CCS Knowledge Sharing in Japan (Phase 2)
Final report
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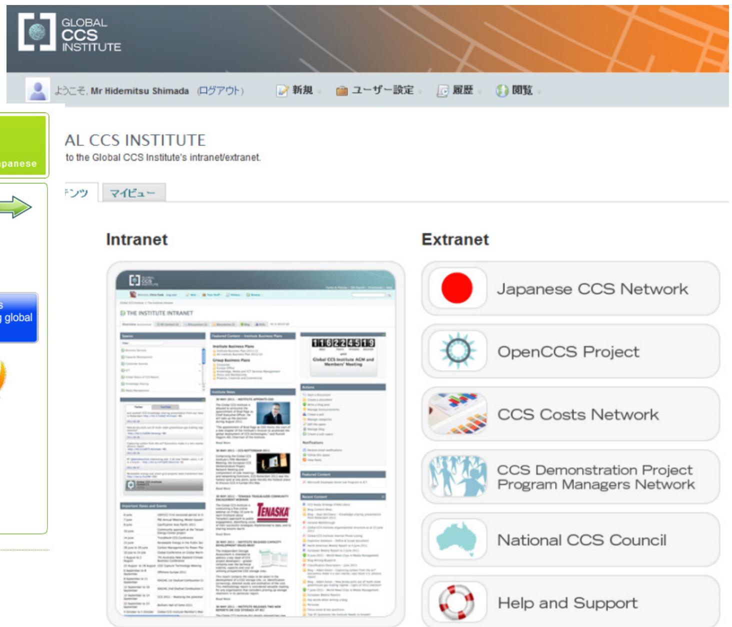
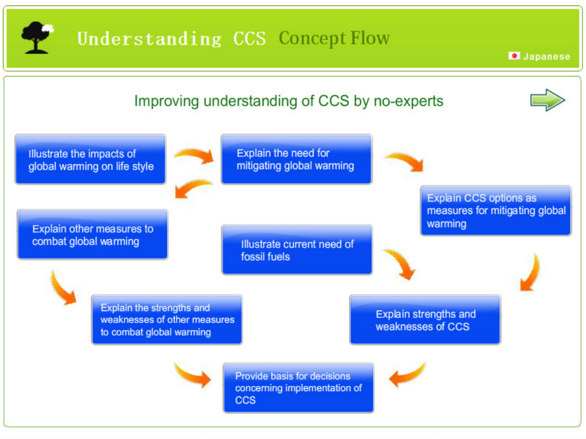
A CCS Communications Framework developed by the Japanese Knowledge Network

August 2013

JGC Corporation





EXECUTIVE SUMMARY

This report describes Phase 2 of a multi-phase project undertaken by the Japanese Knowledge Sharing Network, entitled "Development of a Knowledge Sharing Test Bed for CCS in Japan". The focus of the network has been to:

(1) Develop and test a public outreach program for carbon capture and storage (CCS), based on expert arguments developed in Phase 1 of the project on how to explain the case for CCS through a communications framework.

(2) Address knowledge gaps identified on the topic of CO_2 storage, in particular seismicity induced by injection of CO_2, and the impact of seismicity on any part of the CCS process.

Background

The Japanese Knowledge Sharing Network (the Network) is a Global CCS Institute (the Institute)-funded initiative that involves expert representatives from over 20 CCS-related organizations, sharing knowledge on topics related to CCS communications and seismicity.

The Network's overarching project, "Development of a Knowledge Sharing Test Bed for CCS in Japan", has been developed in collaboration with the Institute, with the aim of creating and testing knowledge management methodologies and tools that can be used to support a structured approach to sharing knowledge within established CCS networks.

The Knowledge Sharing Test Bed focused on CCS Communications

To test the Network's knowledge sharing methodologies, members chose to focus their discussions and activities on a project to improve the communication of CCS in Japan – the "Development of a CCS Communications Framework for Japan" project. The key

themes explored within this project include:

- Determining how members of the CCS community can collaborate most effectively to integrate expert knowledge across the full range of CCS related disciplines, into a coherent body of information that can be used to address identified challenges.
- Determining how this expert knowledge can be distilled and presented in a simpler form that can be understood by stakeholders with different levels of scientific / technical experience and / or understanding

Previous Work: Phase 1[1]

The first phase of the Network Project was completed in 2011. It sought to establish a common communications framework for CCS in Japan that would enable experts to clearly explain the case for CCS to a general audience. Using a variety of knowledge sharing tools, the Network pooled its collective expertise to produce a CCS Argument Map – a comprehensive knowledge management tool that helps breakdown complex issues and provide clear explanations or arguments for each of their component parts.

The Phase 1 Argument Map provided a strong evidence base for justifying the development of CCS technology. The creation of a Phase 1 Draft Action Plan collated the Japanese Knowledge Network Members' opinions on how best to communicate these arguments with external stakeholders and the general public.

Current Work: Phase 2

This second phase of the project sought to actually design and trial a public outreach program and to improve the knowledge base created in Phase 1 with further knowledge sharing activities on priority topics around CO_2 storage (seismicity induced by injection of CO_2, and the potential impact of seismic activity on the geological storage of CO_2.

[1] The Phase 1 report is available to download at http://www.globalccsinstitute.com/publications/developing-ccs-communications-framework-japan

This report summarizes the process and presents the results of the second phase of this project, reporting on two key tasks:

Task 1: Development and dry run of a public outreach program based on the action plan and argumentation model developed in Phase 1.

Task 2: Focused knowledge sharing exercises to address key knowledge gaps regarding seismicity and CO_2 storage.

Method and Outcomes

Task 1: Development and dry run of a public outreach program

The Network split Task 1 into three key stages of work:

- **Task 1.1 - Identification of stakeholders**

  The Network identified key stakeholder groups and their main areas of concern and knowledge needs, using a combination of a general population survey with 979 respondents and analysis of pre-existing community survey data from previous CCS outreach activities and the current Japanese CCS demonstration project in Hokkaido.

  Key stakeholder characteristics such as occupation, levels of scientific understanding and potential interest in, and influence on, implementation of CCS projects in Japan, identified teachers and housewives as priority stakeholders who voiced the most concerns over the deployment of CCS technology. These groups became the focus of the Network's trial public outreach program.

- **Task 1.2 - Development of a public outreach program**

  A public outreach program was then designed, with material created by converting the detailed expert knowledge collated in the Argument Map in Phase 1 of the Communication Framework Project, into simple, factual audiovisual materials targeted to meet the needs of these two stakeholder groups.

- **Task 1.3 - Testing of the public outreach material**

In order to test the outreach material, the Network ran a series of focus group interviews and on-line dialogues with representatives from the targeted stakeholder groups. Participants were monitored during the FGIs in order to evaluate how they gained knowledge and opinions about CCS. The FGIs were run by an independent facilitator rather than a subject matter expert so as to observe participants' questions or concerns toward CCS. The results were then analyzed to judge the effectiveness of the program.

Outcomes

The focus group interviews successfully gathered information on the key areas of concern or anxiety still felt by laypeople when they have been provided with a reasonable amount of outreach material regarding CCS.

Participants in both groups understood CCS consists of capture, transport and storage of CO_2, but the information provided was not sufficient for them to comprehend the state of supercritical CO_2 or the mechanisms of geological storage. This kept them from evaluating whether CCS is a safe technology to store CO_2 for a long period of time.

Analysis of the results showed a reasonable correlation between the educational/occupational backgrounds of participants and their understanding of the outreach material with which they were supplied. This trend was particularly true in participants with education background in science.

There were few differences in the initial concerns voiced by either stakeholder groups. However, there was a reasonable gap between the two stakeholder groups when they were asked about the deployment of CCS near their homes, with housewives considerably more acquiescent than teachers to government-oriented or widely-accepted policies and/or projects.

Some of the focus group participants expressed a belief that CCS could really "benefit" their lifestyle if it led to climate change mitigation. This result implies that it is possible for members of the general public to evaluate the risks of CCS to be less significant than its merits, if they have access to accurate information.

Analysis of all the focus group interview responses and the results of the Network Member discussions on public outreach on induced seismicity resulted in the following key conclusions:

- Due to low levels of basic energy literacy, some elements of simple science communication are required to support more specific messaging around CCS and CCS risk communication.
- This material should be planned carefully to ensure that it is not overly complex and is targeted appropriately at stakeholders, bearing in mind their interests and backgrounds.
- An inadequate amount of information, or information provision without any easy method for clarification or answers to further questions, merely increases concerns among information receivers and affects the acceptance of CCS. Information could be more useful and reassuring to stakeholders if it is accompanied by appropriate levels of expert explanation – while the message is important, having it delivered by a credible messenger is equally important.

Task 2: Focused knowledge sharing exercises to address key knowledge gaps

The Network split Task 2 into three key stages of work:

- **Task 2.1 – Collation of information**

  A literature survey on induced seismicity and any potential impact of seismicity on geological CO_2 storage in Japan was carried out. All relevant information was collated and structured ready for discussion amongst the members of the Network.

- **Task 2.2 – Knowledge sharing**

  As an introductory knowledge sharing exercise, the Institute facilitated a number of seismicity experts (who were also familiar with CCS) to deliver a webinar for the Network Members to introduce them to this topic. The subject matter experts were then encouraged to participate in the future Network knowledge sharing sessions.

Following the webinar, potential themes for collaboration were discussed among the Members, with three areas agreed:

Theme 1: Collation of information that can be used to develop a safety strategy for geological storage of CO_2, while addressing the risk of induced seismicity

Theme 2: Discussion of the potential for liability for damages caused by suspect induced seismicity

Theme 3: Discussion on public outreach concerning induced seismicity

- **Task 2.3 – Development of an Argumentation Model and knowledge base**

  A knowledge-base summarizing information and knowledge relevant to each level of the CCS "Safety and Security Pyramid" was produced using Member contributions to an online discussion.

  As part of the same discussion forum, four experts in CCS applied the "Davis and Frohlich" checklist for induced seismicity to the Chuetsu earthquake (a M6.8 earthquake in central Japan in 2004 that occurred only 20km from the Nagaoka CO_2 injection site). The expert answers were developed to form an argumentation model, detailing the evidence to judge if the Chuetsu earthquake was not induced by CO_2 injection at the Nagaoka test site.

  Both online discussions and face-to-face meeting were held to capture information for a knowledge base from which to build a public outreach strategy specifically concerning the issue of induced seismicity.

Outcomes

An impressive body of research has been collated to help form a solid knowledge base on issues around CO_2 storage and seismicity. Furthermore, it was applied to develop an argumentation model concerning relevance of the CO_2 injection at the Nagaoka test site with the Chuetsu earthquake to demonstrate applicability of this approach to amalgamate experts' knowledge to form a basis for deliberation among wider spectrum of the stakeholders.

With regards to public outreach around the issue of induced seismicity, the following points emerged from the research:

- The scientific basis for CCS, and underground CO_2 storage in particular, have not been shared with laypersons to a degree sufficient for facilitating effective risk communication concerning CCS.
- In the course of risk communication, guiding people to make hasty judgments about the risks of CCS without a sound scientific understanding may lead to inappropriate outcomes. In order to avoid such a situation, risk communication activities should be accompanied by a well-designed program of basic science communication.
- The scope and goals of a science communication program depend on issues that influence the risks of CCS, either directly or indirectly. To establish a comprehensive strategy of science communication, "gaps" in the knowledge of laypersons about a variety of issues need to be evaluated.
- Among those issues potentially relating to the risk of CCS, induced seismicity is a typical example that requires extensive effort in science communication, so that people can understand how earthquakes might be induced by injecting fluid into underground formations and all the actions that can be taken to reduce any risks.

Recommendations for further research

Given the results of the Phase 2 study, it is recommended that a methodology should be developed to integrate risk and science communication, focusing in particular on areas identified as key "knowledge gaps".

The levels of basic science communication required as a support for more specific risk communication for CCS should be explored and trialed for each of these "knowledge gap" areas, with the aim of creating a basic science information pack that could support future CCS communication activities in Japan and internationally.

TABLE OF CONTENTS

1. Acknowledgements and Citations

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The contributing expert community

More than twenty experts from Japanese national organizations, Japanese private organizations and an international organization contributed to this report by expressing their opinions on a voluntarily basis. Their fields vary, including coal, oil & gas, environment, energy, CCS and academia.

