many uncertainties[251] it is possible that information on optimal technologies will evolve rapidly once more pilots are executed and experience on risk preventive measures is acquired. Ideally this would lead to a rapid adaptation of safety standards that would dynamically follow the newest insights in technological developments. In practice, however, adaptation of safety standards such as permits set by administrative agencies may not be that easy, depending upon the legal system. The advantage of exposing operators to strict liability is that this provides additional incentives for investments in research and development and hence for innovation of preventive technologies.

One consequence of the joint use of regulation and liability is that regulation can, in those legal systems that still employ a negligence standard, inform the judiciary of the optimal level of care. Indeed, in many legal systems a breach of a regulatory duty is automatically considered unlawful.[252] This is sometimes referred to as "negligence per sé."[253] The advantage of this model is that the regulator in fact solves the information deficiency for the judge. The judge only verifies whether the regulatory standard has been breached. If that breach stands in a causal relationship with the damage, the defendant's liability will be established. It

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REV. L. & ECON. 371, 371 (2000); Pierre Bentata & Michael G. Faure, *The Role of Environmental Civil Liability: An Economic Analysis of the French Legal System*, 20 ENVTL. LIABILITY, LAW, POL'Y, & PRACTICE 120, 120–28 (2012) (providing empirical evidence with respect to environmental liability in France).

[247] Adelman & Duncan, *supra* note 11, at 35.

[248] *Id.* at 46.

[249] *Id.* at 53 (although the authors qualify the additional incentive provided by liability in this case as "limited").

[250] *Id.*

[251] *See supra* Part I.G.

[252] Adelman & Duncan, *supra* note 11, at 40 n.219.

[253] *Id.*

moreover provides incentives to victims to prove that the regulatory standard was breached. This both facilitates the burden of proof for the victims (in a negligence setting), and makes the victim a *de facto* enforcer of safety regulation. This is an example of a "smart"[254] combination of liability rules and regulatory standards. Of course, the question arises as to whether compliance with regulations will automatically free an injurer from liability; we intend to argue that this should not necessarily be the case.[255]

In summary, regulation will be the primary instrument in controlling CCS-related risks. Liability rules can still play a role, but more as a "secondary backstop" behind a comprehensive, preventive regulatory framework.[256]

Now that the potential role of the liability regime for CCS-related damages has been generally outlined, the next chapter will discuss a few more detailed points concerning the shape of a possible liability regime.

III. POLICY OPTIONS WITH RESPECT TO LIABILITY FOR CCS-RELATED DAMAGE

A. *Again: Goals and Limits of Liability Rules*

Before discussing various aspects of how a liability regime for CCS-related damage could be shaped, we should return once more to the earlier discussion concerning the goals of a CCS liability system and the importance of liability rules generally.[257] The reason is that the particular way in which one wishes to shape a liability regime will strongly depend upon the expectations one has concerning such a regime. Doubts have already been formulated concerning the ability of the liability regime to contribute to prevention, at least as far as long-tail risks are concerned.[258] In that respect it is striking that the literature concerning CCS-related damages stresses the need to expose operators to liability or risk the emergence of a moral hazard.[259] Some claim that operators

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[254] *See* NEIL GUNNINGHAM & PETER GRABOSKY, SMART REGULATION, DESIGNING ENVIRONMENTAL POLICY (1998).
[255] *See infra* Part II.D.
[256] Wilson, Klass & Bergan, *supra* note 72, at 4576.
[257] *See supra* Parts II.A and II.B.
[258] Adelman & Duncan, *supra* note 11, at 22.
[259] *See, e.g.*, Trabucchi & Patton, *supra* note 26, at 3 n.7 (arguing that "[m]oral hazard refers to the specific situation where the risks of an unplanned event increase, because

should be held financially responsible for deficiencies in their operational methods and in the individual site characteristics,[260] as granting operators broad-scale indemnity would create a moral hazard.[261]

Only Adelman and Duncan point to the fact that those earlier studies all view the potential damages resulting from CCS in a rather unbalanced manner and without sufficiently distinguishing between the various phases in the life cycle of the CCS project. They first reference the importance of regulation in the prevention of harm[262] and argue that, concerning long-term stewardship, there is in fact no moral hazard[263] for the simple reason that these risks are so remote that they provide hardly any meaningful *ex ante* deterrence to operators' behavior.[264] That is not an argument for totally excluding CCS operators from liability, but rather for limiting their exposure to liability to the moment where the long-term stewardship starts and liability is transferred to the state. Operators would still be held fully liable for all damage that could emerge up until that moment and would of course be able to choose appropriate insurance or other coverage mechanisms.

This relates to the more general point mentioned in the introduction to the role of liability rules,[265] which is that liability rules have to balance both positive as well as negative externalities,[266] a point that has been made by Gilead.[267] Those who only stress the negative externalities that could potentially follow from a CCS project tend to forget the positive externalities (in terms of mitigating climate change) that CCS could generate as well.[268] Hence, a liability regime should be shaped in such a way that positive and negative externalities are appropriately balanced. If one were, for example, only to stress potentially negative externalities and argue that operators should be held liable for losses that could emerge at an undefined moment in time, this could lead to so-called "crushing" liability and result in socially desirable CCS activities not being undertaken

the responsible party is (partially) insulated from being held fully liable for resulting harm. If CCS facilities are not held completely responsible for the consequences of their actions, arguably they will be less careful in their siting and operating decisions.").

[260] Dooley, Trabucchi & Patton, *supra* note 84, at 386.

[261] Hawkins, Peridas & Steelman, *supra* note 2, at 4407.

[262] Adelman & Duncan, *supra* note 11, at 20.

[263] *Id.*

[264] *Id.*

[265] *See supra* Part II.A.

[266] Gilead, *supra* note 155, at 607.

[267] *Id.* at 589–92.

[268] *Id.* at 592.

at all. This dilemma has also been described by Trebilcock, who warns that a combination of strict liability with joint and several and retrospective liability, especially in cases of long-tail risks, may lead to overly defensive practices.[269]

B. Force Majeure

One question that is often asked in cases of ultrahazardous risks to which strict liability regimes apply (such as nuclear liability) is whether operators should still be held liable if the damage is caused by an act that was beyond the control of the operator, often qualified as "*force majeure*" or "act of God".[270] The basic premise of the economic analysis of tort law is that exposure to liability should provide incentives for behavioral change, i.e., for additional preventive measures.[271] If *force majeure* is defined as an act that is beyond the control of the operator, in principle, the operator should not be held liable for resulting damages since liability could not have a positive effect on his incentives for prevention. However, this requires a qualification for cases of damage caused by natural hazards such as flooding or earthquakes as these are hazards to which CCS sites could be exposed and could potentially lead to substantial damage.[272] The mere fact that damage resulting from a CCS site is caused by a natural disaster should of course not automatically exclude the operator from liability to the extent that those events are reasonably foreseeable. A proper location choice, which is (as previously mentioned) crucial for the prevention of CCS-related risks, will take the possibility of flooding or seismic events into account and hence avoid a CCS storage site in flooding zones or earthquake prone areas.[273] Only when expert opinion holds that a particular natural hazard in the location of the site was reasonably unpredictable should the operator be precluded from liability.[274]

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[269] *See* Michael J. Trebilcock, *The Social Insurance—Deterrence Dilemma of Modern North-American Tort Law: A Canadian Perspective on the Liability Insurance Crisis*, 24 SAN DIEGO L. REV. 929, 930–31 (1987).

[270] *See* Michael G. Faure & Jing Liu, *The Tsunami of March 2011 and the Subsequent Nuclear Incident at Fukushima: Who Compensates the Victims?*, 37 WM. & MARY ENVTL. L. & POL'Y REV. 129, 133 (2012).

[271] *See* Trebilcock, *supra* note 269, at 965.

[272] MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 270–72.

[273] *Id.* at 273–74.

[274] *See also* BERGKAMP, *supra* note 205, at 53 (holding that foreseeability should be an important requirement for liability. Hence, unforeseeability would, from that perspective, preclude liability).

Note that under the nuclear liability conventions operators are only precluded from liability in cases where the natural disaster is of an exceptional character.[275] Similar language is used in the Japanese Act on Nuclear Liability.[276] The tsunami of March 2011 was, however, not considered a natural disaster of an exceptional character in that particular region of Japan.[277] As a result, the tsunami did not preclude the operator Tokyo Electric Power Company ("TEPCO") from liability for the subsequent Fukushima nuclear disaster.[278]

The relevance of the *force majeure* exception is also discussed in CCS-related literature. Since CCS storage sites in Europe were brought under the Environmental Liability Directive through the CCS Directive, it has been held that operators can be precluded from liability on the basis of *force majeure*.[279] However, the same authors hold that liability would still be possible for earthquakes, which could be a significant type of risk in relation to long-term CO_2 storage.[280] This shows that a natural disaster does not automatically constitute *force majeure*. Of course, the question will have to be asked whether the damage resulting from a natural disaster was reasonably foreseeable (e.g., when the CCS storage site was constructed in a flood prone area or in an area exposed to earthquakes).[281] In those cases the site selection could be considered wrongful

[275] The Paris Convention establishes a system of absolute liability. Classical exonerations such as *force majeure*, acts of God, or intervening acts of third persons are no longer applicable. The operator is not liable, however, for damage caused via a grave natural disaster of an exceptional character, unless the laws of the contracting party in whose territory his nuclear installation is situated provide to the contrary. Similar stipulations can be found under the Vienna Convention, which also regulates nuclear liability. *See* LIU, *supra* note 201, at 210–12.
[276] If the nuclear damage is caused by a "grave natural disaster of an exceptional character or by an insurrection" the nuclear operator can be exonerated from liability on the basis of § 3 of the Act on Compensation for Nuclear Damage. *See* Act on Compensation for Nuclear Damage, Act No. 147 of 1961, § 3, *available at* https://www.oecd-nea.org/law/legislation/japan-docs/Japan-Nuclear-Damage-Compensation-Act.pdf [https://perma.cc/C7VM-6MM3].
[277] The government of Japan did not admit the earthquake and tsunami to be disasters of an "exceptional character." *See* Taiga Uranaka, *Japan Says No Limits to Tepco Liability from Nuclear Disaster*, REUTERS (May 2, 2011), http://www.reuters.com/article/2011/05/02/us-japan-tepco-idUSTRE7412PK20110502 [http://perma.cc/HZP7-SDX9]; *No Limits for TEPCO's Liability in Fukushima Crisis, Japan Says*, POWERNEWS (May 4, 2011), http://www.powermag.com/no-limits-for-tepcos-liability-in-fukushima-crisis-japan-says/ [http://perma.cc/9MAG-VFBZ].
[278] *See* Faure & Liu, *supra* note 270, at 192.
[279] MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 277.
[280] *Id.* at 281.
[281] Adelman & Duncan, *supra* note 11, at 37.

and thus lead to operator liability.[282] Only if the damage resulting from a natural disaster were to be considered totally unforeseeable and not preventable by reasonable measures taken by the operator would *force majeure* preclude liability.[283]

C. *Attribution of Liability*

The issue of liability attribution has different angles. It basically amounts to who should be held liable for CCS-related risks in cases where many parties are involved.[284] As was explained during the discussion on the CCS project life cycle,[285] there may be different parties in the various phases of the CCS chain, differing more particularly between CO_2 capture, transportation, and storage. In this particular case we focus on storage, whereby liability is mostly allocated to the licencee of the storage site, i.e., the operator. One could ask whether, in the case of CCS, liability should be channeled to the operator. In law and economics literature, channeling is usually considered inefficient[286] as it negatively affects the incentives of parties who could influence the accident risk to take care.[287] Channeling liability to the licencee is therefore generally rejected[288] and would not be recommended in a future liability regime concerning CCS-related risks. There is only one example where a channeling seems unavoidable: climate change liability for CO_2 emissions.[289] After all, if there were no channeling this could theoretically lead to liability for all operators who originally created the CO_2 and sequestered it at the CCS site. The costs of such an allocation might be prohibitive;[290] hence, for that particular damage liability can be channeled to the operator.[291]

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[282] *Id.*
[283] This is, moreover, in line with U.S. case law concerning the question of whether natural disasters constitute an excuse from environmental liability. For a detailed discussion, *see* Andri Wibisana, *The Myths of Environmental Compensation in Indonesia: Lessons from the Sidoarjo Mudflow, in* REGULATING DISASTERS, CLIMATE CHANGE AND ENVIRONMENTAL HARM: LESSONS FROM THE INDONESIAN EXPERIENCE 277–354 (Michael Faure & Andri Wibisana eds., 2013).
[284] *See* Klass & Wilson, *supra* note 1, at 178–79.
[285] *See supra* Part I.F.
[286] *See, e.g.*, MICHAEL G. FAURE & TON HARTLIEF, INSURANCE AND EXPANDING SYSTEMIC RISKS 127 (2003).
[287] *Id.*
[288] *Id.* at 127–28. *See also* Michael J. Trebilcock & Ralph A. Winter, *The Economics of Nuclear Accident Law*, 17 INT'L REV. L. & ECON. 215, 232–35 (1997).
[289] Havercroft & Macrory, *supra* note 112, at 35.
[290] *Id.*
[291] *Id.*

D. *Effect of Regulation*

It was mentioned earlier that regulation would be the primary tool for reducing CCS-related risks.[292] The question then arises whether following regulations or, say, permit conditions, would excuse an operator from tort liability. Although this is a highly debated issue,[293] most legal systems reject such a regulatory compliance defence.[294]

One can find a clear economic rationale for this rule. If compliance with a regulatory standard or licence would automatically result in a release from liability, the potential injurer would have no incentive to invest in more care than the regulation asks from him, even if this could reduce the expected accident costs.[295]

These reasons also seem compelling in the case of CCS. If compliance with regulation were to free an operator from liability, liability rules could not play their desirable supplementary role.[296] Moreover, a compliance with regulation defence would potentially make strict liability meaningless,[297] especially since safety requirements can develop rapidly in such a volatile technological environment.

