Technology Collaboration Programme
by IEA

IEAGHG Technical Review 2020-TR03 September 2020

IEAGHG Monitoring Network Virtual Discussion Panel: Regulation, Industry and Research - Translating Monitoring Research to Meet Commercial Needs

IEA GREENHOUSE GAS R&D PROGRAMME

International Energy Agency

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 30 member countries and beyond. Within its mandate, the IEA created Technology Collaboration Programmes (TCPs) to further facilitate international collaboration on energy related topics. To date, there are 38 TCPs who carry out a wide range of activities on energy technology and related issues.

DISCLAIMER

The GHG TCP, also known as the IEAGHG, is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the IEAGHG do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

This virtual discussion panel on 'Regulation, Industry and Research - Translating Monitoring Research to Meet Commercial Needs' was facilitated and organised by IEAGHG..

COPYRIGHT

ACKNOWLEDGEMENTS AND CITATIONS

TThis report describes a virtual panel discussion for the IEAGHG Monitoring Network. This report was prepared by Samantha Neades, IEAGHG with input from the panellists.

IEAGHG would like to thank the IEAGHG Monitoring Network Steering Committee for their efforts in facilitating this webinar:

- Charles Jenkins, CSIRO
- Frederick Gal, BRGM
- Jun Kita, Marine Ecology Research Institute (MERI)
- Katherine Romanak, Bureau of Economic Geology at the University of Texas
- Lee Spangler, Montana State University
- Rob Trautz, Electric Power Research Institute (EPRI)
- Susan Hovorka, Bureau of Economic Geology at the University of Texas
- Tom Daley, Lawrence Berkeley National Laboratory
- Ziqiu Xue, Research Institute of Innovative Technology for the Earth, Kyoto (RITE)
- Tim Dixon, IEAGHG (Chair)
- James Craig, IEAGHG,
- Samantha Neades, IEAGHG

IEAGHG would also like to thank the panellists for their contributions to the event:

- Tim Dixon, IEAGHG (Moderator)
- Susan Hovorka, Bureau of Economic Geology at the University of Texas
- Sunil Varma, Department of Mines, Industry Regulation and Safety, Australia
- Scott Wehner, Caprock Carbon LLC, USA
- Eva Halland, Norwegian Petroleum Directorate, Norway
- Jørg Aarnes, DNV GL, Norway
- Charles Jenkins, CSIRO
- Katherine Romanak, Bureau of Economic Geology at the University of Texas

The report should be cited in literature as follows:

'IEAGHG Monitoring Network Virtual Discussion Panel: Regulation, Industry and Research - Translating Monitoring Research to Meet Commercial Needs, Report of Discussion Panel, 2020-TR03, September 2020.'

Further information or copies of the report can be obtained by contacting IEAGHG at:

IEAGHG, Pure Offices, Cheltenham Office Park
Hatherley Lane, Cheltenham,
GLOS., GL51 6SH, UK
Tel: +44 (0)1242 802911
E-mail: mail@ieaghg.org Internet: www.ieaghg.org

Contents

Introduction

This discussion panel was held by webinar on Wednesday 12th August at 10pm BST, with the theme of engaging regulators, looking at 'Regulation, Industry and Research - Translating Monitoring Research to Meet Commercial Needs'. The panellists comprised different CO_2 storage monitoring stakeholders; operators, regulators and researchers and attendees were asked to submit questions for the panellists to consider prior to the event, of which over 120 were received. 70 participants joined the event, in addition to the 8 panellists involved.

The aim of the panel was to discuss the translation of CO_2 geological storage monitoring research into regulations and commercial-scale projects. It began with a scene setting presentation and framing questions with in-depth and thoughtful discussion with operator, regulator and research representatives from the US, Australia, and Norway.

This discussion panel was an ideal opportunity for all stakeholders actively engaged in CO_2 geological storage projects and practical research in monitoring to share and learn about how the information from research and our Monitoring Networks can be used to meet commercial needs.