2. Objectives of the project

Knowledge sharing is a critical need for the Carbon Capture and Storage (CCS) community and is an area in which the Global CCS Institute is playing a central role. Although the Global CCS Institute is implementing a community-centred knowledge-sharing program through both digital and face-to-face channels, it is also willing to explore how additional knowledge management methodologies and tools may be used to support structured and effective knowledge sharing networks – particularly where the internationalization of knowledge can be strengthened. The project "Development of a CCS Communications Framework for Japan" is a part of such an endeavour. Central themes of the community, explored through communication and collaboration among members of the Japanese network, include:

i. How the Global CCS Institute and its members can collaborate to synthesize expert knowledge relating to issues identified, which is distributed over a wide variety of disciplines/research areas, into a coherent body of knowledge.

ii. How the Global CCS Institute can distil detailed expert knowledge and present it in a simpler form that can be understood by stakeholders with different levels of scientific/technical literacy.

The output from Phase 1 forms a sound basis for further exploration of the two main themes of the community related to the knowledge sharing and communications mentioned above. It is felt that there are some areas in need of improvement and further development:

- The draft action plan and argumentation model(AM) are based predominantly on expert viewpoints and their consistency with the expectations and needs from a wider range of stakeholders has yet to be tested before they are used in the public outreach programs that the Global CCS Institute member organizations envisage;
- The scope of the draft argumentation model(AM) is constrained by the degree of availability of existing knowledge: some (possibly region-specific) knowledge gaps in key areas, for example the relationship between CCS and seismicity, will need to be filled in order to build the confidence of stakeholders.

The objectives of Phase 2 are twofold;

i. Development and dry run of a public outreach program based on the action plan and argumentation model(AM) that were developed in Phase 1,

ii. Wider knowledge sharing exercises to fill gaps in key areas.

Output from Phase 2 will be structured into the following three project cornerstones, to be easily and effectively utilized by the Global CCS Institute;

- Know-how on coordinating and facilitating community-based knowledge sharing,
- Representations of knowledge in a variety of forms, ranging from argumentation models(AMs) to simpler audiovisual formats, in accordance with the spectrum of expectation and literacy of stakeholders,
- Experience with, and recommendations for improvement of, the Global CCS Institute digital platform, with clear definition of specific context and use-cases.

3. Task 1: Development and dry-runs of a public outreach program

3.1 Task 1.1: Identification of stakeholders

Categorization of stakeholders from the perspective of designing a public outreach program in Task 1.2 was proposed based on an analysis of their characteristics, such as occupation and scientific/technical literacy. Communication with the individual categories of stakeholders thus identified was prioritized, taking into account their interest in and influence on the implementation of CCS projects in Japan. The results were used to identify a key target group of stakeholders for the subsequent subtasks.

3.1.1 CCS stakeholders in Japan

CCS stakeholders in Japan can be categorized as “senders” and “receivers” of information with regards to CCS.

There is an on-going discussion over the deployment of CCS in Japan within government (mainly the Ministry of Economy, Trade and Industry) and public agencies (such as the National Institute of Advanced Industrial Science and Technology (AIST) or the Research Institute of Innovative Technology for the Earth (RITE)). Private firms such as Japan CCS Co., LTD. and various engineering companies are also involved in the development of core CCS technologies. Amongst these proponents of CCS, there is nonetheless ambiguity in who should conduct outreach activities in relation to CCS. The receivers of outreach information, on the other hand, are exemplified in the “toolkit” published by Global CCS Institute as media, NGOs, local communities, education, and Unions (CSIRO, 2012). Thus far in Japan, media and NGOs show little CCS-specific enthusiasm but it is important to note that there is a growing distrust in science/technology in general because of a number of technological failures caused by or related to the Great East Japan Earthquake in 2011.
Based on the past large-scale facility siting experiences in Japan, stakeholders at local community level can be attributed to local municipalities, local assembly members or political groups, mayors, neighborhood associations, farmers and fishers, merchants, women’s associations, housewives, schools and teachers and environmental groups. The above entries can be classified as follows:

- Senders (experts)

Government, research institutes/researchers, and engineering companies

- Receivers (non-experts)

Non Governmental and Non Profit Organizations

Media

Local Community

(local municipalities, local assembly members or political groups, mayors, neighborhood associations, farmers and fishers, merchants, women's associations, housewives, schools and teachers and environmental groups)

General Public

In selecting key target groups within the abovementioned stakeholders for the public outreach program, preliminary researches have been made in order to understand the interest of local communities and the general public.
In respect to local communities, the results of past public explanation gatherings held at the CCS demonstration site in Japan (see 4.1.2 below) were thoroughly examined for this purpose. With regards to the general public, Itaoka *et al.* (Itaoka et al, 2009) have rightly revealed that their awareness of CCS was very low. For the purpose of further examining the general public's interests in and perceptions of CCS, we conducted an on-line questionnaire survey (see 4.1.3 below).

3.1.2 Survey on Local Communities

Japan has already made a decision to conduct a CCS demonstration project shortly in the city of Tomakomai in Hokkaido prefecture after a series of geological studies; the local community of the site has thus already been invited to a series of explanatory gatherings when this research was commenced.
The explanation gatherings held in Tomakomai were attended by many local residents. As shown in Table 3-1, among those who participated in the gatherings, housewives and teachers of local schools most frequently voiced their concerns and expressed opinions about CCS.

Table 3-1 Questions and opinions raised in the public explanation gatherings

Gender	Occupation	Opinions/Questions
M	Teacher	The Chuetsu Earthquake in Nagaoka might have been caused by CO_2 injection
F	Housewife	What kind of damage is expected in the event of an earthquake?
M	Teacher	CO_2 injection may induce earthquake because it has mass.
M	Farmer	Are there any damage to crops or the environment?
F	Housewife	Why is CO_2 injected in the ocean?
M	Unknown	Global warming is not true.
M	Teacher	There is a vested interest behind CCS.
M	Teacher	It is more cost-effective to invest in other technologies such as solar.

3.1.3 Questionnaire survey of the General Public

In order to further examine the general public's interests in and perceptions of CCS, an on-line questionnaire survey was carried out from the 2nd to 9th July, 2012. The parent population of the survey participants was 420,000 individuals who voluntarily registered themselves to our affiliate marketing firm through a number of online programs. During the survey period, the firm e-mailed the questionnaire to and collected responses from those men and women in their 30's to 70's who live in Tokyo metropolitan area (Figure 3-1). Valid sample responses were 979, and they all agreed to participate in the Focus Group Interview (FGI; see Task 1.3) in which a simple communication package developed in the public outreach program (Task 1.2) was to be presented.

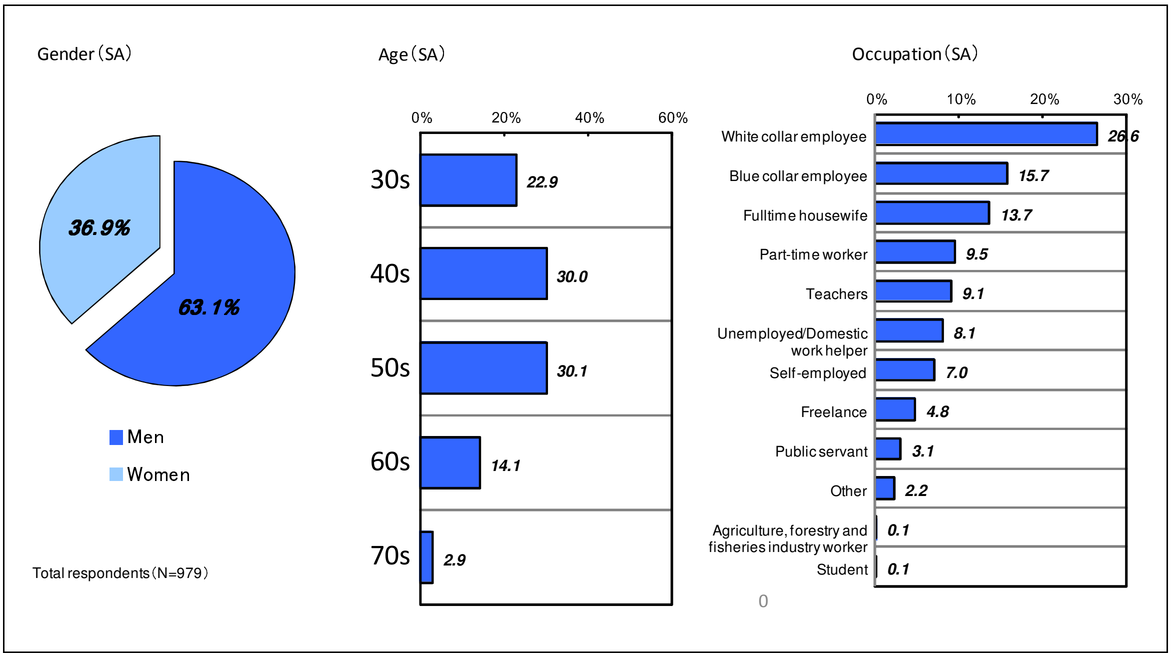


Figure 3-1 Result of Questionnaire Survey (Respondents' demographics)

As the first step, the respondents' perceptions and attitudes toward global warming countermeasures were investigated. Then they were asked a number of questions as they were shown some visual aids related to CCS.

When the respondents were asked to rank questions or concerns about CCS, "Costs of CCS", "Impacts to the natural environment", and "Technical safety of capture and storage technologies" were the three most chosen questions/concerns (Figure 3-2). However, when ranked in order of which were given the top priority, the "Costs of CCS", "the basis for the necessity of CCS" and "Adverse effects to humans" were the most numerous in that order. The result of this survey is fully described in Appendix 1.

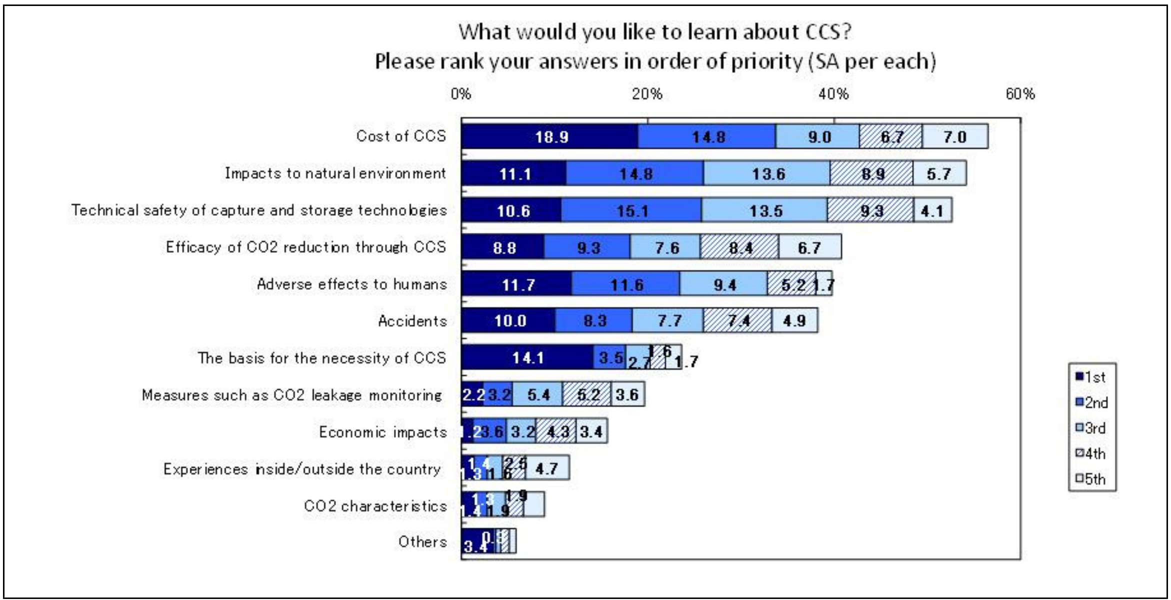


Figure 3-2 Result of Questionnaire Survey (Concerns or questions about CCS)

Besides, as can be seen from Figure 3-3 the top four concerns/anxieties about safety measures of CCS were related to CO_2 leakage, revealing respondents' fear about the leakage *per se* rather than its consequences.