However, that is not to say that safety regulation does not have an influence on operators' exposure to liability. To the extent that safety regulation is effective it would force operators to choose optimal locations, monitor risks, and implement safety standards that contribute to prevention of risk exposure. Hence, compliance with efficient safety standards could reduce operators' exposure to liability (while not formally precluding liability in the event damages occurred).[298]

E. *Causation*

Together with the question of whether regulatory compliance affects liability, the way in which the law deals with causal uncertainty

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[292] *See supra* Part II.C.
[293] For example, in the debate preceding the Environmental Liability Directive, Member States could not reach agreement on this point; as a result, it is left to the Member States whether to include such a compliance with permit defence or not.
[294] Michael G. Faure & Roger Van den Bergh, *Negligence, Strict Liability and Regulation of Safety under Belgian Law: An Introductory Economic Analysis*, 12 GENEVA PAPERS ON RISK & INS. 95, 109–10 (1987).
[295] *Id.*; Shavell, *supra* note 217, at 365.
[296] Adelman & Duncan, *supra* note 11, at 46 (arguing that liability can be a useful complement to traditional regulatory requirements).
[297] Faure & Van den Bergh, *supra* note 294, at 110.
[298] *See also* Havercroft & Macrory, *supra* note 112, at 20.

has an important bearing on the potential scope of operators' liability. Causal uncertainty is especially important with regard to so-called toxic torts whereby a part of the population is exposed to hazardous substances or radiation and a certain disease, e.g., cancer, is subsequently discovered.[299] In these cases it is often not known which individual (among a larger population) was victim of a tort and which received their disease as a result of the background risk.[300] Uncertainty often prevails, whereby experts can only establish that there is a probability of, say, 40% that a particular event caused a particular damage.[301] Instead of the traditional approach where the plaintiff has to prove that it was more probable than not that the event caused the damage (i.e., more than 50%) legal systems now increasingly use proportional liability.[302] Under this standard, if experts judge that the likelihood the tortfeasor caused the damage was 40%, he will be ordered to compensate 40% of the victim's loss.[303]

Causation may also be an issue as far as the potential damage resulting from CCS is concerned. The extent to which this is the case will of course depend upon the nature of the particular damage.[304] In the rare instance of high concentrations of CO_2 resulting in sudden death, it may not be that difficult to establish a causal link with the CO_2 release. Causation may, however, become more difficult to establish for geological impacts, particularly with respect to water resources. The more remote these impacts, the more difficult it will be to prove the causal link. Causation will be especially hard to prove in cases of atmospheric releases giving rise to climate change liability. But with any causal uncertainty, the most effective remedy is to rely on expert evidence concerning the likelihood that a particular damage was related to the CO_2 storage site, and to translate that likelihood into a proportional amount of compensation with which to award the victim. One way of doing that might be to relate the liability to the amount of CO_2 stored (if damages were caused by different storage sites).[305] In that way crushing liability (and

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[299] *See* Jeffrey Trauberman, *Statutory Reform of "Toxic Torts": Relieving Legal, Scientific and Economic Burdens on the Chemical Victim*, 7 HARV. ENVTL. L. REV. 177, 179–200 (1983).
[300] *See* Samuel D. Estep, *Radiation Injuries and Statistics: The Need for a New Approach to Injury Litigation*, 59 MICH. L. REV. 259, 262–71 (1960).
[301] Problems related to causal uncertainty can especially arise in cases of environmental liability; the solutions in many legal systems are not always very clear. *See generally* MARK WILDE, CIVIL LIABILITY FOR ENVIRONMENTAL DAMAGE: A COMPARATIVE ANALYSIS OF LAW AND POLICY IN EUROPE AND THE U.S. (2nd ed. 2013).
[302] *See* Havercroft & Macrory, *supra* note 112, at 25.
[303] *See* BERGKAMP, *supra* note 205, at 287–91, 368–69.
[304] *See supra* Part I.E.
[305] *See* Havercroft & Macrory, *supra* note 112, at 24–25.

thus overdeterrence) could be avoided by making the operator only liable for the damage that was actually caused by the CO_2 storage site. The effectiveness of this system will, of course, to a large extent depend upon whether experts are able to reasonably assess the likelihood that the damage can be allocated to the CO_2 storage site. In practice, this will obviously give rise to debates.

F. *Joint and Several Liability*

To some extent, joint and several liability are the reverse of proportional liability (or channeling of liability as previously discussed).[306] Under joint and several liability, joint tortfeasors are held liable for all the damage to which their behavior might have contributed.[307] Joint and several liability basically means that a victim can choose which operator to sue and claim full compensation from one operator even when more than one operator contributed to the loss.[308]

Joint and several liability regimes have often been introduced to relieve the burden of proof from victims.[309] Victims could collect the entire damage from one of the contributing tortfeasors who could in turn exercise recourse against the other liable parties.[310] An argument in favor of joint and several liability is that it gives potential injurers incentives for mutual monitoring.[311] However, if one of the actors were insolvent, inefficiency may arise since recourse could become impossible.[312] Joint and several liability is controversial since an injurer could in principle also be held liable for a portion of the damage not caused by his activity, thus potentially increasing his liability exposure.[313] Questions of joint

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[306] *See supra* Part III.C.
[307] *See* Tom H. Tietenberg, *Indivisible Toxic Torts: The Economics of Joint and Several Liability*, 65 LAND ECON. 305, 306 (1989).
[308] Joint and several liability was therefore meant to assist the judiciary in circumstances where it was impossible to reasonably ascertain the relative contributions of different parties. *See* RICHARDSON, *supra* note 202, at 163–64.
[309] *See* BERGKAMP, *supra* note 205, at 303.
[310] *Id.*
[311] *See* Tietenberg, *supra* note 307, at 306.
[312] *See* Lewis A. Kornhauser & Richard L. Revesz, *Sharing Damages among Multiple Tortfeasors*, 98 YALE L. J. 831, 832–37 (1989) (analyzing joint and several liability under full solvency); Lewis A. Kornhauser & Richard L. Revesz, *Apportioning Damages among Potentially Insolvent Actors*, J. LEGAL STUD. 617, 620–23 (1990) (analyzing instances of insolvency).
[313] For this reason joint and several liability for environmental harm is opposed by Lucas Bergkamp, *The Proper Scope of Joint and Several Liability*, TIJDSCHRIFT VOOR MILIEUAANSPRAKELIJKHEID 154–55 (2000). *See also* BERGKAMP, *supra* note 205, at 300–03.

and several liability obviously do not arise when there is only a single operator, in which case attribution of liability is unproblematic.[314] It is only when multiple (potential) tortfeasors are involved either in different phases of the project life cycle or operation of the storage site. Joint and several liability increases the potential scope of liability for CCS operators.[315] Therefore, Adelman and Duncan argue that the case for joint and several liability in cases of CCS-related damage is weak.[316] Given the scale of these operations the number of potential defendants should be traceable and joint and several liability could potentially lead to overdeterrence.[317] When considering the positive externalities generated by CCS, policymakers may be cautious with the introduction of joint and several liability for CCS operations.[318]

G. Long-Tail Risk: Limit in Time?

An issue that is extensively discussed in CCS-related literature is the way in which liability law should deal with long-tail risks, given the potentially long latency period of risks.[319] As already mentioned there seems to be a consensus that operators' exposure to liability should depend upon the different phases in the CCS project life cycle.[320] For the entire CCS sequestration, that is to say from the design and operation (injection) until the closure and post-closure phase, all seem to agree that operators should in principle be held liable.[321] It is only as far as the long-term stewardship is concerned, which can in principle take an indefinite period of time, that operators should no longer be exposed to liability.[322] This is strongly argued in a recent study by Adelman and Duncan,[323]

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[314] *See* David Gerard & Elisabeth J. Wilson, *Environmental Bonds and the Challenge of Long-Term Carbon Sequestration*, 90 J. ENVTL. MGMT. 1097, 1099 (2009).
[315] Adelman & Duncan, *supra* note 11, at 42–43.
[316] *Id.* at 45–46.
[317] *Id.*
[318] For a similar conclusion with respect to environmental harm, especially in cases of causal uncertainty, see BERGKAMP, *supra* note 205, at 303–06.
[319] *See also* Avelien Haan-Kamminga, *Long-term Liability for Geological Carbon Storage in the European Union*, 29 J. ENERGY & NAT. RES. L. 309, 309 (2011); John Pendergrass, *Long-term Stewardship of Geologic Sequestration of CO_2*, 43 ENVTL. L. REP. 10659, 10659–60 (2013) (discussing the issues of long-term liability).
[320] *See supra* Part II.C.
[321] *See* Havercroft & Macrory, *supra* note 112, at 35.
[322] This refers to the last phase in the CCS project cycle as identified *supra* in Table 1 in Part I.F.
[323] Adelman & Duncan, *supra* note 11, at 22.

which to some extent goes against earlier, less balanced studies[324] that seemed opposed to any type of preclusion of CCS operator liability. Adelman and Duncan claim that, given the long latency periods, long-term liability in fact offers only nominal deterrence.[325] According to them, liability for long-term stewardship after closure of the site should be transferred to the government.[326] They provide convincing economic arguments for such a preclusion of liability, including the fact that any future damages will be discounted to present value and thus have a very limited deterrent effect.[327] They even argue that these long latency periods could create perverse incentives to operators to manage their insolvency so as to avoid long-term liability.[328] Given that liability is an adequate instrument for targeting short-term risks, latency periods substantially reduce the deterrent value of liability rules.[329] It is therefore more useful to introduce a rigorous regulatory framework for addressing preventive measures aimed at the prevention of long-term liability risk[330] and limiting operator liability to the moment when the site is transferred to the government. Moreover, in many legal systems (such as the United States), a statute of limitations would put a limit on the temporal liability of operators.[331] De Figueiredo suggests a time limit of ten years from the end of CO_2 injection for operator liability.[332]

Others stress the importance of operators remaining liable during the entire operational phase,[333] which can include not only the phase of operation (CO_2 injection) but the period of post-closure monitoring as well.[334] Given that the period of operation (CO_2 injection) could take one to thirty years[335] and the period of post-closure monitoring ten to thirty years,[336] operators could potentially be exposed to liability for a total of eleven to sixty years. It is only for long-term stewardship that liability

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[324] In the sense of not clearly distinguishing between the different phases in the CCS project life cycle.
[325] Adelman & Duncan, *supra* note 11, at 6.
[326] *Id.* at 20.
[327] *Id.* at 28–29.
[328] *Id.*
[329] Adelman & Duncan, *supra* note 11, at 46.
[330] Based on the criteria discussed above *supra* Part III.C.
[331] *See* De Figueiredo, *supra* note 93, at 383–86.
[332] *Id.* at 396.
[333] Trabucchi & Patton, *supra* note 26, at 15.
[334] Adelman & Duncan, *supra* note 11, at 59.
[335] Trabucchi & Patton, *supra* note 26, at 8.
[336] Adelman & Duncan, *supra* note 11, at 59.

would, in this model, be shifted to the state.[337] Others seem to agree with this model, but argue that if a transition of CCS projects to the state were to occur, operators would have to provide sufficient funds to cover the costs of long-term stewardship.[338] This also seems to some extent be the approach followed at the policy level. For example, under the European CCS Directive, after the closure of a site, liability can be passed on to the state when certain strict conditions have been met—including the provision of a financial contribution for the post-transfer period covering, at a minimum, monitoring costs for the next thirty years.[339] The IEA document also states that liability could only be transferred to the operator when (1) there is evidence that there is no significant risk of physical leakage or seepage; (2) a minimum time period has elapsed from the cessation of the injection; and (3) a financial contribution is provided for the long-term stewardship of the site.[340]

These potential solutions seem to comply with the economic insights mentioned earlier: some (rightly) argue[341] that holding operators liable out of principle reasons even during the period of long-term stewardship may have no additional value as far as providing incentives for deterrence. However, the foresight for industry to be held liable even in this period of long-term stewardship could potentially create serious barriers to start CCS projects as a result of which the positive externalities resulting from CCS would not emerge. Sufficient incentives for industry would in the first place be provided through rigorous and effective safety regulation. Moreover, the supplementary deterrent effect from liability rules would still exist since operators would still be held liable for a considerable amount of time during operation and during the post-operation monitoring period. In that respect, differences of course exist between the amounts of time mentioned in the literature[342] and the approach followed at the policy level—for example, in the CCS Directive.[343]

[337] This period could, according to the literature, potentially be very long and even last 1,000 years. *See* Gerard & Wilson, *supra* note 314, at 1099.
[338] Wilson, Klass & Bergan, *supra* note 72, at 4581.
[339] MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 7–9.
[340] IEA, *supra* note 213, at 9.
[341] Adelman & Duncan, *supra* note 11, at 6.
[342] For example, by Trabucchi and Patton, who refer to an operation period of thirty years. Trabucchi & Patton, *supra* note 26, at 8–10. Also, by Adelman and Duncan, who seem to add a period of post-closure monitoring of ten to thirty years. Adelman & Duncan, *supra* note 11, at 59.
[343] Where liabilities could be passed on to the state much more quickly, provided a

Instead of focusing on discussions on the relevant periods, it is more important to stress that, differently than one may perhaps expect, a transfer of long-term liability to the government should not necessarily be opposed from an economic perspective for the simple reason that such a long-tail liability will not provide additional incentives for deterrence. Moreover, as will be argued below,[344] liability for long-term exposure is also largely uninsurable[345] and would thus potentially expose operators to uninsurable risks. In sum, the approach of limiting the liability exposure of operators in time can be supported on economic grounds.

H. Remedies: Limit in Amount?

The question arises whether a financial limit (a so-called cap) should be put on the amount of liability.

The arguments in favor of a cap are advanced in some literature, either generally or to stimulate first movers. For example, De Figueiredo, Reiner and Herzog argue, with the example of nuclear liability in mind, that a liability cap may be desirable.[346] However, they equally argue that a liability cap could be detrimental to carbon storage from a public perception point of view.[347] This may give a wrong signal to the public that CCS (like nuclear energy) is really a catastrophic type of risk and can therefore lead to a stigmatization of CCS.[348] Trabucchi and Patton seem to be more generally in favor of liability caps. Referring to additional enabling legislation, they mention the need of introducing damage thresholds,[349] but they provide hardly any motivation. They refer to *inter alia* the example of the Price-Anderson Act[350] (regulating nuclear liability) and the Oil Pollution Act of 1990,[351] which equally have a limitation

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financial contribution covering at least the costs for monitoring for thirty years is provided and other conditions are met.

[344] *See infra* Part V.D.

[345] Wilson, Klass & Bergan, *supra* note 72, at 4581.

[346] De Figueiredo, Reiner & Herzog, *supra* note 133, at 652.

[347] *Id.*

[348] *Id.*; *see also* Haake & Marsh, *supra* note 50.

[349] Trabucchi & Patton, *supra* note 26, at 16. This would mean that operators would be responsible for consequences up to a dollar threshold per occurrence plus remediation costs.

[350] For the compensation system under the Price-Anderson Act, *see* Michael Faure & Tom Vanden Borre, *Compensating Nuclear Damage: A Comparative Economic Analysis of the US and International Liability Schemes*, 33 WM. & MARY ENVTL. L. & POL'Y REV. 219, 240–45 (2008); *see also* LIU, *supra* note 201, at 236–38.

[351] *See* HUI WANG, CIVIL LIABILITY FOR MARINE OIL POLLUTION DAMAGE: A COMPARATIVE AND ECONOMIC STUDY ON THE INTERNATIONAL, US AND CHINESE COMPENSATION REGIME 207–12 (2011), *available at* http://repub.eur.nl/pub/22278 [http://perma.cc/YJ47-BSD8]

on liability.[352] Also, Wilson, Klass, and Bergan argue in favor of liability caps but only during the post-closure period.[353] In another study, Klass and Wilson provide a more balanced picture. They ultimately conclude that generalized damage caps (which exist in the Price-Anderson Act for Nuclear Liability) would not be appropriate for CCS as a general matter, but only in the early years to encourage pilot projects.[354] A general liability cap would undermine the credibility of CCS in the eyes of the public,[355] but a more limited cap may help first movers to manage the financial risk of the new CCS technologies.[356]

Adelman and Duncan are, however, strongly opposed to liability caps, even to promote first movers.[357] They argue that financial caps are unnecessary because the projected magnitude of the potential damage for pilot projects would be limited; and moreover, it would not be the potential damage that would constitute the most important barrier, but rather technological uncertainties.[358] Those would not be removed with a financial cap.[359] In that sense, liability caps would only have a symbolic value.[360]

Economic analysis strongly supports the arguments against financial caps. From an economic perspective it is important for the potential injurer to be fully exposed to the social costs of his activities. Otherwise the desirable internalization of the negative externality would not take place.

