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Monitoring and reporting of GHG emissions from CCS operations under the EU ETS

Sina Wartmann[a], Heleen Groenenberg[b*], Scott Brockett[c]

[a] Ecofys Germany, Landgrabenstr. 94, 90443 Nürnberg
[b] Energy Research Centre of the Netherlands, P.O.Box 56890, 1040 AW Amsterdam
[c] European Commission, DG Environment, 1049 Brussels

Abstract

The EU Emissions Trading Scheme (EU ETS) may prove a powerful incentive to advance operations of CO_2 capture and storage (CCS) in the European Union, provided that the CO_2 market price is sufficiently high and predictable, and CCS operations will be included in the scheme. This will require clear rules for accounting emissions from CCS installations. The European Commission aims to complement the 2007 Monitoring and Reporting Guidelines (MRGs) for the EU ETS with annexes for CCS operations. This paper presents insights gained from work on these MRGs.

Keywords: CCS, monitoring, ETS, accuracy

1. Introduction

In January 2008 the European Commission released its proposal for an enabling policy framework for CO_2 capture and storage in the European Union[1]. The most outstanding element of this proposal was a Directive for the Geological Storage of CO_2, which would effectively regulate the risks of CO_2 storage. The Directive regulates proper site selection, complemented with appropriate monitoring and history matching of results from monitoring and dynamic flow simulations. After a site has been closed and it has been demonstrated that it behaves as expected and that no CO_2 leaks to the atmosphere, an operator may hand over liability to the national authority. Furthermore, the proposal includes a number of amendments to the existing legislative framework. The risks of capturing CO_2 would be regulated in existing EU Directives [2], because these risks have much in common with those common to the chemical and power generation sectors. Transport of CO_2 will be regulated as for gas pipelines, i.e. subject to Environmental Impact Assessment at EU level but otherwise regulated under national law. Lastly, a number of other Directives that are currently incompatible with CCS will need to be modified to accommodate CCS[3].

* Corresponding author: tel +31 224 564516; fax +31 224 56; email: groenenberg@ecn.nl
1 COM(2008) 18 final
2 the Integrated Pollution Prevention and Control Directive (96/91/EC) and the Large Combustion Plant Directive (2001/80/EC)
3 including the Environmental Impact Assessment Directive (85/337/EC), the EU Regulation for the Shipment of Waste (1013/2006), The Water Framework Directive (2000/60/EC), The Waste Framework Directive (2006/12/EC) and the Environmental Liability Directive (2004/35/EC)

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An important amendment anticipated in the proposed Storage Directive would regard the Emissions Trading Directive, which is to include CCS operations in the future. In its January 2008 proposal for a review of the EU ETS, the European Commission considered that from 2013 onwards, installations capturing, transporting or storing CO_2 should be covered by the trading scheme 'in a harmonized manner', in order to encourage and incentivize large scale deployment of the option. After 2013 there would be no free allocation of emission allowances for installations in the power sector, and all allowances would be auctioned, and CO_2 captured and transmitted for storage would not count as emitted under the ETS. This would enhance incentivization of CCS operations in power installations. As emissions stored are credited under the ETS, there must be a corresponding debit for any leaked emissions from the elements of the CCS chain, and this is ensured by including of CO_2 capture and storage operations in the ETS, is its importance for addressing the risks of any leakage to the atmosphere. Greenhouse gas permits under the EU ETS require a monitoring scheme to be in place that is tailored to the various GHG emission sources in an ETS installation, and any emissions to the atmosphere would need to be offset under the EU ETS by returning a respective amount of emission certificates to the national competent authority. Pending the adoption of a reviewed ETS in which CO_2 capture, transport and storage operations would be included, CCS chains may in its entirety be opted in into the trading scheme through Article 24 of the ETS Directive. Again, installations that include a full CCS chain would not need to hand in allowances for any CO_2 stored.

The inclusion of CCS in the ETS has induced a need for monitoring and reporting guidelines for CCS operations in the EU ETS. While an important element in the proposed Directive on geological storage is the selection of non-leaking sites, and the proposal also requires monitoring to identify, and measures to correct, any leakage, the quantification of any leakage from storage operations in the ETS still needs to be addressed. The IPCC already gave an outline for accounting procedures for CCS in its 2006 Guidelines, which should provide binding guidance for accounting in the national inventories. These cover site characterization, monitoring and the use of history matching to assess site performance. If emission reductions realized in CCS operations under the EU ETS are to be deducted from national emissions, these guidelines should be the starting point for monitoring and reporting of these emissions.

