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A framework to add incentives for managements after CO_2 injections

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Abstract

Carbon capture and storage (CCS) has an issue in the managements after CO_2 injection into geological formations, while CCS is expected to contribute large emission reductions in terms of cost-effectiveness. The incentives to conduct CO_2 monitoring and to prevent CO_2 leakage for long time should be considered as well as those for CO_2 injection. This paper proposes a baseline-credit scheme for the purpose and discussed its virtues and shortcomings. The scheme is similar to Reducing Emissions from Deforestation and Degradation in Developing Countries (REDD) scheme for preventing deforestation. In addition, numerical example calculations for the expected monitoring costs under the scheme were shown.

Keywords: CCS incentives; Sustainable development; Monitoring cost; Financing mechanism

1. Introduction

Global warming is a serious issue for humankinds and large emission reductions induced by human activities are required. Most studies of long-term analyses indicate that it is almost impossible to achieve deep emission reductions without large operations of carbon capture and storage (CCS) as sustainable mitigation measures in the world. For example, according to a recent IEA's estimate, numbers of 35 and 20 new annual installed CCS plants (500 MW for each) for coal and gas, respectively, will be required in the world between 2010 and 2050 in order to achieve halving CO_2 emissions by 2050 [1].

However, some crucial issues for such a large number of CCS implementation will exist. Implementation of CCS will require long time managements not only of injection but also monitoring after injection. Risks of potential leakage of CO_2 may come out years later after CCS operator has terminated injection into a geologic formation. In cases where such risks are realized, CCS operator that should have a responsibility for managements of stored CO_2 might be out of the responsibility after passing a few decades. De Figueiredo et al. [2] point out that examples of potential tort causes of action include trespass, nuisance, negligence, and strict liability under the current regime in

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United States, but there are issues whether the injured parties could even bring a private litigation to begin with because the tort system often has statutes of limitation. On the other hand, if the operator takes full responsibility, unbounded legal liability could discourage diffusion of CCS. The operators will have large barriers to implementation of CCS due to long-term risks for future CO_2 leakage and its compensation. That is unsustainable. Several literatures [2][3][4][5] have proposed to transfer the liability for CCS from the operator to the nation or national authority after CO_2 injection operation or a certain monitoring period after injection. Additionally, risks of CO_2 leakage is important issues of concern for lay people [6].

Therefore, monitoring of stored CO_2 will play a crucial role for public awareness and liability or timeliness of transfer of liability to sustain the CCS. Monitoring is actually needed for a wide variety of purposes: to ensure and document effective injection well controls; to verify the quantity of injected CO_2; to optimize the efficiency of the storage project; to demonstrate with appropriate monitoring techniques; to detect leakage and provide an early warming of any seepage or leakage, etc [7]. Monitoring activities should usually be conducted for long-time periods. Incentives of management for stable stored CO_2 including monitoring will be needed for the operators even after injection periods. Five options will be considered.

1) CO_2 cap (or Tax) only
2) Regulation for CCS injection companies by government
3) Implementation of monitoring after injections by government or government-related institutions
4) Environmental bond scheme; a market-based mechanism
5) Baseline-credit: Providing incentives making implementations maintaining activities including monitoring even after CCS injection to private companies

1) The scheme would be effective to storage CO_2 but ineffective to monitor CO_2 after injection. 2) It can become potentially a large barrier to CCS implementation due to long-term liability for CCS implementation companies. 3) It will be practically difficult, if CCS is implemented at many storage sites. 4) The scheme was proposed by O. Edenhofer et al [8][9]. Entrepreneurs of CCS must buy CCS-bond when CO_2 storage is implemented. The bond can transfer the liability with price mechanism. When CO_2 leakage does not occur after a certain time periods, the bond is refunded with interest. However, if CO_2 leakage is occurred, the bond is refunded with devaluation. The entrepreneurs having the bond have incentives to prevent CO_2 leakage. The proposal as mentioned, however, the initial payment buying the bond will be large for the entrepreneurs. 5) The scheme should be also investigated particularly for large implementation of CCS in the world and will be discussed in this paper.