If the liability therefore is limited to a certain amount, the potential injurer will consider the accident as one with a magnitude of the limited amount. Hence, he will spend on care to avoid an accident with a magnitude equal to the limited amount, and he will not spend the care necessary to reduce the total accident costs. Obviously, the amount of care spent by the potential injurer will be lower, and a problem of underdeterrence arises.[361] The amount of optimal care, reflected in the optimal standard—being the care necessary to reduce the total accident costs[362]

(discussing the nature of the liability regime and the limitation of liability in the U.S. Oil Pollution Act).

[352] Trabucchi & Patton, *supra* note 26, at 17–21.

[353] Wilson, Klass & Bergan, *supra* note 72, at 4581.

[354] Klass & Wilson, *supra* note 1, at 164–65.

[355] *Id.* at 168.

[356] *Id.* at 171, 177.

[357] Adelman & Duncan, *supra* note 11, at 64.

[358] *Id.* at 63–65.

[359] *Id.* at 64.

[360] *Id.*

[361] WANG, *supra* note 351, at 311–23.

[362] *See id.* for a more detailed critical analysis of financial caps, especially in the context of marine oil pollution damage.

efficiently—will be higher than the amount the potential injurer will spend to avoid an accident equal to the statutory limited amount.[363] Thus, as a result of the cap, too little care is taken.[364]

It should also be mentioned that in the areas where financial caps on liability exist, such as for marine oil pollution and nuclear liability, those caps are also heavily criticized in the literature.[365] These economic arguments therefore support Adelman and Duncan, who argue against financial caps, both in general and also for pilot projects.[366] Financial caps may, as they argue, be unnecessary and ineffective.[367] They could also lead to undercompensation and underdeterrence as shown in economic analysis. Moreover, they could equally have the undesirable effect of signaling that CCS is in fact (like nuclear power) a highly risky activity which would thus precisely have the opposite effect of even reducing public support for CCS.[368] As a result, the liability of the operator should in principle be unlimited in amount.

IV. PRINCIPLES OF FAIR AND EFFICIENT COMPENSATION

Until now, it has been stressed that from an economic perspective the compensatory function is not the main goal of liability rules.[369] Moreover, the limits of liability rules in providing compensation for CCS-related damage were sketched. So far, the study has mainly addressed how liability rules, but probably more importantly, their alternatives (like standards and regulation), can provide incentives for prevention. However, from a policy perspective, the compensation issue is important as well. If CCS activities would cause damage victims will call for compensation, given the political sensitiveness of and public support for CCS. The remainder of this Article will hence focus on the question through what type of instruments this compensation can be provided. However,

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[363] *See* Michael G. Faure, *Economic Models of Compensation for Damage Caused by Nuclear Accidents: Some Lessons for the Revision of the Paris and Vienna Conventions*, 2 EUR. J. L. & ECON. 21, 28 (1995).

[364] The reason for the underdeterrence is obviously the same as for the underdeterrence which results from the insolvency of the injurer. Underdeterrence arises because the injurer is not exposed to full liability, either as a result of his insolvency or as a result of a cap.

[365] *See* Faure, *supra* note 363; *see also* Trebilcock & Winter, *supra* note 288.

[366] Adelman & Duncan, *supra* note 11, at 64.

[367] *Id.*

[368] *See* De Figueiredo, Reiner & Herzog, *supra* note 133, at 652.

[369] Michael Faure, *A Multilayered Approach to Cover Damages Caused by Offshore Facilities*, 33 VA. ENVTL. L.J. 357, 403 (2015).

before addressing the different instruments, first the question will be asked whether compensation fits at all into an economic framework of accident law. Moreover, since prevention remains more important than cure, the question also arises how compensation can be organized in such a manner that it has positive effects for prevention or at least does not negatively affect the incentives of the various stakeholders to invest in prevention. After these general principles of fair and efficient compensation have been sketched in this section, the next parts will focus on the various instruments that could be employed to provide compensation: being insurance (V); alternative compensation mechanisms (VI); and government intervention (VII).

A first important principle is that no matter how compensation is organized, the incentives for preventing damage should always remain intact.[370] This means that, in principle, the duty to compensate should rest upon the party who actually contributed to the risk; however, incentives are also provided to potential victims to mitigate the damage.[371]

A second, related, principle is that a duty to contribute should also be related to the amount in which a specific activity or entrepreneur contributed to the risk.[372] This remains important if a collectivization of the compensation takes place. If such a risk differentiation is respected, the compensation will give incentives for prevention to contributors.[373] This is not only important from the perspective of operators, but also for potential victims. This hence also means that in principle the individual seeking a particular protection will pay for this protection to the extent that he/she is exposed to the risk. Higher risks do from this perspective pay a higher contribution to a financing solution than lower risks. According to this principle, there should be no shifting of risks and costs to a collective.

The reason behind this principle is the idea that making individuals pay according to the risk they pose will make them aware of their exposure to a particular hazard and may hence have a positive impact on their behavior, i.e., provide incentives for prevention.[374] Hence the efficiency reason behind risk differentiation is to provide incentives for prevention, risk reduction, and/or mitigation of damage.[375]

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[370] *Id.*
[371] *Id.*
[372] *Id.*
[373] *Id.*
[374] *Id.*
[375] Faure, *supra* note 369, at 403.

Moreover, these principles are not only important from an efficiency point of view (providing optimal incentives for prevention to all stakeholders in the risk), but also include a fairness element.[376] Indeed, if the principles were not followed, it would mean that good risks would have to pay for the bad risks as well and would therefore in fact subsidize bad risks.[377] This negative redistribution should be avoided and therefore a compensation mechanism (no matter how it is organized) should in principle be financed by the parties actually contributing to the damage. But again, risk differentiation also is important from the victim's perspective. A solidarity on the basis of which all (tax payers) pay for those exposed to risk could imply a redistribution whereby those who accepted risk are rewarded by those who faced no risk.[378]

Such a solidarity may hence be at odds with efficiency and distributional principles. However, it is easier to apply this risk differentiation to potential injurers (to the extent that their contribution to the risk can be established); it is much more difficult to apply this to potential victims. Indeed, in many developing countries, individuals may simply not have another option than choosing to live in a hazard prone area (e.g., close to a CCS storage site).[379] In such a case, a reverse argument could be made, being that there would be a case in favor of providing compensation for that individual (who apparently had no alternative solution than to reside in the hazard prone area) from the collective. There is, in that particular case, nothing inherently unfair about redistribution.

A third general principle is that, to the extent possible, a solution should be introduced at the lowest administrative cost possible.

Fourth and finally, where possible, a competitive market solution may (if it is less costly) be preferred to a bureaucratic intervention by government. The market will usually be able to provide coverage at lower costs.[380] However, there may be some (perhaps exceptional) cases where a government monopoly in the provision of disaster insurance could provide better results than competitive markets.[381]

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[376] *See generally id.*
[377] *Id.*
[378] *Id.*
[379] *Id.*
[380] *See* Veronique Bruggeman, Michael G. Faure & Karine Fiori, *The Government as Resinsurer of Catastrophic Risks?*, 35 GENEVA PAPERS ON RISK & INSURANCE THEORY 369, 381 (2010).
[381] This would more particularly be the case in Switzerland. For a discussion, *see generally* Winand Emons, *Imperfect Tests and Natural Insurance Monopolies*, 49 J. INDUS.

V. INSURANCE

A. *Demand and Supply*

1. Demand

The demand for insurance will depend upon the attitude to risk of the operator. Since the attitude to risk is strongly related to the wealth of an individual, the degree of risk aversion will hence also depend upon the available assets of the CCS operator. For relatively small expected losses, a wealthy operator could be risk neutral and hence not have a demand for coverage. In that case, the demand for insurance would only emerge if insurers could manage, for example, claims handling more effectively. It would then mostly be for the reduction of transaction costs and not for risk aversion that insurance would be taken out.

The degree to which CCS operators have a demand for insurance may hence strongly depend upon their own risk attitude which in turn is related to their assets. Normally it is fair to state that especially for smaller operators risk aversion is higher and hence a demand for some type of coverage (insurance or alternatives)[382] may emerge.

Generally, a distinction is made between two types of insurances; there are on the one hand insurances that individuals take to protect themselves against the future losses that they may suffer themselves, either in their income or in their property.[383] Fire insurance is a typical example.[384] These types of insurances are referred to as first-party insurance.[385] Insurances can also be taken for the risk that one has to compensate damage suffered by a third party.[386] These are therefore referred to as third-party insurances.[387] A liability insurance is a typical example of a third-party insurance. In that case the potential injurer

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ECON. 247 (2001); Thomas von Ungern-Sternberg, *The Limits of Competition: Housing Insurance in Switzerland*, 40 EUR. ECON. REV. 1111 (1996); THOMAS VON UNGERN-STERNBERG, EFFICIENT MONOPOLIES: THE LIMITS OF COMPETITION IN THE EUROPEAN PROPERTY INSURANCE MARKET (2004).

[382] *See infra* Part VI.

[383] Michael Faure, *Catastrophic Risks and First-Party Insurance*, 15 CONN. INS. L.J. 11, 11–14 (2008).

[384] *Id.*

[385] *Id.*

[386] *Id.*

[387] On those different type of insurances for environmental liability, *see* Michael G. Faure, *Environmental Damage Insurance in the Netherlands*, ENVTL. LIABILITY 31, 31–41 (2002).

takes insurance against the risk he runs of having to compensate the potential victim.[388]

In the case of CCS, both first-party and third-party insurance can be relevant. First-party insurance will then be taken by the operator for the property damage he could suffer to his installations. However, most likely it will be a liability insurance that plays the most important role in case of CCS. In that case coverage is demanded for the risk that damage is suffered by a third party.[389] Moreover, first-party insurance may obviously play a role as well in order to protect particular victims of CCS-related risks. In that case, victims do not take only first-party insurance for the CCS-related risks but also general accident insurance or property insurance, which may also serve to cover CCS-related risks as long as they are not excluded from the insurance policy.[390]

2. Supply

Turning now to supply, an important condition for insurability (both first-party and third-party) is that insurers have information on the likelihood that the particular event will occur and on the potential damage that may result from the manifestation of the risk. Insurers generally acquire this information on the basis of a past loss history record—in other words, statistics.[391] If statistics on the past loss history are not available, insurers will rely on risk assessment modeling to assess the likelihood of the risk.[392] Predictability is hence a crucial requirement to keep a risk insurable, but a lack of predictability should not immediately lead to the conclusion that risks are uninsurable. The crucial question is whether insurers are able to cope with uncertainty by charging an additional risk premium.[393] However, the reaction of insurers to calculate an additional risk premium obviously works only if there is a willingness to pay by the insured. This willingness to pay will, however, to a large extent depend upon the extent to which the insured recognizes that there are, albeit uncertain, additional risks for which

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[388] Faure, *supra* note 383, at 11–14.
[389] *Id.*
[390] Given that it concerns relatively new risks, one cannot see why insurers would explicitly exclude CCS-related risks from coverage. *See* RICHARDSON, *supra* note 202, at 371 (on first-party victim insurance).
[391] Faure, *supra* note 383, at 11–14.
[392] *Id.*
[393] As has been suggested by Howard Kunreuther, Robin Hogarth & Jacqueline Meszaros, *Insurer Ambiguity and Market Failure*, 7 J. RISK & UNCERTAINTY 71, 71–72 (1993).

additional cover needs to be extended.[394] If, as a result of information deficiencies, the potential insured does not recognize these risks, he will not be willing to pay the additional risk premium and insurance cover will not take place. The same problem could also arise in the reverse case where the insured holds that the new risk (like CCS) is in fact manageable and reasonably calculable, but he is not able to convey this message to the insurer as a result of which the insurer charges an excessively high-risk premium which the insured is not willing to pay. It may, more particularly, be this lack of information (and the resulting unwillingness to pay) which may explain why these additional risk premiums are seldom charged. The result is more often that a market for the particular new risk will simply not emerge or alternatives (e.g., risk-sharing agreements) will be developed.[395]

3. Predictability of CCS-Related Risks

Applying these insights to the risks created in case of CCS, many point at problems with uncertainty[396] and lack of data. Klass and Wilson, for example, indicate that some of the conditions of insurability—more particularly related to predictability of the risk and a well-established time period—may not be met in the case of CCS;[397] moreover, there may be legal uncertainty in the current situation as well.[398] Legal uncertainty may more particularly exist in those legal systems that have not sufficiently clarified the exposure to risk of CCS operators in the different phases of the CCS project life cycle.[399] It is more particularly a fear for liability also in the phase of long-term stewardship that may create the legal uncertainty which could endanger insurability. Trabucchi and Patton therefore point again at the CCS project life cycle and argue that in the phases before sequestration (hence the capture and transport) transfer of risk to a third party (more particularly an insurer) may be possible,[400] but that especially as far as the risks related to the sequestration are

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[394] *Id.*
[395] The advantage of a risk-sharing agreement is that operators themselves may, better than insurers, be able to obtain accurate information on the exposure to risk and thus cure the information asymmetry.
[396] *See also supra* Part I.G.
[397] Klass & Wilson, *supra* note 1, at 163.
[398] *Id.* at 164.
[399] *Id.*
[400] Trabucchi & Patton, *supra* note 26, at 8–9.

concerned, the lack of real, readily accessible data may make the predictability of the risk difficult.[401]

Doubts are especially formulated with respect to the ability of insurance to cover long-term liability since especially the long-term liability may endanger insurability.[402] On the other hand, some indicate that although uncertainties about risks will remain even under the best of circumstances, this does not mean that an *ex ante* valuation of the risk would be impossible.[403] It is said that site specific risk analysis may be possible and could provide information on the specific risks related to one particular site.[404] It is even argued that it is possible to make probabilistic estimates of the expected loss values for every specific site based on a site-specific risk assessment.[405] This is confirmed in other research where it is even said that the risks related to CCS are "known, predictable, and manageable."[406] These rather optimistic statements are of a very general nature and do not distinguish between the different phases in the CCS project life cycle. One has the impression that those statements about the possibility of risk assessments and hence the predictability of the risk especially apply to the risks that may arise during the operation and probably the post-closure monitoring period, but less to the uncertain period of long-term stewardship. Therefore, in policy documents, it is also held that insurance can basically only play a role during the operation of the plant.[407] Also, the EU CCS Directive still involves large uncertainties for operators[408] *inter alia* concerning the moment when the legal liability will be transferred from the operator to the state. Those factual and legal uncertainties may also endanger insurability.

