TOMAKOMAI CCS DEMONSTRATION PROJECT

- ACHIEVEMENTS AND FUTURE OUTLOOK

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Abstract

The Tomakomai CCS Demonstration Project is being conducted over a nine-year period from JFY* 2012 to 2020. The original plan comprised a four years construction, three years CO_2 injection and two years post-injection monitoring period, aiming to establish CCS technology for practical use by around 2020.

The main objectives and tasks of the project were; 1) demonstrate a full-chain CCS system from capture to storage, 2) demonstrate that the CCS system is safe and reliable, 3) remove concerns about earthquakes by the data collected (As Japan is an earthquake-prone country, removing concerns regarding earthquakes by establishing that natural earthquakes will not affect the CO_2 stored, and conversely that the CO_2 injection will not induce perceptible tremors is vital), 4) enhance the understanding of CCS through information disclosure and public engagement activities and, 5) acquire operational technology as well as strive towards practical implementation.

The project achieved the following results. 1) The operation of a full chain CCS system from capture to storage was conducted successfully, and the target of 300,000 tonnes of CO_2 injection was achieved in November 2019. 2) No micro-seismicity or natural earthquakes attributable to CO_2 injection were detected in the vicinity of the injection area. 3) The time-lapse monitor seismic surveys showed clear anomalies reflecting the evolution of the CO_2 plume. 4) No abnormalities suggesting seepage of injected CO_2 into the ocean have been detected in the marine environmental survey. 5) 2018 Hokkaido Eastern Iburi Earthquake of moment magnitude (Mw) 6.6 did not affect the CO_2 stored. 6) The public outreach program has been largely successful, with no major opposition to the project. Information disclosure and diligent efforts to secure the understanding of local stakeholders were of utmost importance.

As a future step, the Japanese government plans to implement a CCU demonstration project making efficient use of the Tomakomai facilities and CO_2 ship transportation. JCCS is presently supporting a feasibility study being conducted by the Ministry of Economy, Trade and Industry (METI) and the New Energy and Industrial Technology Development Organization (NEDO). (*JFY denotes April of calendar year to following March)

Keywords: *CCS; demonstration; two-stage absorption; micro-seismicity, earthquake; public outreach*

1. Introduction

The Tomakomai CCS Demonstration Project, Japan's first full-chain CCS demonstration project is being conducted by Japan CCS Co., Ltd. (JCCS) in Tomakomai City, Hokkaido Prefecture, Japan. The project has been conducted over a nine-year period from JFY 2012 to 2020. The project was commissioned to JCCS by METI between JFY2012 and 2017, and from JFY2018 by NEDO with subsidies from METI.

JCCS was founded in May 2008 when a group of major companies with expertise in CCS-related fields, including electric power, petroleum, oil development, and plant engineering, joined forces to answer the Japanese government's call for development of CCS technology. The project schedule is shown in Fig.2 respectively.

Prior to the selection of Tomakomai as the demonstration project site, site surveys and a site selection process were conducted from JFY 2008 to 2011. At first, there were 115 candidate locations. After an evaluation of existing data and site surveys, Tomakomai was finally selected due to technical reasons including the confirmation of a good reservoir and overlying cap rock, and that no active faults were found at the Tomakomai site. In addition, the local community, in particular the Tomakomai city mayor supported the project. The support by the city mayor was decisive. Furthermore, the Tomakomai CCS site was located in an oil exploration area, and one of the leading shareholders of JCCS had acquired a lot of geological data. The abundance of existing geological data made it possible to characterize the CCS site within a limited period.

The original project schedule comprised a four-year construction, three-year CO_2 injection and two-year post-injection monitoring period, aiming to establish CCS technology for practical use by around 2020.

The main objectives and tasks of the project are as follows:

- Demonstrate a full-chain CCS system from capture to storage
- Demonstrate that the CCS system is safe and reliable
- Remove concerns about earthquakes by the data collected;
    - No influence by natural earthquakes on CO_2 stored
    - No perceptible earth tremors induced by CO_2 injection
- Disclose project information and data and enhance understanding of CCS by local residents
- Acquire operational technology as well as strive towards practical implementation.

As Japan is an earthquake-prone country, removing concerns regarding earthquakes is vital.

The actual CO_2 injection period was three years and eight months. The target of 300,000 tonnes of CO_2 injection was achieved in November 2019. Monitoring operations are being continued (Fig.1).

This paper presents the main results and the lessons learned from the project.

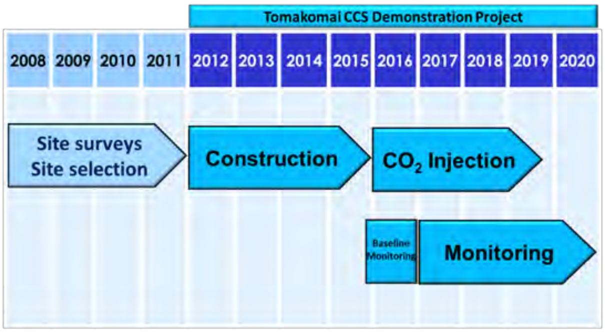


Figure 1: Project schedule

2. Overview of the Tomakomai Project

The project scheme and a bird's eye view of the facilities are shown in Fig.2 and Fig.3 respectively. The CO_2 source is an HPU (hydrogen production unit) of an oil refinery neighbouring the capture facility. At the HPU, hydrogen is produced by a PSA (pressure swing adsorption) process and a portion of the CO_2-rich PSA off gas is sent to the CO_2 capture facility by a pipeline 1.4km in length. At the capture facility, gas phase CO_2 of 99% or higher purity is recovered from the off gas by an activated amine scrubbing process with a maximum capacity of 25.3 tonnes per hour (~200,000tonnes/year), and is sent to the injection facility.

