Study of geological storage for a candidate CCS demonstration Project in Tomakomai, Hokkaido, Japan

Yoshinori Yamanouchi*, Motonori Higashinaka, Toru Yoshii, Norifumi Todaka

1*Japan CCS Co., Ltd., Sapia Tower 19F, 1-7-12, Marunouchi, Chiyoda-ku, Tokyo, 1000005, Japan

Abstract

The Prime Minister of Japan declared: Japan should positively commit itself to setting a long-term reduction target. For its midterm goal, Japan will aim to reduce its emissions by 25% by 2020, if compared to the 1990 level, consistent with what the science calls for in order to halt global warming. In order to achieve this target, the government considers CCS (Carbon dioxide Capture and Storage) as an essential method and aims to improve CCS technology to practical levels.

Japan CCS Co., Ltd. (JCCS) was established in May, 2008 in order to study the potential and feasibility of CCS demonstration projects in Japan. The company was commissioned by the Ministry of Economy, Trade and Industry (METI) in Japan. Major shareholders of JCCS include electric power companies, upstream to downstream petroleum companies, material companies, engineering companies, etc.

In 2008, an investigation of candidate sites for the CCS demonstration was done over Japan and several promising offshore sites were selected. One of the selected candidate sites is the Tomakomai offshore site in Hokkaido prefecture, located in the northern part of Japan where there are petroleum refineries, paper mills and power plants close to the site. The Yufutsu oil and gas field is located in the eastern part of Tomakomai city where much geological data has been obtained through oil and gas exploration. Basic geological modes were constructed and CO2 reservoir simulation was performed to predict the movement of the stored CO2. Simulation results show us that a sufficient volume of CO2 could be safely stored in the saline aquifers at the Tomakomai site for a demonstration period and afterward. From October to November in 2009, a 3D seismic survey was implemented to confirm the geological potential of the site. Ocean bottom cables enabled us to survey in front of the Tomakomai Port. The survey area (full-stacked area) was 3.0km (N-S) by 2.7km (W-E) and about 2km from the shoreline with several target formations at a depth of about 1,100~3,000m. This survey was conducted in 4 patches using 2to 3 sets of ocean bottom cables with the total number of receiver and shot lines being 10 and 26, respectively. Results of this survey were utilized in building the detailed 3D geological model for the CO2 reservoir simulation. Basic plant designing to capture CO2 at the hydrogen process in the petroleum refineries is currently ongoing. The captured CO2 will be injected at 250,000 ton/year for 4 - 5 years in the demonstration project. Many local organizations, such as the Tomakomai city government and the fisheries cooperative, cooperated to carry out the 3D seismic survey. The Tomakomai government has been strongly willing to invite the CCS demonstration project to the city. By their continuous cooperation is possible to carry forward the feasibility study in order to start the CO2 injection in 3-4 years.

© 2010 Elsevier Ltd. All rights reserved

Keywards: Large scale demonstration; 2 emission sources; Takinoue; Tomakomai CCS Promotion Council

* Corresponding author. Tel.: +81-3-6268-7384; fax: +81-3-6268-7385.
E-mail address: yoshinori.yamanouchi@japanccs.com.

1. Introduction

In order to avoid the most dramatic climate changes we need to mitigate carbon dioxide (CO\(_2\)) emissions as soon as possible and geological storage is a promising technology to reduce emission to the atmosphere. The G8 leaders declared at the Hokkaido Toyako Summit in 2008 to “strongly support the launching of 20 large scale CCS demonstration projects globally by 2010, with a view to beginning broad deployment of CCS by 2020”. As its mid-term target, Japan will aim to reduce its emissions by 25% by 2020 compared to 1990 levels. This is consistent with what the science community has been calling for in order to halt global warming. In order to reduce CO\(_2\) emission and achieve the target, the government considers CCS as an essential method and aims to improve CCS technology to practical levels by demonstrating a CCS total system which consists of CO\(_2\) capture, transport and store.

Japan CCS Co., Ltd. (JCCS) was established in May, 2008 to study the potential and feasibility of a CCS demonstration project in Japan. This study was commissioned to the company by the Ministry of Economy, Trade and Industry (METI) in Japan. Major companies, having relationships with CCS including electric power companies, upstream to downstream petroleum companies, material companies, engineering companies, etc., invest and participate in JCCS. JCCS has been carrying out comprehensive investigation for large scale demonstration projects in Japan; several sites were screened from 115 candidates for a CCS demonstration project with Tomakomai as one of promising candidates. Tomakomai city located in southern Central Hokkaido where was held Hokkaido Toyako summit in 2008.