B. Capacity

An important condition for the insurability of any risk is not only that the risk should be predictable; in addition, the insurer must also have sufficient capacity in order to have money available once the risk

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[401] *Id.* at 10.
[402] *See* De Figueiredo, Reiner & Herzog, *supra* note 133, at 654.
[403] Adelman & Duncan, *supra* note 11, at 17.
[404] Trabucchi & Patton, *supra* note 26, at 13.
[405] Trabucchi, Donlan & Wade, *supra* note 38, at 389, 391.
[406] Hawkins, Peridas & Steelman, *supra* note 2, at 4407.
[407] *See* IEA, *supra* note 213, at 12 (arguing that insurance is generally considered to only be appropriate during the operation of the plant but may not be applied indefinitely across the post-closure phase).
[408] *See* MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 7, 9.

would materialize.[409] That may more particularly be a problem when there is only a relatively small number of insured interested in the product that the insurer wishes to sell. Not only may the small number of insured (especially in the initial phase of developing a CCS project) be problematic, the same is the case for the high barriers to market entry created by the need for expert knowledge in CCS-related risks and for creating sufficient capacity. For CCS, that may obviously limit the insurability of the risks. It could therefore lead to a situation in which the total pool of insured is relatively too small and that not enough insurance capacity could be generated to cover the loss when it would occur. The economic principle is simply that the total amount of premiums generated by the pool of insured should be large enough to cover the potential risk when it would materialize.[410] This is obviously more difficult when the number of insured is small and, like in the case of CCS, the potential damage could be quite substantial. Obviously, these problems are larger in the initial phase of the development of CCS and may disappear when more experience with CCS projects is obtained and more operators participate in the market.[411] However, one should not judge too quickly that the large magnitude of the potential damages makes the risk uninsurable. There are quite a few techniques that insurers can use to make risks with a large potential magnitude insurable.

A first possibility is to use co-insurance. This simply amounts to the possibility of many insurers jointly covering one particular project.[412] If there were one CCS site to be covered, four insurers could decide to cover the risk together, each covering 25%, thus being able to generate higher capacity.

Another obvious solution to deal with the capacity problem is reinsurance. Through reinsurance an insurer effectively shifts a part of his risk to a reinsurance company in exchange for a reinsurance premium.[413] Large risks like CCS-related risks could be reinsured through the international reinsurance market, thus creating higher capacity.

A third possibility is pooling by insurers. This has to be distinguished from pooling by operators, which is usually qualified as a risk-sharing agreement.[414] In the case of pooling by insurers, insurance

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[409] In simple words: insurers need to hold sufficient financial resources to meet the claims they can expect. *See* RICHARDSON, *supra* note 202, at 332–33.
[410] *Id.*
[411] *Id.*
[412] *Id.*
[413] *Id.*
[414] *Id.*

companies decide to cover a particular risk on a non-competitive basis for an entire sector.[415] A risk where pooling by insurers typically takes place is the nuclear risk.[416] Insurance of nuclear risks is provided through the so-called nuclear pools.[417] Since those risks were considered to be very large, the major national insurance companies in every nuclear country decided to pool their resources in the 1950s on a non-competitive basis in order to be able to provide coverage for them.[418] These pools provide cover for the third-party liability and to some extent first-party insurance for the damage caused to the nuclear power plant as well.[419] Pooling is not only used in nuclear liability insurance but also with other risks—for example, with environmental liability insurance.[420] Environmental pools exist in many countries.[421] However, pooling between insurance companies may be problematic from an insurance perspective since insurance companies pool their resources on a non-competitive basis and thus exclude the normal competitive process.[422] The (European) competition authorities have increasingly paid attention to those pools, especially examining the compatibility of pooling by insurers with European competition policy.[423] A recent study that has been executed on behalf of the European Commission has also examined the amount of co(re)-insurance pools currently available in Europe.[424] The study identified a total of fifty-one pools, many of which focus on catastrophic risks (such as nuclear, environmental, and terrorism related risks).[425] The CCS-related literature has also pointed at the possibility of pooling by insurance operators and has in that respect argued that antitrust waivers for participating parties may be necessary.[426] Antitrust waivers may perhaps

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415 *See, e.g.*, Michael Faure & Roger Van den Bergh, *Liability for Nuclear Accidents in Belgium from an Interest Group Perspective*, 10 INT'L REV. L. & ECON. 241, 250–51 (1990).
416 *Id.*
417 *Id.*
418 For details, *see id.*
419 *Id.*
420 *Id.*
421 *See generally* Faure & Van den Bergh, *supra* note 415.
422 *Id.*
423 *See* Commission Regulation (EU) No. 267/2010 of 24 March 2010 on the application of Article 101(3) of the Treaty on the functioning of the European Union to certain categories of agreements, decisions and concerted practices in the insurance sector.
424 EUR. COMM'N AND ERNST & YOUNG, STUDY ON CO(RE)-INSURANCE POOLS AND ON AD-HOC CO(RE)-INSURANCE AGREEMENTS ON THE SUBSCRIPTION MARKET (July 2014), *available at* http://ec.europa.eu/competition/sectors/financial_services/KD0414707ENN.pdf [http://perma.cc/M27F-QTM9].
425 *Id.*
426 *See* Trabucchi & Patton, *supra* note 26, at 9.

be too strong a suggestion. Even within the boundaries set by competition policy, it should be possible to, on the one hand, enjoy the benefits of cooperation from pooling and, on the other hand, still have the benefits of competition—more particularly when not just one insurance pool covering CCS-related risks would be created, but rather different pools between which competition would still exist.

C. Risk Differentiation

Insurability requires that two important dangers, being moral hazard and adverse selection, are remedied.[427] Moral hazard in insurance refers to the phenomenon that the behavior of the insured injurer will change as soon as the risk is removed from him.[428] Moral hazard can especially be a problem in case of liability insurance. Moral hazard can be controlled by either monitoring the behavior of the insured and adapting the premium correspondingly or to still expose the insured partially to risk.[429] This of course requires a differentiation of the policy conditions to the particular risk. These principles of course apply in a similar way to CCS-related risks as well. It was already mentioned that the CCS literature refers to the danger of moral hazard[430] as follows:

> Moral hazard refers to the specific situation were the risks of an unplanned event increase, because the responsible party is (partially) insulated from being held fully liable for resulting harm. If CCS facilities are not held completely responsible for the consequences of their actions, arguably they will be less careful in their siting and operating decision. Therefore, the incentive to capture, transport site characterise, and inject carbon dioxide in an environmentally sound and protective manner may be diminished. The potential for risk increases because the chances of an unpredictable event occurring due to poor siting/operating decisions increase.[431]

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[427] RICHARDSON, *supra* note 202, at 354. On moral hazard and adverse selection in insurance, *see generally* Gerhard Wagner, *Tort Law and Liability Insurance, in* TORT LAW & ECON. 377, 386–92 (Michael Faure ed., 2009).
[428] *See generally* Wagner, *supra* note 427.
[429] *Id.* at 389–92; Steven Shavell, *On Moral Hazard and Insurance*, 95 QUARTERLY J. ECON. 541–62 (1979).
[430] For a detailed description of moral hazard for the case of CCS-related risks, *see* Trabucchi & Patton, *supra* note 26.
[431] *Id.* at 22 n.7.

They apply this moral hazard to the lack of exposure to liability, but the same moral hazard could obviously arise if full insurance cover were available.

However, although the CCS-related literature indicates that moral hazard may be an issue in case of CCS (thus stressing the need for providing appropriate incentives for prevention), the literature equally indicates that there are ample possibilities of risk differentiation, which could thus remedy the moral hazard risk.[432] It is mentioned that it is very well possible to identify different risk profiles on the basis of the type and upkeep of a storage site.[433] As we also made clear above, the CCS-related literature clearly shows that the technological knowledge is developed to such an extent that it is possible to differentiate the risk prevention measures that operators can and should take[434] and that hence differentiated premiums could be charged based on the differing technical characteristics of the site and the type of operation.[435] In principle, a comprehensive system of mapping and ranking of potential sequestration sites would be possible.[436] Such a mapping and ranking could obviously be used by insurers to apply an adequate system of risk differentiation.[437] Like with ordinary environmental insurance, insurers can rely on compliance with third-party environmental management systems, certification, or ISO standards to verify the adequacy of the preventive measures taken by operators.[438]

It has often been mentioned that as far as environmental insurance is concerned, an important role can be played by regulation.[439] Regulatory requirements with respect to siting of CCS facilities, operation, and post-closure monitoring[440] are important elements that can all be laid down in regulation. In that respect, properly tailored regulation

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[432] *See generally id.*

[433] MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 11.

[434] *See supra* Part I.D.2.

[435] *See, e.g.*, Adelman & Duncan, *supra* note 11 (indicating that risk differentiation is possible on the basis of the choice of the sequestration site, but also the care measures taken during the operation).

[436] *See id.* at 60 (which according to them should be neither technically demanding nor cost-prohibitive).

[437] *See id.* at 14 (mentioning that a risk profile of the particular site and operator has to be designed and operational risk management systems need to be demanded.).

[438] RICHARDSON, *supra* note 202, at 364.

[439] The importance of regulation of CCS was already stressed above in Part III C.

[440] *See* Trabucchi & Patton, *supra* note 26, at 16 (who also in that respect see an important role for a public-private CCS safety board).

can assist the risk differentiation by the insurer.[441] Given the informational advantage of the regulator (most insurers probably not being specialized in CCS-related risks), *ex ante* regulation can have the major advantage that (as most insurers do) the insurer can primarily require the CCS operator to comply with regulatory standards.[442] Violation of regulatory standards by the insured will often be a cause for refusal of coverage or for a recourse action by the insurer.[443] This shows again the importance of a smart collaboration between the regulator and the insurer whereby, on the one hand, the regulator informs the insurer about minimum safety standards (laid down in regulation) and, on the other hand, the insurer becomes *de facto* the enforcer of regulatory standards. The promulgation of *ex ante* regulatory standards can thus facilitate risk differentiation by the insurer and in that way contribute to an important extent to the insurability of the CCS-related risk.

D. *Insurability of CCS?*[444]

Should, taking into account the criteria for insurability discussed above, CCS-related risks be considered insurable or not? As the CCS-related literature has made clear, it is probably wrong to put the question in those general terms since it very much depends on the different phases of the CCS project life cycle.[445] Depending upon the phase of the CCS project, there may be particular problems that could endanger the insurability of CCS-related risks and more particularly the risk of liability towards third parties for CCS-related damage. Looking at the criteria we have discussed above for insurability of risks, there could be a serious problem of insurer ambiguity, i.e., the problem that CCS is a new technology and that hence actuarially reliable information on CCS-related risks may to a large extent be lacking. There can be high uncertainty concerning the specific probabilities of damage, as well as on the potential magnitude of the damage if the risk would materialize.[446] There may

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[441] *See* RICHARDSON, *supra* note 202, at 360–66.
[442] *Id.*
[443] *Id.*
[444] On the insurability of other unconventional oil and gas extraction methods, *see* David A. Dana & Hannah J. Wiseman, *A Market Approach to Regulating the Energy Revolution: Assurance Bonds, Insurance, and the Certain and Uncertain Risks of Hydraulic Fracturing*, 99 IOWA L. REV. 1523–93 (2014).
[445] *See supra* Part I.F.
[446] *See* MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 13; *see also supra* Part II.G (on the discussion of uncertainties relating to CCS-related risks).

hence be considerable information deficiencies which may reduce the appetite of insurers for CCS-related risks.[447] Insurer ambiguity may lead to reduced supply or, if the risk is covered at all, high premiums corresponding to the insurer ambiguity.[448] If, however, that high-risk premium does not correspond with the risk perception of operators, there may be no corresponding willingness to pay those high premiums and a market for covering the particular risk may not emerge.[449]

In addition, capacity may be a serious problem as well since the potential number of players is (at least at this moment) limited and the potential damage could be quite large.[450] Some of the traditional remedies to create larger capacity (co-insurance, reinsurance, and pooling by insurers) could be employed, but still it is uncertain whether those would be able to generate the substantial amounts that may be necessary to cover the damage which could result from CCS-related risks.

Lacking information on the side of insurers is not only a problem as far as fixing an adequate premium and predicting the risk is concerned, but also for the necessary risk differentiation in order to cure the dangers of moral hazard and adverse selection. However, it was held that the regulator can in that respect help insurers and thus promote the insurability of CCS-related risks by providing a tailored regulatory framework on which insurers could largely rely to judge CCS-related risks and differentiate premiums accordingly.[451]

Looking at the specific phases of the CCS life cycle, there are considerable differences. To put it simply: traditional (environmental) insurance is good in insuring sudden and accidental events and is less suited for the so-called long-tail risks.[452] This can be understood: given the asbestos nightmare, insurers dislike risks that could expand very long in time and create potential risk exposures for many decades.[453] Looking at the CCS project life cycle, it can therefore be held that (if the other problems mentioned above could be cured) insurance may be available for the injection and operation phase, but may already become

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[447] *See Implementation of Directive 2008/31/EC on the geological storage of carbon dioxide, Guidance Document*, EUR. COMM'N 4, 6 [hereinafter Guidance Document 4] (where it is suggested that "lack of sufficient knowledge about the behaviour of sequestrate CO_2 also will inhibit insurance offerings.").
[448] *Id.*
[449] *See also* MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 13.
[450] *Id.*
[451] *Id.*
[452] *Id.*
[453] *Id.*

more difficult during the post-closure monitoring (where probably other alternatives will have to be examined) and will totally be excluded in case of long-term stewardship (for which liability should anyway be transferred to the state).

Also, the Environmental Protection Agency ("EPA") Financial Responsibility Guidance mentions that insurance companies may not be willing to underwrite policies for the entire life of a project which could last for a minimum of fifty years.[454] That is why most of the literature related to CCS holds that as far as the long-term stewardship of storage sites is concerned the storage site should (under specific strict conditions)[455] be transferred to the state.[456]

As far as insurability is concerned, a similar conclusion can therefore be reached as with the exposure of liability in time: it was held above that exposing operators to the long-tail risk, more particularly to the damage which might occur during the period of long-term stewardship, does not seem useful as it may not provide *ex ante* the incentives for prevention.[457] When discussing the same issue here from an insurability perspective a similar conclusion is reached, i.e., that liability for damage that could occur during the period of long-term stewardship should also be excluded because such liability exposure may be uninsurable.[458]

CCS-related literature is equally pessimistic concerning the current possibilities of insurance cover for CCS-related risks. For example, Wilson et al. hold that "CCS might violate many of the conventional rules of insurability."[459] Conventional insurance requires: (1) a sufficient number of similar and uncorrelated events to allow for risk pooling; (2) clearly calculable losses; (3) a well-established time period for potential losses; (4) frequent enough losses to calculate premiums; and (5) that the insured party has no incentive to cause the loss.[460] CCS may violate many of those conditions,[461] as we illustrated. Also, in policy documents it is therefore

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[454] Insurance companies would usually underwrite policies with maximum terms of five to ten years that can be renewed. *See* EPA, GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE 18 (July 2011).
[455] Which are, for example, laid down in the CCS Directive.
[456] *See* MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 7–9; Trabucchi & Patton, *supra* note 26, at 15.
[457] *See supra* Part II.G.
[458] *Id.*
[459] Wilson, Klass & Bergan, *supra* note 72, at 4580. They refer more specifically to the "lack of experience with large-scale CCS and inherent geologic heterogeneity" which may create problems.
[460] *See* Klass & Wilson, *supra* note 1, at 163.
[461] *Id.*

held that *de facto* specific policy terms and conditions have not yet been made available for a cover for CCS-related risks as a result of which precise terms and limits of coverage cannot be determined.[462]

As a result of those observations, there may only be a limited role for insurance to cover CCS-related risks. Insurance could only play a role in the phase of injection and operation and most likely not in later phases. Moreover, insurance could only play that role if particular problems, discussed in this section, would have been adequately addressed. Given those limits of the traditional insurance markets in providing cover for CCS-related risks, there may be good arguments to examine whether alternative compensation mechanisms may be able to overcome some of the problems of traditional insurance markets.