As a similar issue that climate mitigation faces recently, there is a high-visibility framework related to deforestation, or Reducing Emissions from Deforestation and Degradation in Developing Countries (REDD) by United Nations Framework Convention for Climate Change (UNFCCC). Deforestation seriously continues under the lack of incentives protecting forestry particularly in developing countries and large CO_2 emissions are still generated by deforestation. Although forestry is an important sink for carbon mitigation potentials, the carbon loss due to tropical deforestation is offset by expanding forest areas and accumulating woody biomass. The IPCC WG3 [10] estimated emissions from deforestation in the 1990s to be at 5.8 $GtCO_2$/yr. The Clean Development Mechanism (CDM) credits can be obtained just only by afforestation or reforestation efforts in forestry under the Kyoto Protocol, and cannot be obtained by efforts protecting current forest. Because, for deforestation or forest degradation, there are methodological concerns associated with additionally and baseline setting and whether leakage could be sufficiently controlled or quantified to allow for robust carbon crediting [10].

In order to mitigate such situations, the 13th Conference of the Parties (COP13) on UNFCCC decided to develop a new framework in order to reduce CO_2 emissions from deforestation and forest degradation, and to achieve sustainable management of forests. The estimation techniques of the baseline of deforestation and forest degradation, their measuring and monitoring, reductions in risks of wildfire etc. are now seriously considered and assessed. In addition, funding schemes by World Bank etc. or emission trading schemes are considered in the new framework. CCS has a similar issue in the managements after CO_2 injection into geological formations.

This paper proposes a framework to add an incentive for the managements of stored CO_2 after CO_2 injection. The incentive credits should be generated by setting a baseline in which a reasonable rate of CO_2 leakage is assumed scientifically. The incentive credits can be covered by a global funding scheme supported mainly by developed countries or can be traded through markets. However, this paper discusses that the global funding scheme is better than emission trading schemes through global markets. Appropriate frameworks for specific sectors should be designed considering characteristics of each sector and technology. The framework proposed in this paper will be able to promote large deployment of CCS and contribute the global warming mitigations and global environment throughout long-term.

2. Recent trend of REDD

REDD was proposed by Costa Rica etc. at COP11 in 2005, has been discussed at COP or the Subsidiary Body for Scientific and Technological Advice (SBSTA) to this day. Bali Action Plan at COP13 in 2007, have agreed to address "enhanced national/international action on mitigation of climate change, including, inter alia, consideration of: policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries [11]." Thus, REDD is fund or market based new mechanisms in order to achieve sustainable management for current forests.

However, REDD financing mechanism still remains issues in design and implementation. According to IEA [12], for example, it is necessary to quantitatively monitor forests in order to verify how deforestation be controlled and to provide a positive incentive, such an international financing mechanisms to reduce emissions from deforestation and degradation. There are particularly concrete issues including method of monitoring; that is costly and difficult to scientifically assess, development of baselines; that are necessary to assess e.g., mitigation performance and estimations of past trends of deforestation emissions, leakage; that refers to deforestation activities that move from one area to another, and environmental risk; that is associated with high uncertainty in inventory estimates and permanence.

3. Similarities and differences on risks between CCS and reducing deforestation

As described above, there are scientific uncertainties on both CCS and reducing deforestation and there are many issues to be considered. Reliable monitoring to prevent leakage is important for both mitigation options. The similarities and differences are summarized in Table 1.

In terms to a REDD mechanism including monitoring, several studies have been conducted at the national, regional and global scale to estimate the mitigation potential. Although these estimates vary widely due to different assumptions by land areas, baselines, etc, for example, Shohgen and Sedjo estimate that for 27.2 US$/t$CO_2$, deforestation could potentially be virtually eliminated at the long-term [10]. Over 50 years, this could mean a net cumulative gain of 278,000 MtCO_2 relative to the baseline, by tropical regions. For lower prices of 1.36US$/t$CO_2$, only about 18,000 Mt$CO_2$ additional could be sequestered over 50 years. Also, averaging the results of different studies suggest that for a price of 100US$/t$CO_2$, global emissions from deforestation could be reduced by 3,950 MtCO_2/yr in 2030 [10].