Welcome

Tim Dixon, General Manager of IEAGHG, was the moderator and welcomed all and explained the IEAGHG Monitoring Network, one of IEAGHG's storage networks which bring together experts and practitioners in the area. This particular Network has been running for 16 years and aims to assess new technologies and techniques as they become available, determine the limitations, accuracy and applicability of monitoring techniques, disseminate information from research and storage projects around the world, as well as to engage with relevant regulatory bodies. The panellists were introduced:

Susan Hovorka, researcher (Bureau of Economic Geology at the University of Texas, USA),

Sunil Varma, regulator (Department of Mines, Industry Regulation and Safety, Australia),

Scott Wehner, operator (Caprock Carbon LLC, USA),

Eva Halland, regulator (Norwegian Petroleum Directorate, Norway),

Jørg Aarnes, regulator (DNV GL, Norway),

Charles Jenkins, researcher (CSIRO, Australia),

Katherine Romanak, researcher (Bureau of Economic Geology at the University of Texas, USA).

Setting the Scene

Sue Hovorka gave a brief presentation to set the scene and looked into what the role of monitoring is in a CO_2 storage project. Monitoring is used to reduce uncertainty, whether it is geological characterisation uncertainty or fluid flow uncertainty. The areas that can be measured and monitored are in the subsurface with conformance and containment monitoring, in changes in rock and fluid

physics and chemistry, in near surface zones with environmental monitoring and in addition, atmospheric, soil and water monitoring (see figure 1, below).

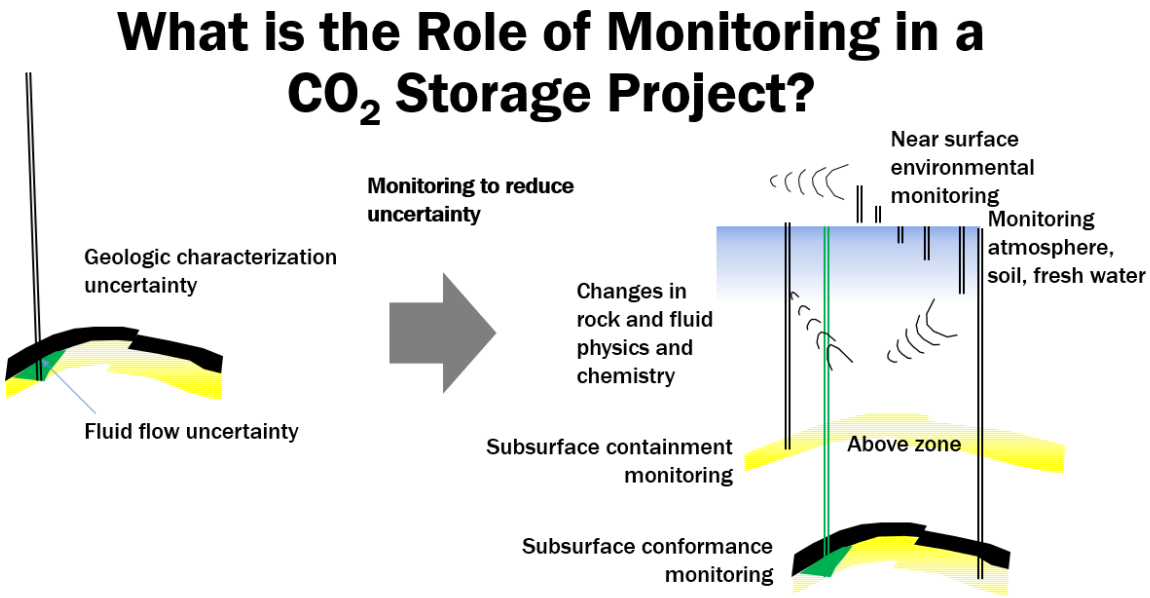

***Figure 1**. The role of monitoring in a CO_2 storage project, Sue Hovorka, IEAGHG Monitoring Network Virtual Discussion, August 2020*

The focus of the panel is the evolution of monitoring for CCS; with research and development (R&D) projects usually evolving to commercial projects. R&D projects are asking questions to try and get answers using scientific approaches, they are testing tools and validating model assumptions via observations. Commercial projects are answering regulatory and business questions, relying on mature tools to document conformance and compliance, and using models to provide confidence in project performance (figure 2, below).