Finally it should be mentioned that not many insurance companies seem yet willing to provide policies covering CCS-related risks.[463] In the literature only two Swiss companies (Zürich and Swiss Re) are mentioned as offering insurance policies for CCS-related risks.[464]

VI. ALTERNATIVE COMPENSATION MECHANISMS

As we just explained that traditional insurance markets may not be able to cover CCS-related risks in a satisfactory manner (or only to a limited extent), the question arises whether alternative compensation mechanisms could be used that could better deal with some of the problems that traditional insurers are confronted with in covering CCS-related risks. The search for alternative compensation mechanisms is not new. The CCS-related literature has largely addressed whether other instruments like bonding or a special fund could better deal with CCS-related risks than insurance.[465] Also, in policy documents, it is realized that insurance may have its limits in providing financial security for CCS-related risks as a result of which many alternatives like funds, escrow, bank guarantees, and letters of credit are examined.[466] Also in the EPA Financial Responsibility Guidance Document, a variety of alternatives to insurance is mentioned that operators or owners can use to satisfy financial responsibility, such as the use of trust funds, surety bonds, letters of credit, escrow accounts, or self-insurance.[467]

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[462] *See* Guidance Document 4, *supra* note 447, at 7.
[463] Havercroft and Macrory referred to a 2012 report holding that "off the shelf" insurance solutions for CCS liability would not exist. Havercroft & Macrory, *supra* note 112, at 36.
[464] *See* Aldrich, Koener & Keith, *supra* note 58, at 10.
[465] *See, e.g.*, Wilson, Klass & Bergan, *supra* note 72, at 4578.
[466] *See* Guidance Document 4, *supra* note 447, at 4–6, 26–28.
[467] *See* GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE, *supra* note 454, at 9.

Within the scope of this Article, a few interesting alternatives will be addressed, also because they have been discussed in CCS-related literature. First, attention will briefly be paid to self-insurance (A); next, the potential of risk-sharing agreements will be explored (B), as well as the possibilities of guarantees and deposits (C). In this part, first the theoretical ability of a particular alternative compensation mechanism will be explained; next, a critical evaluation of the comparative strengths and weaknesses of the particular mechanism will be discussed, especially in the light of its possible application to CCS-related risks.

A. Self-Insurance

1. Theory

Self-insurance is a mechanism whereby larger players in the market do not take insurance coverage at all but run the risk themselves.[468] In fact, self-insurance can take two different forms. One is pure self-insurance, which in fact is nothing else than major companies constituting a reserve for future losses.[469] In a technical sense, this cannot be considered as "insurance" for the simple reason that there is no risk spreading, no risk distribution, and hence no loss spreading after an accident happens.[470] Self-insurance in that sense is merely a reserve for potential losses whereby operators use their balance sheet to guarantee payment in case a major accident would happen. Reserves do allow for a risk spreading in time but not between various parties exposed to a risk.

Another possibility is the creation of a so-called captive.[471] A captive is in fact an insurance company that is created by industry.[472] Many large oil and gas operators have created their own insurance companies (referred to as captives).[473] The reason for doing so is that, in this way, they can satisfy a statutory duty (in the countries where this exists)

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[468] *Id.*
[469] *Id.*
[470] *See* FAURE & HARTLIEF, *supra* note 286, at 144.
[471] *See, e.g.*, PAUL A. BAWCUTT, CAPTIVE INSURANCE COMPANIES, ESTABLISHMENT, OPERATION AND MANAGEMENT (1991); *see also* TONY DOWDING, GLOBAL DEVELOPMENTS IN CAPTIVE INSURANCE (1997).
[472] *See* Lucas Bergkamp, Nicolas Herbatchek & Suriya Jayanti, *Financial Security and Insurance, in* THE EU ENVIRONMENTAL LIABILITY DIRECTIVE: A COMMENTARY 118, 128–29 (Lucas Bergkamp & Barbara J. Goldsmith eds., 2013).
[473] *Id.*

to show financial coverage but avoid that a transfer of fund to a third party (the insurance company) would be necessary.

2. Evaluation

Self-insurance (either via reserves, captives, or using the capital market) obviously has several strengths and weaknesses.

The advantage from the industry's perspective is obviously that it is a relatively low-cost solution; operators can take care themselves of providing guarantees for future losses and do not have to transfer risks to an insurance company which may create additional transaction costs.[474] Moreover, for major operators, forcing them to shift risks to an insurance company may make little sense—especially in cases where the credit rating of the operator is in fact higher than that of an insurance company.[475]

Moreover, using self-insurance at least partially has an advantage in curing the so-called moral hazard risk that will always emerge in case of insurance: by taking a substantial retention the operator will still be exposed to risk as a result of which moral hazard (created through insurance) can be controlled.[476]

The disadvantages of self-insurance (no matter what form it takes) may also be obvious: self-insurance is obviously not necessarily a waterproof guarantee against insolvency.[477] That would only be the case if regulation could guarantee that the money set aside for covering the CCS-related losses would only be used for that specific goal. Moreover, self-insurance could hence lead to an externalization of risk in case of insolvency.[478] Smaller operators without strong balance sheets or credit rating could simply run the risk of liability, and if the risk materialized they would simply pass on the costs to the tax payer.[479] Self-insurance can hence only be considered ineffective financial security if guarantees can be provided that the reserves set aside will actually be used for the potential losses for which they were earmarked. Otherwise, the risk would also exist that in case of insolvency, the trustee in bankruptcy could simply collect the assets, and money may not be available to compensate victims.

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[474] *Id.*
[475] *Id.*
[476] *See* Shavell, *supra* note 429.
[477] RICHARDSON, *supra* note 202, at 373.
[478] *Id.*
[479] *Id.*

Self-insurance could be a valuable strategy for major players that would be engaged in CCS, such as large energy companies with substantial balance sheets. For smaller and medium-sized players, self-insurance could only play a role as a deductible, in addition to other hedging strategies. If self-insurance would be offered by operators as a financial guarantee, serious controls should therefore be imposed to verify the viability of the self-insurance as a reliable guarantee.[480] This is why in the EU policy document with respect to the financial security for CCS self-insurance is in fact considered as the most risky option because no protection is provided from claims of creditors.[481] Self-insurance is equally mentioned in the EPA Financial Responsibility Guidance Document.[482] According to this document, owners or operators can expect to provide documents such as annual financial statements that show profits and losses for the year and statements verifying total net worth and networking capital, to be confirmed by an independent auditor.[483] It is the Underground Injection Control ("UIC") program director who will decide whether the information submitted is sufficient to make a determination on the owners' or operators' financial stability.[484] The EPA Guidance Document considers self-insurance beneficial for owners or operators because it is likely to have the lowest overhead costs.[485] However, there is a high risk of failure, especially in the post-injection site care period since in that period the injection site is no longer in operation and profitable.[486] The Guidance Document moreover provides recommended specifications concerning self-insurance holding *inter alia* that the owner or operator should have a tangible net worth of at least $100 million; specific ratings by credit rating agencies would be required as well.[487]

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[480] Financial tests would thus have to be developed to assess an operator's financial capability to face liability for CCS-related risks. For a comparison with the financial security under the Environmental Liability Directive, *see* Bergkamp, Herbatchek & Jayanti, *supra* note 472, at 128.
[481] *See* Guidance Document 4, *supra* note 447, at 27 (mentioning that "certainty also depends on stringency of required financial tests.").
[482] In the definitions, it is held that "self-insurance allows the owner or operator to submit financial statements and other information to prove that they are likely to remain in operation, based on indicators of the economic health of the organisation, and that they will be able to complete all required GS activities." *See* GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE, *supra* note 454, at x.
[483] *Id.* at 8.
[484] *Id.* at 8–9.
[485] *Id.* at 19.
[486] *Id.* at 22.
[487] *Id.* at 36–38.

B. Risk-Sharing Agreements

1. Theory

A risk-sharing agreement or a pool is a system whereby operators mutually agree to share each others' losses. It resembles insurance, but there are, as will be explained in more detail, a few fundamental differences. The basic difference is that insurance involves a third party (the insurance company), whereas in a risk-sharing scheme the operators are both insured and insurer; there is hence no involvement of a third party.[488]

Unlike in the case of commercial insurance, where *ex ante* information about the probability of a certain risk and its magnitude should be available to allow the calculation of an *ex ante* charged premium, in a risk-sharing agreement policy, each member's contribution can be agreed upon beforehand and only actually paid *ex post*.[489] This characteristic makes it possible for a risk-sharing agreement to deal with uncertain risk, for which the statistical data about the occurrence are rare or the probability and size is less predictable. As long as a risk differentiation can be made among the members, a risk-sharing agreement can be feasible, since an *ex ante* charging of premiums is no longer necessary. Only the relative contribution of each member to the risk has to be known.

Another difference between a risk-sharing agreement and insurance concerns the costs. In an insurance policy, the risk is shifted to the insurer at the price of a premium.[490] The premium is not recoverable by the insured no matter whether the insured risk materialized or not.[491] In a risk-sharing agreement, a member only contributes if an accident happens; the duty to compensate can either be postponed or the contribution can be carried over to the following year if there is no accident.[492] A member can also recover his contribution by not creating the risk and leaving the pool.[493]

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[488] Jason E. Doucette, *Wading in the Pool: Interlocal Cooperation in Municipal Insurance and the State Regulation of Public Entity Risk Sharing Pools—A Survey*, 8 CONN. INS. L.J. 533, 533–47 (2001).
[489] *Id.*
[490] *Id.*
[491] *Id.*
[492] RICHARDSON, *supra* note 202, at 373.
[493] *Id.*

2. Pooling in the Price-Anderson Act

Many examples of pooling arrangements exist.[494] It is, however, interesting to briefly discuss risk pooling in the Price-Anderson Act since that model has equally been mentioned as an interesting example in the CCS-related literature.[495]

In the United States, nuclear liability is governed by the Price-Anderson Act of 1957,[496] which has been revised approximately every decade.[497] According to the Price-Anderson Act, each license issued should have and maintain a financial guarantee to cover public liability claims.[498]

The existing capacity of the insurance market (provided by a monopolistic national pool, American Nuclear Insurers ("ANI")) to provide is $300 million.[499] If an accident creates damage in excess of $300 million, a retrospective premium needs to be called upon all American nuclear operators licensed by the Nuclear Regulatory Commission ("NRC").[500] This premium is payable in annual instalments up to a certain maximum amount per incident per power plant and is determined according to the size and number of reactors each plant has.[501] In October 2008, the NRC adapted the amounts in the second tier to inflation and set the amount at $111.9 million, with a maximum annual retrospective premium of $17.5 million per reactor per year.[502] Regarding the first tier, American nuclear insurers decided to make available from 1 January 2010 a maximum limit of $375 million for domestic nuclear third-party liability. That hence means an increase of 25% compared to the last limit of $300 million which was established in 2003.[503]

In July 2013, NRC adapted the amounts to inflation.[504] As of September 10, 2013, the following amounts apply: $375,000,000 in the first

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[494] For a detailed discussion, *see, e.g.*, LIU, *supra* note 201, at 296–303.
[495] *See, e.g.*, De Figueiredo, Reiner & Herzog, *supra* note 133, at 653; Haake & Marsh, *supra* note 50, at 5–6.
[496] Pub. L. No. 85-256, 71 Stat. 576–77 (1957).
[497] The Price-Anderson Act has been revised in 1967, 1975, 1988, and 2005.
[498] Pub. L. No. 85-256, 71 Stat. 567–77 (1957).
[499] *See* Faure & Van den Bergh, *supra* note 415, at 244.
[500] *See id.* at 253.
[501] Faure & Vanden Borre, *supra* note 350, at 243.
[502] 10 C.F.R. § 140.11(a)(4); Increase in the Primary Nuclear Liability Insurance Premium, 75 Fed. Reg. 16646 (Apr. 2, 2010).
[503] *See generally* AM. NUCLEAR INS., http://www.nuclearinsurance.com [https://perma.cc/KK9B-FVXV] (last visited Jan. 22, 2016).
[504] 10 C.F.R. § 140.11(a)(4); Increase in the Primary Nuclear Liability Insurance Premium, 75 Fed. Reg. 16646 (Apr. 2, 2010).

tier and in the second (collective) tier $121,255,000 per reactor per accident, plus 5% for legal expenses.[505] Thus, since that date the total amount of compensation available in the United States is $13,616,046,000 [$375,000,000 + (104 * ($121,255,000 + $6,062,750))], with a maximum contribution of $18,963,000 per reactor per calender year.

If a catastrophic accident happens, which needs the collection of retrospective premiums through years, the victims do not need to wait until the operators have paid all the premiums. The NRC guarantees those retrospective premiums, or, in other words advances the compensation in the second tier and later collects this from the operators.[506]

The premium under the second layer of the Price-Anderson Act is financed through a so-called retrospective premium scheme.[507] Hence, premiums do not have to be paid *ex ante*, but only *ex post* after the nuclear accident materializes.[508] This retrospective premium scheme was introduced in 1975.[509] Initially, the financial requirement was satisfied with the coverage from private insurance and a government indemnity agreement.[510] This was because the nuclear industry was not thought to be capable to bear all the burdens at its infancy period, and the Price-Anderson Act intended to encourage the development of the nuclear industry.[511] However, after years of development, it was believed that the industry should take its responsibilities.[512] This was achieved by phasing out federal indemnity and establishing a system of retrospective premiums paid by nuclear operators.[513]

Under the retrospective premiums scheme, if an accident leads to the damage in excess of $375 million, all qualified nuclear operators are obliged to pay the retrospective premiums up to $121.255 million.[514] This arrangement is a form of a risk-sharing agreement. However, different from the usual understanding about risk-sharing agreements, this arrangement is a mandatory system. It is effectively imposed by statute.[515] Rather than the voluntary pooling of operators, the retrospective premiums

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[505] *Id.*
[506] Faure & Vanden Borre, *supra* note 350, at 260.
[507] *Id.* at 243.
[508] *Id.*
[509] *Id.*
[510] *Id.* at 252.
[511] *Id.* at 242–43.
[512] H.R. Rep. No. 94-648, at 10 (1975).
[513] *Id.*
[514] Pub. L. No. 85-256, 71 Stat. 576–77 (1957).
[515] *Id.*

scheme is established according to the legislative requirement of the amended Price-Anderson Act.[516] This arrangement ensures that all nuclear power plant operators participate in the system and provide strong capacity. Besides, this system is used only when the primary instrument—the insurance market—fails to cover the full damage. In other words, the retrospective premiums scheme provides an upper layer of compensation for victims.