Table 1 Similarities and differences on risks between reducing deforestation and CCS

	CCS	*Reducing deforestation*
Management period	Operation period: 30years Monitoring period: 20-30 years (or more)	Management period: several decades
Site characterization	Site specific (e.g., land availability, access to plant area, incremental capital cost and energy needs regarding CO2 capture and injection, reservoir, storage capasity, trapped	Site specific (e.g., mitigation estimate due to natural variability, differences in baseline assumptions and data quality, carbon sinks due to species, age and stand structure)
Risks	Leakage from the storage site to the atmosphere	Leakage from one area to another (intra-national, international), Emissions from the terrestrial carbon sink
Impact of risks	Local environmental impact (e.g.,groundwater, land, human) No effest on carbon mitigation options	Biodiversity loss, soil degradation, desertification, lack of carbon sequestration, watershed protection, promotion of livelihoods of forest-dependent communities, e.g.
Mechanisms of incentive for monitoring	Not applicable	Under consideration about financing mechanisms (fund and market-based mechanisms) by REDD
Sustainable development	Futher studies will be needed (In particular, long-term liability must be shown to be compatible with sustainable development)	Promotion of synergy between mitigation and adaptation will advance sustainable development

4. Example numerical calculations on baseline-credit for CCS

4.1. Methods

This study explored how the baseline-credit scheme providing incentives to conduct CO_2 monitoring and to prevent CO_2 leakage works and how conditions are required. If the actual leakage is lower than the baseline, the credit can be sold; otherwise the credit must be bought. The entrepreneurs managing post-injection periods have incentives to conduct CO_2 monitoring and to prevent CO_2 leakage. The conceptual diagram of this study is shown in Figure 1.

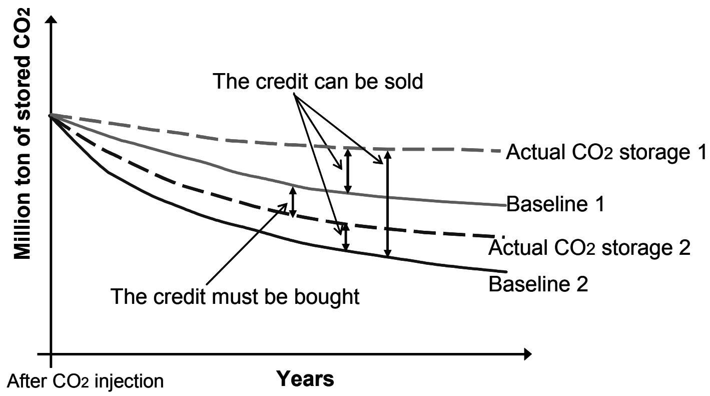

Figure 1 Conceptual diagram on baseline-credit for CCS

The proposal includes virtues that the barriers for CCS injection entrepreneurs will be low and that many entrepreneurs for monitoring CO_2 will be implemented if the baseline is reasonable. However, the credits depends on baseline setting; if the baseline is set with higher leakage rate than the average projected rate, the incentives to conduct CO_2 monitoring and to prevent CO_2 leakage for CCS entrepreneurs will be large but unreasonably low price credit will be provided to the carbon market. In contrast, if the baseline is set with lower leakage rate, the incentives will be small.

4.2. Example numerical calculations

Leakage rate of baseline setting was based on IPCC SRCCS [7] for example numerical calculations. According to IPCC, it is very likely the fraction of stored CO_2 retained is more than 99% over the first 100 years, and it is likely the fraction of stored CO_2 retained is more than 99% over the first 1000 years. The monitoring costs were quoted literatures [13][14], as shown in Table 2.