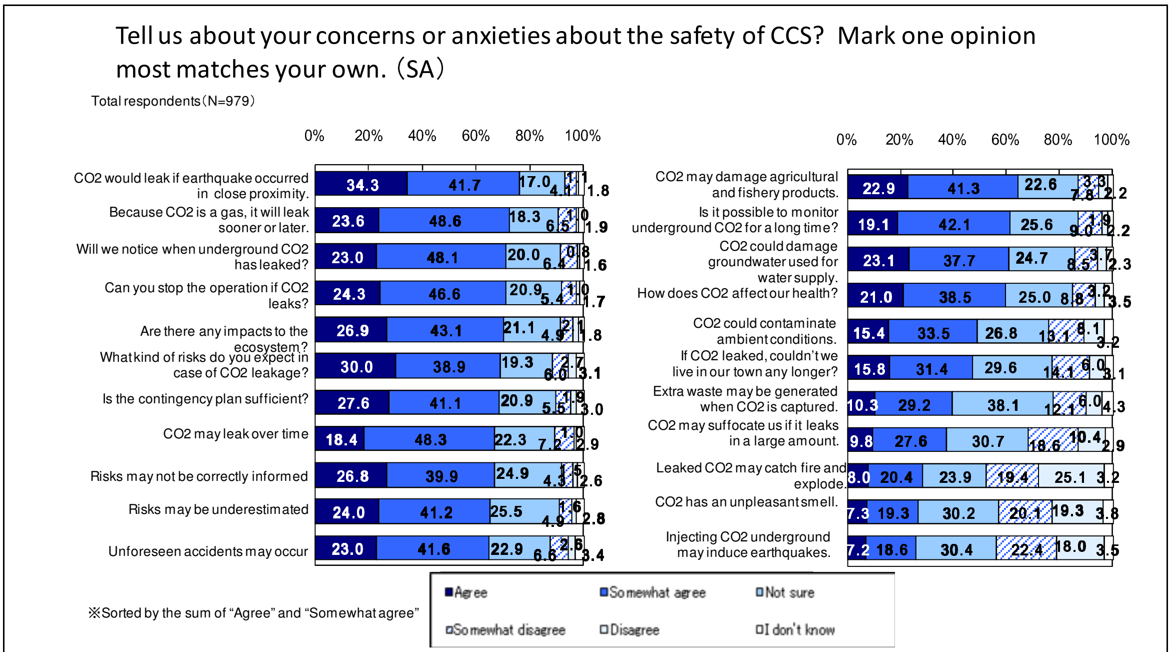


Figure 3-3 Result of Questionnaire Survey (Concerns or questions about safety of CCS)

3.2 Task 1.2: Development of a public outreach program

A public outreach program was designed, targeting two types of stakeholders (housewives and teachers). A communication strategy was then designed as a core of a test public outreach program. Conversion of detailed expert knowledge associated with the key technical messages into a simpler audiovisual form was also attempted, again taking into account identified requirements of the focus group.

3.2.1 Communication models and their design

As discussed in the Phase-1 final report (GCCSI 2011), in which "Argumentation model(AM)" was developed after a series of knowledge sharing discussions amongst network members in order to assist the deployment of CCS in Japan, there are two stages of outreaching for general public and local community (Figure 3-4).

Stage 1 is aimed to win the understanding from general public that CCS is necessary by providing them with concrete evidence to support the importance of climate change measures to lessen its impact to our everyday life. Also, the role and advantages and disadvantages of CCS and other measures in mitigation portfolio needs to be clearly explained.

Stage 2 focuses on winning acceptance of local community for the deployment of CCS in its vicinity. This could be done by forging a trusting relationship between locals and proponents.

As discussed in the stakeholders were identification (Task 1.1), Japan needs a strategic outreach program developed by a decisive player. And it is likewise important to satisfy both Stage 1 and Stage 2.

In considering outreach programs that would materialize such outcomes, we drew experiences from two distinct attitude-change models in socio-psychological field.

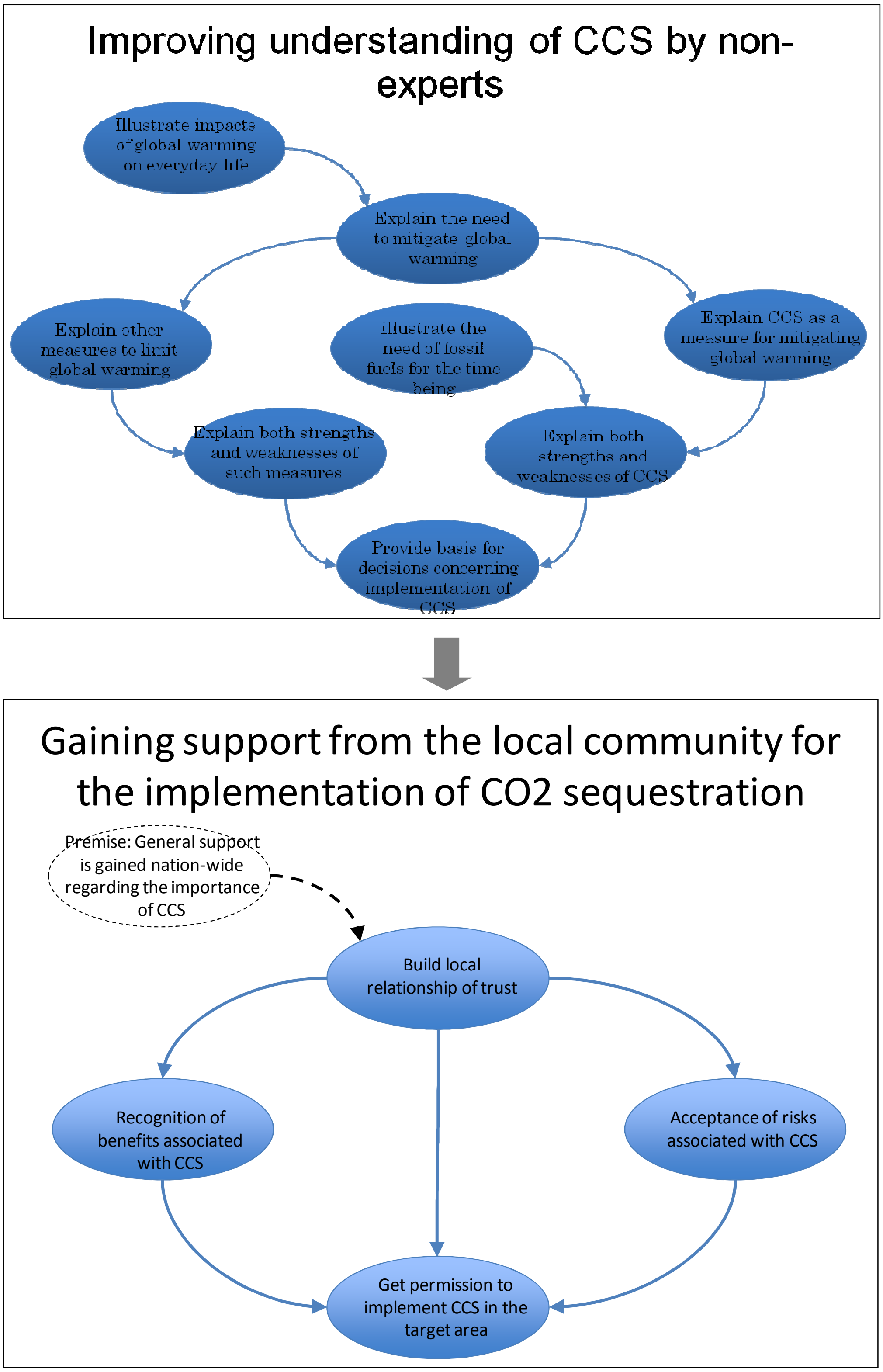


Figure 3-4 Outreach Stage-1 (top) and Stage- 2 (bottom)

■Risk Communication Model

As shown in Figure 3-5, traditional outreaching focuses on “persuasion” by sending audience positive information about the objects in question. This is so-called “persuasive communication”. When an information receiver has a negative attitude towards product X, for instance, only positive information about the product is provided in order to change her attitude, as one can see from a traditional motor vehicle advertisement to convey the qualities of the vehicle to those indifferent to it. In the risk communication model, on the other hand, technical and negative information, such as the vehicle’s specifications and defects, is provided to win the trust of consumers.

Figure 3-6 clearly shows the Risk Communication Model that explains how information receivers (above) change their attitude in relation to senders’ information (bottom). According to this model, information receivers tend to feel honesty when the sender is willing to reveal potentially negative types of information, and this leads to a stable relationship between senders and receivers which can serve as the basis for building Public Acceptance or consensus.

The risk communication model tries to reach a consensus by fostering a trustful relationship between information senders and receivers, which may materialize from sending negative and positive types of information about the objects in question to the audience (Kinoshita et al. 1990).

In outreaching CCS, therefore, it is important to thoroughly discuss how both the strengths and weaknesses or merits and demerits of CCS can be disseminated to the public.

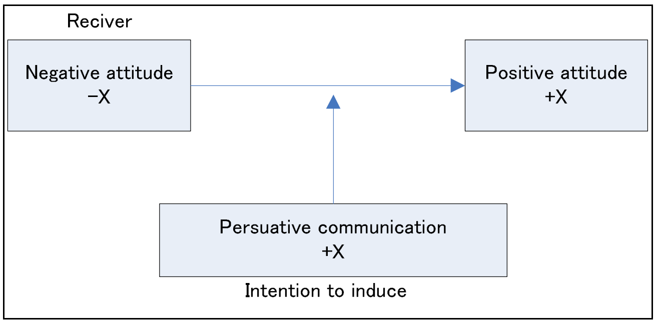


Figure 3-5 Traditional Persuasive Communication Model (Source: Kinoshita et al. (1990))

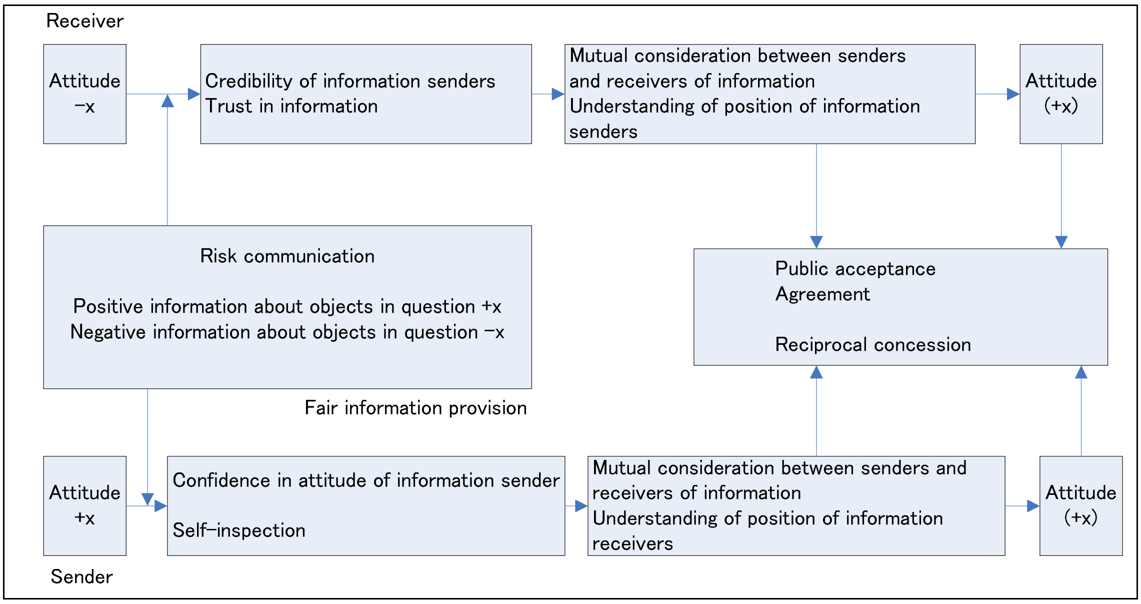


Figure 3-6 Risk Communication Model (Source: Kinoshita et al (1990))

■Elaboration likelihood model

An elaboration likelihood model is a social psychological theory which states that people in general show one of the two distinct reactions to, or have two information processing "routes" to deal with persuasions such as advertisements (Petty and Cacioppo, 1986). The first is the "core" route through which people make up their minds based on a careful consideration of the information provided. This is the reaction when they have enough motivation and capabilities to do so.

The other is called the "peripheral" route and this occurs when people do not possess enough motivation and capabilities to process the information given, and thus they make judgments based on peripheral circumstances such as the information senders' expertise or the number of reasons put forward, that have little to do with the essentials of the problem in question, rather than the information *per se*.

In applying this model to CCS outreach, it can therefore be said that those who have relatively higher interest or knowledge in CCS – NGOs, intellectuals and/or the local residents – should be given somewhat technical information. The Argumentation Model (AM) developed in Phase 1 is the very tool for this purpose. But easier and simpler messages should be given to the general public.

3.2.2 A public outreach program for the target stakeholders

According to CO_2 Capture Project (CO2 Capture Project, 2012), the best practice for outreach and education on CCS can be summarized as follows:

- integrate public outreach into project management;
- establish a strong outreach team;
- identify key stakeholders;
- conduct and apply social characterization;
- develop an outreach strategy and communication plan;
- develop key messages;
- develop outreach material tailored to the type of audience;
- actively oversee the outreach throughout the life of the CO_2 storage project; and
- be flexible, refine the outreach.

A public outreach program for the dry-runs to be assessed in the next task was developed based on the findings of the preliminary questionnaire survey and Risk Communication Model as described above.