In this paper we will explore approaches to quantify any emissions occurring along the CCS chain without jeopardizing the greenhouse gas integrity of the ETS. This paper outlines ideas conveyed during the ongoing development of a CCS Annex to the 2007 Monitoring and Reporting Guidelines for the EU ETS at DG Environment, including views expressed by Member States in ETS working groups and suggestions in a BERR report on the issue (Zakkour [1]). The paper starts from the presumption that the procedure site selection for any CO_2 storage under the ETS will be scrupulous, and that liability will have been regulated in the proposed Storage Directive. In the following an outline is provided from the clauses concerning site selection in the proposed Directive on geological storage (section 2). Then the basic principles for the ETS MRGs are discussed (section 3). Possible approaches to accounting emissions from CO_2 capture and transport are dealt with (section 4) before monitoring of CO_2 storage operation is discussed, including detection limits and accuracy in ongoing monitoring experiments, and conceivable approaches to deal with these in accounting rules for CO_2 storage operations (section 5). The paper ends with a number of recommendations (section 6).

2. Monitoring and reporting principles

Based on Article 14 and the Annexes IV and V of the EU-ETS Directive, monitoring and reporting guidelines were first adopted in 2004, and a revised version was adopted in 2007. The generic approaches in the MRG were aligned with the approach in the IPCC 2006 Guidelines for national inventories: emissions are monitored and reported by the operator of a site and verified by a third party Key principles for monitoring, reporting and verification activities are also partly taken from the IPCC GL: completeness, consistency, transparency, and trueness, the latter reflecting accuracy of report estimates. The MRG principles require that all emissions from all

GHGs (under the ETS) and all sources in the site are to be covered, that monitoring approaches need to be the same over time[4], they must be clear. Furthermore, a third party must be able to come to the same emission result, and monitoring approaches may not systematically over- or underestimate the real emission value. The principle "improvement of performance in monitoring and reporting emissions" supports the operator in constantly seeking improvement of approaches used, with support from the verifier. "Faithfulness" expresses that an installation's verified emission report is to be capable to be depended upon by its users with regards to its content. In the revised MRGs from 2007, a new principle "cost-efficiency" was included. This reflects the experience that in choosing approaches, a balance between data quality and costs needs to be achieved.

The principle of trueness has been implemented also in a quantitative way into the MRGs. Approaches are required to deliver specific maximum uncertainty levels, which are stricter for larger emitters. This is aimed at creating more or less comparable levels of uncertainty in reported emissions across all Member States. An average level of uncertainty for all emissions reported under the current system can be estimated to lie between +/-2.5% and +/-5%.

3. Monitoring and reporting of CO_2 capture and transport under the MRGs

3.1. CO_2 capture

Capture plants can either be combined with production plants[5] or be capture installations in their own right receiving e.g. flue gases from a production plant. CO_2 arises from the production activities, i.e. through the combustion of fuels as well as through the energy intensive capture-process. Emissions from capture are usually fugitive emissions or emissions from venting, in case technical circumstances require flue gases or captured CO_2 to be vented to the atmosphere. The draft MRGs for CCS suggest to determine these emissions by an input-output balance. The input includes all CO_2 arising from production and capture activities. These can be calculated using the existing provisions in the MRG for the respective production activity and the provisions for combustion for the capture activity. The output includes all CO_2 transferred to the CO_2 transport pipeline system, determined by measurement. Emissions can be calculated as the difference between input and output. The 2007 MRGs already include a provision for the transfer of CO_2 streams out of an ETS installation, allowing the transferred stream to be deducted from emission balance for the installation. The approach for capture can thus directly be integrated into the existing MRGs.

CO_2 from biomass, which is not accounted for under the EU-ETS[6], might also be captured and then transferred to the transport network for storage purposes. Using the above mentioned measurement approaches, accounting of capture CO_2 from biomass would lead to an overestimation of captured (as well as transported and stored) CO_2 with regards to the provisions of the EU-ETS. Although supportive to the prevention of climate change, this would lead to a distortion of the system: an amount of CO_2, which would not have been accounted for in the emissions report for an installation without capture, would, in the case of capture, be accounted for as being transferred and thus being deducted from the installations emission balance, leading to an underestimation of the installations emissions. Accounting for storage of biomass CO_2 would require reporting the amount of biomass CO_2 in all installations in the CCS chain. The information would need to be handed over from the capture installation to the transport network and further to the storage site. While biomass CO_2 cannot be accounted for under the EU-ETS, the proposal for a revision provides, in its article 24a, that Member States might decide to put in place respective emission reduction mechanisms comparable to today's national Joint Implementation projects. Such mechanisms would lead to the issuance of reduction certificates for the amount of non-EU-ETS CO_2 stored, the certificates could then be used for compliance within the EU-ETS.