2. Project Overview

The Tomakomai demonstration site is located in Tomakomai City in the south-western part of Hokkaido Prefecture, northern part of Japan.

A planned CO\(_2\) injection point is located below the sea floor, approximately 3 km offshore from the Tomakomai Port which is integrated into the Tomakomai industrial area. The Tomakomai industrial area has wide variety of industries such as the paper industry, the petroleum refinery, the automobile industry, and the power industry. Within a 100km radius from the CO\(_2\) storage site, large-scale CO\(_2\) emission sources such as the power plants, petroleum refineries, integrated steelworks and paper mills more than 100,000s ton of CO\(_2\) per year.

The large-scale CCS demonstration project at the Tomakomai site has been planned to demonstrate a comprehensive process which is composed of:

- CO\(_2\) capturing processes from two different CO\(_2\) emission sources,
- CO\(_2\) transportation processes by gas pipeline and tanker trucks,
- CO\(_2\) injection and storage processes from the onshore injection base into the offshore reservoir formation below the sea floor, through an injection well.

Project schematic diagram of this site is shown on Figure 1.

For the CO\(_2\) emission sources, 2 types of CO\(_2\) supply bases have been planned:

The first CO\(_2\) supply base will feed gaseous CO\(_2\) at approximately 200,000 ton/year from the newly installed CO\(_2\) capturing facilities in the existing hydrogen production facilities of a refinery and the second CO\(_2\) supply base will feed liquefied CO\(_2\) at approximately 50,000 ton/year from existing CO\(_2\) capturing facilities in the hydrogen production facilities of another refinery.

At the first supply base, a bulk gas stream is separated from the up-stream of the PSA (Pressure Swing Adsorption) facilities of the hydrogen production facilities, then the gaseous CO\(_2\) is removed from the bulk gas around 60% by the new CO\(_2\) capturing facilities. Captured CO\(_2\) (200,000 ton/year) will be transported to the injection base approximately 2 km from the first supply base. For the short-distance CO\(_2\) land transportation method, a medium pressure gas pipeline has been planned. The new CO\(_2\) capture facilities will be used to construct and demonstrate the CO\(_2\) capture system which uses energy-saving activated amine. The CO\(_2\) transportation model by short-distance medium pressure gas pipeline will be demonstrated, as the first supply base is adjacent to the injection base.

At existing CO\(_2\) removal facilities in the second supply base, CO\(_2\) liquefaction facilities (compressor, dehydrator, liquefier) and storage-loading facilities (storage tanks, liquefied CO\(_2\) loading facilities) will be installed and will produce liquefied CO\(_2\) 50,000 ton/year. This liquefied CO\(_2\) will be transported to the injection base approximately 80km from the CO\(_2\) liquefaction facilities by land. For the land transportation method, transportation by tanker
trucks has been planned, as this is a domestically established method for liquefied CO₂ transportation. For the medium-distance liquefied CO₂ transportation less than 100 km, this is less costly than rail tank transportation.

At the second supply base, as with the first supply base, the CO₂ emission source is hydrogen production facilities in the refinery, however the second supply base uses only existing wet-type CO₂ removal facilities to capture gaseous CO₂. The captured CO₂ will be liquefied, stored, then transported to the injection base. From the transportational point of view, as the liquefied CO₂ is transported to the injection base by tank trucks, we will be able to demonstrate and then establish a comprehensive transportation system including liquefaction, storage, shipping, and receiving facilities.

At the new injection base, supercritical CO₂ will be produced from gaseous CO₂ (transported from the first supply base through the medium pressure gas pipeline), and also from the liquefied CO₂ (transported from the second supply base by the tank trucks). Supercritical CO₂ will be mixed there and then injected into and stored in the reservoir (an aquifer located 3 km off shore of Tomakomai city) through an injection well (a deviated well, or an ERD well). The injection well will be drilled from the injection base.

The injection base will receive two different phase CO₂, (gaseous and liquefied) from the first and second supply bases respectively. Each CO₂ type will be pressurized by the centrifugal type supercritical compressor and the supercritical pressure pump respectively. Demonstration of the mixing and injection process of supercritical CO₂ from different supply sources and different CO₂ phases will contribute to the development of further larger scale CCS operations.