Table 2 Examples of monitoring cost on CO_2 storage

	Case 1	*Case 2*
CO_2 Storage ($MtCO_2$)	258	20
CO_2 Storage ($MtCO_2$/yr)	8.6	1
Operational period (years)	30	20
Closure period (years)	50	30
Monitoring cost		
Pre-Operational (M$)	5.7-9.8	
Operational period (M$)	23-38	
Closure period (M$)	14-32	
Total cost (M$)	42-81	60
Total cost (US$/$tCO_2$)	0.16-0.31	3
Annual Monitoring cost		
Closure Period (M$/yr)	0.28-0.64	1.2

(Sources: Case 1:S.Benson et al.[13], Case 2: RITE [14])

Using currently reported monitoring costs, the monitoring cost generated by the baseline-credit when the actual leakage is zero is simply presented as follows:

Annual amount of baseline CO_2 leakage ($MtCO_2$/yr) = Total amount of CO_2 storage ($MtCO_2$) × Annual leakage rate to be agreed for the baseline (1)

Monitoring cost under the baseline-credit scheme (US$/$CO_2$) = Annual monitoring cost (Million US$/yr) / Annual amount of baseline CO_2 leakage ($MtCO_2$/yr) (2)

If the above cost is lower than the expected future price of carbon market, the incentives to conduct CO_2 monitoring after injection of CO_2 and to prevent CO_2 leakage will be encouraged.

4.3. Results

The example calculations based on above are shown in Table 3. The baseline of 1%/100yr leakage rate in Case 1 expects generating incentives for monitoring CO_2 and securing CCS because the cost is lower than carbon price of

EU-ETS (12.5-37.5 US$/t-$CO_2$ (10-30 EUR/t-CO_2)) or estimated price of REDD (27.2 US$/t-$CO_2$) etc. The cost of monitoring CO_2 under the baseline of 1%/10yr rate in the Case 1 is low because of a high leakage rate baseline, and therefore the incentives will be large. However, according to the cost estimations based on the other reported costs of monitoring stored CO_2 as in Case 2, the costs of monitoring CO_2 will be more than 60 US$/t-$CO_2$. The cost is higher than current carbon market prices and has small incentives to conduct monitoring CO_2 after injections.

Table 3 Example of monitoring cost after taking into account CO_2 leakage

	Case 1			*Case 2*		
Baseline setting	*Annual CO_2 leakage rates*			*Annual CO_2 leakage rates*		
	1%/10yr	*1%/ 100 yr*	*1%/ 1000 yr*	*1%/10yr*	*1%/ 100 yr*	*1%/ 1000 yr*
	0.001	*0.0001*	*0.00001*	*0.001*	*0.0001*	*0.00001*
Amount of annual leakage ($MtCO_2$)	*0.258*	0.0258	0.00258	0.02	0.002	0.0002
Monitoring cost (US$/t$CO_2$)	1.09-2.48	10.85-24.8	108.5-248.1	60.0	600.0	6000.0

5. Discussions

According to example numerical calculations (Table 3), the estimate costs for all the assumed baselines of CO_2 leakage rate in Case 2 are higher than current carbon price or expected cost of REDD. The appropriate baseline setting for CO_2 leakage rate is a key in the schemes, and the baseline should be set based on the expected carbon price in the market and the expected global average monitoring cost. On the other hand, the baseline of 1%/100yr leakage rate as well as of 1%/10yr in Case 1 would generate large incentives for the CO_2 monitoring. In addition, the scheme will promote careful site-selection and monitoring in pre/during injection in order to increase the value of credit after injection.

However, relating to potential leakage of CO_2 or storage security mechanism, it would be crucial to identify estimation of CO_2 storage capacity in geologic formations. The effective of geological storage depends on a combination of structural and stratigraphic, hydrodynamic, and geochemical trapping mechanisms [7]. Additionally, as to the trapping mechanisms and CO_2 storage capacity, S. Bachu et al. [15] claim that there are still gaps in knowledge that will be covered only through further studies and field experience. CO_2 leakage rates and storage capacity through scientific information are clarified in the future and therefore desirable baseline setting could be potentially provided. Thus, the baseline-credit scheme for CCS after injection of CO_2 should be considered for sustainable CCS management.

6. Conclusions

A framework to add an incentive for the managements after CO_2 injection was proposed. In order to achieve sustainable development of CCS, the entrepreneur will have to consider cost-effective methods and framework for CCS.The scheme has a possibility to make the barrier of CCS implementations small for many of the entrepreneurs and to promote large deployment of CCS and contribute the global mitigation.

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