■Outreach team:

Consists of experts from a public agency specialized in technological development and researches in various fields including CCS.

■Key stakeholders:

As recognized important in the local community survey explained in 3.1.2, housewives and teachers were chosen amongst those preliminary questionnaire survey participants as general public who have little or no knowledge about CCS (and thus have little incentive to forward CCS).

- Housewives were chosen to represent the “anxious” demographic
- Teachers were chosen to represent a demographic that is influential in a community and that tends to be opinion leaders in various social gatherings (They are important players in educating future generations but this survey did not take into account such aspects)

Both demographics also frequently raised their concerns and opinions in public gatherings in Tomakomai.

■Communication plan:

The team planned to provide simple messages explaining both advantages and disadvantages of CCS to typical housewives and teachers.

■Outreach material:

The team developed a simpler audiovisual form with PowerPoint slides which contains animated illustrations about various aspects of CCS and its efficacy.

■Consideration of key messages:

The technical safety of capture and storage facilities, especially CO_2 leakage and its impact on human health were determined to be our key messages.

Although the vast majority of questionnaire respondents raised the necessity of CCS as one of their main concerns, the program did not elaborate on it because its main purpose was to assess how the general public reacts to information about risks.

Likewise, cost discussion was omitted because the team was not able to obtain reliable cost analyses.

Key messages about the merits and demerits of CCS to be shown in the slides were chosen from the AM developed in Phase1. Other important messages/aspects of CCS selected from preliminary survey results were also elaborated on in the slides.

3.3 Task 1.3: Assessment through dry-runs

Based upon the public outreach program developed in the previous task, a series of dry-runs, including face-to-face FGIs and on-line dialogues with targeted stakeholders groups, were carried out. The draft argumentation model(AM) developed in Phase 1 was presented to two groups of people to see if there were any discrepancies between the expectations and their actual needs. Participants were monitored during the dry-runs in order to evaluate how they gain knowledge and opinions about CCS. The result was then analyzed to judge the effectiveness of the program. This analysis also identified how the AM could be modified.

3.3.1 Design of Focus Group Interview

Interview Design:

Before conducting the FGI, the research team conducted a preliminary questionnaire survey to assess the understanding of climate change and CCS. The questionnaire was answered by 979 randomly selected individuals who voluntarily registered themselves online to a private research company with little or no previous knowledge about what they would be asked. Among them, those housewives and teachers in the Tokyo metropolitan area who had little or no knowledge about CCS (and thus had no clear incentives to deploy CCS) and skepticism about the need for CO_2 reduction were chosen to be the participants of the FGI.

One FGI was conducted for each group. Participants of each group were seated at a round-table in a research room equipped with a one-way mirror in Tokyo (Figure 3-7) to be observed by the research team members. The participants were then asked to read one or two PowerPoint slides at a time about various aspects of CCS to discuss if they understood what they read. Both groups were led by the same female facilitator who was recruited from a private company; she had little, if any, knowledge about CCS either. There was no CCS expert present in the room.

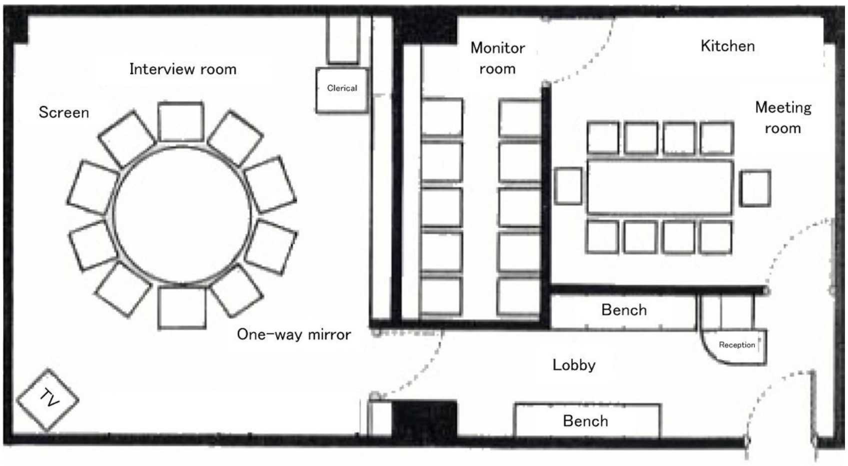


Figure 3-7 Participants' interview room (up) and its floor plan (bottom)

Scope and purpose of the survey:

The FGI aimed at assessing concerns about risks and interests of general public in relation to CCS when they are given information about its merits and demerits.

The scope of the interview was to:

- collect background information of the participants;
- identify participants' awareness of global warming;
- recognize participants' knowledge and understanding of CCS;
- explain safety measures of CCS and evaluate how well they are understood;
- explain possible CCS - earthquake linkages and evaluate their understanding;
- explain merits and demerits of CCS and evaluate their understanding; and
- measure the degree of public acceptance towards the deployment of CCS.

Composition of the Groups:

・Six housewives (from the Tokyo metropolitan area, age 30 to late 40's、have children)

*One housewife was later found to have a BS degree.

・Six teachers (Table 3-2)

Table 3-2 Description of teachers participated in the FGI

Gender	Age	School type	Subject
F	57	Elementary school	All
M	50	Elementary school	All
M	49	Middle school	English
M	45	Middle school	Social science
M	30	High school	General science
F	45	High school	English

Date:

Housewife group: August 1st, 2012 from 14:00 to 16:00

Teacher group: August 1st, 2012 from 18:00 to 20:00

3.3.2 Summary results of the Focus Group Interview

■About global warming

Most participants in both groups answered that they feel warming through hotter summers and changes in climate patterns compared to the past.

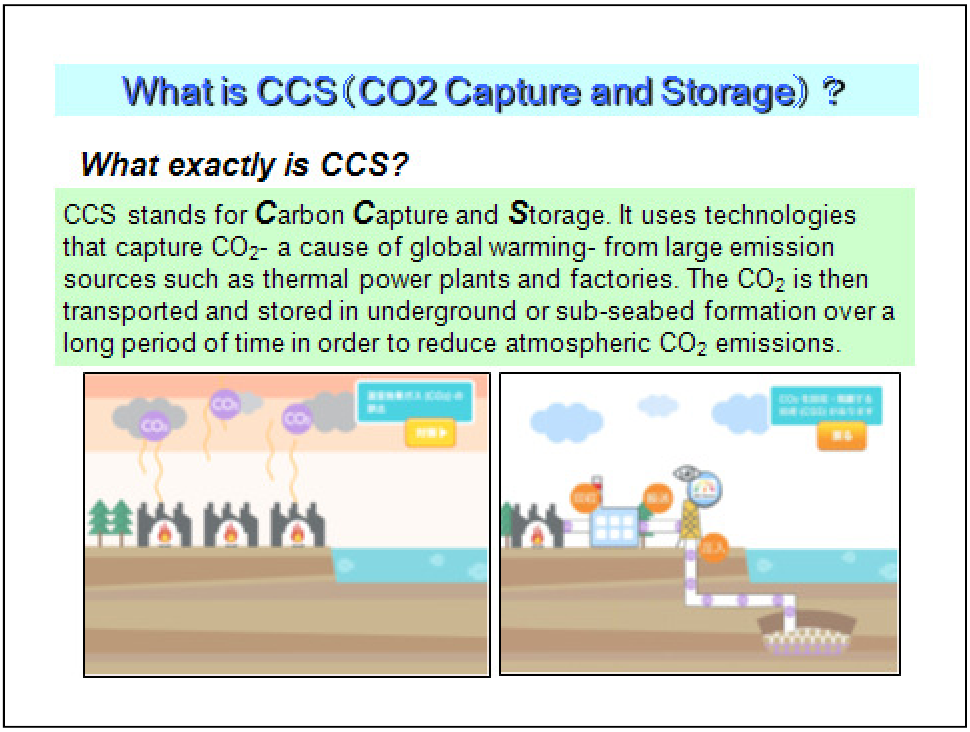
Teachers said that a number of environmental issues including global warming are now incorporated in their teaching materials.

■About CCS

□Preliminary awareness survey

None of the participants had previous knowledge about CCS.

□Introduction of the "What is CCS?" slide



Housewives roughly understood the mechanism of CCS, although some questions needed to be answered before its deployment. Teachers were concerned about the reliability of the technology.

The common concerns in both groups were as follows;

- how CO_2 (as a gas) is injected;
- what happens to the stored CO_2 after a long time;
- how long is "a long period of time" and how big this installation is; and
- whether there are any risks associated with the leakage of the stored CO_2.

■Safety of CCS

□Introduction of "How is CO_2 stored?" slide

How is CO2 stored?

CCS consists of "capture", "transport", and "storage".

In the "capture" part, CO_2 is separated from emissions through chemical or other technical processes before it is captured.

In the "transport" part, the captured CO_2 is sent to a storage site through various means, such as a pipeline.

In the "storage" part, the CO_2 is forced into the ground through injection wells some thousand meters deep.

Although participants in both groups said that they roughly understood the three different processes involved in carrying out CCS, they did not particularly comprehend how storage works. They also had difficulties in understanding the structure of the CCS system and its relationship with geological formations. They said this was because very little was explained about the behavior/pressures and so on of the stored CO_2. They also stated that the picture in the slide evoked some concerns about earthquake (or induced seismicity for teachers) and the resistance of ground installations and pipelines. The common concerns are summarized in the table below.

Housewives	● Most participants do not understand the state of CO_2 underground and the overall mechanism that makes storage possible. ➢ CO_2 is a gas. How can it be stored? ➢ What does stored CO_2 look like? ➢ How is "compressed" CO_2 stored? ➢ Most participants are concerned about the impact on seismicity/earthquake of CCS, especially underground pipelines. ➢ The Great East Japan Earthquake reveals that nothing can be fully predicted. ➢ What if the installment is damaged by earthquake? Any impacts on marine fauna?
Teachers	● Most participants do not understand the state of CO_2 underground and the overall mechanism that makes storage possible. ➢ Where will the stored CO_2 go? ➢ How can CO_2 be stored in bed rock? Does CO_2 seep into the rock?

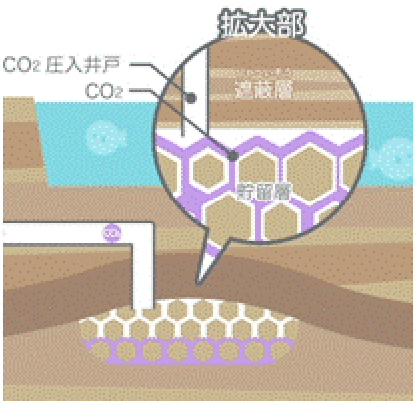
☐Introduction of "How can we be sure that CO_2 does not leak?" slide

How can we be sure that CO2 does not leak?

Injection of CO_2 into deep saline aquifers involves CO_2 as a supercritical fluid that has properties between those of a gas and a liquid.

CO_2 is injected beneath the layer called "cap layer" that traps the CO_2 underground.

Injection of supercritical CO_2 is done in geologic formations with a cap layer such that it stays underground for a long period of time.



All the participants understood very little about what supercritical CO_2 would look like. With regards to the "cap layer", the following concerns or questions were raised:

- explanation is not enough to believe whether CO_2 stays underground; and
- CO_2 does not leak "for a long time" sounds like it will leak eventually.

The common concerns are summarized in the table below.

Housewives	● No participants understand what supercritical CO_2 looks like. They are interested in the behavior of CO_2 underground. ➢ Does the CO_2 underground remain supercritical indefinitely? ● The cap layer is not easy to comprehend either. ➢ Does the layer prevent the escape of CO_2 for sure? ● Most explanations are difficult for the participants to visualize. ➢ The damage caused by the Great East Japan Earthquake was unprecedented. These explanations no longer address people' concerns. ➢ Explanations are so full of jargon and technical issues that are difficult to understand.
Teachers	● No participants understand what supercritical CO_2 looks like. ➢ Gas-liquid condition is not easy to visualize. ● The cap layer is not easy to comprehend either. ➢ There is a difference between what they think they can do and how things work in reality in terms of the containment of CO_2 under a cap layer. ● Other opinions/questions include: ➢ If the layer contains CO_2 for "a long time", does the CO_2 leak after the long time? ➢ What if too much CO_2 is injected? ➢ What if CO_2 loses its supercriticality?

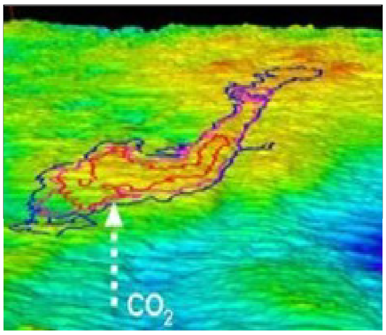
☐Introduction of “How can we manage CO_2 underground?” slide

How is underground CO2 managed?