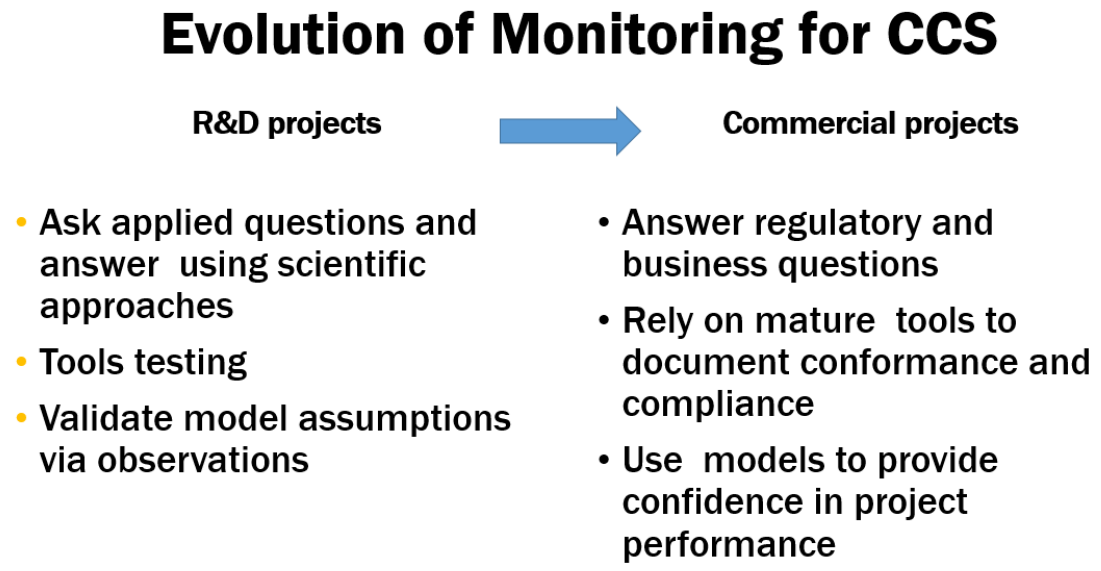

***Figure 2**. The evolution of monitoring for CCS, Sue Hovorka, IEAGHG Monitoring Network Virtual Discussion, August 2020*

The commercial drivers of monitoring; regulatory compliance, development of best practice and commercial viability are all interlinked, and all affect each other in different ways (figure 3, below).