This case makes it possible to demonstrate the safety and the reliability of CCS, through the integrated system consisting of CO₂ capturing process from multiple CO₂ emission sources, CO₂ transportation processes, and the CO₂ injection process, simultaneously with identifying technical problems, assessing cost-cutting methods/strategies, and establishing the operational framework.

Figure 1  Project Schematic Diagram
Geological background of this region is as shown in Figure 2. Tomakomai is located in the Ishikari-Hidaka area, Hokkaido, where the geological structure is controlled by NNW–SSE-trending fold and fault (thrust) belts. The northeast rolling hills of this area are situated in front of the westward-propagating fold. Therefore, offshore Tomakomai has not been noted to have experienced the typical structural deformation after Miocene. There are no active faults from surrounding geological data which is supported by existing seismic data. The main target reservoir for CO₂ storage at Tomakomai is the Takinoue formation of middle Miocene age. It is an approximately 600 m succession of volcanic rock and pyroclastic rock. The Takinoue formation is overlain by over 500 m thickness mudstone consists of the Biratori and Karumai formation and the Fureoi formation, which are in turn overlain by the quaternary formations (Figure 3).
Based on the existing offset well data and 2D seismic data, the Takinoue formation composed of very thick volcanic rocks and pyroclastic rocks is widely spread in this area. Large storage volume and thus large aquifer-size is expected due to its total rock volume size. These conditions lead to long-term mitigation of the sudden reservoir pressure rise caused by CO₂ injection into the reservoir. Furthermore, due to the thickness of the formation, a sufficient injection rate is expected to be accomplished by a long perforation interval along the hole though its permeability is relatively low.

More than 500m thickness mudstone functions as an impermeable formation as it is known that the Takinoue formation has maintained high salinity and formation pressure through geological time. This fact suggests the saline aquifer of Takinoue formation has a single pressure compartment. Seal capacity and huge aquifer size are the subsurface feature of this site.

The Candidate injection point is situated in the marginal part of the four-way closer with a gentle northern dip. A structural high is approximately 10km south of the site indicating that injected CO₂ will move seaward through geological time. The critical injection point and perforation intervals will be determined after 3D seismic survey and survey well drilling.

3. Progress & Activity

In order to evaluate seal integrity and reservoir potential, a 3D seismic survey was conducted in 2009. From October to November, 2009, a 3D seismic survey was acquired to ensure the geological potential of the site offshore from Tomakomai. Ocean bottom cables enabled us to acquire 3D seismic data in front of the Tomakomai Port. Tomakomai port is an international port and there are many ships in front of the port all the day. Shallow sea-depth and a sea-berth for a petroleum refinery prevented the 3D seismic survey by seismic vessels which tow several streamer cables. An ocean bottom cable survey (Figure 4) which does not occupy sea surface and does not restrict the navigation of ships, is suitable for such an inshore area.

The survey area (full-stacked area) was 3.0 km (N-S direction) by 2.7 km (W-E direction) and about 2 km from the shoreline (Figure 5). This survey was conducted in 4patches using 2 or 3 ocean bottom cables. Receiver cables 3 km in length were laid on the sea-floor in the N-S direction and the shot lines were orthogonal to receiver lines. To obtain a 2.7 km shot-receiver offset, shot lines were extended 1.35 km out of the receiver area. Total number of receiver lines and the shot lines are 10 and 26, respectively and the water depth of this area is from 20 m to 40 m. 4-component seismic sensors were installed to the ocean bottom cables, which include three component digital accelerometers (vertical, inline and cross-line) and pressure sensors (hydrophone). Sensors were packed in 40cm length flat containers, which are less influenced by tidal currents. Three component accelerometers enable not only P-wave seismic survey but also P-Sv converted wave seismic survey which will provide S-wave velocity structure information. The air-gun volume was 1,500 in³ which was sufficient for the 3000 m depth reservoir.

A couple of target formations exist at depths of about 1,100 m – 3,000 m. The results of this survey are utilized to build the detailed 3D geological model for the CO₂ simulation. The upper reservoir, which is at 1100 m-1200 m, is expected to consist of sand channels. 3D survey results are utilized to find the distribution of the sand channels. This upper reservoir is the secondary target of this project. The lower reservoir, which depth is 2,500 m – 3,000 m, consists of volcanic rock and pyroclastic rock. To find its facies distribution, detailed seismic interpretation is currently being undertaken. Lower reservoir is main target of this project.