3.2. CO_2 transport

4 Approaches can of course be changed, but this should then be taken into account in the timeline. Changes of approaches are allowed as far as they improve the quality of the monitored emission data.

5 In this case, the term production plant is meant to include both the combustion of fuels for energy production purposes as well as industrial production of any kind.

6 CO_2 from biomass use is accounted for as leading to zero emissions. This is unproblematic in the case of emission calculation, but requires specific provisions in the case of emission measurement, where CO_2 from biomass and from fossil origin cannot directly be distinguished.

Emissions from CO_2 pipelines include mainly fugitive emissions, emissions from venting and potential leakages in the pipeline. Experiences with pipeline transport indicate that leakages can usually be detected and repaired very quickly, and fugitive emissions are usually low. Basically, an input-output approach as in the case of capture emissions can be used, the input being the CO_2-stream transferred into the pipeline and the output being the CO_2 stream transferred out of the pipeline (e.g. to the injection facilities at the storage site or a transport network managed by a different operator). Continuous measurement allows to achieve a high accuracy – the provision for transferred CO_2 requires +/-1.5% maximum fugitive emissions[7]. Even so, as the overall amount of CO_2 transported in the network is so large, an accuracy of +/-1.5% still allows a considerable amount of fugitive emissions to remain undetected. Assuming a transported amount of 5 Mt per year, an error of +/-1.5% could mean 70kt of CO_2 emissions per year. Such emission levels are common to a medium-sized emitter under the EU-ETS. Therefore, operators of transport networks are required to estimate the emission factor for fugitive emissions every five years. This emission factor is to be determined by measurement campaigns focusing on potentially emissive parts of the pipeline, e.g. at booster stations or bifurcations. On this basis an overall emission factor for the whole pipeline is to be established. It is assumed that it will be considerably lower than +/-1.5% of the transported CO_2 mass. This emission factor can be used for cross-checking of the input-output balance results, or even for emission calculation, unless leakages or venting have occurred and the result of the input-output balance is not considered as sufficiently reliable by the respective competent authority.

Apart from the monitoring approaches there are several other issues regarding the transport of captured CO_2. One is the fact that in the long term, transport networks are expected to become complex. They may be operated by various parties and cross EU Member State borders. The Directive on geological storage does not cover this issue specifically at the moment, on the basis that they can be addressed as the complexity arises in practice, and on the basis of experiences with the early phase of CCS deployment where transport networks are likely to be simple. There would be potential issues for MRGs to be resolved. A simple, but not very cost-efficient option is to require measurements, whenever the operator of a network changes.

4. Monitoring of CO_2 injection and storage

4.1. Monitoring experiences

The growing interest in CO_2 storage in geological formations has enhanced the development of monitoring methodologies that would help to assure site integrity and permanence of the CO_2 storage. A number of large scale CO_2 storage operations is up and running, and monitoring programs have been tailored to the specific geological characteristics of each of the sites, and the objective of the monitoring.

For instance, CO_2 derived from coal gasification plant has been injected into the Weyburn Oilfield (onshore Saskatchewan) since 2000, for the purpose of enhanced oil recovery from a carbonate reservoir. The Weyburn field is in a tectonically quiet region and therefore considered to be highly suitable for the secure storage of CO_2. A monitoring program has been carried out to date, including direct sampling of reservoir fluids, and passive seismic methods. Surface monitoring focused on determining the concentration of various gases within the soil (Riding and Rochelle [2]). In Sleipner, where CO_2 is injected since 1996 frequent time-lapse seismic surveys have provided a large reference dataset applicable to the general understanding of large-scale storage in saline aquifers. The monitoring program includes 3D baseline and repeat time-lapse surface seismic surveys, as well as baseline and repeat gravimetric surveys. At In Salah, where CO_2 storage was designed specifically for environmental purposes, a comprehensive monitoring programme has been developed. The monitoring program includes 3D baseline and repeat seismic surveys, microseismicity, microgravimetry, surface EM, downhole fluid sampling, as well as soil gas and microbiology baselines (CO_2ReMoVe [3]).