CCS involves the monitoring of underground CO_2 for a long period of time.

The monitoring is conducted from the monitoring well or onshore/offshore facilities in order to keep track of the condition of the underground CO_2.

Should leakage of CO_2 ever occur, the Leak Detection System would detect and contain the leak to a minimum.



（The example of underground CO_2 behavior : GCCSI 2012）

The condition of underground CO_2 can be monitored onshore.

Many Participants thought that the slide explained very little about how CO_2 is managed because the picture did not show the scale and area measurement and color interpretation. They also point out that they wanted to know how long “a long time” would be. Some felt that CCS fills their neighborhood with CO_2. Some others believed that the reason why CO_2 needs to be monitored is because it is dangerous.

The common concerns are summarized in the table below.

Housewives	● Not interested in CCS because its societal need is not explained. ➢ All these explanations are too technical for the general public to understand. ➢ It is hard to listen to a series of these explanations unless "why" in terms of its necessity is clearly accounted for. ● Its mechanism is not well explained. ➢ How can CO_2 be stored? ➢ Will the CO_2 go somewhere else later on? Otherwise the ground is filled with it and needs to be managed again. ● The picture is incomprehensible. ● Other opinions include: ➢ How long is a "long time"? ➢ How big is the whole system? ➢ Is CO_2 collected locally or globally?
Teachers	● The picture is utterly incomprehensible. ➢ Does the picture show a cross-sectioned view or birds-eye view of the site? ➢ Which part of the storage site is shown? ● CCS is considered dangerous. ➢ The reason why they monitor the site is because they know CCS is dangerous. ➢ Underground CO_2 is not safe; that is why it has to be monitored. ● CO_2 will stay at the injection site if it leaks. ➢ CO_2 is heavier than the air, so it suffocates us if it leaks and stays at the site

■About CCS and Earthquake

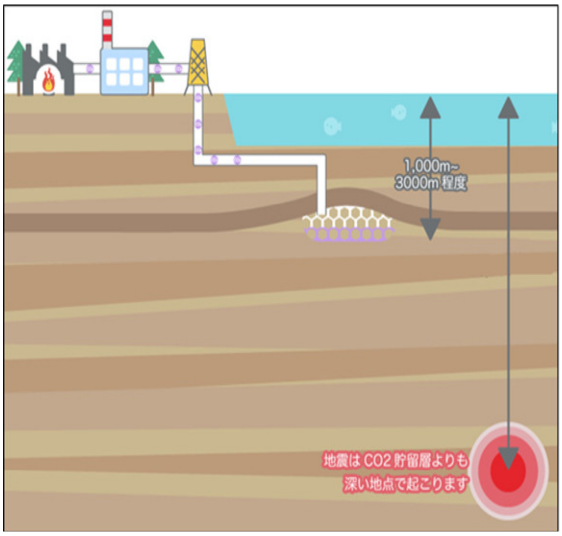
□Introduction of "Japan has many earthquakes. How can we safely store CO_2 underground?" slide

Japan has many earthquakes. How can we safely store CO2 underground?

Before CCS, various geophysical investigations of underground formations will be conducted so as to avoid earthquake-prone zones.

The geological formation where CO_2 is injected is located shallower than the depth earthquakes commonly occur .

Besides, underground seismic activity tend to be smaller than above ground.

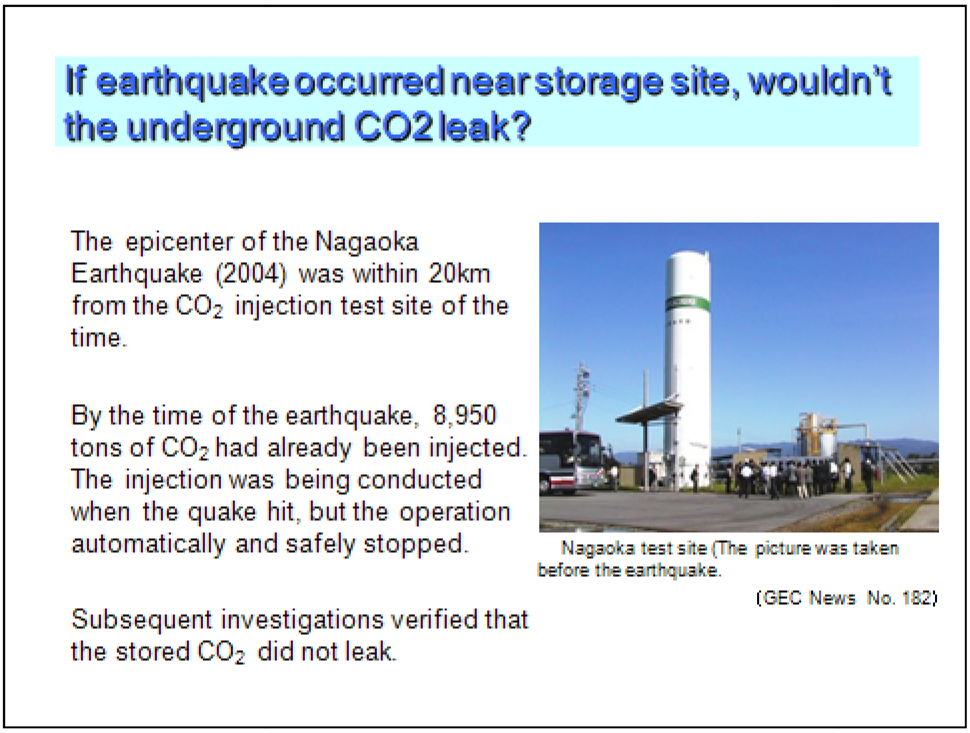


Several housewives were not able to understand the slide because they do not understand supercritical CO_2. Some said that explanation should be based on an assumption that earthquakes are unavoidable, rather than saying it won't happen. Some teachers thought that the explanation of the picture was not very logical. They also said that the consequences of possible earthquake to ground facilities should sufficiently be described.

The common concerns are summarized in the table below.

Housewives	● The explanation is easy to understand. ● Their knowledge about earthquakes is limited: they tend to believe what experts say when it comes to the nature of earthquakes. ● But the Fukushima Power Plant accident evokes a sense of distrust with experts. ➢ Earthquakes are unavoidable. They feel comfortable with measures built upon an assumption that earthquakes are inevitable. ● Explanations need to be specific. ➢ The slide is not convincing because it does not discuss how far the installation should be from active faults.
Teachers	● Some earthquakes originate from a shallow epicenter; Epicenter-storage site relationship in terms of distance contributes little to assure the safety of CCS. ➢ CO_2 needs to be stored further down. ➢ What happens to underground pipelines? ➢ What does a tsunami do to installations above ground?

☐Introduction of "If earthquake occurred near the storage site, wouldn't the underground CO_2 leak?" slide



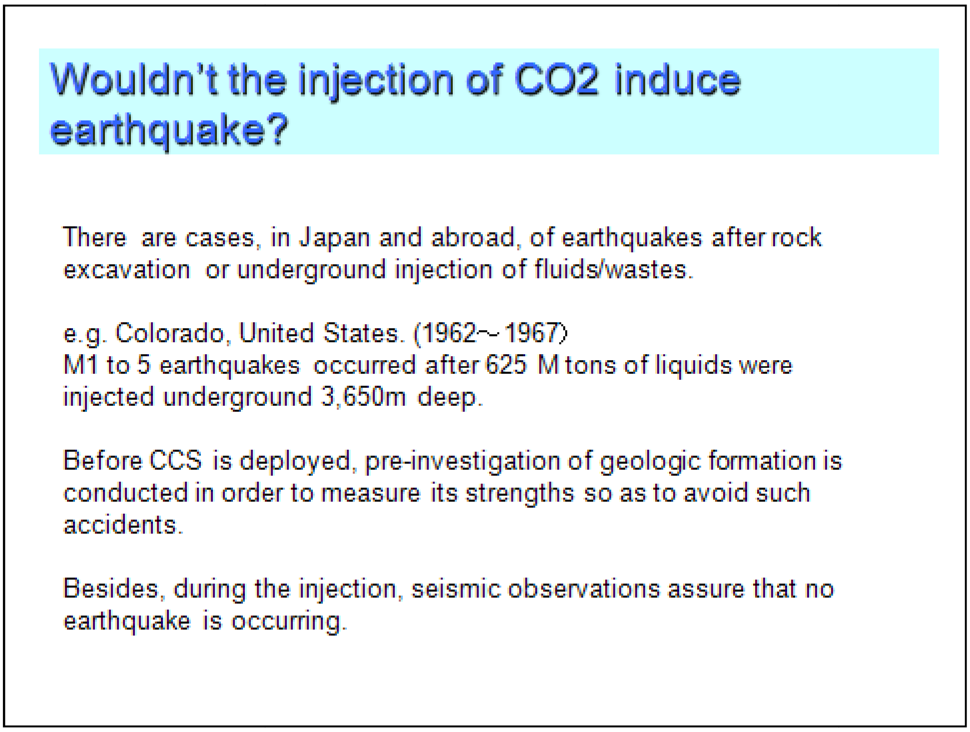
The majority of the participants considered the slide's explanation did not assure that CCS is safe because;

- the slide does not explain possible consequences of a bigger earthquake than the one in Chuetsu;
- the picture is taken before the earthquake, and thus it does not show damage to the installment; and
- safety measures for the transportation phase are not explained.

The common concerns are summarized in the table below.

Housewives	● Most participants of this group appreciate this example, although it does not explain if CCS withstands bigger earthquakes. ● Safety measures for the transportation phase are not explained. ➢ CO_2 is injected in a supercritical state. What will happen to this type of CO_2 if an earthquake hits during the transportation phase. ● The picture should show the pre and post-earthquake condition of the installation.
Teachers	● The Chuestu Earthquake is much smaller than the Great East Japan Earthquake. This example therefore does not convince teachers. ● Explanation is not logical. ➢ The previous slide discusses underground injection but this one talks about onshore injection.

☐Introduction of “Wouldn’t the injection of CO_2 induce earthquake?” slide



Few participants imagined induced earthquakes as possible consequences of CO_2 injection, but the explanation resulted in them thinking about it. All the participants questioned whether a preliminary investigation of the site could avoid seismic effects for certain.

The common concerns are summarized in the table below.

Housewives	● Some participants of this group have confidence in current technology. ➢ The Colorado tremor was half a century ago. We have better technology now. ● Some others do not believe in earthquake “prediction” through “pre-investigation”.

Teachers	● Induced earthquake concept is new to all the participants.
	● Some take this example as a possible scenario under CCS.
	    ➢ There are so many active faults beneath us that it is difficult to predict earthquakes.
	    ➢ All these explanations have just scratched the surface of the matter.
	    ➢ We are concerned about the next destructive earthquake. CCS will just add fuel to the fire.

■Merits and acceptability of CCS

□Introduction of "What are the merits of CCS?" slides

What are the merits of CCS？

①Advanced technology that contributes to global warming mitigation.

The Toyako Summit held in 2008 recognized the need to develop advanced technologies including CCS, along with the needs to improve energy efficiency and to develop renewables in tackling global warming.

②Significant CO2 reduction.

Through CCS, the large amount of CO_2 from thermal power plants and factories can be significantly reduced.

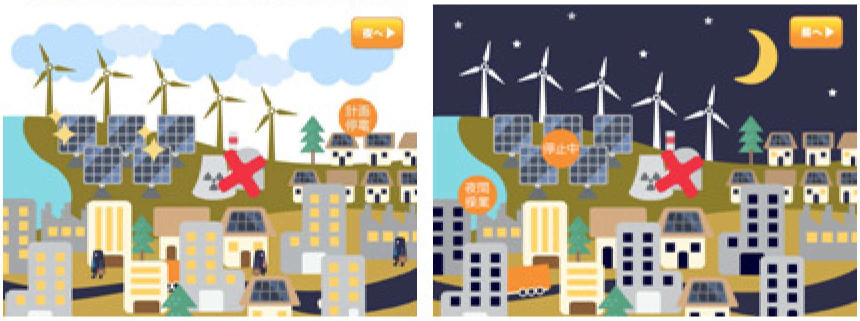
③Stable supply of energy

By deploying CCS at thermal power plants -the major energy source of the moment-, stable supply of energy and significant reduction of CO_2 can go together.

A scenario where CCS is implemented at a thermal power plant and our current lifestyle may be maintained.

④Global warming mitigation without changing our current lifestyle.

The incorporation of CCS in the global warming mitigation portfolio will contribute to a rapid reduction of CO_2, allowing slower adjustment to changes in the energy structures and lifestyles than when only other measures are employed.