At the injection facility, the gas phase CO_2 is compressed and injected into two offshore reservoirs deep below the seabed of the Tomakomai port area, namely, the sandstone layer of the Lower Quaternary Moebetsu formation at 1,000 to 1,200 m in depth and approximately 3 km off the coastline, and the volcanic and volcaniclastic Miocene Takinoue formation at 2,400 to 3,000 m in depth and approximately 4km offshore.

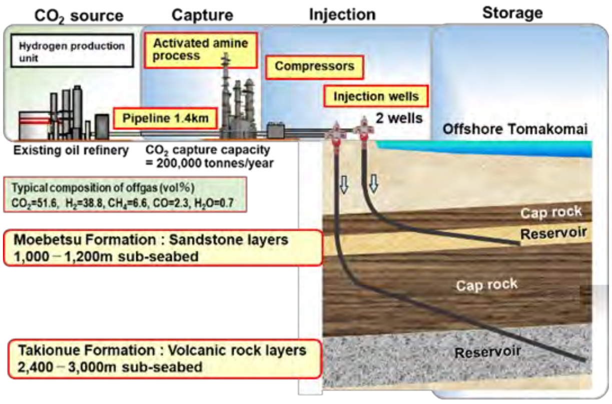


Figure 2: Project scheme

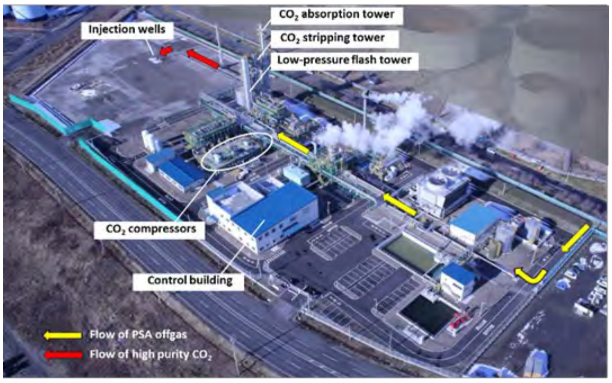


Figure 3: Bird's eye view of facilities

3. Key Results of Tomakomai Project

3.1 CO_2 capture

The CO_2 capture process used in the Tomakomai project is a commercially proven amine scrubbing process (OASE® by BASF), and the capture facility is comprised of a two-stage CO_2 absorption tower, a CO_2 stripping tower and a Low-Pressure Flash Tower (LPFT), as shown in Fig. 4. The maximum CO_2 capture rate is 25.3 tonnes per hour.

The PSA off gas enters the lower stage of the two-stage CO_2 absorption tower, where CO_2 is absorbed by an amine solution pouring from the upper part of the tower, thereby generating a CO_2 rich amine. The CO_2 rich amine is sent to the LPFT, where 60-70% of CO_2 is stripped by the effect of depressurization and the heat of CO_2 flow from the CO_2 stripping tower, and a CO_2 semi-lean amine is generated. The greater part of the semi-lean amine is recycled to the upper part of the lower stage of the CO_2 absorption tower, and the remainder is sent to the CO_2 stripping tower. In the CO_2 stripping tower, the semi-lean amine is heated by an amine reboiler, where the CO_2 is stripped and sent to the LPFT. The regenerated CO_2 lean amine is recycled to the upper stage of the CO_2 absorption tower. Finally, CO_2 of 99% or higher purity is captured at the top of the LPFT.

The two-stage absorption system results in a significant reduction of the amine reboiler duty in the CO_2 stripping tower as only a small amount of semi-lean needs to be sent to the CO_2 stripping tower. The reboiler duty was measured as approximately 0.9 GJ/t-CO_2 or less for the typical composition of PSA off gas as shown in Table 1, which is a significantly low energy consumption.

The gross capture energy including the boiler efficiency and pump electricity was about 1.2 GJ/t-CO_2 .

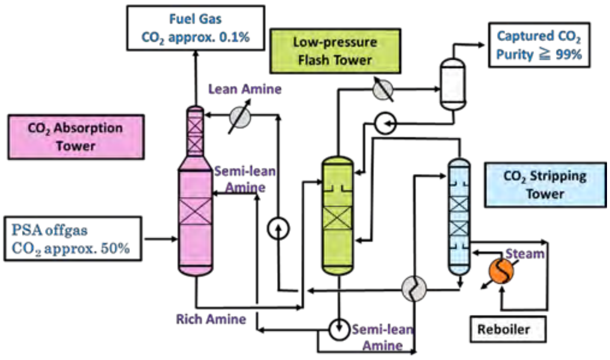


Figure 4: Two-stage absorption process

Table 1: Reboiler duty

	FY2016	FY2017	FY2019
CO_2 recovery (t/h)	25.3	24.3	26.4
Reboiler duty (GJ/t-CO_2)	0.923	0.882	0.915

3.2 CO_2 injection and monitoring

3.2.1 Reservoirs and injection wells

A schematic geological section is shown in Fig.5 with profiles of the injection wells. For CO_2 storage, the Tomakomai project targets two independent reservoirs of different depths and different lithofacies.

The shallow reservoir is a sandstone layer of the Moebetsu formation (hereinafter "the Moebetsu formation"), located at a depth of 1,000 m to 1,200 m below the seabed. This reservoir is a Lower Quaternary saline aquifer and is approximately 200 m thick with an average porosity of 22%.

The deep reservoir is the T1 Member of the Takinoue formation (hereinafter "the Takinoue formation"), located at a depth of 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 with an average porosity of 13%.