The survey result was also used to determine the survey well position. In the survey well drilling, detailed logging data and core samples will be obtained. With those well data, seismic interpretation and reservoir property analysis will be updated and high-integrity reservoir model will be created.

This survey is the base-line survey of the CO₂ monitoring time-lapse seismic survey. Generally, an ocean bottom cable survey is more suitable for time-lapse survey than streamer cable survey because of its repeatability of receiver position as the survey is in water depth less than 40m, and receiver position error is expected to be less than 5 m (about 10% of maximum water depth.). An acoustic positioning survey enables to the position of receivers to be determined with 1m accuracy. Then cable position will be corrected if the receiver position repeatability is not sufficient. In addition, the towing length of an air-gun array is about 50 m, much shorter than streamer cable, so air-gun shot position is also easily repeatable.

This year a secondary 3D seismic survey is being acquired from July to September. The survey area is located on the western and southern side of the previous survey. Its main purpose is to cover the entire reservoir formation
structure called the Tomakomai Ridge[4] and to have an existing deep well in the 3D seismic area for detailed interpretation. The additional information of the structure will provide a reliable long-term CO₂ storage simulation.

![Figure 4 Schematic Diagram of shallow-water 3D Seismic Survey](image)

In addition, this year survey well drilling is scheduled based on the results of 3D seismic survey (Figure 6). The aim of this survey well is to obtain formation samples and physical property data. Reservoir characterization will be updated by cuttings and core analysis, wireline logging, and hydraulic testing from the survey well.

Detailed engineering study, procurement, and construction of the surface facility and drilling injection well for the demonstration project will be carried out after a comprehensive investigation by METI.

![Figure 5 3D Seismic Survey of 2009 & 2010](image)
4. Public Acceptance

Demonstration projects are valuable to build public consensus on the development of widespread uptake of CCS. To promote a CCS project, obtaining local consent is always the top concern. Several CCS projects in other parts of the world are currently suspended because failing in the consensus process. Our public acceptance activity on Tomakomai project is steadily achieving a cooperative relationship with the local people.

Many local organizations such as Tomakomai local government and fisheries cooperative cooperated to carry out the 3D seismic survey and the Tomakomai city government has been strongly willing to invite the CCS demonstration project. With continuous cooperation and discussion with them, we will carry forward the feasibility study in order to start the CO2 injection in 2–4 years.

On April, 2008, "Tomakomai CCS Promotion Council" was established in Tomakomai city. The council is composed of local government, industries, local fishermen’s cooperative, and academic experts and is aimed at the promotion of the CCS project. JCCS has been attending this promotion council as an observer, and been providing various kinds of information to the local parties concerned and the local people. Of great importance for the first large scale CCS demonstration here in Japan is, of course, promoting the CCS project together with them through close dialogue with them, and it is the very first step in initiating this project.

5. Conclusion

The large-scale CCS demonstration project on the Tomakomai site was planned to demonstrate a comprehensive process which is composed of two different CO2 emission sources, gas pipeline and tanker trucks, and injection into a saline aquifer. A thick reservoir formation composed of volcanic rock and pyroclastic rock is widely spread in this area with mudstone more than 500 m in thickness functioning as an impermeable formation. Seal capacity and huge aquifer size are the subsurface feature of this site. To investigate this site accurately, two 3D seismic surveys and the drilling of a survey well will finish by the end of this fiscal year.

The Tomakomai demonstration project has successfully addressed cooperative relationship with the local people as the first step. Establishment of the Tomakomai CCS Promotion Council will lead toward project success, and will
Contribute to local development. The last figure illustrates the future image of Tomakomai city as CO₂ free town (Figure 7).

Figure 7  Future Image of CO₂ Free Town

Acknowledgement

This study is part of the results of "Demonstration of CO₂ reduction technologies" commissioned by METI in 2009. The authors would like to acknowledge the METI for permission to publish this paper. Several helpful discussions with the member of JCCS are gratefully acknowledged. We should like to express our grateful thanks to the Tomakomai local government and those in industry who extended us their kind assistance. At the end, we would like to express their sincere gratitude to the Tomakomai fisheries cooperative who understood CCS project and assisted in 3D seismic surveys.

Reference