A scenario where only renewables are employed to curb CO_2 and our current lifestyles may need to be changed.

Housewives responded positively to the idea of a “stable supply of energy”.

Teachers gave favorable responses to a change in their lifestyles. And they proposed that merits should emphasize the efficacy of CCS in terms of the amount of CO_2 reduced. Some teachers also proposed to reorganize the slides or combine messages 3 and 4.

A brief intervention by facilitator helped some participants understand “stable supply” and “little or no change” in lifestyle will materialize by continuing the use of thermal power plants with CCS.

□Acceptability

Teachers more clearly opposed to CCS deployment in their vicinity than housewives did so because, in their view, the disadvantages outweigh the advantages. They were particularly dissatisfied with the lack of contingency plans for CO_2 leakage.

The common concerns are summarized in the table below.

Housewives	• All the housewives reluctantly support the deployment of CCS in their vicinity. ➢ If that is the policy the government decides, we must agree. ➢ If its risks and benefits are clearly explained, and if its merits outweigh demerits, I can support the deployment. ➢ Then, every municipality has to have a CCS project to be equal.
Teachers	• A few teachers are supportive of the deployment if risks are clearly disclosed. • Some others absolutely oppose to it. ➢ Risks of CO_2 leakage and its consequences are not at all clear. It should not be built in my or anybody's backyard. ➢ We saw a sudden change from absolute safety to complete despair in the Fukushima Power Plant accident. There is no such thing as "absolute safety" as explained here.

3.3.3 Discussion

The FGIs successfully gathered information about what concerns or anxieties laypeople may have when they are given a reasonable amount of outreach material about CCS. The interviews did not produce a hostile atmosphere like that in the so-called NIMBY(Not In My Back Yard) case, but interviewees criticized unreasonable or illogical messages provided.

The research team had an impression that participants' educational/occupational background had some correlation with understanding of the material sent: There were three interviewees (one housewife and two teachers) who have scientific educational backgrounds and this could have been resulted in differences in the degree of understanding.

There was little difference in concerns or anxieties among housewives and teachers, but there was a reasonable gap between the two when they were asked about the deployment of CCS in their vicinity; housewives more easily "surrendered" to government-oriented or widely-accepted policies and/or projects. We, therefore, may want to further argue whether scientific knowledge sharing (so-called Science Communication) is necessary before risk communication takes place.

Some participants considered a change in their lifestyle as a “benefit” of CCS if it leads to climate change mitigation. This implies that the general public may evaluate risks of CCS smaller than its merits if the right amount of information is given.

Lastly, although we provided messages that focus on people’s concerns or anxieties about CCS, interviewees’ questions remained unsolved. This is most likely because the FGIs were conducted without any explanation from professionals. This implies that an inadequate amount of information merely increases concerns among information receivers and lowers the likelihood of acceptance.

References

CO2 Capture Project (2012), CCS STAKEHOLDER ISSUES REVIEW AND ANALYSIS, FINAL REPORT FEBRUARY 2012 (http://www.co2captureproject.org/reports/stakeholder_issues_report_March_2012.pdf)

Commonwealth Scientific and Industrial Research Organisation (2011), Communication and Engagement Toolkit for CCS Projects (http://www.globalccsinstitute.com/publications/communication-and-engagement-toolkit-ccs-projects)

GCCSI (2012), Public perceptions of low carbon energy technologies: Results from a Scottish Large Group Process (http://cdn.globalccsinstitute.com/sites/default/files/publications/38531/scottishlgpreport.pdf)

GCCSI (2011) , Development of a Knowledge-Sharing Test Bed for CCS in Japan

Itaoka Kenshi, Okuda Yuki, Saito Aya, and Akai Makoto (2009), Influential information and factors for social acceptance of CCS: The 2nd round survey of public opinion in Japan, Energy Procedia 1 ,4803-4810

Kinoshita Tomio, Kikkawa Toshiko(1990), Risk Communication niyoru Ninchikodo no Henka(3), The 31st Research Paper Presentation Collection, The Japanese Society of Social Psychology

Petty, R. E., & Cacioppo, J. T. (1986), Communication and Persuasion: Central and Peripheral Routes to Attitude Change. New York: Springer-Verlag.

4. Task 2: Knowledge sharing exercise to fill gaps in key areas (Seismicity)

Through discussion among the members on seismicity induced by injection of CO_2 and the impact of seismicity on any component of CCS, but geological storage in particular, it is recognized that knowledge of the current members on such technical issues is limited. On the other hand, few experts on seismicity are familiar with CCS. Hence this is an area that requires active and widespread knowledge sharing to bridge the gap. The following subtasks were carried out as an exercise in knowledge sharing in this emerging area.

4.1 Collation of relevant information

A literature survey concerning induced seismicity and any potential impact of seismicity on the geological storage of CO_2 in Japan was carried out by Dia Consultants, a Japanese geological consulting company. During this survey the following information was collated and structured, prior to its discussion among the members:

- the theoretical background on seismicity;
- details of mechanisms by which earthquakes can be induced by injection of fluid into deep geological formations;
- examples of past earthquakes that are believed to be induced by fluid injection in various industrial sectors; and
- an example of an earthquake in Chuetsu, which occurred in the vicinity of a geological storage pilot project at Nagaoka

A report has been produced in Japanese and formed a basis for a presentation given during a webinar (see next section).

4.2 Knowledge sharing exercise

Experts on seismicity, who are also familiar with CCS, were invited to give a webinar for the network participants using the Global CCS Institute platform. These experts were also invited to participate in the collaboration by joining the subsequent discussion sessions.

Following the webinar, potential themes for collaboration were discussed among the members. As a result, the following three themes were agreed:

- Theme 1: Collation of information needed to further development of a safety strategy for geological storage of CO_2 by addressing the risks of induced seismicity;
- Theme 2: Discussion on the potential for liability for damages caused by suspected induced seismicity; and
- Theme 3: Discussion on public outreach concerning induced seismicity

(1) Collaboration for "Theme 1"

With regard to Theme 1, a "Safety and security pyramid" (Benson, 2007) was developed (Figure 4-1), and information collated by the members are structured according to the individual "layers" of the pyramid. Table 4-1 shows key references to each layer. Also, it was agreed to use this structure as a basis for the knowledge-base to be developed in Task 2.3.

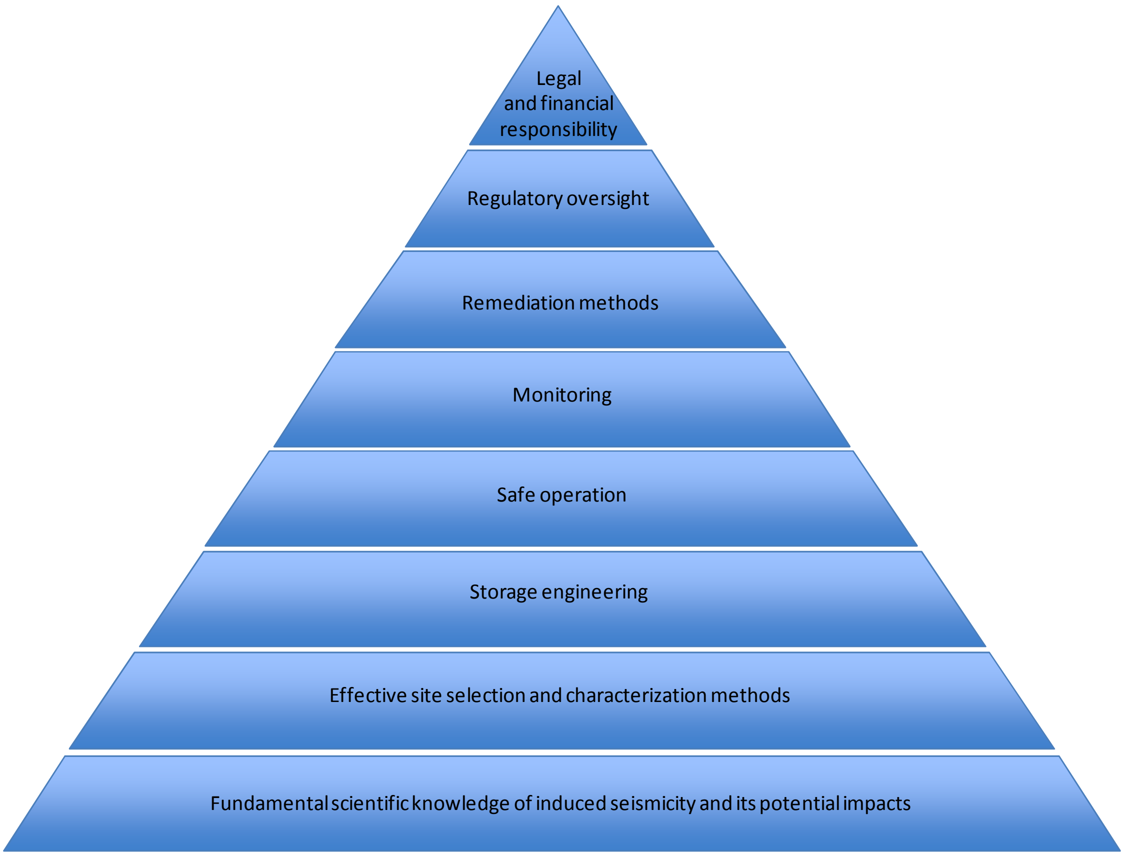


Figure 4-1 Safety and security pyramid for induced seismicity (after Benson (2007))

Table 4-1 Key references for each layer in “Safety and security pyramid”

Legal and financial responsibility	• Cypser and Davis (1998)[*2] • NRC report[*1] Chapter 4: Government roles and responsibilities related to underground injection and induced seismicity
Regulatory oversight	• NRC report[*1] Chapter 4: Government roles and responsibilities related to underground injection and induced seismicity
Remediation methods	• USDOE protocol for induced seismicity associated with EGS[*4]
Monitoring	• NRC report[*1] Chapter 6: Steps toward a “Best practices” protocol • USDOE protocol for induced seismicity associated with EGS[*4]
Safe operation	• NRC report[*1] Chapter 6: Steps toward a “Best practices” protocol • USDOE protocol for induced seismicity associated with EGS[*4]
Storage engineering	• NRC report[*1] Chapter 5: Paths forward to understanding and managing induced seismicity hazard and risk in energy technology development • Van Eijs et.al., (2006)[*5]
Effective site selection and characterization methods	• NRC report[*1] Chapter 6: Steps toward a “Best practices” protocol • Davis and Frohlich (1993)[*3]
Fundamental scientific knowledge of induced seismicity and its potential impacts	• NRC report[*1] Chapter 1: Induced seismicity and energy technologies Chapter 2: Types and causes of induced seismicity Chapter 3: Energy technologies: How they work and their induced seismicity potential • Output from Task 2.1

*1: National Research Council of the National Academies. Induced Seismicity Potential in Energy Technologies, The National Academies Press, 2012.
*2: Cypser, D.A. and Davis, S.D., Induced seismicity and the potential for liability under U.S. law, Tectonophysics 289, 239-255, 1998.
*3: Davis, S.D. and Frohlich, C., Did (or will) fluid injection cause earthquakes: criteria for a rational assessment. Seismol. Res. Lett. 64, 207-223, 1993.
*4: Majer, E.M. et.al., Protocol for addressing induced seismicity associated with enhanced geothermal systems, DOE/EE-0662, 2012.
*5: Van Eijs, R.M.H.E., Correlation between hydrocarbon reservoir properties and induced seismicity in the Netherlands, Engineering Geology 84, 99-101, 2006.

(2) Collaboration for “Theme 2”

Through on-line collaboration among the members covering issues based on Cypser and Davis (1998), a flow-chart for assessing the potential for liability for damages caused by suspected induced seismicity under U.S. law was drawn (Figure 4-2).