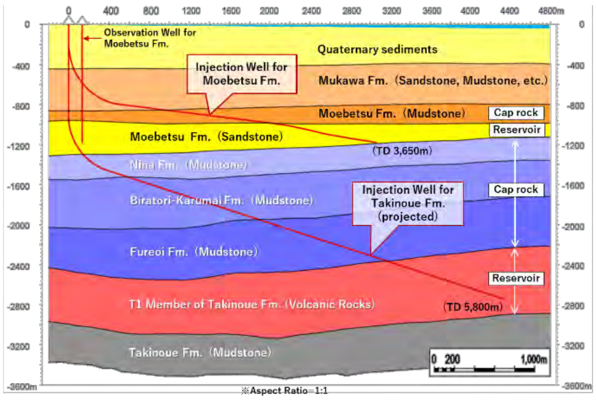


Figure 5: Schematic geological section

The injection well for the Moebetsu formation is an extended reach drilling (ERD) well with a maximum inclination of 83 degrees and a horizontal reach of approximately 3km (Fig. A). The injection interval of the injection well for the Moebetsu formation is approximately 1.2 km in length. The injection well for the Takinoue formation has a maximum inclination of 72 degrees with a horizontal reach of approximately 4.3 km. The injection interval of the injection well for the Takinoue formation is approximately 1.1 km in length. The onshore to offshore injection scheme saved drilling cost and avoided disturbing the harbor operations and fishing activities.

3.2.2 Monitoring System

In order to confirm that CO_2 is injected and stored safely and stably, it is necessary to monitor the behavior of the injected CO_2 in the reservoirs. As Japan is highly susceptible to earthquakes, it is also necessary to allocate systems to monitor and verify that there is no relationship between the CO_2 storage and seismicity. The schematic diagram of the monitoring system, the layout of the monitoring facilities and the monitoring items are shown in Fig.6, Fig.7 and Table 2 respectively.

At the two injection wells, downhole temperatures and pressures are continuously monitored. Temperature and pressure sensors and downhole seismometers are installed in the three observation wells. An ocean bottom cable (OBC) 3.6 km long permanently buried below the seabed with 72 seismometers is deployed directly above the storage area of the reservoirs. Four ocean bottom seismometers (OBSs) are placed above and surrounding the CO_2 storage areas. Additionally, one onshore seismic station is set up in the northwestern part of Tomakomai City.

3.2.3 Marine Environmental Survey

In Japan sub-seabed CO_2 storage is governed by the Act for the Prevention of Marine Pollution and Maritime Disaster, reflecting the London Protocol, and administered by Ministry of the Environment (MOE). On February 22, 2016, METI submitted a permit application for offshore CO_2 storage at Tomakomai area to MOE attaching a prescribed monitoring plan that provided for the conduct of seasonal marine environmental surveys consisting of chemical measurements of seawater and sea bottom sediments, as well as plankton and benthos observation at twelve