In a simple scheme the compensation regime under the Price-Anderson Act could hence be sketched as follows:

TABLE 2. COMPENSATION UNDER THE PRICE-ANDERSON ACT SINCE 2013

Operators' liability	$375 million
Retrospective premiums	$121.255 million/operator
Total compensation	$13.6 billion[517]

3. Risk-Sharing for CCS?

Just looking at the problems that emerge with the insurance of CCS-related risk and the theory and practice with risk-sharing agreements, it is not difficult to argue that a risk-sharing agreement may be an attractive solution to cover CCS-related risks more particularly where traditional insurance markets may fail. A risk-sharing agreement does not necessarily require *ex ante* actuarial information which would be necessary if premiums are asked (like in an insurance model). Moreover, *ex ante* premiums may not necessarily have to be paid as a result of which risk-sharing does not create liquidity problems. An optimal risk pooling mechanism would also create strong incentives for mutual monitoring and could hence contribute to sharing of information on this new and technically complicated risk, thus raising safety levels of all operators in the sector. In that sense, a risk-sharing agreement could even increase general safety. However, the experience with the nuclear

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[516] *See* Faure, *supra* note 415, at 252.

[517] This amount consists of the $375 million of the operators' liability + 104 (the total amount of operators in the United States) multiplied with their contribution to the second tier of $121,255,000 + 5% for legal expenses. The correct total amount since 2013 is therefore $13,616,046,000. The maximum contribution per reactor per calendar year to the second tier since 2013 is $18,963,000.

sector shows that an important condition for a risk-sharing agreement to work is that risks are relatively comparable.[518] Moreover, mandatory safety regulation can, to an important extent, facilitate risk-sharing, thus reducing the need for mutual monitoring. The voluntary creation of a risk-sharing agreement is, moreover, more likely in a regime of mandatory financial security.[519]

The CCS-related literature is therefore not surprisingly enthusiastic concerning the potential of risk-sharing agreements.[520] Many refer to the example of the Price-Anderson Act we discussed[521] and also at the policy level, there is some interest in risk-sharing agreements.[522] In sum, if particular conditions are met, a risk-sharing agreement between operators may be a valuable instrument to cover CCS-related risks.

C. *Guarantees, Deposits, and Bonds*

1. Theory

Obviously many parties could provide a financial guarantee to the operator.[523] Such a financial guarantee could be provided by a mother company or another third party that would presumably have a stronger financial capacity than the operator. It could also be provided by a financial institution such as a bank. In particular cases the guarantee could take the form of a letter of credit.

All of those guarantees have a simple theoretical basis: a presumably stronger third party (either a corporate entity or a financial institution) basically puts its balance sheet at risk by guaranteeing that it will cover the liabilities of the operator in case a particular risk would materialize.[524]

For the policymaker or regulator, the advantage may be that a stronger guarantee is provided than when only the operators' assets were at stake. Operators themselves would presumably use these types of

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[518] *See* Faure, *supra* note 415, at 282.
[519] *See infra* Part VII.A.
[520] *See* Havercroft & Macrory, *supra* note 112, at 7, 36.
[521] *See, e.g.*, De Figueiredo, Reiner & Herzog, *supra* note 133, at 653; Havercroft & Macrory, *supra* note 112, at 7; Trabucchi & Patton, *supra* note 26, at 18.
[522] However, Guidance Document 4 in Article 19 Financial Security and Article 20 Financial Mechanisms of the European Commission are remarkably silent on the potential of risk-sharing agreements.
[523] *See* Faure, *supra* note 415, at 252.
[524] *Id.* at 253, 271.

guarantees when regulatory authorities find it necessary (and hence hold that merely relying on self-insurance is not sufficient). However, in particular cases, the costs of those guarantees can be quite high.[525] If it would be a guarantee by a related corporate entity, then that should not necessarily be the case; but it may be different if guarantees would have to be provided by a bank. Compared to insurance, one can hold that if insurers specialize in CCS-related risks, they may have more information for an appropriate risk differentiation and premium setting as a result of which the costs of insurance could be lower than the costs of a bank guarantee.

An alternative is to require the operator to provide *ex ante* a deposit into a guarantee account.[526] The idea would be that a direct guarantee is provided by depositing a sum of money corresponding to the potential damage in order to cover future losses that could result from the CCS-related activity. Trust funds, stand-by trust funds, and escrow accounts are also comparable instruments.[527] In all those cases (although there are differences), money is set aside to serve for a specific purpose in the future.

Yet another alternative is to use the capital market and more particularly bonds, whereby the interest rate on the bond reflects the accident rate.[528] Investors have hence the opportunity to buy a bond creating a warrant in favor of the operator of their choice.[529] If, for example, during the period of the bond (say one year) no accident happened, the amount of the guarantee provided by the bond would be paid with interest. If, however, the risk materialized, the bond posted would be used to cover the damage.[530]

2. Evaluation

The enthusiasm in the sector for the just mentioned deposits will logically be relatively small. The obvious reason is that it leads to an immediate immobilization of capital for losses that may not even materialize in the future. It hence leads to a large liquidity problem. If the

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[525] *Id.* at 260.
[526] *Id.* at 252.
[527] *Id.*
[528] *Id.*
[529] *See* Faure, *supra* note 415, at 252.
[530] For an explanation of the working of these cat bonds, *see* Jean-Robert Tyran & Peter Zweifel, *Environmental Risk Internalization through Capital Markets ("ERICAM"): The Case of Nuclear Power*, 13 INT'L REV. L. & ECON. 431–44 (1993).

deposit should, moreover, be large enough to cover all potential losses, it would be substantial and could hence create liquidity problems for the operators involved and may for that reason not be very popular. Also, bank guarantees may not be a new attractive alternative. The reason is that they are often considered relatively expensive, compared to insurance.[531] Corporate guarantees can, in some cases, be used. The problem is, however, that they do not always provide a good protection from potential claims of the operators' creditors.[532] A guarantee would only provide security to victims if a third party (guarantor) would directly accept obligations towards the authorities or potential victims to compensate in case of harm.[533] Whereas this may be a scenario that could be used to guarantee compliance with obligations to clean up polluted sites, given that damage resulting from CCS can have a widely varying character, it is not likely that those type of guarantees would be provided specifically for CCS-related risks.

Guarantees and deposits are discussed in the CCS-related literature, but apparently not with great enthusiasm.[534] The deposit is apparently only used as a guarantee in Germany where a draft CCS Act of 2009 mentioned that an operator must deposit with the competent authority the equivalent of 3% of the emissions trading allowances which the storage saves each year.[535] However, this may obviously only provide a security for the climate-related risks (the risk of future emissions) but not for other types of damage that could result from CCS. In the EU Guidance Document 4, the corporate guarantee and escrow accounts are not considered reliable financial securities since they may all be subject to claims of creditors.[536] The EU Guidance Document 4 is more enthusiastic concerning a deposit which has the advantage that if the money is deposited to the competent authority, it is no longer subject to claims of creditors of the operator; the disadvantage is obviously the high cost of

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[531] Moreover, they are held not to provide additional security for the competent authority. *See* Havercroft & Macrory, *supra* note 112, at 49.

[532] A problem is that a guarantee provided, e.g., by a related company, is usually not specified for a particular goal and will therefore generally support the activities of an affiliated company. However, when that company runs into insolvency, the guarantee will be used to deal with all claims of the mass of creditors. There is hence no guarantee that the proceeds would only be used to satisfy the claims of victims of CCS-related damage. In concurrence with the other creditors, victims may not be able to enforce their claims.

[533] *See* Bergkamp, Herbatchek & Jayanti, *supra* note 472, at 127.

[534] *See, e.g.*, De Figueiredo, Reiner & Herzog, *supra* note 133, at 653.

[535] *See* IEA, *supra* note 213, at 30.

[536] *See* Guidance Document 4, *supra* note 447, at 26–27.

a deposit.[537] Another disadvantage of a deposit is that substantial amounts of capital would have to be immobilized for a potentially longer period of time. That capital can hence not be used for other societal valuable activities, whereas the likelihood that it should ever be used to satisfy claims of victims may be small.

The EPA Guidance Document equally discusses guarantees and deposits under different headings. Corporate guarantees can be used within the framework of self-insurance. A corporate guarantee can be used if it is owned by a parent corporation to benefit a corporate subsidiary in which it owns at least 50% of the subsidiaries voting stock and has been in business for at least five years.[538] With corporate guarantees, the relative financial risk to the government is, however, considered to be high.[539] Trust funds are considered useful for activities that are relatively certain in terms of occurrence and costs, such as post-injection site care and site closure demonstration but not for activities of uncertain frequency and costs.[540] The relative financial risk to the government may be low, but the costs of a trust fund can be high.[541]

The instrument that is mostly mentioned for covering CCS-related risks and that is based on the capital markets, is bonding.[542] A problem with any use of capital markets, including bonding, is that most of the so-called catastrophe bonds ("CAT bonds") are always used for catastrophes which are essentially sudden events.[543] CAT bonds usually have a short period of cover within which either the catastrophe happens (and hence the bond is lost) or nothing happens (and the profit on the bond is made).[544] CAT bonds are, however, typically not used for long-term risks.[545] That is why the CCS-related literature mentions that

[537] *See id.* It is remarkable that the Guidance Document 4 considers the bank guarantee or the irrevocable standby letter of credit as providing excellent certainty and having low costs (at least for credit worthy parties).
[538] For the further conditions, *see* GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE, *supra* note 454, at 17.
[539] *Id.* at 45.
[540] *Id.* at 21.
[541] The EPA Guidance Document equally contains recommended specifications concerning *inter alia* the wording of the trust documents. *Id.* at 26–27.
[542] *See* Wilson, Klass & Bergan, *supra* note 72, at 4580. For a further detailed analysis of the feasibility of bonding schemes for geological storage, *see generally* Gerard & Wilson, *supra* note 314.
[543] Jasvin Josen, *Catastrophe Bonds—fear of the unknown?*, DERIVATIVE TIMES (June 5, 2015), http://derivativetimes.blogspot.com/2012/06/catastrophe-bonds-fear-of-unknown.html [http://perma.cc/X38D-A3QS].
[544] *Id.*
[545] *Id.*

bonding is problematic given the potentially long-tail character of the CCS-related liability risks.[546] For that reason, it may not be an appropriate instrument to cover CCS-related risks.[547] Bonding could therefore at best be used during the operation/injection period, but not for liability during the post-closure monitoring.[548]

The surety bond is discussed in the EPA Financial Responsibility Document as a guarantee related either to a specific performance or a financial guarantee.[549] However, the document also recognizes that a bond may not be useful to cover long-term liabilities and would therefore not be available for post-injection site care and site closure.[550]

D. Summary

This overview of alternative compensation mechanisms shows that there are particular instruments that each have their strengths and weaknesses.[551] That may well be an important argument not to necessarily express a preference for the use of one exclusive instrument, but rather to look for which combination of particular instruments could be indicated as financial security for which particular operator and for which specific phase in the project life cycle of CCS.[552]

For example, as far as the phase of operation and injection is concerned for larger operators, self-insurance (or eventually even captives) may well work. For smaller operators, self-insurance could be used for a first layer (as a kind of retention), depending upon their balance sheet. In both cases, in a regulatory environment where financial security would be demanded, regulatory authorities of course need to carefully verify the adequacy of the self-insurance that has been offered and, moreover, it

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[546] *See* Klass & Wilson, *supra* note 1, at 162 (arguing that "[b]onding works well for short timeframes, but over the fifteen to thirty years required for post-closure financial responsibility, bonding could tie up capital and prove less efficient than insurance-based instruments."); *see also* Gerard & Wilson, *supra* note 314, at 1100.
[547] *See* Klass & Wilson, *supra* note 1, at 162; *see also* Gerard & Wilson, *supra* note 314, at 1100.
[548] It is, moreover, considered to be relatively costly. *See* Havercroft & Macrory, *supra* note 112, at 47.
[549] GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE, *supra* note 454, at 11–12.
[550] *Id.* at 18, 21–22.
[551] *See generally* Guidance Document 4, *supra* note 447; GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE, *supra* note 454.
[552] For that reason, the EPA Financial Responsibility Document explicitly recommends the use of multiple instruments rather than a single instrument to meet financial responsibility. *See* GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE, *supra* note 454, at 38–39.

should equally be guaranteed that the self-insurance remains available as long as the risks can materialize.

In the phase of operation and injection, insurance or self-insurance may play a role. Eventually, guarantees could be used as well, although important conditions would have to be met to verify the viability of the guarantee. The same would be true for bonding. There may not be much enthusiasm on the capital market for these types of bonds.

As far as the second phase of post-closure monitoring is concerned, the alternatives already become more limited. Given the also potential long-tail character of post-closure monitoring, insurance may not be an option here. Self-insurance may play a role, but the difficulty is that the post-closure monitoring requirement may also extend over many years. This hence requires a regulatory agency (under the assumption there would be a mandatory financial security) to monitor the adequacy of the provided self-insurance also on a regular basis. However, the option of self-insurance should not be ruled out since it remains a low-cost option for operators. Provided specific conditions (as far as the reliability of the offered balance sheet protection is concerned) are met, this may be an adequate instrument.

Bonding may not be viable for post-closure monitoring given the long-tail character (whereas bonds are typically suited for short-term risks). The most appropriate instrument to deal with financial security for post-closure monitoring is probably a risk-sharing agreement between operators. Provided specific regulatory conditions are met (minimum safety standards) and a reasonable comparability of the risk, the advantage would be that this could be a low-cost alternative for operators. It would also provide incentives for mutual monitoring and thus contribute to improved safety and investments in technological innovation.

As far as the phase of long-term stewardship is concerned, we have ruled out liability for this long-term risk,[553] as a result of which for that phase alternative compensation mechanisms would not be needed from the operator. That may, however, require a role of the government in facilitating compensation.

VII. THE ROLE OF GOVERNMENT IN FACILITATING COMPENSATION

At various instances, it has already been stressed that there may be an important role for government in facilitating compensation for

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[553] *See supra* Part IV.G.

CCS-related risks. However, one has to be careful: such a facilitation does not necessarily mean that government would have to pay the compensation. That could, as the literature has rightly mentioned, amount to an undue subsidization of CCS operators and create a moral hazard risk.[554] However, we will argue that government can play an important role in facilitating financial security and, depending upon the various phases in the CCS project life cycle, this facilitative role could take different forms. An important role of government is obviously to organize facilitative strategies to stimulate insurability.[555] In this respect, we for example argued above that an important task of government would be to create an appropriate regulatory framework providing minimum safety standards for CCS. Such a regulatory framework could stimulate risk differentiation and control of moral hazard by insurers[556] but also the creation of risk-sharing agreements between operators.[557] Depending on the various phases of the CCS project life cycle, and more particularly as far as long-term stewardship is concerned, there may be an argument for government intervention, not only in a facilitative role, but even in taking over liability from operators. This then specifically concerns the phase of long-term stewardship. In that respect, one should recall that the intervention of government to provide relief would certainly not be limited to the case of CCS. Governments intervene, sometimes on the basis of international conventions[558] and in other cases on the basis of national law,[559] in a more or less generous manner. Also, in the literature concerning CCS-related risks, government compensation programs, such as the National Flood Insurance Program ("NFIP") in the United States, are called upon as one of the potential solutions to financing CCS-related risks.[560] Hence, in addressing the role of government in facilitating compensation, some comparison with a similar role of government in providing relief for victims of catastrophes can be instructive.