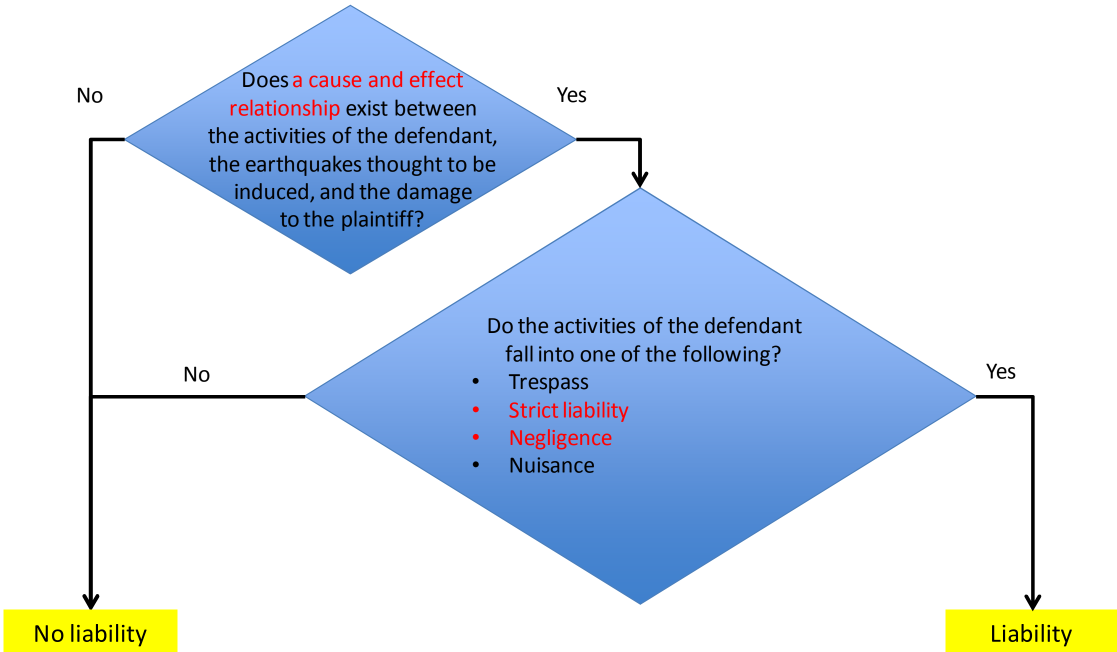


Figure 4-2 A flow-chart for assessment of potential for liability under U.S. law

<u>Cause and effect relationship</u>

Checklists can be convenient tools to help a wide range of stakeholders, including governmental bodies, regulatory authorities and site operators, to discuss and assess the potential to trigger seismic events through sub-surface fluid injection, and to aid in determining if a seismic event is or was induced. Two checklists, one to address each of these two circumstances—the potential for induced seismicity and the determination of the cause of a felt event—were developed nearly two decades ago by Davis and Frohlich (1993). Their work recommends a list of ten “yes” or “no” questions to establish “whether a proposed injection project is likely to induce a nearby earthquake” and a list of seven similar type questions to establish “whether an ongoing injection project has induced an earthquake.” The latter evaluates four factors related to possible cause: background seismicity, temporal correlation, spatial correlation, and injection practices. In Table 4-2 the seven questions are listed and are specifically phrased so that a “yes” answer would indicate underground injection induced the earthquake(s) and a “no” answer would indicate the earthquake(s) were not caused by injection.

Table 4-2 Seven questions aimed at establishing whether a cause-and-effect relationship exists between fluid injection and induced seismicity.

	Question	Earthquakes Clearly NOT Induced	Earthquakes Clearly Induced	I Denver, Colorado	II Painesville, Ohio
	Background Seismicity				
1	Are these events the first known earthquakes of this character in the region?	NO	YES	YES	NO
	Temporal Correlation				
2	Is there a clear correlation between injection and seismicity?	NO	YES	YES	NO
	Spatial Correlation				
3a	Are epicenters near wells (within 5 km)?	NO	YES	YES	YES?
3b	Do some earthquakes occur at or near injection depths?	NO	YES	YES	YES?
3c	If not, are there known geologic structures that may channel flow to sites of earthquakes?	NO	YES	NO?	NO?
	Injection Practices				
4a	Are changes in fluid pressure at well bottoms sufficient to encourage seismicity?	NO	YES	YES	YES
4b	Are changes in fluid pressure at hypocentral locations sufficient to encourage seismicity?	NO	YES	YES?	NO?
	TOTAL "YES" ANSWERS	**0**	**7**	**6**	**3**

SOURCE: Davis and Frohlich (1993)

Two injection wells are evaluated in Table 4-2. The well in Denver, Colorado, was located at the Rocky Mountain Arsenal, which was shown to be definitely the cause of induced earthquakes in the mid 1960s. The Painesville, Ohio well, also known as the Calhio well which was injecting liquid waste from agricultural manufacturing, was investigated as a cause of earthquakes and revealed ambiguous results; the scientists who examined the data could not correlate fluid injection at the well with the earthquakes, partly because the observed seismicity was similar to historical (natural) seismic activity in the area.

As an exercise for experts in the Japanese Knowledge Sharing(KS) network, the same checklist was applied to other seismic events, i.e. and attempt was made to apply it to the Chuetsu earthquake (see Section 4.3).

Strict liability

In the United States "strict liability" or "absolute liability" is usually considered to arise from "abnormally dangerous activities". Section 520 of the Restatement (Second) of Torts (American Law Institute, 1979) states that to determine whether an activity is abnormally dangerous and consequently subject to strict liability, the following issues should be considered (Cypser and Davis (1998):

(a) existence of a high degree of risk of some harm to the person, land or chattels of others;

(b) likelihood that the harm that results from it will be great;

(c) inability to eliminate the risk by the exercise of reasonable care;

(d) extent to which the activity is not a matter of common usage;

(e) inappropriateness of the activity to the place where it is carried on; and

(f) extent to which its value to the community is outweighed by its dangerous attributes.

Although all these factors are important not all of them must occur for an activity to be considered "abnormally dangerous". Whether or not a particular activity is judged to be abnormally dangerous may depend to a relatively great extent on only one factor, or a sub-set of the factors.

The first two factors, (a) and (b), respectively the degree of risk and the likelihood that the harm caused will be great, must be judged together. There will be a high probability of an activity being considered "abnormally dangerous" if the degree of risk and the likelihood of significant harm are both large. On the other hand, if either factor is zero, then the other factor has no meaning in this context and the activity will not be "abnormally dangerous". In many cases an intermediate situation may arise in which one factor has a high value and the other one a low value. In such a case, the activity may still be considered "abnormally dangerous". For example, this could occur if the potential level of harm is very high, even if the probability (risk) of some harm actually occurring is small.

The answer to Factor (c) "Can we eliminate the risk of inducing quakes?" must be at present "no". It is impossible to predict accurately the timing and locations of induced seismicity when geological stress states (Zoback and Zoback, 1980) and fault locations are inadequately known, and the mechanisms by which strain energy is released by seismicity are not understood completely understood, even though there is a good understanding of the general mechanisms (NRC, 2012).

In the present context Factor (d): “common usage” not mean “undertaken by most people every day”. Instead this term refers to an activity engaged in widely and frequently by a large proportion of a human population. For example, in the U.S. many people are employed by the mining, geothermal energy and oil and gas extraction industries, and many more people use the products of these industries. However, these activities involve only a relatively small percentage of the total U.S. population and hence these activities are not considered “common usage”.

Again in the U.S., how a court would interpret Factors (e) and (f) to assign strict liability in a given case may depend upon the extent to which the CO_2 storage locality is appropriate (the court may consider the population density and why the project was located there), or the value of the project to the local community (the court may assess whether the income of a large proportion of the community depends upon the activity and whether the entire community benefits substantially from the project). Hence seismicity induced by mining in an isolated community may have a relatively low likelihood of being considered due to an “abnormally dangerous activity”. In contrast, there is a greater likelihood that CO_2 injection-induced seismicity occurring in a metropolitan area would be considered “abnormally dangerous”.

Negligence

“Negligence” is another potential basis for liability. As an example, in negligence cases, courts in the U.S. consider: whether the risk of harm was foreseeable; the duty of the responsible party to avoid that harm by taking appropriate precautions; a standard of care; and the damage caused by failing to meet that standard. The relationship between the burden of precautions needed to avoid injury and the liability for negligence was described algebraically by judge Learned Hand (United States v. Carroll Towing Co., Inc., 1947). The Hand formula has been adapted to induced earthquakes as follows (Cysper and Davis, 1988):

If $P\ L > B$; then the defendant is liable

where: P: probability of inducing a damaging quake; L: severity of the resulting injury; B: burden of precautions on potential inducers.

This formula has been used by U.S. courts both qualitatively and quantitatively (substituting dollar sums for *B* and *L*).

The standard of care is usually taken to be the level of care that would be given by a "reasonably prudent person". The question is: "did they use the same care and caution that a reasonable and prudent person of like skills and intelligence would use under similar circumstances?" Professionals who are involved in CO_2 storage must use their skills and knowledge to mitigate the risks of injury. It may not necessarily be the case that professionals will avoid liability in a legal case simply by obeying regulations. For example, in the U.S., only minimum standards are specified by relevant laws and regulations and these standards do not determine the standard of care.

Seismicity has been shown to be induced by varied human activities (e.g. NRC, 2012), and has been discussed in wide-ranging scientific literature for many years, it could be argued that, at least in a general sense, inducing seismicity is a foreseeable risk. This is not to say that the risk of harm being caused by induced seismicity is necessarily foreseeable since it is clear that the probability of triggering seismicity will vary between different industries, the locations of the activities involved and the methods used. However, since the degree to which harm is foreseeable is one criterion by which negligence can be determined, it follows that "reasonable prudent professionals" should consider the potential for induced seismicity when developing CO_2 storage plans.

It is only through appropriate site investigations that the degree of risk arising from possible induced seismicity can be judged and appropriate mitigation plans developed. These investigations need to be continued throughout the lifetime of project, commencing during site selection and the initial phases of a project. The investigations need to include (Davis and Frohlich, 1993): determining the sub-surface stress states of rocks; establishing fault locations; determining an area's seismic history; and monitoring seismicity before and during the project.

From a legal perspective these investigations may be needed to demonstrate due care even if industry standards or prevailing regulations do not require them (Cypser and Davis, 1998). It is noteworthy that even though these investigations are expected to be expensive, most likely it would be much costlier to pay compensation to injured parties, defend legal actions, or possibly even abandon a project.

In the context described above the members of the Japanese KS network will continue discussions aimed at addressing the question “What is the duty to take precautions to avoid harm in the case of induced seismicity associated with the geological storage of CO_2?” This, also, will serve as an opportunity to check the validity of the safety strategy being discussed in Theme 1.

(3) Collaboration for “Theme 3”

Outputs from Task 1 have been uploaded to the GCCSI digital platform. Both an on-line discussion and a face-to-face meeting among the network members were carried out aimed at developing an outreach strategy concerning induced seismicity. Key outcomes of the discussion are the following;

i. An important observation in Task 1 is that the scientific basis for CCS, and underground storage in particular (e.g. covering injection of super-critical CO_2 into an underground reservoir via deep wells, trapping mechanisms of stored CO_2 and potential impacts of CO_2 on humans and the wider environment) has not been shared with laypersons to a degree sufficient for facilitating effective risk communication concerning CCS.
ii. In the course of risk communication, guiding people to make hasty judgments on the risks of CCS without a sound scientific understanding may lead to inappropriate outcomes. In order to avoid such a situation, risk communication activities should be accompanied by a well-designed programme of science communication.
iii. The scope and goals of a programme of science communication depend on issues that influence the risks of CCS, either directly or indirectly. To establish a comprehensive strategy of science communication, “gaps” in the knowledge of laypersons on a variety of issues need to be evaluated.
iv. Among those issues potentially relating to the risk of CCS, induced seismicity is a typical example that requires extensive effort in science communication so that people can understand how earthquakes can be induced by injecting fluid into underground formations, how can we avoid it, etc.

This issues are discussed further in Chapter 6.

4.3 Development of argumentation model(AM) and knowledge-base

(1) Knowledge-base for induced seismicity

Based on the on-line discussion among the members, a knowledge-base summarizing information and knowledge relevant to each level of the Carbon Capture and Storage (CCS) "Safety and Security Pyramid" (Figure 4-1) was developed. In Appendix 2 separate sections cover each level of this pyramid, starting at the bottom and working upwards to the top.

The summaries focus on aspects of each issue in the pyramid that are relevant to induced seismicity that might be caused by CCS. However the points made are illustrated by hyper links to:

- two documents that describe aspects of induced seismicity that potentially could be caused by a wide range of human activities (Cysper and Davis, 1998; NRC, 2012); and
- a single report that presents a protocol for addressing induced seismicity associated with enhanced geothermal systems (Majer et al. 2012).

(2) Argumentation model(AM)

As a part of the on-line discussion, four members who have expertise in seismology were invited to fill the "Davis and Frohlich" checklist for induced seismicity (Table 4-2) applied to the Chuetsu earthquake. Their answers were integrated to form an argumentation model(AM) shown in Figure 4-3, which claims the "Chuetsu earthquake was not induced by CO_2 injection at the Nagaoka test site". This model is subdivided into the following arguments (and arguments described subsequently) together with pieces of evidence to support it;

- Earthquakes of the same type as the one in Chuestsu have occurred repeatedly in the same region in the past.
- There is no clear temporal correlation between CO_2 injection and the Chuetsu earthquake.
- There is no clear spatial correlation between CO_2 injection and the Chuetsu earthquake.