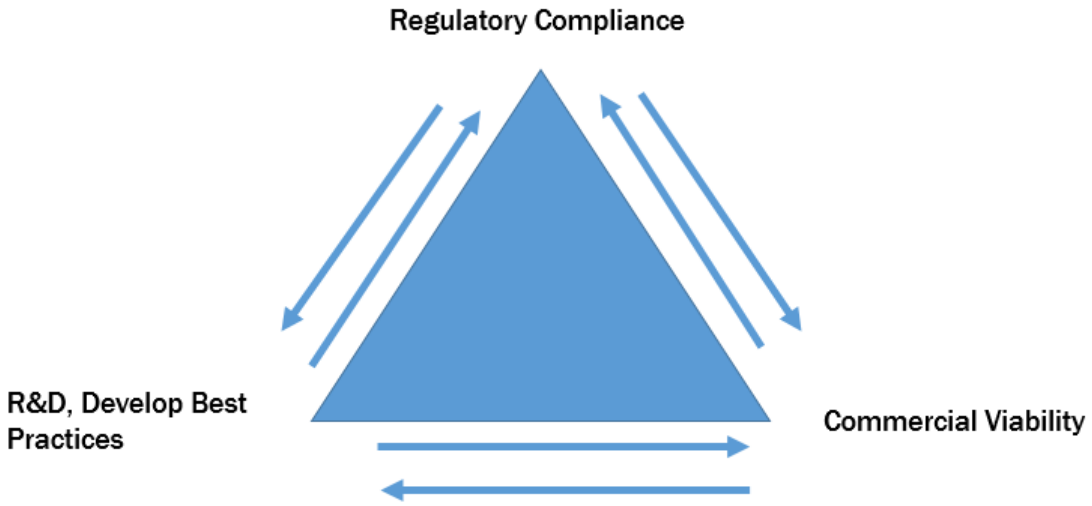

***Figure 1**. Commercial Drivers of Monitoring, Sue Hovorka, IEAGHG Monitoring Network Virtual Discussion, August 2020*

Responses from Panellists

The Monitoring Network Steering Committee sorted through the 124 questions asked by registrants in advance of the event and summarised the range of questions with eight key framing questions to help shape the panel discussion. The questions were put by Tim to the panellists and the resulting discussion is summarised below.

We are discussing the evolution of monitoring storage projects from R&D to commercial projects. From your own perspective, what stage are we in now? How have R&D, learning-while-doing, and regulation fed into current status?

Eva Halland (*Norwegian Petroleum Directorate, Norway*) began by noting that we have learnt a lot through the offshore projects (such as Sleipner and Snøhvit), and what we're seeing from research projects is that lots of technologies are have already been tried and tested. We now need to be more specific on what we need from a CO_2 storage monitoring site and how we can do this cost effectively. Accuracy is key, the uncertainty is that we have to be very clear and professional in what we can see and what we can monitor. There are a lot of technologies and a lot of 'nice to have' technologies; we need to be focussed on needs and cost efficient technologies to meet them. The current Northern Lights project is looking into this; it is working to approve technology but also showing that it is possible to do such a CCS project whilst looking at cost efficiency and how we can work to reduce project cost.

Sunil Varma (*Department of Mines, Industry Regulation and Safety, Australia*) agreed with Eva; in Western Australia they are strong believers in objective-based regulation rather than prescriptive-based regulation, they depend on the operator to propose a monitoring strategy and the regulator then approves on the merits of the programme.

Jørg Aarnes (*DNV GL, Norway*) noted that from a commercial perspective, it is important that the monitoring toolset provides flexibility in delivering cost effective monitoring programmes to deliver the objectives, providing assurance to stakeholders in a risk based context and in different geological settings. We do need to continue learning by doing, but we do have a mandatory toolset that allows us to move forward with commercial projects and therefore upscale CCS.

Scott Wehner (*Caprock Carbon LLC, USA*) agreed with the other panellists, there is a need for continued development of cost efficient technologies. From a CCUS operator's perspective, there is a plethora of monitoring options that provide at least qualitative options to feed the models and simulations. In reality, a lot of the basic monitoring techniques were developed over decades in the oil and gas industry; the more we can reduce the cost (nowadays, costs a lot of time tend to be associated with the labour aspects rather than the technology aspect). We've come a long way already, but there is still the need to make it much more cost effective; from an operator's perspective, these projects still have to be a profitable endeavour. However, operators would be open to requests for new technologies being tested alongside proven technologies as long as they did not interfere with the operations.

Charles Jenkins (*CSIRO, Australia*) added that a key point of focus of researchers currently is the near surface; assuring people that the consequences they're afraid of aren't going to happen. This is an area we need to reduce upon what we're called to do; research is still ongoing here. This is a societal problem as much as a technical one, and that's the area that researchers are pressing on to bring down the costs and reduce those false positives.