The wide range of monitoring methods has triggered the question what combination of methods would be preferable. Starting from a cost-efficiency point of view a prioritization of monitoring technologies has been suggested based on the costs of and the information provided by various monitoring technologies (BP *et al.* [4]).

[7] The achievable uncertainty increases with the diameter of the pipelines, for large diameters, the untertainty requirement could result problematic.

Useful information may be obtained at low cost by wellhead monitoring and sampling, microseismics, geochemical and geomechnical measurements, surface flux measurements, dynamic modeling, and possibly micro gravity measurements. Focused application of logging and 4D seismics, which are more costly, is recommended as well. Inexpensive though but arguably less valuable methods that could be considered include for instance satellite imaging, while cross-well or surface electromagnetic studies may be considered too expensive to be worth their result.

This cost-benefit prioritization may indirectly deal with the accuracy that may be achieved using each of these methods, which is important. Not only would the inclusion of CCS in a cap-and-trade system require due accuracy in emissions estimates, such as in the EU, also in absence of such a system accuracy in monitoring is desirable. In the US, performance standards or retention rates for CO_2 storage sites are an important ingredient of the debate on CCS, and such standards would require minimization of uncertainties in seepage estimates as well.

4.2. The proposed Directive on Geological Storage of CO_2

Monitoring and reporting guidelines for CCS operations under the ETS can start from the supposition that site selection and liability eventually will have been dealt with adequately in the proposed Directive on geological storage. The Directive stipulates that a geological formation may only be selected if under the proposed conditions of use there is no significant risk of leakage, and if no significant negative environmental or health impacts are likely to occur. Exploration and storage permits will be issued by the Member States, and any application for a storage permit will include the characterization of the storage site and an assessment of its security, monitoring plans, closure plans and corrective measure plans in the event of leakage. The European Commission has the right to review draft storage permit decisions by the Member States with the help of a dedicated panel and issue an opinion, but the final decision lies with the competent authority of the Member State.

A site is closed after injection has ceased, and the operator has demonstrated with monitoring and history matching that the site behaves as expected. The operator is required to issue a report, demonstrating that all available evidence indicates that all CO_2 stored in the site will be completely contained for the future. After having done so, the operator may hand over liability to the competent authority. Again, the European Commission may issue a (non-binding) opinion on any Member State decisions in this respect. Once liability has been handed over, monitoring may cease. If any leakages or significant irregularities are identified, monitoring shall be reactivated to assess the scale of the problem and the effectiveness of corrective measures. There will be no recovery of costs incurred from the former operator after the transfer of responsibility of the competent authority. Finally, operators are required to make adequate provisions prior to permit application to ensure that they can meet all obligations arising both under the storage permit and under the EU ETS, including closure procedures and post-closure provisions.

All monitoring provisions under the Directive on geological storage address the behavior of the CO_2 plume in the storage complex, including the existence of seepage events. At the same time, quantification of such events is not included. This means, that detection of seepage will take place under the Directive on geological storage, while quantification will take place under the MRGs. Therefore, the detection of a seepage event at a storage site under the Directive triggers the start of quantification activities for the respective seepage event under the MRG. Generally, it is considered helpful that monitoring plans under the Directive on geological storage and the EU-ETS Directive are aligned as far as possible and assessed in an integrated way, as they complement each other.

4.3. Quantification of seepage

4.3.1. The role of detection limits

One of the elements in the discussion on monitoring of CO_2 storage reservoir regards the minimum amount of CO_2 that may or would to be detected. Various approaches are conceivable to establishing detection limits (Benson, [5]). If a prescribed detection limit would be considered desirable, this may be defined in various ways. These include e.g. the fraction of a background CO_2 flux; as the percent of the CO_2 that will be injected into the storage reservoir; a specified amount of CO_2 emissions per year; a prescribed CO_2 flux, or some method that depends on the monitoring equipment used. Each of these approaches has its own merits and drawbacks in terms of simplicity, or type of storage projects they would favor.

One question however that arises in the discussion on detection limits, is whether there is a need to consider detection limits in the first place. Any seepage that is too small to be detected can by definition not be quantified and included in any emission accounting. A stance taken in the EU context therefore is that site selection must be scrupulous, and that any seepage that is too small to be detected can safely be disregarded, provided that a good monitoring program aimed at detecting any seepage that might occur has been implemented. Instead, it might be more worthwhile to consider accuracies in estimates of any seepage that can be detected, as discussed in the following.