- Changes in fluid pressure due to CO_2 injection were not sufficient to induce seismicity.

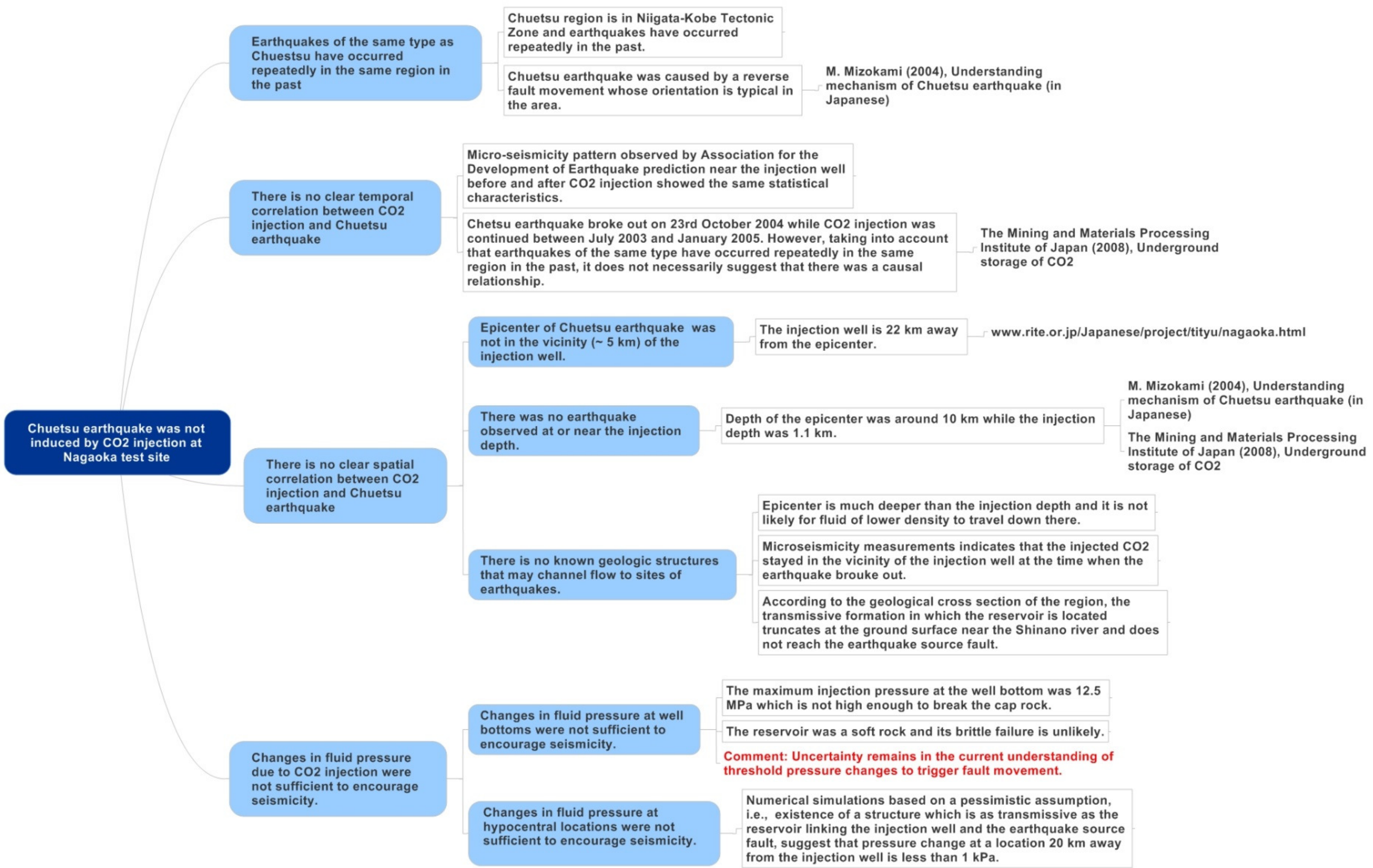


Figure 4-3 Argumentation model(AM): the Chuetsu earthquake was not induced by CO_2 injection at the Nagaoka test site

5. Discussion

In Phase 2 of the study, the following two tasks were carried out;

- Task 1: Development and dry run of a public outreach program based on the action plan and argumentation model(AM) that were developed in Phase 1; and
- Task 2: A wider knowledge sharing exercises to fill gaps in key areas. Seismicity that might be induced by injection of CO_2 and the impact of the seismicity on any component of CCS, but geological storage in particular, were identified as priority issues.

The FGIs that were carried out as a part of Task 1 successfully gathered information about what concerns or anxieties laypeople may have when they are given a reasonable amount of outreach material about CCS. The research team had an impression that participants' educational/occupational background had some correlation with understanding of the material sent. Since the FGIs were conducted without any explanation from professionals, participants' concerns or anxieties remained unsolved. This implies that inadequate information, both in terms of quantity and characteristics, merely increases concerns among information receivers and lowers the likelihood of acceptance.

Outputs from Task 1 have been uploaded to the GCCSI digital platform. As part of Task 2 (Theme 3), both on-line discussion and a face-to-face meeting among the network members were carried out aimed at developing an outreach strategy concerning induced seismicity. Key outcomes of the discussion are the following;

- An important observation arising from the results of Task 1 is that the scientific basis for CCS, and underground CO_2 storage in particular (e.g., injection of super-critical CO_2 into a reservoir via deep wells, mechanisms by which stored CO_2 is trapped underground, and potential impacts of CO_2 on humans and the wider environment), has not been shared with laypersons to a degree sufficient for facilitating effective risk communication concerning CCS.
- In the course of risk communication, guiding people to make hasty judgments about the risks of CCS without a sound scientific understanding may lead to inappropriate outcomes. In order to avoid such a situation, risk communication activities should

be accompanied by a well-designed programme of science communication.

- The scope and goals of a science communication programme depend on issues that influence the risks of CCS, either directly or indirectly. To establish a comprehensive strategy of science communication, "gaps" in the knowledge of laypersons about a variety of issues need to be evaluated.
- Among those issues potentially relating to the risk of CCS, induced seismicity is a typical example that requires extensive effort in science communication, so that people can understand how earthquakes might be induced by injecting fluid into underground formations, how can we avoid it, etc.

In the course of on-line discussions, information about science communication was also collated by the network members, which is summarized below.

Science Communication: a definition (Lloyd Spencer, D. 2010)

- Science communication may be defined in broad terms as: *the popularization of science.* In practical terms this means distilling the results of scientific enquiry (which are usually published in papers or books conforming to the conventions and practices of scientific writing) into a form that is readily understood by the public.
- There are several aspects of this that are crucial to the process:
  - ✓ Distillation necessarily involves condensation; a reduction in complexity to present the essential information.
  - ✓ If the goal is actually to get that information across to the public (as opposed to simply putting it in the public domain and letting interested parties find it if they so wish), then the information must be made, in some way, engaging.
  - ✓ Almost invariably in popular communication there will be some sort of value put on the information, either explicitly or implicitly. Science communication is very seldom neutral.

Practice of Science Communication: Storytelling (Lloyd Spencer, D. 2010)

- The most effective communication is that which involves storytelling. Story, or narrative, can be thought of as "a mode of thinking, a structure for organizing our knowledge, and a process for the vehicle of education" (Bruner 1986, p119).

- The power of story lies in its "narrative effect," whereby it creates interest and enhances understanding and memory of the information being conveyed in the story. When it comes to science communication specifically, this effect manifests itself by increasing attention and eliciting faster and fuller comprehension of information (Norris et al 2005).
- Storytelling, then, should be at the core of any programme that purports to produce better communicators rather than just conduct research on communication.

Practice of Science Communication: Engaging (Lloyd Spencer, D. 2010)

- It is essential to attract attention to the information being conveyed. Design of the way the information* is packaged will affect whether the public engages or not.
- There is an ample literature from the discipline of design studies that demonstrates how people are impacted by different designs (Crilley et al 2008).
- The point being that elements of design influence whether members of the public engage with information in the first place and continue to give it their attention.

** Communication design is a mixed discipline between design and information– development which is concerned with how media intermission such as printed, crafted, electronic media or presentations communicate with people. A communication design approach is not only concerned with developing the message aside from the aesthetics in media, but also with creating new media channels to ensure the message reaches the target audience. Communication design seeks to attract, inspire, create desires and motivate the people to respond to messages, with a view to making a favorable impact to the bottom line of the commissioning body, which can be either to build a brand, move sales, or for humanitarian purposes. Its process involves strategic business thinking, using market research, creativity, and problem–solving.*

Practice of Science Communication: Enhancing creativity (Lloyd Spencer, D. 2010)

- What skills are best for communicating will depend upon the method of delivery of the information. Nevertheless, it is a fact that not all forms of communication are equal even if they contain the same information and tell the same story. The creativity of the communicator in the way he or she delivers the story will affect its reception.
- For enhanced writing about factual information there has been the development

of a genre of writing called creative nonfiction writing* (Gutkind 1997). In essence, it involves the application of techniques of writing usually associated with fiction to the presentation of nonfiction, with the one stipulation that the information presented must be true and factual.

** Creative nonfiction (also known as literary or narrative nonfiction) is a genre of writing that uses literary styles and techniques to create factually accurate narratives. Creative nonfiction contrasts with other nonfiction, such as technical writing or journalism, which is also rooted in accurate fact, but is not primarily written in service to its craft. As a genre, creative nonfiction is still relatively young, and is only beginning to be scrutinized with the same critical analysis given to fiction and poetry. For a text to be considered creative nonfiction, it must be factually accurate, and written with attention to literary style and technique. "Ultimately, the primary goal of the creative nonfiction writer is to communicate information, just like a reporter, but to shape it in a way that reads like fiction."*

Based on the discussion summarized above, the following recommendations are made for a potential continuation of the Japanese knowledge sharing test bed.

(1) Development of a methodology integrating risk communication and science communication taking into account a "knowledge gap" among laypersons corresponding to each of the key issues relating to the risk of CCS

Science communication is a relatively new concept but a variety of applications have been reported in a variety of scientific disciplines and related industrial sectors. In the area related to CCS, a number of examples exist. They include:

- Japan CCS Co., Ltd. has produced a "manga" style creative fiction on the basics of CCS that was presented at the GHGT-11 meeting in Kyoto in 2012. No official evaluation of its contribution to dissemination of relevant knowledge on CCS has not been reported yet. (It might be feasible to invite Japan CCS Co., Ltd., as a member of the Global CCS Institute, to informally comment on this).
- USDOE(Department of Energy) produced a video titled "Carbon in underground" in which a characters representing a "rookie" CO_2 molecule who comes into an underground storage learn about the mechanisms to retain CO_2 in the storage from his/her seniors.
(http://blog.energy.gov/blog/2011/05/26/move-over-american-idol%E2%80%A6)

- Mindfuel, a non-profit organization committed to increasing science literacy and awareness, developed an on-line game titled "CO_2-connect" (http://www.wonderville.ca/asset/co2-connection) . It says "Help Kelvin as he embarks on the noble task of reducing the province of Alberta's carbon footprint! Joined by his trusty companion Celsius, Kelvin travels the province helping to capture and store carbon dioxide. Have fun as you learn about calculating a carbon footprint."

For this purpose, the following tasks should be attempted:

- On-line interviews with a large group of people, to evaluate "knowledge gaps" among laypersons corresponding to each of the key issues that influence the risks of CCS;
- Analysis of the effort needed to communicate science as a basis of risk communication concerning each of the key issues; and
- Comparison of different risk communication strategies, i.e., with and without science communication, through dry runs involving two or more focus groups. The dry runs should continue longer than Phase 2 to accommodate testing the different modes of science communication described below.

(2) Development of methodologies and an information package to be used in the course of science communication on CCS

Methodologies of science communication and contents to be tested in (1) will be developed through a further knowledge sharing exercise among members of the Japanese knowledge sharing test bed in the following tasks:

- development of science communication methodologies corresponding to the size and nature of the "knowledge gaps" in the individual issues relating to the risks of CCS, including development of science cafés, story telling, on-line discussions, and use of the approaches described below, e.g., creative nonfiction;
- specification of the scientific content to be communicated based on the argumentation models that have been developed in Phase 1 and 2; and
- evaluating a variety of creative nonfiction types to establish their suitability for this communication, including for example a "manga" that was developed by Japan

CCS and distributed at the GHGT-11 this year, and “games” that were developed in a number of existing public outreach programmes on CCS (see appendices in the Phase 1 report);

- inviting cartoonists and/or game makers to enhance creativity while members of the network participate as an expert group to assure authenticity.

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