Katherine Romanak (*Bureau of Economic Geology at the University of Texas, USA*) felt it was interesting that from the DNV point of view they see the available large monitoring toolset as giving flexibility; this is correct but it should be noted that having all these options can get out of control – just because we can measure it, doesn't mean we should. Another thing lost about near surface monitoring in the regulations is that when we do monitor the near surface, what is it that we are actually looking for? It is thought that we are simply looking for leakage, but we're actually looking for something that looks anomalous. Once an anomaly is found, its source needs to be attributed either to the CCS project, or some other source, such as environmental variability caused by climate change. This ties into the other important thoughts about cost and safety. Care needs to be taken with monitoring; there is a need to understand what needs to be monitored and not over-monitoring in order to be cost effective.

Sue Hovorka (*Bureau of Economic Geology at the University of Texas, USA*) added that in the push to commercialisation, we may be missing the chance to invest in research into cost reduction. A lot of time is spent looking at successful projects, and not on those that haven't worked; more R&D should be done on imperfect projects to ascertain the difference between these and fine projects. The CaMI site in Alberta does work somewhat towards this, as does the Otway project which is looking at injection into a shallower fault.

Katherine readdressed the topic of learning while doing. The way a storage project is set up is safe; the safety comes in the doing, in making sure we have correct techniques, programmes and regulations. With the upscale that is required in CCS for emissions reductions targets, learning while doing is appropriate – but how do the regulators feel about learning while doing? Sunil noted that regulators like to stick to tried and tested methods, so whilst learning while doing is nice to have, when it comes to commercial projects it's what the operator proposes and then regulators approve this. He noted that the South West Hub in Australia are encouraging research of some aspects, adding that most regulators would approve research in addition / alongside an approved monitoring programme. Eva agreed, noting that the regulator needs to know that the technologies proposed will work and it's

up to the operators to choose the technologies rather than the regulator; the regulator needs to know that the proposed technologies tells them what they need to know to assure the project. It's important for governments and operators to take part in smaller demonstration projects to test out other technologies, especially when looking at storing more for less money. Scott agreed, adding that the operator will chose the most cost effective and least costly programme, but could potentially be open to an additional proposal to test a technology alongside proven methods. Charles noted that the Quest project (Shell) is good example of learning while doing; showing that objectives can be achieved with fewer technologies and therefore a lower cost. Jørg explained that in the commercial realm if there is an agreement of what the monitoring objectives are, then there is a discussion on what technologies are used to meet these specific needs. He emphasised the difference between onshore and offshore in these objectives, noting that the Northern Lights project's base case monitoring is intended to focus on contingency monitoring and not assurance monitoring; it's not only about only looking at the technologies to use, but also the objectives needed from the monitoring programme and with regards to different geological settings.

The IEAGHG Monitoring Network usually reviews developing technologies. Where do you see the greatest improvements in monitoring technology have been in the last ten years both from a technical and regulatory perspective?

Charles noted that the standout from his recent work on this would be the development of distributed acoustic sensing and distributed temperature sensing, using fibre optics down the wellbore which are able to give continuous readings. This particularly combined with permanent surface seismic source sensing are game changers, meaning that continuous seismic surveying can be done at much less cost, the temperature measurements tell a lot about the integrity of the wellbore and how to manage injectivity which are big questions; these development in technologies can make an enormous difference and are not CCS-specific, but can be applied widely across the oil and gas industry. In addition in assurance monitoring the regulators potentially have to carry a high amount of risk and the work of Katherine at the BEG and others on attributing near-surface signals and being able to say that they are not necessarily aspects of the CCS project is absolutely key.

Scott has seen great strides in work being more interrogative into the reservoir and CO_2 complexes, adding that InSAR is qualitative but provides a cost effective and timely view of molecules in the subsurface. K wave theory would also provide a low cost option, providing real-time 3D observations of frontal movements in the CO_2 complex.