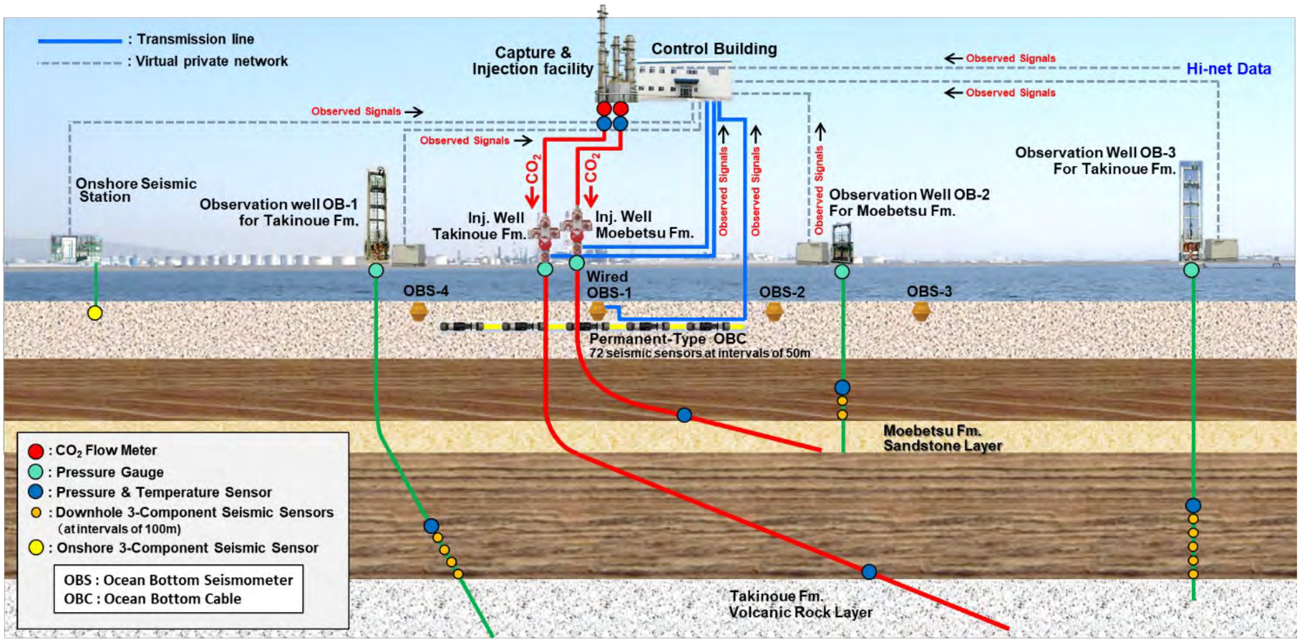


Figure 6: Schematic diagram of monitoring system

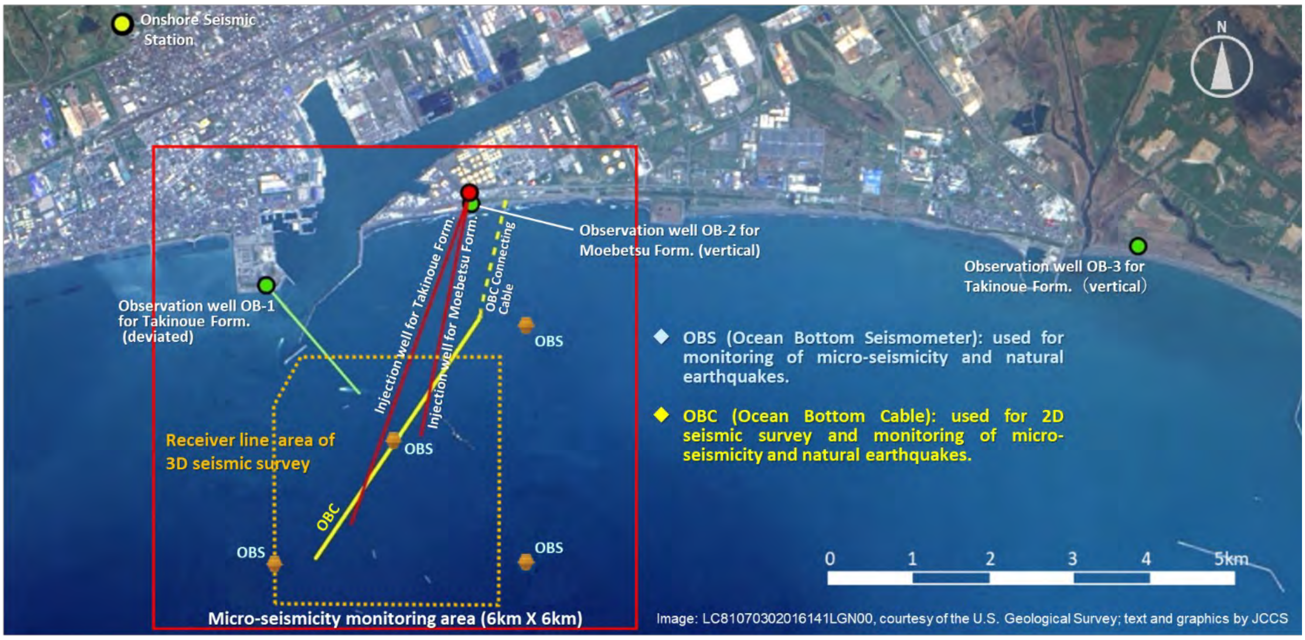


Figure 7: Layout of monitoring facilities

Table 2: Monitoring items

Equipment/Work	Monitored Items
Injection facilities	Temperature, pressure, CO_2 injection rate
Injection wells	Downhole: temperature, pressure Wellhead: pressure
Observation wells	Downhole: temperature, pressure, seismicity
Ocean Bottom Cable (OBC)	Seismicity, receiver for 2D seismic survey
Ocean Bottom Seismometers (OBS)	Seismicity
Onshore seismometer	Seismicity
2D seismic survey 3D seismic survey 2D seismic survey plus mini-3D survey	Distribution of CO_2 in reservoir
Marine environmental survey	Marine data (physical, chemical properties, biological habitat, etc.)

survey points above and surrounding the injection areas during and after CO_2 injection, as shown in Fig. 8.

In the February 2016 monitoring plan, the marine environmental survey consists of four phases: “regular survey (regular seasonal marine environmental survey)”, “additional survey” of regular survey, “precautionary survey”, and “contingency survey”, in which a threshold line based on the relationship between partial pressure of CO_2 (pCO_2) and dissolved oxygen (DO) of sea water was used as the criterion for transition of survey phases. The initial threshold line was established based on data obtained in seasonal baseline surveys conducted between August 2013 and May 2014 in accordance with the requirement of MOE.

In case of exceedance of the threshold line, an "additional survey" of chemical re-measurements of sea water was to be conducted at the point(s) of the exceedance. In case of exceedance of the threshold line in the additional survey, CO_2 injection was to be suspended, and the survey phase would proceed from the "regular survey" to a "precautionary survey" consisting of re-re-measurements of sea water at the point(s) of the exceedance. In case of exceedance of the threshold line in the precautionary survey, a "contingency survey" of re-re-re-measurements of sea water was to be conducted.

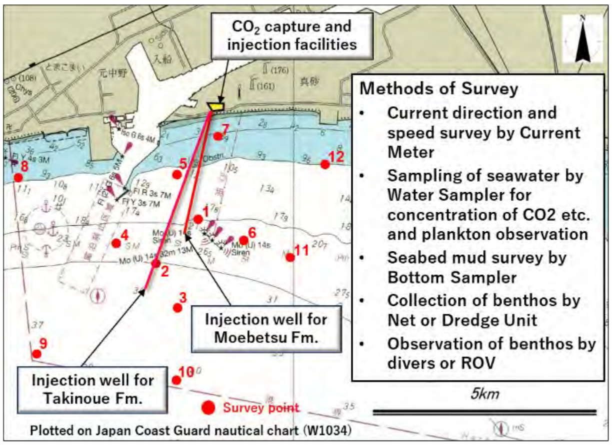


Figure 8: Marine Environmental Survey

3.2.4 Injection Results

The injection record of the Moebetsu formation is shown in Fig.9. As for the injection well for the Moebetsu formation, the maximum operational limit of downhole pressure during CO_2 injection was set as 12.6 MPaG, which is 90% of the leakoff pressure of the cap rock obtained from an extended leakoff test conducted during the drilling of the injection well. During periods of injection, the downhole pressure rose only slightly from an initial pressure of 9.3 MPaG to a maximum pressure of 10.0 MPaG implying that the injectivity of the Moebetsu formation was very high.