4.3.2. Accuracy

An issue that bears a more direct relevance for emission accounting is the accuracy in estimates of emissions that can be detected. The proposed EU Directive on the Geological Storage of CO_2 stipulates that a monitoring plan must be part of the application for a storage permit, and that its implementation will be part of the permit requirements. Yet, the Directive does not prescribe any monitoring approach. Instead, it suggests groups of monitoring techniques, including technologies that can detect presence, location and migration of the CO_2 in the subsurface, technologies that can provide information about plume behavior (3D simulation in 3D models), and technologies that can provide wide areal spread across the complete storage complex. Monitoring equipment is to be based on the best available technology at the time the monitoring plan is designed. The Directive does not address uncertainties in the monitoring program or detection limits. As yet, it is uncertain to what extent the CCS Annex to the 2007 Monitoring and Reporting Guidelines will contain more prescriptive wording regarding the monitoring equipment used.

A host of in situ measurement is available to image and detect the CO_2 plume and migration of the CO_2. Seismic methods are commonly used for monitoring the CO_2 plume, especially surface 3D seismics, a main asset being its ability to effectively visualize the full CO_2 plume in the deep underground. Under favorable circumstances 3D seismics can offer spatial resolution down to a few meters or less. In principle CO_2 in the reservoir may be quantified, but this is very difficult, and additional data from well logs, core studies and well-based seismic measurements is required. Down-hole pressure measurements are a prerequisite in this respect and a well-established method in the oil and gas exploration industry. Electromagnetic monitoring involves the measurement of subsurface variations in electrical conductivity, as may be produced by migration of CO_2 in the subsoil. A relatively novel technique is the measurement of gravity down the well. This offers the potential for higher resolution monitoring of CO_2 movement, by measuring the gravity response of CO_2 layers near the monitoring well. An important limitation of all these in situ measurements is their restricted capacity to quantify the amount of CO_2 in the underground. The precision of these methods have not been systematically assessed, but it has been estimated that the precision will most likely not be more than on the order of ±20% (Benson [5]).

Measurement approaches using in particular eddy covariance and flux accumulation methods are more suitable for quantifying seeping emissions. However, emissions need to be detected and located before monitoring equipment can be installed at the right locations, baseline emissions arising from e.g. the decomposition of soil organic matter would need to be measured too, and all in all substantial efforts may be needed to quantify a relatively small seepage. Likewise, soil gas and soil sampling methods, while providing limited quantitative information about the CO_2 seeped, are labor intensive methods in view of the large surface that may overly the storage complex.

5. Monitoring of CO_2 injection and storage under the MRGs

5.1. Estimating emissions from CO_2 injection facilities and enhanced oil recovery activities

Emissions from storage sites include fugitive as well as vented emissions from injection (similar to the ones from transport), break-through CO_2 from enhanced oil recovery activities and leakage emissions from the storage site. In this section, only emissions from injection and EOR activities are addressed.

In order to avoid accuracy problems comparable to the ones encountered in transport, emissions are measured directly instead of using an input-output balance. Emissions from venting can be measured by continuous emission measurements, while fugitive emissions are measured continuously directly at the point of injection.

Injections of CO_2 in enhanced oil recovery (EOR) operations are likely to have an additional source of emissions, namely the breakthrough of CO_2 with the produced hydrocarbons. Emissions sources for CO_2 EOR operations thus include:
- the oil-gas separation units and gas recycling plant, where fugitive emissions of CO_2 could occur;
- the flare stack, where emissions might occur due to the application of continuous positive purge systems and during depressurization of the oil production installation;
- the onsite power plant, used to power the operations;
- a CO_2 purge systems, to avoid that high concentration CO_2 will extinguish the flare.

It was considered that any fugitive emissions occurring at the platform can be rerouted in a gas containment system to the flare or purge system to avoid the accumulation of explosive gaseous mixtures. Emissions from the onsite combustion activities and flare stack could therefore be calculated in accordance with existing stipulations for these emission sources in Annex II of the 2007MRGs (Zakkour [1]).

5.2. The uncertainty supplement

The above addressed large uncertainties in quantifying any seepage from the storage reservoir are at odds with the accuracy generally required by the 2007MRGs for emission accounting under the ETS.