Eva explained that with regards to the greatest improvements in monitoring technologies, again, it's down to cost. Fibre optics are very important and there is hope that it will evolve much more in the coming years, with improvements being seen in seismic and electromagnetic already, but these three areas should be looked into more. In terms of seabed monitoring it's more key to look at assurance; looking at the baseline and monitoring any changes. It's challenging in an offshore environment but this needs more improvements.

CCS is an international venture. What are the best approaches and limitations on translating monitoring progress in one country into another? Is it by working with standards? By publishing more scientific information? Or by more regulatory alignment?

Katherine expressed that In the Offshore Workshop Series for example, the CCS community has been discussing how to learn from doing together, worldwide. Stakeholders involved in this international venture come from different perspectives and different experiences. There is now an opportunity with ACT (Accelerating Carbon Technologies) to learn by doing projects together from the start. This

cooperation along with collaboration efforts like the IEAGHG Research Networks giving the chance to work together internationally, and the willingness of project operators to test new technologies at their projects, is an invaluable undertaking but challenging from a scientific standpoint. Jørg agreed adding that standards have a role to play and there is a lot of guidance in standards but what they really do is harmonise practices and processes rather than sharing learnings. International collaboration and shared learning will really allow projects to move forward. Whilst standards have a role and regulations have a role, what's key is to learn from each other and progress forward. Regulations are non-prescriptive and more objective-based, which is reflected on the ISO standards for EOR and CO_2 storage. Scott noted the importance of this industry publishing and putting into the public domain our findings to continue the international learning efforts.

Monitoring is often considered critical for obtaining the social license-to-operate. Do you agree? How much monitoring is needed to meet this need?

Eva remarked that the license to operate is one of main things with monitoring. Public perception and acceptance is key, they need to know whether the project is safe, whether the CO_2 will behave as it's supposed to etc., so it's important for the regulator to be precise and clear on what the operator has to demonstrate. This is something that regulators can work more on. In Norway the EU CCS Directive is used which is based mostly on onshore storage and then it has been adapted to apply to offshore scenarios. We want to see that when the CO_2 is stored, it is moving the way that is expected and there is no leakage. If the operator cannot show this, the project won't be accepted. Currently, several laws and regulations are very strict in that they have to show that so much CO_2 is accounted for in the measurements. Another aspect important for licensing and societal issues is the uncertainty; it's not always possible to measure everything, for example at the Sleipner project the operators have injected so much CO_2 into the Utsira formation but all of the injected CO_2 cannot be accounted for and we need to be ok with this uncertainty. More clarity is needed on inevitable uncertainties in the measurements.

Katherine agreed that this is extremely variable depending on the stakeholders and the area where operation is taking place; there is variability in goals and what stakeholders care about – and it's a balancing act. It is crucial to have the capabilities to respond to any stakeholder concerns that may arise and there is a need for contingency monitoring. Sue added that it is important that the technical project proponents work closely with all the stakeholders to find out what matters and to find it with precision. We need to define what 'safe' means, what 'acceptable' means, for understanding and acceptance from all stakeholders.

Scott noted that CO_2 EOR operations are economically challenged if losses even approach 10% of injected CO_2. Losses as noted here are assumed to be at the reservoir and not atmospheric because it is the reservoir oil recovery efficiency of the CO_2 that is paramount in the hydrocarbon operation. He asked what percentage of loss is actually too high for only CO_2 storage, noting that as an operator he was yet to get that from the regulators. His position was that if operators are managing and monitoring projects in order to keep losses to a minimum for economic purposes, are monitoring regulations excessive since the operator cannot financially allow it to exceed rather low levels in the first place? Tim remarked that most regulations ask for it to be permanent but don't set a quantitative amount – this isn't specified. Charles agreed this was very specific to EOR to concentrate losses of this magnitude. In saline storage, the assumption is zero and this is verified with monitoring methods and if you don't see it, the assumption is that the CO_2 is stored. There are no limits for how much leakage would be acceptable to meet climate mitigation goals; monitoring modalities and procedures don't expect us to count the molecules, it's more subtle than that. The ISO Standard 27916 ('Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery',

2019) has a quantification formula to address these but in pure CO_2 storage (CCS), quantification is only done in the case of suspected leakage.