On the other hand, the Takinoue Formation, a volcanic and volcaniclastic rocks layer, indicated very low injectivity at the injection well. An exploration well drilled near the injection well found the formation to be composed of lava and tuff breccia, and good injectivity was confirmed by water injection tests. However, when the injection well was drilled, the reservoir around the well was found to be dense tuffaceous rock and the injectivity was confirmed to be very low. Test injections into the Takinoue Formation were conducted from February 6 to February 23, 2018, and from July 31 to September 1, 2018. As the injectivity of the Takinoue formation was much lower than expected, the cumulative injection of CO_2 ended in 98 tonnes.

The spatial lithological variation of volcanic and volcaniclastic rocks is in general very large, and we learned that it was very difficult to predict their heterogeneity in advance.

The target of 300,000 tonnes of CO_2 injection was achieved in November 2019. Monitoring operations are being continued.

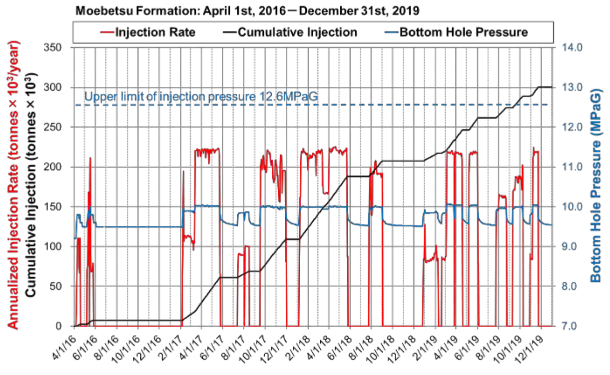


Figure 9: CO_2 injection record of Moebetsu Formation

3.2.5 Monitoring Results

The seismicity monitoring results in the monitoring area for micro seismicity are shown in Fig. 10 and 11 respectively. The detectability is Mw (moment magnitude) > -0.5. Before the start-up of CO_2 injection, a total of nine events were detected, whereas a total of three events were detected during injection, and one event was detected after injection. As shown in Fig.10, all the events have occurred in the same area with a depth of approximately 6 to 8 km and in the Cretaceous basement igneous rocks. No micro-seismicity or natural earthquakes attributable to CO_2 injection have been detected in the vicinity of injection area between start-up of injection and October 3, 2020.

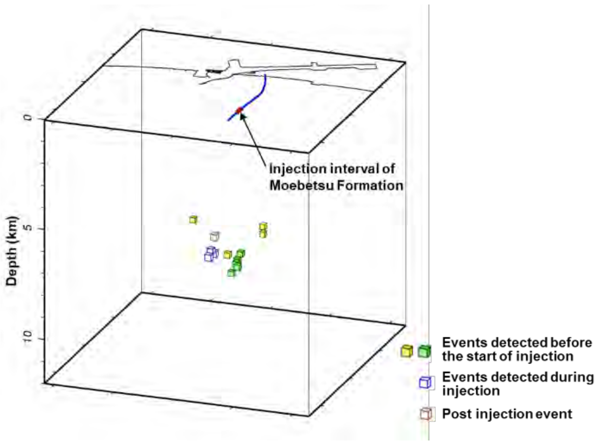


Figure 10: Micro-seismic events detected (1)

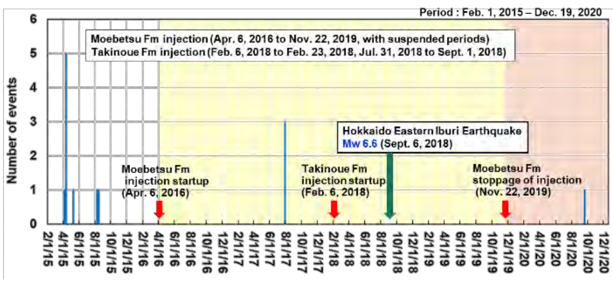


Figure 11: Micro-seismic events detected (2)

We have conducted seismic surveys two times before injection, three times during injection and two times after termination of injection. The time-lapse monitor seismic surveys at cumulative CO_2 injection of approximately 65,000, 207,000 and 300,000 tonnes into the Moebetsu Formation have detected amplitude anomalies. Growth of the anomaly is observed in the seismic data acquired at 65,000 tonnes and 300,000 tonnes injection, indicating the evolution of the CO_2 plume (Fig. 12).

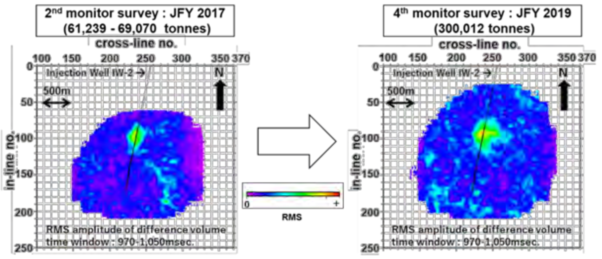


Figure 12: Comparison of 2nd and 4th monitor surveys

3.2.6 Marine environmental survey results

In June 2016, the spring regular survey was conducted, and the initial threshold line shown in Fig.13 was exceeded at several survey points. In July, in accordance with the monitoring plan, re-measurements of sea water were conducted as an "additional survey", and again resulted in exceedances of the threshold. The prescribed "precautionary survey" was further conducted, and again resulted in exceedances of the threshold. A "contingency survey" of re-re-remeasurements of sea water was conducted from August to September, but resulted in no exceedances of the threshold.