Various approaches are conceivable to reconcile the two. One option would be to require a storage operator participating in the ETS to systematically overestimate any seepage from the reservoir in order to ensure, that emissions are definitely not underestimated (Wartmann and Harnisch [6]). While in principle good site selection and risk management should ensure zero leakage, any estimate of CO_2 that would unexpectedly seep would need to be adjusted upwards, using a so-called uncertainty supplement. This uncertainty supplement would need to equal the difference between the accuracy that the monitoring scheme can provide, and the maximum uncertainty required by the MRGs for seepage emissions at storage sites, currently being +/-7.5%. This approach also encourages development of more accurate quantification technologies in the long-term.

5.3. The Scientific Panel

To date little experience with methods for quantifying CO_2 seepage from geological reservoirs exists. The methods are mostly still under development or applied and evaluated at scientific level, in contrast with the development of MRGs for other activities under the EU ETS. These could build on considerable practical experience with the relevant technologies and methodologies.

The development of MRGs for CCS including specific quantification approaches for seepage from storage sites did thus not seem feasible at this point in time. Instead, it was suggested to utilise the existing scientific experience through a scientific panel for issues connected to leakage quantification. The purpose of this panel is to support the set-up and assessment of monitoring plans under the EU-ETS at CO_2 storage sites. In order to avoid set-up and assessment through the same institution, the body would be split in two groups, each responsible for only one of the respective tasks. In order to enhance efficiency, the panel is suggested to be combined with the panel for assessment of storage site permit applications under the Directive on geological storage. Through the involvement of this body in these activities, comprehensive practical experience from emission quantification at storage sites could be collected and evaluated by one EU expert group. This information would be used for future quantification activities and for the development of future MRGs for seepage emissions from CO_2 storage sites. The body could furthermore identify areas where additional scientific research activities are warranted and give direct feedback to the scientific community. The body could thus facilitate the use and expansion of scientific and implementation knowledge on the monitoring of CCS sites. In addition, this approach would support a harmonized implementation of quantification approaches throughout the EU.

6. Conclusions

This paper has endeavored to outline the intricacies in and possible solutions to accounting GHG emissions from future CCS operations under the EU ETS, which eventually will be laid down in the Monitoring and Reporting Guidelines. The MRG principle of trueness provokes a need not to overestimate or underestimate any emissions arising from an ETS installation. Accuracy requirements have been specified for emissions reported by installations in all sectors covered by the EU ETS in order to guarantee the greenhouse gas integrity of the scheme, and will need to apply to CCS operations as well. Such accuracy requirements may be well within reach for the reporting of GHG emissions from CO_2 capture and transport installations. For CO_2 storage operations, accuracy requirements under the MRGs may well pose a greater challenge in view of the limited experience to date with monitoring of seepage from CO_2 storage, and insight in the uncertainties involved. A possible way out would seem to require operators to overestimate any seepage by adjusting any estimate derived from measurements and modeling upwards with a so-called uncertainty supplement. While this approach would seem a good solution to ensure the greenhouse gas integrity of the EU ETS, it is a partial solution only, a principal difficulty being that the magnitude of the uncertainty itself in any seepage estimate is mostly unknown.

Therefore, there is an apparent need not only to quantify emissions from CCS operations, but also to get a better understanding of the uncertainties involved. More scientific underpinning is required for appropriate monitoring approaches for CCS operations, in particular for estimating any seepage from the reservoir. This will allow for a better founded trade-off between a higher accuracy in the emission estimates and the costs involved. Such a trade-off is crucial in countries or regions that have an ETS, but it is just as important in parts of the world that do not dispose of an emissions trading scheme. This includes for instance CCS operations in the US, where discussions often focus on performance standards or CO_2 retention rates, but also in non-Annex I countries, should CCS at some point be included in the Clean Development Mechanism. If a future CCS operator in the developing world would be to surrender Certified Emission Reductions for any CO_2 that unexpectedly would seep, underpinned quantification of seepage and the uncertainties surrounding it will be imperative.

While widespread experience with monitoring CO_2 operations and quantify emissions from these is lacking, it is important to accumulate and exchange monitoring experiences. This could be done by a scientific panel at EU level which could support the set-up and assessment of monitoring plans under the GHG permit of storage operations, collect and evaluate experiences and recommend new scientific research in monitoring (Wartmann and Harnisch [7]). Such an approach would effectively support a harmonized implementation of quantification approaches in the EU and elsewhere.

7. References

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