Cost of CCS remains a barrier. How does the cost of monitoring enter into this picture? Who decides how much monitoring is enough? How much of the monitoring cost is CAPEX and how much OPEX?

Charles noted Philip Ringrose's (*Equinor*) presentation on Sleipner at GHGT-14 where they gave a number for monitoring costs at the offshore project of two Euros per tonne of CO_2. This low number shows that the difficulty is not the actual or potential cost, it's the liability that operators are asked to take on with having custody of sites post-injection or closure. Monitoring costs aren't small, but in the scheme of things they don't dominate; the cost of what might happen is the issue.

From an operator's perspective, different companies will differ depending on their allowed practices of business. Scott informed all that in the US, the decision on what is mandated or prescripted are generally negotiable between the parties. Each project is unique, one monitoring approach won't necessarily work for another site. If we want to store CO_2, the costs must fit the project and the investors. The cost of MRV (monitoring, reporting, and verification) as a whole is a huge consideration amongst CCS and CCUS projects; they have small investment returns over many years to reach a pay out, and carbon incentives can help. As an example, a current onshore CCS project in the US has costs of around $31 per tonne for capture and approximately $12 /tonne for the CCS and storage side, meaning $43 per tonne in total. In the States with a 45Q tax credit, that leaves around $7 to take care of servicing debt, insurances, extra costs and hopefully a profit, and monitoring costs are a significant part of this. In this example, monitoring is 14% of the total capture and sequestration project, but 50% of the sequestration aspects itself. This is where the operators and regulators may argue as there is a small profit margin even with the credit systems in place.

The need for, duration, and type of monitoring after the end of injection has been controversial. What approach do you recommend to develop best practices? The same at every site or variable depending on what parameter?

Post-injection monitoring guidance, rules and regulations differ worldwide. An extreme example is the California Low Carbon Fuel Standard (LCFS), which notes that sites eligible must be able to monitor the CO_2 over 100 year post-injection, which is very long term. Sue agreed this was an extreme example, and felt that we need to communicate with California more about this and try to ascertain what they are trying to accomplish with this and the resulting costs. For example, if they want to measure atmospheric releases over existing wells, this can be done over such a long period relatively easily. However if they ask for seismic surveys regularly, this would be more of a costly problem compared to basic ongoing soil gas monitoring. Scott agreed that annual seismic surveys are not economic for a project. Again, each site is unique and some techniques won't work at certain sites. Scott argued that monitoring post-injection should be minimal unless there's been something going on during the project lifetime that means monitoring should be at a higher level – and in this case perhaps the project should have been closed early. In North America alone there are over 140 CO_2 EOR and CCUS projects; 97% of these are still active with some being 35-40+ years old. New CCS and CCUS projects are going to last just as long and if there's no operational problems, i.e. losses, issues will manifest themselves in the first couple of years of a project which is therefore when monitoring levels should be more significant. After the operation is monitored in detail in the initial stages, this can be tapered off fairly quickly as long as proper operational procedures are being practiced with proper management. If there are no issues of CO_2 molecules outside the storage formation after 40 years, why should this differ after closure (except for minimal diffusion dispersion and/or pressure relaxation), so limited monitoring assurance should satisfy.

Jørg noted that this is where ISO Standard 27914 ('Carbon dioxide capture, transportation and geological storage — Geological storage', 2017) deviates slightly from regulations as it does not promote time-based criteria for closure, it only promotes the technical-based criteria. That is in line with the ethos of our community; regulations should only call for continued high level monitoring after closure where the technical criteria has demonstrated there is a risk for future incidents. Projects should be encouraged to use the power of the standards as part of their dialogue with regulators to see if we can move away from time-based criteria in both the LCFS and other regulations. Charles agreed, adding that we have the practices for doing this – we don't need arbitrary time scales, but performance-based targets. We need to use the practices we have.

