GHGT-12

Tomakomai CCS Demonstration Project in Japan, 2014 Update

Yutaka Tanaka*, Masanori Abe**, Yoshihiro Sawada*, Daiji Tanase*, Toshikazu Ito*, Tetsuo Kasukawa*

*Japan CCS Co., Ltd., SAPIA TOWER 19F, 1-7-12, Marunouchi, Chiyoda-ku, Tokyo, 100-0005, JAPAN
**Japan Petroleum Exploration Co., Ltd., SAPIA TOWER 12F, 1-7-12, Marunouchi, Chiyoda-ku, Tokyo, 100-0005, JAPAN

Abstract

A large-scale CCS demonstration project is currently being undertaken by the Japanese government in the Tomakomai area, Hokkaido prefecture, Japan. The project is scheduled to run for the period JFY 2012 - 2020 to demonstrate the viability of CCS system from CO₂ capture through to injection and storage. 100,000 tonnes per year or more of CO₂ derived from an industrial source will be injected and stored in two different saline aquifers under the seabed in the offshore area of the Tomakomai Port. Construction of ground facilities and preparation of monitoring systems are progressing on schedule for planned CO₂ injection startup in 2016.

Keywords: CCS; demonstration; offshore; carbon dioxide; capture; storage; monitoring; Tomakomai

1. Introduction

The study for the CCS demonstration project in Japan was started by the Ministry of Economy, Trade and Industry (METI) just before the G8 Hokkaido Toyako Summit in 2008, following successful completion of the Nagaoka project, in which 10,400 tonnes of CO₂ was injected and stored into an onshore saline aquifer between 2003 and 2005 [1].

Japan CCS Co., Ltd (JCCS) was established in 2008 by leading Japanese companies of various categories to promote demonstration of CCS in Japan. JCCS was commissioned by METI in 2008 to investigate and survey candidate sites for implementing a large-scale CCS demonstration project in Japan. In JFY 2008, from 115 potential

* Corresponding author. Tel.: 81-3-6268-7382; fax: 81-3-6268-7385.
E-mail address: yutaka.tanaka@japanccs.com
sites, JCCS selected three candidate sites (including the Tomakomai area in Hokkaido prefecture) for further geological surveys and engineering studies [2].

As a result of the extensive amount of geological and geophysical data amassed from previous oil and gas exploration in the Tomakomai area (composed of core analyses, loggings, 2D seismic surveys and so on), only limited additional on-site investigation works were required to evaluate the suitability of the Tomakomai area for geological CO2 storage. JCCS completed its review of the suitability of the Tomakomai area in October 2011, the earliest of the three candidate sites.

Subsequently, a special committee organized by METI for implementing the CCS demonstration project evaluated and finalized two reports (entitled “Geological evaluation report of the Tomakomai area” and “Basic Plan of CCS demonstration project at the Tomakomai area” [3][4]) prepared by JCCS. The committee concluded that the Tomakomai area was a suitable site for the CCS demonstration project. In February 2012, METI decided to implement the project at the Tomakomai area and called for public tenders for the necessary preparation works, such as engineering, procurement and construction (EPC) of the facilities for the first four-year period JFY 2012 - 2015. METI formally commissioned the preparation works to JCCS in April 2012 [5].

Construction of the CO2 capture facilities, the CO2 injection facilities and the CO2 monitoring systems (for the behavior of the injected CO2 and seismicity) are currently progressing on schedule for planned CO2 injection startup in 2016. This paper outlines the plan for the demonstration project and provides an update on the project’s current progress and status.

2. Outline of the Tomakomai demonstration project

2.1. Overview of the demonstration system and the overall project schedule

The Tomakomai CCS demonstration project is planned for the period from JFY 2012 to 2020. Tomakomai City has a population of 175,000 people. The city’s economy is driven by a diverse range of industries, including fisheries, paper manufacturing and oil and gas. Tomakomai Port is an international port and serves as Hokkaido’s primary port.