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[554] *See* Trabucchi & Patton, *supra* note 26, at 2 (arguing that no financial risk management framework should inappropriately subsidize or otherwise provide economic advantage for CCS over future, as yet undeveloped or improved, technologies designed to make coal a cleaner source of power).

[555] *See* MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 25 (arguing that the aim of a liability framework "should be to create the market conditions in which private insurance products can be offered in the CCS market.").

[556] *See supra* Part VI.C.

[557] *See supra* Part VI.B.

[558] Such as in the case of the international conventions for nuclear liability.

[559] For example, this occurred in the United States via the September 11th Victim Compensation Fund. For details, see generally Bruggeman, Faure & Fiori, *supra* note 380.

[560] *See* Trabucchi & Patton, *supra* note 26, at 18–19.

First, a simple but effective facilitative strategy will be discussed, being the provision of compulsory financial security via regulation (A). Next, the question will be asked to what extent direct compensation by government should be provided for particular phases in the CCS project life cycle (B). In some cases (for example as far as terrorism-related risks are concerned), government takes up a role as reinsurer of last resort, more particularly when, given limited supply, a large capacity could not be generated. The question arises whether such a rule should also be allocated to government in the case of CCS-related risks (C).

A. Compulsory Financial Guarantees?

1. Theory

In law and economics research several criteria have been advanced to analyze where mandatory financial security may be indicated. The most important reason for introducing compulsory insurance is insolvency. Insolvency may pose a problem of underdeterrence. If the expected damage largely exceeds the injurer's assets, the injurer will only have incentives to purchase insurance up to the amount of his own assets.[561] He is only exposed to the risk of losing his own assets in a liability suit.[562] The judgment proof problem may therefore lead to underinsurance and thus to underdeterrence.[563] Jost has rightly pointed out that, in these circumstances of insolvency, compulsory insurance might provide an optimal outcome.[564] By introducing a duty to purchase insurance coverage for the amount of the expected loss, better results will be obtained than with insolvency whereby the magnitude of the loss exceeds the injurer's assets.[565] However, the literature has equally formulated a few conditions

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[561] *See generally* Peter J. Jost, *Limited Liability and the Requirement to Purchase Insurance*, 16 INT'L REV. L. & ECON. 259 (1996).
[562] *Id.*
[563] *Id.*
[564] *See id.* A similar argument has been formulated by Mattias K. Polborn, *Mandatory Insurance and the Judgment-proof Problem*, 18 INT'L REV. L. & ECON. 141 (1998) and by Göran Skogh, *Mandatory Insurance: Transaction Costs Analysis of Insurance, in* ENCYCLOPEDIA OF LAW AND ECONOMICS, II, CIVIL LAW AND ECONOMICS (Boudewijn Bouckaert & Gerrit De Geest eds., 2000). Skogh has also pointed out that compulsory insurance may save on transaction costs.
[565] *See* Howard C. Kunreuther & Paul K. Freeman, *Insurability, Environmental Risks and the Law, in* THE LAW AND ECONOMICS OF THE ENVIRONMENT 304–16 (Anthony Heyes ed., 2001).

and warnings when introducing compulsory financial security.[566] One warning is that the moral hazard problem should of course be controlled. If moral hazard cannot be controlled, the regulator should even consider a prohibition of liability insurance.[567]

Second, if one were only to introduce compulsory insurance (as compared to mandatory financial security, which is obviously broader) this should only be done when no restrictions on the insurance market exist. If high concentration would exist, premiums would be too high and this could equally reduce the incentives of insurers to control the moral hazard risk.

Third, from a policy perspective, it may not be wise to limit the duty to provide financial security to insurance. If the policymaker were to introduce compulsory insurance, it would become totally dependent on insurance to fulfill the duty to insure. This could create an undesirable situation whereby insurers would become *de facto* licensors of the industry, which could be problematic from a policy perspective.[568] Insurers under compulsory insurance *de facto* become surrogate regulators which at least has the advantage that it provides them strong arguments for effective risk management.[569] That may hence be a strong argument towards a flexible approach, i.e., not to limit the provision of mandatory security necessarily to insurance, but to allow the market itself to suggest a wide variety of financial and insurance instruments, as long as they can guarantee compensation when the accident happens.

2. For CCS?

To a large extent, some of the arguments in favor of mandatory financial security may apply to CCS-related risks as well.[570] Especially where smaller and medium-sized operators may also be involved in CCS, they could create a risk of major damage of which the magnitude could go beyond their personal assets.[571] In that case an insolvency risk would

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[566] For a summary of those warnings, *see generally* Michael G. Faure, *Economic Criteria for Compulsory Insurance*, 31 GENEVA PAPERS ON RISK & INS. 149 (2006); *see also* RICHARDSON, *supra* note 202, at 360–66.
[567] Steven Shavell, *The Judgment Proof Problem*, 6 INT'L REV. L. & ECON. 45–58 (1986).
[568] *See* Alberto Monti, *Environmental Risk: A Comparative Law and Economics Approach to Liability and Insurance*, 9 EUR. REV. PRIVATE L. 51, 51–79 (2001).
[569] RICHARDSON, *supra* note 202, at 362–63.
[570] For other arguments in favor of mandatory insurance, *see* Dana & Wiseman, *supra* note 444, at 1546–71.
[571] *See generally* Faure, *supra* note 566.

merge and hence a danger of externalization of the damage.[572] Also in the CCS-related literature, some arguments are made in favor of compulsory financial guarantees, more particularly by Trabucchi and Patton.[573] However, the warnings we formulated above may apply to the case of CCS as well. As mentioned, it may be dangerous to mandate financial security when it is not certain that the market can deliver the required financial security.[574] This therefore calls for caution, especially when concerning new risks such as CCS. One way of dealing with this cautious approach is to allow sufficient flexibility as far as the form of financial security is concerned and hence not to limit this necessarily to insurance. An important condition would only be that the regulator would accurately verify whether the form and amount of the financial security offered by the operator would be adequate to cover the potential damage emerging from the CCS operation.

When referring to the possibility of introducing mandatory financial security for CCS, one should once more differentiate between the various phases of the CCS life cycle. Recall that, as has been mentioned above, insurance may be available during the first phase of CO_2 injection, but may already become more problematic during the second phase of post-closure monitoring and may not be available at all during the final phase of long-term stewardship. However, the mere fact that insurance is, for example during the phase of post-closure monitoring, difficult to obtain, should not be an argument against imposing compulsory financial security. The key issue is that compulsory financial security should not automatically be equated with insurance. As we have discussed in detail, operators should be provided a freedom to make use of alternative compensation mechanisms. It does indeed not make sense to force large and well-capitalized operators to take out insurance which would not substantially improve their financial situation and only lead to the costs of paying premiums. In those situations, alternatives like a controlled self-regulation[575] could be preferred.

One way of approaching this issue is shown in the European Union where a Guidance Document has been issued describing the possible financial security and financial mechanisms that could be used to cover

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[572] *Id.*

[573] Trabucchi & Patton, *supra* note 26, at 14 (arguing in favor of the mandatory purchase of third-party instruments or self-insurance), 16 (demanding evidence of financial responsibility for the operating life of the facility).

[574] *See generally* Jost, *supra* note 561.

[575] *See, e.g.*, Guidance Document 4, *supra* note 447.

CCS-related risks.[576] The advantage of such a guidance note is that it provides information to licensing authorities on the type of financial security that could be accepted when offered by CCS operators. Such an approach with a guidance note has the advantage of allowing sufficient flexibility and avoiding unnecessary costs (e.g., forcing also major energy companies that would be engaged in CCS to transfer risks to an insurance company). The model followed in the EU seems to allow for sufficient flexibility by, on the one hand, mandating financial security but, on the other hand, leaving flexibility to local regulators to determine the amount and form of financial security—also taking into account the specific risks posed by the particular site and the specific features of the operator involved. That may hence be a model for other jurisdictions as well.[577] As was already mentioned, a similar model is basically followed in the United States as well: owners or operators of geological sequestration wells must demonstrate and maintain financial responsibility for performing corrective actions on wells in the area of review, injection well plugging, post-injection site care and site closure, and emergency and remedial response.[578] The way in which operators and owners can demonstrate financial responsibility has been worked out in the EPA Guidance Document on UIC.[579] The approach followed in the United States is hence similar to the approach followed in Europe by providing guidance on the type of instruments that could be considered as a sufficient demonstration of financial responsibility which will be reviewed by the UIC director.[580] The EPA Guidance Document also has a similar type of flexibility as far as the meeting of the specified financial test criteria is concerned. The document does list particular qualifying instruments, but this list is not considered to be exhaustive or absolute as a result of

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[576] *Id.*

[577] *See generally id.* The EU Guidance Document 4 on the implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide follows from Article 7(10) of the CCS Directive, which states that applications for storage permits must include proof that the financial security or other equivalent provision as required under Article 19 of the Directive will be valid and effective before commencement of the injection. This hence amounts to a financial security requirement as defined in Article 19 of the Directive, which holds that "Member States shall ensure the proof that adequate provisions can be established, by way of financial security or any other equivalent, on the basis of arrangements to be decided by the Member States, is presented by the potential operator as part of the application for a storage permit."

[578] *See* GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE, *supra* note 454.

[579] *Id.*

[580] *See id.* at 6–7 (on the owner or operator submission requirements and the director review responsibilities).

which owners or operators may also use other financial instruments if the UIC program director finds them satisfactory.[581]

B. *Direct Compensation by the Government?*

1. Theory

A second way in which government could play a role in facilitating compensation for CCS-related damage is to provide outright compensation to the victims. In that case, the role of government would not (as when it mandates financial security) be merely facilitative, but government would intervene directly to compensate the damage itself.[582] These type of government-based compensation models are well-known from the experiences with the *ex post* compensation by government of victims of (natural) disasters.[583] Usually this involves *ex post* relief through lump sum payments to victims that are financed by the general tax payers.[584]

However, damage resulting from CCS has to be clearly qualified as a technological or manmade disaster.[585] In that case the primary instrument to be used should be liability law. An exposure of the potential operator to liability is, as we have repeatedly argued above,[586] necessary in order to expose the CCS operator to the social costs of its activity. Compensation by the government would from that perspective lead to an externalization of the risk to society (more particularly the tax payer) and would thus create a moral hazard on the side of operators.

2. For CCS?

From that perspective one can understand that much of the CCS-related literature is strongly against any type of financial intervention

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[581] *Id.* at 9.
[582] *See generally* Veronique Bruggeman, Michael Faure & Tobias Heldt, *Insurance Against Catastrophe: Government Simulation of Insurance Markets for Catastrophic Events*, 23 DUKE ENVTL. L. & POL'Y F. 185, 190–92 (2012).
[583] *See generally id.* There are many examples of *ex post* compensation by government to victims of catastrophes. It can take the form of either a structural fund solution (e.g., in Austria or Belgium) or *ad hoc* relief (such as the well-known September 11th Victim Compensation Fund in the United States).
[584] Precisely this redistributional character of compensation via government is debated since disaster expenditures (e.g., by the Federal Emergency Management Agency in the United States) are often politically motivated. *See* Thomas A. Garrett & Russell S. Sobel, *The Political Economy of FEMA Disaster Payments*, 41 ECON. INQUIRY 496–509 (2003).
[585] *See, e.g.*, *id.*
[586] *See supra* Parts III.A, IV.A.

by government, arguing that this would amount to an undesirable subsidy of CCS.[587] A transfer of risk to the public (i.e., the tax payers) would proffer a competitive disadvantage to environmentally superior operations;[588] public financing is therefore considered to distort or eliminate the impact of market forces.[589] A transfer of liability to the state could amount to an undesirable subsidy,[590] and therefore most of the CCS-related literature has argued that limiting liability of CCS operators (and thus transferring the risk to the state) would be undesirable.[591] In that respect, it could also be argued that government-provided compensation would violate the principles of fair and efficient compensation discussed above,[592] arguing that the duty to contribute financially should in principle be related to the amount in which a specific activity or entrepreneur contributed to the risk.[593]

The question of where government should financially intervene is unavoidably linked with the question of whether the liability of the CCS operator should be limited, and that again depends on the question of what precise goals have to be fulfilled with a liability regime. Above, we have argued that there is no reason to put a financial limit (a so-called cap) on the liability of the operator.[594] However, it has equally been argued that there are reasons to limit the liability of CCS operators in time. The simple economic reason is, as especially strongly argued by Adelman and Duncan,[595] that long-term liability will be discounted to today's present value and can therefore not have any deterrent effect whatsoever. From that perspective it was argued that a transfer of liability for the long-term stewardship from the operator to the state can be defended on economic grounds.[596] However, some current regulations have so-called "claw-back" provisions, allowing the state to recover costs from the operator when they are later discovered to have been at fault.[597]

The positive arguments in favor of transferring liability for long-term stewardship to the state seem convincing. It can make optimal use

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[587] *See* MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 7, 14.
[588] *See* Trabucchi & Patton, *supra* note 26, at 11.
[589] *See id.* at 14.
[590] *See* MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 7, 14.
[591] *See cf.* Klass & Wilson, *supra* note 1, at 108.
[592] *See supra* Part V.
[593] *Id.*
[594] *See supra* Part IV.H.
[595] *See* Adelman & Duncan, *supra* note 11.
[596] *See supra* Part IV.G.
[597] *See* Havercroft & Macrory, *supra* note 112, at 6.

of the capacity of government to distribute risks over time and even over future generations.[598] Moreover, operators would even for the long-term stewardship not completely be off the hook since an advance payment could still be required for the costs of monitoring during the long-term stewardship.[599] However, that means that once these costs are paid, liability of the operator ends and is shifted to the government.[600] Monitoring costs are of course substantially lower than the total potential damage which keeps liability exposure of operators within reasonable limits (in time). In addition to the argument that liability for long-term risk would not generate positive incentive effects, one can also point once more at the positive externalities that can be generated by CCS technology. As many have stressed, the most important barrier to successfully developing CCS is precisely the potential liability for long-term stewardship.[601]

Finally, it should be mentioned that society has (at the international level but also in legislation of national legal systems) often provided subsidies for starting industries.[602] For example, the goal of the nuclear liability conventions as they emerged in the 1960s was clearly to protect nuclear operators from potentially broad liability.[603] In that particular case of the nuclear liability conventions there were, moreover, financial limits on the liability of power plant operators which is not at all what is proposed in this particular case.[604] Government intervention would only apply to the phase of long-term stewardship which is hence much more limited than in the case of the nuclear liability conventions.