In October 2016, METI reported all the results to MOE. After assessment of the results, MOE judged that the exceedances of the threshold were not caused by CO_2 leakage, and instructed METI to revise the monitoring plan by adding the implementation of new investigation items such as towed pH sensor survey and side-scan sonar bubble detection to the "additional survey" before proceeding to the "precautionary survey".

A supplemental permit application with the revised monitoring plan was accepted by the MOE on February 1, 2017, and CO_2 injection was resumed on February 5, 2017, after a six-month suspension.

Subsequently, in the regular seasonal marine environmental surveys, "additional surveys" were conducted on two occasions following exceedances of the threshold line. Each time, no anomalies of pH, bubbles from the seabed or re-exceedance of the threshold were detected. All the results were reported by METI to MOE, and METI received official statements from MOE on each occasion that seepage or threats of seepage of injected CO_2 into the ocean were not detected. Another exceedance of the threshold was detected in August 2020 at 5 survey points, and an "additional survey" was completed by November 2020, resulting in no anomaly.

As for chemical measurement of sea bottom sediments, and plankton and benthos observation, no abnormalities have been detected.

Under the Act for the Prevention of Marine Pollution and Maritime Disaster, METI must obtain permission from the MOE every five years forever, as long as this 300,000 tonnes of CO_2 remains in the reservoir. Preparations of the permit application for the next five years from JFY 2021 to 2015 are underway.

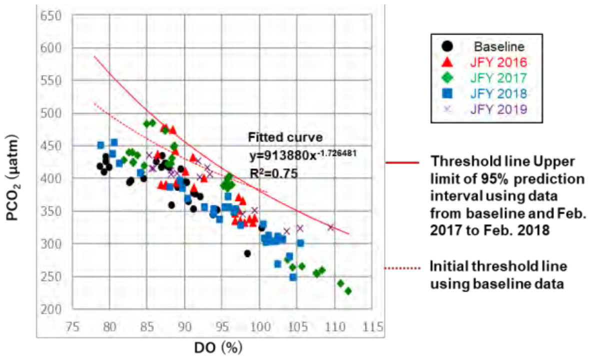


Figure 13: Results of marine environmental survey

3.3 Public Outreach

3.3.1 Public outreach activities

As the project is being conducted close to the center of Tomakomai, a large industrial city with a population of approximately 170,000, extensive public outreach is being carried out. A survey conducted in 2011 for the residents of Tomakomai found that their main concerns were information disclosure, safety of CO_2 storage, and dissemination to the young generation, which were reflected in our public outreach activities.

We concentrated our efforts on securing the trust of the local community through sustained communication as well as risk communication on such topics as CO_2 leakage and induced seismicity.

Our public outreach activities have comprised forums for local residents (Fig.14), panel exhibitions, exhibits at environmental conferences, site tours (Fig.15), lectures, and experiment classes for schoolchildren. We have also maintained an information disclosure system in the city hall of Tomakomai.

As a result of these activities, we have maintained a good relationship with the local community. We would like to stress the importance of information disclosure and diligent efforts to secure the understanding of local stakeholders.

A key factor was the strong support of the city mayor and the local government, which formed the Tomakomai CCS Promotion Association in April 2010, during the site selection process to attract the CCS demonstration project to Tomakomai City. The association has been chaired by the mayor of Tomakomai and comprises all the major local industries including the fishery cooperatives.

Figure 14: CCS Forum for Citizens

Figure 15: Site Tour

3.3.2 Experience of Major Earthquake

Our activities and public acceptance of CCS in Japan were subjected to a serious trial by the occurrence of a major earthquake in September 2018. The moment magnitude (Mw) was 6.6 (Japan Meteorological Agency Magnitude 6.7), which is quite large even in Japan. The epicenter was 30km from the injection area, at a depth of 37km (Fig.16), and caused massive destruction in a nearby village. A maximum acceleration of 158gal was recorded at the demonstration site, but no damage was incurred by the facilities.

The diagram in Fig.17 shows the conditions in the Moebetsu formation injection well before and after the earthquake. We had been injecting from July, which is indicated by a rise in the bottomhole temperature and pressure. Five days prior to the earthquake, the supply of CO_2 from the refinery stopped due to technical reasons, causing a suspension of injection, and the temperature and pressure in the well were in decline. It was during this decline that the earthquake struck. It caused a black out, and our data acquisition system lost power, causing a break in the data.

However, when we regained power three days later the continuation of the decline in the well temperature and pressure can be observed, clearly indicating that the conditions in the reservoir where unaffected by the earthquake.

JCCS convened an expert review meeting one month after the earthquake. A comprehensive review was conducted, and the unanimous conclusion was that no leakage of CO_2 had been caused by the earthquake, and that there was no data suggesting a connection between the CO_2 storage and the earthquake. As part of this discussion, the stress change caused by the CO_2 injection at the hypocenter of the earthquake was calculated and found to be about 1/1000th of the pressure change exerted on the earth's crust by tidal forces, and was therefore negligible.

The technical data including the data shown in Fig.17 was posted on our website 6 days after the earthquake [1]. After convening the expert review meeting, a detailed report was posted on our website.

Major earthquakes are typically not one-time occurrences but are followed by numerous aftershocks. The largest aftershock of the Eastern Iburi Earthquake to date occurred on February 21, 2019, recording a moment magnitude (Mw) of 5.6 (Japan Meteorological Agency Magnitude 5.8). Once again, we posted our data on our website 5 days later, explaining that there was no indication of CO_2 leakage, and no data suggesting a connection between the injection area and hypocenter.

In our response, we have made an effort to respond as quickly as possible, and to include technical data with our explanation. We believe this is important, as a large amount of false news is distributed over social media after an earthquake, and there is a risk that the project may be misunderstood.