Figure 1 shows the location of the project site and overview of the demonstration system. The CO2 source for the demonstration project is offgas from the PSA (Pressure Swing Adsorption) hydrogen purification system in the

![Diagram](image-url)
hydrogen production unit of an oil refinery located near the Tomakomai Port. The offgas is transferred to the neighboring CO₂ capture facility through a pipeline. Gaseous CO₂ of 99% purity is recovered in the capture facility from the offgas by a commercially proven amine scrubbing process at the rate of 100,000 tonnes per year or more and is sent to the injection facility just next to the capture facility. At the injection facility, CO₂ is compressed and injected into two different offshore reservoirs by two separate deviated injection wells.

The major targets and tasks of the project are to:
- demonstrate the viability of the full CCS system, from capture through to injection and storage;
- confirm existing technologies adopted in the system work properly and efficiently;
- demonstrate that large-scale CCS systems are safe and reliable;
- confirm the effectiveness of the site selection guidelines prepared by METI (by demonstrating no CO₂ leakage);
- demonstrate that anxiety about the risk of earthquakes associated with CCS is not justified, specifically, by showing that:
  - natural earthquakes do not influence or negatively impact stored CO₂; and
  - CO₂ injection does not cause any perceptible increase in earth tremors;
- confirm guidelines for building and improving geological models;
- prepare technical standards and guidelines for operations and safety in the project;
- share information and data from the project with the public and relevant community groups in order to increase awareness and understanding of the benefits and viability of CCS; and
- clearly define areas which need to be further improved or issues that need to be resolved to allow the technology to move to a commercial scale.

Japan's 4th Strategic Energy Plan, approved by the cabinet in April 2014, states to promote development of next-generation high efficiency coal thermal power generation technologies and the CCS technology for the efficient and stable use of fossil fuels, as well as long term reliance on renewable energies. For practical use of CCS technology around 2020, R & D will be conducted. METI and Ministry of Environment (MOE) started a joint project in 2014 to survey geological reservoirs which could be used for commercial scale CCS projects in the future. The CO₂ geological storage capacity in Japan has been estimated by Research Institute of Innovative Technology for the Earth (RITE) as approximately 146 gigatonnes in total [6].

Figure 2 shows the overall schedule of the demonstration project including the investigation and survey period which prior to the start of the Tomakomai project (from JFY 2008 to 2011). During the preparation period (from JFY 2012 to 2015), all of the necessary facilities and systems will be prepared and constructed, including: CO₂ capture facility, CO₂ injection facility, two injection wells, three observation wells and various monitoring systems including onshore and offshore seismometers. Baseline data from all of the monitoring systems will also be acquired during this period. Following the preparation period, CO₂ will be injected for three years and monitored for five years. The detailed operation and monitoring schedule after 2016 is to be determined during the preparation period.

2.2. Reservoirs and the injection points

The Tomakomai project uses two reservoirs for CO₂ storage. The first reservoir is the T1 Member of the Takinoue Formation, located at a depth of approximately 2,400 m to 3,000 m below the seabed. This reservoir is a
Miocene saline aquifer composed of volcanic and volcaniclastic rocks and is approximately 600 m thick. The formation has an estimated porosity of 3 to 19% and an estimated permeability of 0.01 md to 7 md. The Takinoue Formation is covered by approximately 1,100 m of Miocene mudstone (Fureoi Formation, Biratori-Karumai Formation and Nina Formation) as cap rock, as illustrated in Figure 3. The formation has an anticlinal structure with a NNW-SSE trending axis in a wider range. The planned storage point for the Takinoue Formation is located the north-eastern wing of the anticline and is located about 4 km offshore.

The second reservoir is a sandstone layer of the Moebetsu Formation, located at a depth of approximately 1,100 m to 1,200 m below the seabed. This reservoir is a Lower Quaternary saline aquifer and is approximately 100 m thick. The formation has an estimated porosity of 20 to 40% and an estimated permeability of 9 md to 25 md. The reservoir is covered by thick mudstone layer of the Moebetsu Formation (approximately 200 m thick) as cap rock. The Moebetsu Formation has a gentle monocline structure with a NE dip of 1 to 3 degrees at the planned storage point (which is located about 3 km offshore).