We invite the panel to look to the near term and more distant future. To improve monitoring, what is needed in the near term? In the longer term?

Sunil remarked that the continuation of research, demonstration and deployment is important, along with more industry in common participation and supporting policies. Scott emphasised that from an operator's perspective, it's all about costs and we have to find a way to make things economic in today's market. Eva agreed, adding that regulators need the researchers to continue working on good characterisation and looking into how to handle uncertainty. When talking about monitoring, we need to know what to monitor, how detailed and what is acceptable; we need to be clear on the consequences of any leakage and uncertainty in measurements. It's important to inform the public on why we are undertaking CCS, why we are injecting the CO_2 for emissions reductions targets.

Katherine felt that more sensor reliability for process-based monitoring would help to differentiate between natural fluxes and project consequences. We need to upscale CCS to meet targets, we need to look at the interaction of plumes (which is currently being looked at in Illinois). We are really good at monitoring projects that are successful, but we need more experience in monitoring failure scenarios and more experience with quantification.

Charles hears from operators that they would like a way to assess the condition of wells (especially old wells) more easily. Old wells are always identified as a risk in projects and it would be good to have an easier way to find out the condition of such wells. Sue agreed that more practice is needed on failure scenarios and more done on poorer wells will help us to better understand the failure mechanisms of them, which will allow us to deal with remediation effectively.

Summary & Wrap-Up

Tim concluded the discussion panel by summarising and thanking all the panellists for their views and the audience for their good questions. This ninety minute virtual panel discussion dove into detailed conversation between operators, regulators and researchers and gave insights into what is needed from different perspectives to help translate monitoring research into commercial needs. Some of the key messages we heard during the discussion included:

- More should be done to reduce costs and improve the cost efficiency of monitoring techniques,

- Regulators rely on operators to propose a monitoring strategy and techniques suitable for the site,

- Regulators are strong believers in objective-based regulation rather than prescriptive-based regulation,

- Regulators prefer monitoring techniques which are tried and tested, but encourage monitoring R&D on demonstration sites,

- Some of the greatest developments in monitoring over the last ten years are the development of DAS and distributed temperature sensing along with permanent surface seismic sensing, and near-surface attribution monitoring, to improve monitoring efficiency,

- Practices and processes need to be harmonised with international collaboration and shared learning to allow projects to move forward,

- Public perception and acceptance is key and it's important to inform the public on the reasons as to why we are undertaking CCS, why we are injecting the CO_2 for safe storage; the importance of meeting emissions reductions targets and the need for CCS,

- It is crucial to have the capabilities to respond to any stakeholder concerns that may arise and therefore there is a need for contingency monitoring,

- Every site is unique in terms of its geology, project specifics and stakeholders, so monitoring techniques and strategies will be used differently at different sites,

- Projects should be encouraged to use the power of available and applicable standards as part of their dialogue with regulators to move away from time-based to performance-based criteria,

- More practice is needed with failure scenarios.

Panellists

***Panellists**, IEAGHG Monitoring Network Virtual Discussion, August 2020*

Previous Monitoring Network Meetings

The development of this discussion panel was prompted by the current travel restrictions and built upon material from the attendees, the Steering Committee and the 13th meeting of the IEAGHG Monitoring Network held on 20-22 August 2019 hosted by the University of Calgary. For a copy of the report of the 13th meeting contact tom.billcliff@ieaghg.org quoting report number 2020-02. For more information on the IEAGHG Monitoring Network see https://ieaghg.org/networks/monitoring-network.

IEA Greenhouse Gas R&D Programme

Pure Offices, Cheltenham Office Park, Hatherley Lane,
Cheltenham, Glos. GL51 6SH, UK

Tel: +44 1242 802911 mail@ieaghg.org
www.ieaghg.org