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[598] Government intervention in this case thus creates a form of cross-time diversification, which the private market could not achieve. *See* Howard Kunreuther & Erwann Michel-Kerjan, *Challenges for Terrorism Risk Insurance in the United States*, 18 J. ECON. PERSP. 201, 210 (2004).
[599] *Liability*, GLOB. CCS INST., http://hub.globalccsinstitute.com/publications/carbon-dioxide-capture-and-storage-and-unfccc-recommendations-addressing-technical-18 [http://perma.cc/LRH3-N63K] (last visited Jan. 22, 2016).
[600] *Id.*
[601] *See, e.g.*, Hawkins, et al., *supra* note 2, at 4405 (suggesting that "[t]he lack of a regulatory framework specifically for CCS increases uncertainty and complicates project uptake. Alongside unfavourable economics, it is the most often quoted barrier that stands in the way of CCS deployment."); *see also* Trabucchi, Donlan & Wade, *supra* note 38, at 388 (stating "[h]owever, because it represents a new and relatively unproven technology, concern about potential liability associated with CCS often is cited as a significant barrier to project deployment.").
[602] Tom Vanden Borre, *Shifts in Governments in Compensation for Nuclear Damage: 20 Years after Chernobyl, in* SHIFTS IN COMPENSATION FOR ENVIRONMENTAL DAMAGE 261–311 (Michael Faure & Albert Verheij eds., 2007).
[603] *Id.*
[604] *Id.*

C. *Reinsurer of Last Resort*

1. Theory

In various legal systems an interesting model has been developed whereby the government acts as reinsurer of last resort.[605] Under this approach of government involvement, the State takes at least part of the risk for losses from catastrophes.[606] Even though government intervention is required (since the private insurance market cannot provide adequate catastrophe insurance coverage), the underlying philosophy of this approach is that private insurance should keep on playing a significant role in allocating compensation for victims of catastrophes.[607] This option then usually takes the form of a multi-layered insurance program.[608] Such a program is normally administered by private insurance companies, meaning that they sell insurance, collect premiums, and pay claims.[609]

There can indeed be arguments to favor such a reinsurance by government, assuming that capacity on the private insurance market is indeed severely falling behind. It can be held that without state intervention, insurance coverage for disasters would simply not have developed.[610] Reinsurance by the State can then be considered as an adequate method to resolve the uninsurability problem.[611] A condition is, of course, that the government charges an actuarially fair premium for its intervention.[612] This type of government intervention has, moreover, the advantage that *ex post* relief sponsored through the public purse can be avoided.[613]

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[605] Bruggeman, Faure & Fiori, *supra* note 380.
[606] *Id.*
[607] *Id.*
[608] *Id.*
[609] *Id.*
[610] *See, e.g.*, Scott E. Harrington, *Rethinking Disaster Policy*, 23 REG. 40 (2000); Howard C. Kunreuther, *Mitigating Disaster Losses through Insurance*, 12 J. RISK & UNCERTAINTY 171, 180–83 (1996); *see also* Reimund Schwarze & Gerhard Wagner, *In the Aftermath of Dresden: New Directions in German Flood Insurance*, 29 GENEVA PAPERS ON RISK & INS. 154 (2004).
[611] These public-private initiatives to cover extreme risks are also supported by OECD recommendations. *See* Alberto Monti, *Public-private Initiatives to Cover Extreme Events, in* EXTREME EVENTS AND INSURANCE: 2011 ANNUS HORRIBILIS 27–38 (Christophe Courbage & Walter R. Stahel eds., 2012).
[612] Michael G. Faure, *Financial Compensation for Victims of Catastrophes: A Law and Economics Perspective*, 29 L. & POL'Y 339, 358 (2007).
[613] *See generally* Richard A. Epstein, *Catastrophic Responses to Catastrophic Risks*, 12 J. RISK & UNCERTAINTY 287 (1996); *see also* Howard C. Kunreuther & Mark Pauly, *Rules*

2. For CCS?

There is not a lot of discussion on the role of government as reinsurer of last resort in the CCS-related literature. We mentioned that some authors refer to the NFIP in the United States as an example for CCS,[614] and Makuch *et al.* refer to public-private liability funds for CCS.[615] To some extent the intervention of government as reinsurer of last resort is also considered as a "public-private partnership."[616] There seems yet not to be sufficient information available to evoke that this type of intervention would—in this stage of the development of CCS technology and the knowledge about the risks and potential damage—be necessary. Indeed, such an intervention of government as reinsurer of last resort typically happens for catastrophic risks where it is argued that the traditional commercial (re)insurance market cannot provide sufficient capacity to cover the risks.[617] Government then steps in to provide additional supply.[618] Although we have indicated above that there may indeed also be potential capacity problems in the provision of insurance,[619] we have equally argued that a variety of alternative compensation mechanisms could be developed as well such as a risk-sharing agreement between operators.[620] Hence, it seems that at this stage calling for a role for government as reinsurer of last resort simply comes too early, since it may be that market solutions (such as risk-sharing agreements) can still be developed.

The literature has indicated that such an intervention by government should be non-distortive in the sense that the government should only intervene when market solutions are not available.[621] Moreover, government intervention should always have a temporary character in order to stimulate the development of market solutions.[622] In this stage of the development of the CCS technology, it is not yet known whether there would be a problem with the supply of sufficient capacity. Hence it seems that at this moment it is too early to plead in favor of a role for

rather than Discretion: Lessons from Hurricane Katrina, 33 J. RISK & UNCERTAINTY 101, 113 (2006) (arguing that this government's role in assisting the supply side allows avoiding the inefficiencies and inequities associated with disaster assistance).
[614] *See, e.g.*, Trabucchi & Patton, *supra* note 26, at 18–19.
[615] MAKUCH, GEORGIEVA & ORAEE-MIRZAMANI, *supra* note 28, at 24.
[616] *See* Bruggeman, Faure & Heldt, *supra* note 582.
[617] *Id.*
[618] *Id.*
[619] *See supra* Part VI.B.
[620] *See supra* Part VII.B.
[621] *See* Bruggeman, Faure & Fiori, *supra* note 380.
[622] *See* Bruggeman, Faure & Heldt, *supra* note 582, at 223.

government as reinsurer of last resort for CCS-related risks. Only when it would appear that those capacity problems would be real and that government should hence step in to supply coverage could this be considered.[623]

VIII. POLICY RECOMMENDATIONS

Because conclusions or summaries have been provided at the end of most sections, we can be relatively short at this point because the policy recommendations follow logically from the points discussed in the various sections. The crucial question is obviously at this stage what policymakers could do to stimulate solutions especially for the long-term CCS liability. Starting point for the recommendations is that a liability and compensation regime should provide incentives to stakeholders to prevent the harm to the extent that their incentives for prevention could be affected (and hence a moral hazard could arise). At the same time, the question arises how an effective liability and compensation scheme can be structured in order to stimulate insurability or to stimulate the creation of alternative compensation mechanisms.

Recommendations can be made concerning the precise design of an effective liability mechanism (A), as well as a compensation scheme (B), at the same time asking the question whether there is a particular role for the government (C).

A. Efficient Liability Rules

Efficient liability rules in order to provide incentives to stakeholders to prevent harm and to stimulate insurability can be structured according to the following principles:

- Given the potentially hazardous character of CCS, operators should be strictly liable for damage resulting from CCS.
- Compliance with regulatory standards should not automatically free an operator from liability.
- The risk of causal uncertainty should not be shifted to the operator; rather a proportional liability rule should be applied to deal with causal uncertainty.

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[623] But also then particular conditions for an effective intervention should be respected. For details, *see* Bruggeman, Faure & Fiori, *supra* note 380; *see also* Bruggeman, Faure & Heldt, *supra* note 582, at 221–23.

- Policymakers should be cautious with the introduction of joint and several liability regimes as that could increase the potential scope of liability for CCS operators and could endanger the insurability of the liability.
- Operators should no longer be held liable if, after post-closure monitoring, the site has been properly transferred to the government.
- Liability should in principle be unlimited in amount. The policymaker should hence not introduce financial caps on the liability of the operator.

B. Compensation

Different types of compensation mechanisms can be used for different phases of the CCS project life cycle, potentially also in combination.[624]

1. Operation and Injection

- For large operators self-insurance should be allowed, provided that the regulator regularly verifies the adequacy of the self-insurance provided.
- For smaller operators self-insurance can still be used during the operation as a first layer (retention) in addition to other instruments.
- Other instruments that can play a role in providing compensation in this phase are insurance, potentially bonding (although in a more limited role), and guarantees.

2. Post-Closure Monitoring

- Given the long-term character of post-closure monitoring insurance will usually not be available to cover potential damage in this phase.
- Self-insurance can still be used, just as during the operation and injection phase.

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[624] This hence pleads in favor of a multi-layered approach to the liability for CCS-related damage. *See* Fred Eames & Scott Anderson, *The Layered Approach to Liability for Geologic Sequestration of CO_2*, 43 ENVTL. L. REP. 10653, 10653–55 (2013).

- Bonding may not be useful since bonds are typically used for short-term risks, not for risks with a long-term character.
- A risk-sharing agreement concluded between operators on a voluntary basis could provide compensation.

3. Long-Term Stewardship

- Operators only provide an advancement for monitoring costs that have to be objectively determined on the basis of expert evidence.
- Potential damage during this phase will be directly financed by the government.
- If desirable, the compensation in that phase could be financed via a system of retrospective premiums (like in the Price-Anderson Act).

C. The Government

Also government can take different measures, in addition to designing an optimal liability regime, to which we already referred, in order to stimulate an optimal compensation for CCS-related risks:

- The government should introduce tailored and detailed safety regulation for the prevention of CCS-related risks.
- Regulation should be proactive and dynamic.
- In order to create risk-sharing agreements at regional level (e.g., EU, Asean, Mercosur), safety standards could be harmonised in order to stimulate larger networks of operators willing to engage in risk-sharing agreements.
- The provision of financial security by operators should be made mandatory. However, the precise amount and type of financial security can be decided by local licensing authorities, taking into account location specific circumstances of the particular CCS site and characteristics of the operator. Guidelines at regional level (or OECD) could be provided

on how local authorities should judge the adequacy of the type and amount of financial security offered by operators.

- Government may, if this is judged necessary given the potential scope of the damage and the lacking capacity on commercial insurance markets, in a later phase, decide to act as a reinsurer of last resort to the extent that the market (either via insurance or via alternative compensation mechanisms) cannot generate a sufficient supply of financial security for CCS-related risks.

CONCLUDING OBSERVATIONS

This study started from the assumption that CCS is an interesting and worthwhile technology. That assumption is based on the work of the IPCC that, on the one hand, sees great benefits in CCS as a mitigating strategy for climate change and also holds that the long-term risks with CCS are relatively restricted.[625] Not everyone may be convinced of the blessings of CCS and some have even qualified it as "false hope."[626] The goal of this study was of course not to take any position in this debate. However, many mention that in order for CCS to succeed, there are today still important barriers. Some of those barriers are of an economic nature and those again were not the subject of this study.[627] It is held that today economic drivers for CCS are simply lacking in the absence of comprehensive climate policies that force stringent reductions of CO_2 emissions.[628] At the same time it is also held that one of the barriers for deploying CCS, and hence "moving CCS from hype to pipe,"[629] is the necessity to create a clear legal institutional framework especially dealing with the long-term liability. The fear for liability for long-tail risks could be an important impediment to deploying CCS.[630] This study attempted, using law and economics literature and literature dealing with CCS-related risks,

[625] *See* IPCC, *supra* note 23, at 14.
[626] *See* GREENPEACE, *supra* note 30.
[627] They have, to a large extent, to do with current carbon prices which provide insufficient incentives to economic operators to invest in CCS. *See* COM (2013) 180 final, *supra* note 43, at 14.
[628] *See* Hawkins, Peridas & Steelman, *supra* note 2, at 4405.
[629] *Id.* at 4403.
[630] *Id.* at 4405–07.

to provide an indication how policymakers could provide certainty concerning the potential liability risks by, on the one hand, limiting liability in time and, on the other hand, providing adequate financial security. In this way the potential positive externalities (in terms of reducing climate change) could be appropriately balanced with the potential negative externalities (related to the potential damage resulting from CCS).

Providing certainty on a legal regime dealing with liability and compensation for potential risks is the aspect that was central to this study. However, there are clearly many other aspects concerning the underground injection of CO_2, which need a regulatory framework or where, put differently, the current regulatory framework, either at national or at international level, may inhibit underground injection. These aspects, more particularly dealing with a facilitative regulatory framework encouraging underground injection of CO_2, are obviously of great importance as well even though they were not the subject of this Article.[631]

Of course, particular issues will still have to be worked out in further detail. This concerns *inter alia* the question how long the various phases (operation/injection, post-closure monitoring and long-term stewardship) should take, since opinions in the literature on that point diverge. Also the conditions under which after post-closure monitoring liability could be transferred to government will have to be carefully determined within the regulatory framework. As far as the question was concerned whether there should be liability of operators also for long-tail risks (during the indefinite phase of long-term stewardship) we started from the premise that liability rules should have a deterrent effect and that hence liability for long-term risks does not make any sense as far as providing incentives for deterrence is concerned. However, one should well realize that others may argue that deterrence and economic efficiency are not the only goals of a liability regime. Others could for example hold that, even if it may not provide incentives for prevention, operators should still be held liable for the long-tail risks, simply for distributional reasons (not allowing operators to shift costs of their activities to society at large). That was not the perspective taken in this study where, on the basis of a weighing of positive and negative externalities created by CCS, it is was argued that there are good reasons to limit the exposure of CCS operators in time. That may, however, be an approach that is not shared by all. In that case one could, for example, also imagine a financing of the long-term stewardship via retrospective premiums (according to the model

[631] *See, e.g.*, Wilson, Johnson & Keith, *supra* note 59, at 3476–83.

from the Price-Anderson Act) to be paid by CCS operators. The advantage of such a model would be that in that case not tax payers but operators would still pay for the long-term stewardship. There would, however, also be important disadvantages. One would be that operators would still be confronted with long uncertainty perhaps even with an indefinite character. Moreover, many operators may—when damage would appear after fifty years—not be identifiable any longer or have gone out of business as a result of which the retrospective premiums could only be recovered from operators still in business. This would create negative redistribution and high administrative costs. On balance, it is therefore held that a more radical solution, whereby liability is transferred to the State for the long-term stewardship, would be preferable.

To some extent, many of the problems that were discussed in this Article are not unique to CCS, but are typical for economic activities that may cause long-term damage. Typical for those long-term risks is that often both the occurrence of the damage as well as the amount of the damage are highly uncertain. This is equally the case with potential damage resulting from the storage of nuclear waste, but also with the potential risks related to the use of shale gas or methane, even though there are obviously differences as far as the nature of the risks is concerned between those different activities. But to some extent, the solutions and remedies proposed in this Article to CCS-related risks may have implications as well for other potential risks related to energy exploitation where there is equally still uncertainty concerning the probability and nature of the potential risks. That should obviously be the subject of further research.