During the investigation and survey period, long term CO₂ behavior was simulated to determine the likely extension of the CO₂ plume and the likely CO₂ dissolved area in each reservoir. The simulation was based on injection duration of three years at a rate of 250,000 tonnes per year. Based on the simulation result, the extension of CO₂ in the Takinoue Formation is expected to be stabilized after 200 years, with a major axis of 800 m in the horizontal direction. In the case of the Moebetsu Formation, the result suggests that the extension of CO₂ will be stabilized after 20 years, with a major axis of 600 m in the horizontal direction. In both reservoirs the result indicates that after CO₂ injection is stopped, the pressure in the reservoir will drop rapidly and will stabilize approximately two years.

3. Progress of the preparation works

Figure 4 shows the updated schedule for the preparation period. All preparation works have been progressing smoothly with the cooperation and understanding of the local Tomakomai community.
3.1. Capture and Injection facilities

The CO2 source for the Tomakomai project is offgas from an oil refinery located near the Tomakomai Port. In the oil refinery, high purity hydrogen for hydrotreating is recovered by the PSA system from raw reformed gas. The raw reformed gas is produced from naphtha via steam reforming and CO shift conversion. The remaining gas from the PSA system, referred to as PSA offgas, contains H2, CH4, CO and a large amount of CO2 (44-59% by volume). This gas is currently used as part of the fuel for the reformer furnace. In the demonstration project, up to 60% of the PSA offgas is planned to be diverted to the neighbouring CO2 capture facility through a pipeline.

![CO2 flow diagram](image)

**Fig. 5 CO2 flow from the capture facility to the injection facility**

Figure 5 shows the CO2 flow from the capture facility to the injection facility. At the capture facility, gaseous CO2 of 99% purity is recovered from the PSA offgas by an activated amine process at a rate of 100,000 tonnes per year or more from the PSA offgas. A two-stage absorption system with a low pressure flash tower has been selected to reduce energy consumption in the capture system. As a result, the total energy consumption is reduced to 1.5
GJ/tonne-CO$_2$ or less (including energy required for heat input for amine regeneration and electricity consumption for amine solution circulation). Following CO$_2$ capture, the remaining gas (which contains H$_2$, CH$_4$ and CO) is utilized as fuel for the capture facility’s steam and electric power generation facilities.

At the injection facility, the gaseous CO$_2$ is injected into two different offshore reservoirs through separate injection wells. Each injection pressure is attuned to the individual reservoir conditions, with low pressure compression system for the Moebetsu Formation and high pressure compression system for the Takinoue Formation. All compressors have been selected as centrifugal type to allow the project to obtain operational data and experience which can be applied in future commercial scale CCS projects. Allocation of the injection rate of CO$_2$ into each reservoir depends on the operational load of the oil refinery during the injection period. Allocation of injection rates will also depend on the exact reservoir conditions, which will be determined after the drilling of the injection wells.

In July 2014 on-site construction of the ground facilities was started after the ground-breaking ceremony. The ground facilities are expected to be completed in late 2015 and will be commissioned shortly after that. Figure 6 shows a bird’s eye view of the capture and injection facilities following completion of the ground facilities.

3.2. Injection wells

Two highly deviated injection wells will be drilled from the onshore injection facility site and will target the most promising points of each reservoir. The storage points are located 3 to 4 km offshore.

The injection well for the Takinoue Formation, IW-1, is proposed to have a maximum inclination of 72 degrees and a planned drill depth of 5,800 m, vertical depth of 2,754 m and horizontal reach of 4,347 m.

The injection well for the Moebetsu Formation, IW-2, is proposed to be an extended reach drilling (ERD) well with a maximum inclination of 83 degrees and a planned drill depth of 3,500 m, vertical depth of 1,161 m and horizontal reach of 2,900 m (Figure 7). In IW-2, a perforated liner will be covered by sand control screens at the reservoir zone. The perforated liner and screens will help to minimize sand flow back into the well, which was identified as a risk after observation wells were drilled into that reservoir.

Drilling of the two injection wells will start in October 2014 and is scheduled to be completed in the first quarter of JFY 2015. IW-1 is proposed to be drilled prior to IW-2 to reconfirm the characteristics and conditions of the Moebetsu Formation and to ensure secure drilling of IW-2.
surveys will be performed over the same area during the life of the project. 2D seismic surveys will also be used to recorded. Baseline data on temperature, pressure and seismicity will be collected from the end of JFY 2014. Using the seismometers and the OBC, micro-seismicity and natural earthquakes will be continuously observed and have also been installed above and surrounding the storage points. One onshore seismometer has also been laid out. located directly above the storage points of the reservoirs. Four independent ocean bottom seismometers (OBSs) bottom cable (OBC) has already been installed. The OBC is 3.6 km long and includes 72 seismometers which are monitoring items and Figure 8 illustrates the layout of the monitoring facilities.