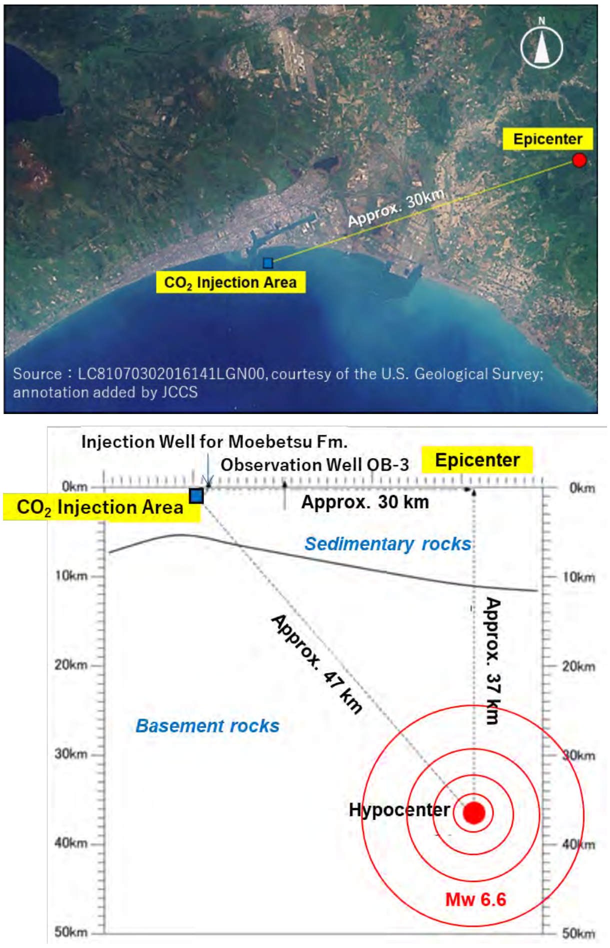


Figure 16: Location of 2018 Hokkaido Eastern Iburi Earthquake

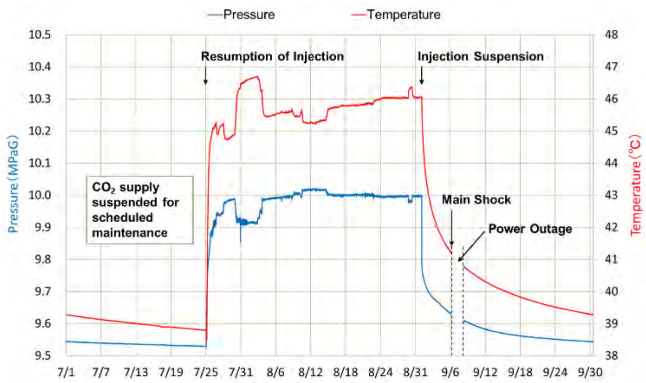


Figure 17: Change in the pressure and temperature of the Moebetsu Formation injection well.

3.4 Cost

Based on the data acquired in the Tomakomai Project, a cost estimate of a 1 million tonnes/yr commercial model was conducted in two steps as follows:

In step 1, based on the Tomakomai facilities, the capacity of which is 200 thousand tonnes/yr, the cost of a 200 thousand tonnes/yr commercial model was estimated under the following conditions.

- As the Tomakomai project was a demonstration project with facilities for testing purposes, a commercial model which excluded these facilities was considered. For example, the injection well and observation wells for the Takinoue formation were excluded, as well as the ocean bottom cable.

- CO_2 source gas was assumed to be separated from the PSA upstream as this provides a CO_2 source gas at a high pressure favorable for CO_2 capture, and that the off gas is returned to the PSA upstream.
- Control building and operator labor costs were assumed to be provided by refinery and not included.
- Fuel gas and electricity costs were based on commercial prices.
- The depreciation period is 25 years. etc.

In step 2, the 200 thousand tonnes/yr commercial model was scaled-up to a 1 million tonnes/yr commercial model and the cost was estimated under the following conditions.

- The CO_2 capture facilities increases from one line of 200 thousand tonnes/yr to two lines of 500 thousand tonnes/yr.
- The number of the injection wells increases from one well to two wells. etc.

The captured CCS cost of the 200 thousand tonnes/yr commercial model was approximately 103 USD/t-CO_2 and the avoided cost was approximately 123 USD/t-CO_2 (1 USD = 108 JPY). The captured CCS cost of the 1 million tonnes/yr commercial model was approximately 57 USD/t-CO_2 and the avoided cost was approx. 67 USD/t-CO_2. (Table 3)

Unit costs are typically not linearly proportional to facility capacity, and the rate of increase in unit costs is less than the rate of increase in facility capacity. The cost estimation indicates that economy of scale plays an important role in reducing costs.

The percentages of each component of the 1 million tonnes/yr commercial model are shown in Fig.18. The percentages for each component in decreasing order are; capture OPEX, injection OPEX, capture CAPEX and injection CAPEX, where capture includes compression costs and injection includes monitoring costs. As we assumed commercial prices for fuel gas and electricity, the percentage of capture OPEX was high. The CCS costs can be reduced in case the operator is able to internally obtain fuel and generate electricity. Injection OPEX is the second largest cost component. In order to reduce this cost, monitoring items need to be minimized.