3.3. Monitoring systems

In order to confirm that CO₂ is injected and stored safely and stably, it is necessary to monitor the behavior of CO₂ in the reservoirs and to set up systems to detect CO₂ leakage out of the reservoirs. As the project is located in Japan, a region which is highly susceptible to earthquakes, it is also necessary to allocate systems to measure and verify any correlation (or lack of correlation) between CO₂ storage and seismicity. Table 1 shows the planned monitoring items and Figure 8 illustrates the layout of the monitoring facilities.

Table 1 Planned monitoring items

<table>
<thead>
<tr>
<th>Items</th>
<th>Observed objects</th>
<th>Observation frequency</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection well</td>
<td>◆Downhole : temperature and pressure</td>
<td>Continuous</td>
<td>◆One injection well for Takinoue Formation</td>
</tr>
<tr>
<td></td>
<td>◆Wellhead : pressure, injection rate of CO₂</td>
<td></td>
<td>◆One injection well for Moebetsu Formation</td>
</tr>
<tr>
<td>Observation well</td>
<td>◆Downhole : temperature and pressure, micro-seismicity</td>
<td>Continuous</td>
<td>◆One observation well converted from the survey well</td>
</tr>
<tr>
<td></td>
<td>and natural earthquakes</td>
<td></td>
<td>◆One observation well for Takinoue Formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>◆One observation well for Moebetsu Formation</td>
</tr>
<tr>
<td>OBC : ocean bottom</td>
<td>◆Micro-seismicity and natural earthquakes</td>
<td>Continuous</td>
<td>◆OBC line passes directly above the injection points of reservoirs.</td>
</tr>
<tr>
<td>cable</td>
<td>◆Signal of 2D seismic survey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OBS : ocean bottom</td>
<td>◆Micro-seismicity and natural earthquakes</td>
<td>Continuous</td>
<td>◆Above the injection point of Takinoue Formation : one unit</td>
</tr>
<tr>
<td>seismometer</td>
<td>◆Signal of 2D seismic survey</td>
<td></td>
<td>◆Surrounding area of injection points of two reservoirs : three units</td>
</tr>
<tr>
<td>Onshore seismometer</td>
<td>◆Micro-seismicity and natural earthquakes</td>
<td>Continuous</td>
<td>◆West region of Tamakomai City</td>
</tr>
<tr>
<td>2D seismic survey</td>
<td>◆Distribution of CO₂</td>
<td>Periodic</td>
<td>◆Utilizing OBC as seismic sensors</td>
</tr>
<tr>
<td>3D seismic survey</td>
<td>◆Distribution of CO₂</td>
<td>Periodic</td>
<td>◆Baseline survey was completed during the investigation period.</td>
</tr>
<tr>
<td>Marine environmental</td>
<td>◆Chemical, physical and biological data</td>
<td>Periodic</td>
<td>◆Monitoring plan is to be drawn up after the baseline survey and marine environmental impact assessment.</td>
</tr>
<tr>
<td>monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At the injection wells, CO₂ injection rate, temperature and pressure will be continuously monitored. In three observation wells, temperature and pressure sensors along with downhole seismometers will be installed. An ocean bottom cable (OBC) has already been installed. The OBC is 3.6 km long and includes 72 seismometers which are located directly above the storage points of the reservoirs. Four independent ocean bottom seismometers (OBSs) have also been installed above and surrounding the storage points. One onshore seismometer has also been laid out. Using the seismometers and the OBC, micro-seismicity and natural earthquakes will be continuously observed and recorded. Baseline data on temperature, pressure and seismicity will be collected from the end of JFY 2014.

A 3D seismic survey of the working area (3.8 km×4.1 km) was first conducted in 2009. Time lapse 3D seismic surveys will be performed over the same area during the life of the project. 2D seismic surveys will also be used to...
supplement the blank period of data between the 3D seismic surveys. In total, four 2D seismic surveys (including the baseline survey completed in 2013) and two 3D seismic surveys will scheduled to be conducted until the project ends in JFY 2020. The OBC system, which was developed by RITE, has been selected to improve the accuracy of data obtained from the repeated 2D seismic surveys with the fixed sensors.

![Fig. 8 Layout of the monitoring facilities](image)

Data obtained from the monitoring facilities during the preparation period will be used to improve and refine the models used to simulate the behavior of CO₂ in the reservoirs (see section 2.2 above). The data obtained from these facilities will be used to continuously improve the accuracy of the models over the life of the project.

Drilling operations for the observation wells for the Moebetsu Formation, OB-2, and for the Takinoue Formation, OB-3, were completed in March 2013 and in April 2014 respectively. Retrofitting work to the observation well for the Takinoue Formation, OB-1, from the existing survey well was completed in January 2014.

### 3.4. Marine environmental monitoring

In Japan, CO₂ geological storage below the seabed is regulated by the Act on Prevention of Marine Pollution and Maritime Disaster (as amended in JFY 2007 to reflect changes to the London Protocol allowing sub-seabed storage of CO₂). Under the Act a marine environmental assessment is necessary before an application to obtain a CO₂ storage permit can be made. In order to complete the assessment, baseline marine surveys (covering chemical, physical and biological aspects) were prepared for each season. These surveys were started in August 2013 and were completed in May 2014.

As required by the Act, periodic assessments are required throughout the demonstration operation period (from JFY2016 to 2020) and in the years following the completion of the project.

### 4. Public outreach

Public outreach is of vital importance to the success of CCS projects. In Tomakomai, consultation with local stakeholders (such as the local government, related organizations including the local fishermen's cooperative and
local residents) started before the first 3D survey in JFY2009. Repeated explanations were also made for local communities in advance of each field survey.

Since JFY 2011 (the final year of the site evaluation process), a wide range of public outreach programs have been implemented. For example:

- CCS forums were held 3 times in Tomakomai (which have been attended by more than 700 people);
- panel exhibitions were organized more than 60 times in Tomakomai, neighboring towns and Sapporo City (the capital of Hokkaido prefecture);
- kids science rooms were organized 10 times in Tomakomai;
- multiple site visits were arranged which the community have been invited to attend.

As a result of these initiatives, community awareness and understandings of CCS and the demonstration project has been growing gradually in the Tomakomai and nearby areas.

On a broader scale however, recognition and understanding of CCS is still relatively low in the wider Japanese community, especially compared to general community knowledge of photovoltaic power generation technologies. In an effort to improve knowledge of CCS in Japan more broadly, in JFY 2013, JCCS attended "Eco Products 2013", the largest environmental exhibition in Japan, and presented a public exhibition on CCS. The exhibition gave JCCS an opportunity to introduce CCS to a large number of people (especially children) and involved three-dimensional models (georama) of CCS and a cartoon movie. Lectures on CCS at various universities were also presented more than 30 times all over Japan.

5. Conclusion

The Tomakomai CCS demonstration project is planned for the period from JFY 2012 to 2020 by METI. The project is intended to demonstrate and verify the viability of large-scale full CCS systems from capture through to injection and storage. The Tomakomai project will capture and store 100,000 tonnes per year or more of CO₂. The CO₂ source is a hydrogen production unit in an oil refinery located near the Tomakomai Port, Hokkaido Prefecture. Gaseous CO₂ with 99% purity will be recovered in the capture facility and will be injected into two different offshore reservoirs (located in the Takinoue Formation and the Moebetsu Formation respectively), by two separate deviated injection wells.

The demonstration facilities will be prepared during the first four-year period (JFY 2012 – 2015). During this period, all of the necessary facilities and systems will be prepared including the CO₂ capture facility, CO₂ injection facility, two injection wells, three observation wells and various onshore and offshore monitoring systems. The preparation works are currently progressing on schedule for planned CO₂ injection startup in 2016. In addition, a wide range of public outreach programs have been developed and run in parallel with the preparation works.

Acknowledgements

The authors would like to express their thanks to METI for their kind permission to share the above information on the Tomakomai CCS Demonstration Project.

References