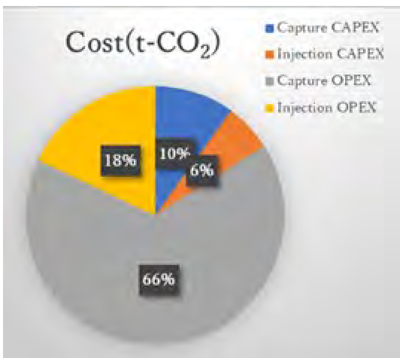


Figure 18: Percentage of CCS cost component (1million tonnes/yr commercial model)

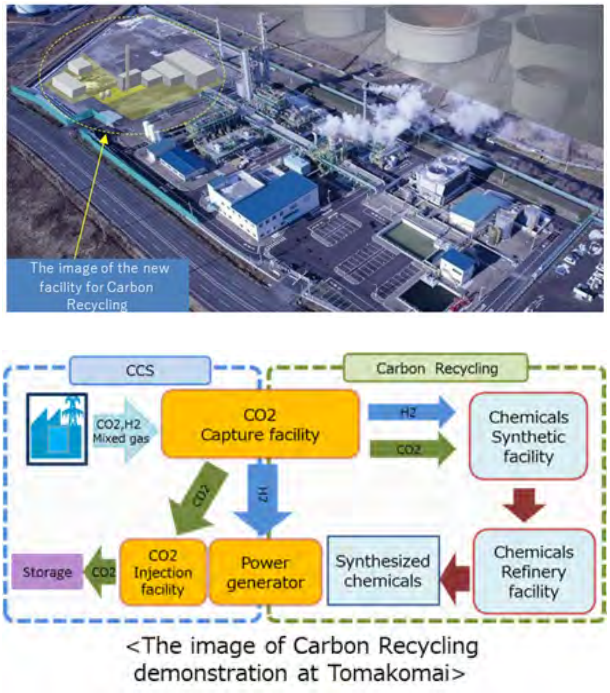
Table 3: CCS Cost 1 USD = 108 JPY

200 thousand tonnes/yr commercial model		1 million tonnes/yr commercial model	
Captured cost	Avoided cost	Captured cost	Avoided cost
103 USD/t-CO_2	123 USD/t-CO_2	57 USD/t-CO_2	67 USD/t-CO_2

3.5 Future Plans for the Tomakomai Site

3.5.1 Carbon recycling

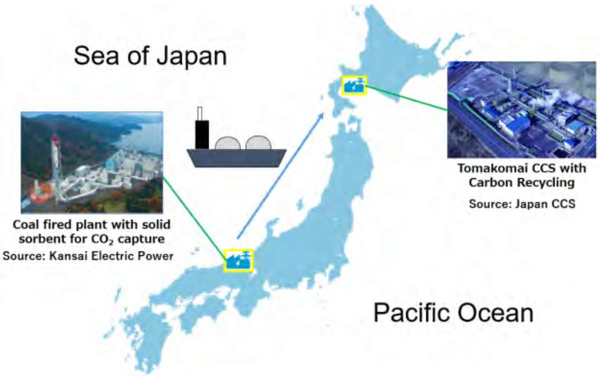
The Japan-Asia CCUS Forum 2020 was held on October 6, 2020. At the forum, METI and NEDO announced that they will promote carbon recycling, which utilizes CO_2 as a resource by converting it into synthesized chemicals, and that they will conduct a CCU (carbon capture and utilization) demonstration project at the Tomakomai site, making efficient use of the facilities (Fig.19). To this end, JCCS is supporting a feasibility study being conducted by METI and NEDO.



Source: METI [2]
Figure 19: Carbon recycling plan at Tomakomai

3.5.2 CO_2 ship transportation [3]

According to existing literature and data, Japan's offshore areas have the potential to store about 150 to 240 billion tonnes of CO_2. A notable point is that while industrial areas that emit a large amount of CO_2 are located mainly in the coastal areas on the Pacific Ocean side, areas suitable for storage are mainly located on the Sea of Japan side. Due to the distances between the source and storage locations, long-distance transportation by ship is believed to be more feasible than land transportation by such means as pipelines. In order to verify this, the Japanese government is currently planning to demonstrate long-distance transportation of CO_2 captured and liquefied at the coal-fired power plant in Maizuru City on the coast of the Sea of Japan to Tomakomai (Fig.20). The transport of liquefied CO_2 at low temperature and low pressure by ship has not yet been demonstrated in the world, and Japan is aiming to be the first country to start the demonstration in 2024. JCCS is taking part in a feasibility study being conducted by METI and NEDO.



Source: Source: METI [2], partly modified by JCCS
Figure 20: CO_2 ship transportation

4. Conclusions

The main objectives and tasks of the project were; 1) demonstrate a full-chain CCS system from capture to storage, 2) demonstrate that the CCS system is safe and reliable, 3) remove concerns about earthquakes by the data collected (As Japan is an earthquake-prone country, removing concerns regarding earthquakes by establishing that natural earthquakes will not affect the CO_2 stored, and conversely that the CO_2 injection will not induce perceptible tremors is vital), 4) widely disclose information on this project through information disclosure and public engagement activities and enhance the understanding of CCS, 5) acquire operational technology as well as strive towards practical implementation.

The project achieved the following results. 1) The operation of a full chain CCS system from capture to storage was conducted successfully, and the target of 300,000 tonnes of CO_2 injection was achieved in November 2019. 2) No micro-seismicity or natural earthquakes attributable to CO_2 injection were detected in the vicinity of the injection area. 3) The time-lapse monitor seismic surveys showed clear anomalies reflecting the evolution of the CO_2 plume. 4) No abnormalities suggesting seepage of injected CO_2 into the ocean have been detected in the marine environmental survey. 5) The magnitude 6.6 2018 Hokkaido Eastern Iburi Earthquake did not affect the CO_2 stored. 6) The public outreach program has been largely successful, with no major opposition to the project. Information disclosure and diligent efforts to secure the understanding of local stakeholders were of utmost importance.

As a future step, the Japanese government plans to implement a CCU demonstration project making efficient use of the Tomakomai facilities and a project to demonstrate CO_2 ship transportation. JCCS is presently supporting feasibility studies being conducted by METI and NEDO.

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