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Tomakomai CCS Demonstration Project

Project at a Glance

Project Description

The Tomakomai CCS Demonstration Project is Japan's first full-chain CCS demonstration project being conducted by Japan CCS Co., Ltd. (JCCS) in Tomakomai City, Hokkaido Prefecture, Japan. The project has been conducted since JFY2012. The Implementation of the project was commissioned to JCCS by the Ministry of Economy, Trade and Industry (METI) between JFY2012 and 2017, and from JFY2018 by the New Energy and Industrial Technology Development Organization (NEDO) with subsidies from METI. The objective is to demonstrate the viability of a full CCS system, from CO_2 capture to injection and storage. After a 4-year period of the construction of facilities, the demonstration operation commenced in April 2016 by capturing, injecting and storing approximately one hundred thousand tonnes/year or more of CO_2 in offshore reservoirs in the Tomakomai port area. On November 22, 2019, the project successfully achieved the target of 300,000 tonnes cumulative sub-seabed CO_2 injection, confirming the safety and reliability of CCS.

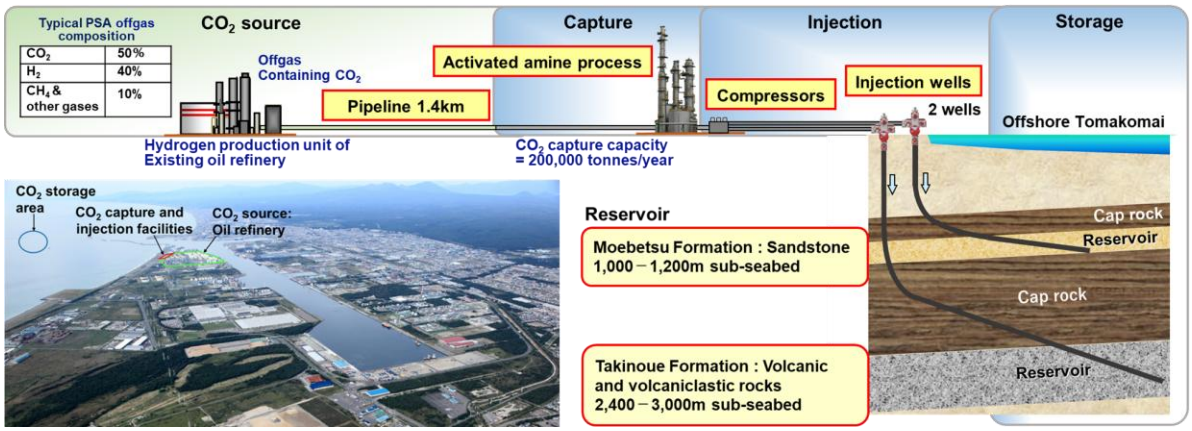
The post injection monitoring stage is being conducted under the commission of NEDO.

Project Site: Tomakomai City, Hokkaido

Main CCS Parameters

CO_2 Source	Capture Type	Reservoir	CO_2 Injected	Storage Type
Hydrogen production unit in oil refinery	Industrial separation/ Chemical absorption	Sandstone layers at 1,000-1,200m depth Volcanic and volcaniclastic rocks at 2,400-3,000m depth	Cumulative injection: 300,110 tonnes Injection period: Apr. 6, 2016 - Nov. 22, 2019	Deep saline aquifers under seabed

Project Scheme



Objectives & Tasks

- Demonstrate an integrated CCS system from capture to storage
- Demonstrate that the CCS system is safe and reliable
- Remove concerns about earthquakes by the data collected
  - Natural earthquakes have no effect on stored CO_2
  - No perceptible tremors are caused by CO_2 injection
- Disclose project information & data and enhance understanding of CCS by the general public
- Clearly define areas to be improved or solved for commercialization

Selection of Tomakomai Area and Project Schedule

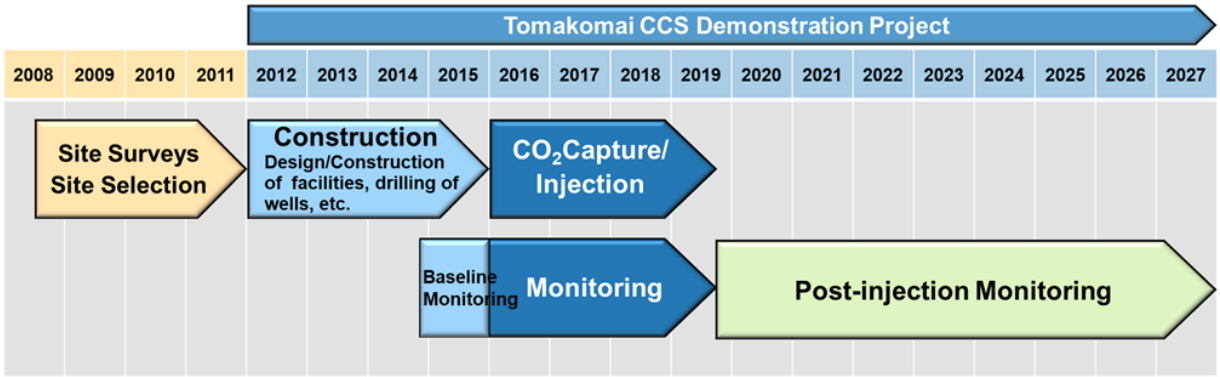
Selection of Tomakomai Area

Tomakomai was selected from among 115 candidate sites as a result of comprehensive investigations and site surveys and was authorized by the Evaluation Committee organized by the Ministry of Economy, Trade and Industry of Japan (METI). The data collected by detailed site surveys were used to establish a geological model and to perform simulation of long-term CO_2 behavior prediction. The results obtained revealed that the geological structures and formations in the Tomakomai area were highly suitable for geological CO_2 storage.

Schedule - Contract Period: From JFY2012 to JFY2027

- From JFY2012 to JFY2015: Construction
  Activities including the design and construction of facilities, drilling of wells, baseline monitoring, and preparation for demonstration operation were carried out.
- From April 2016 to November 2019: CO_2 capture/injection
  On November 22, 2019, the target of 300 thousand tonnes of CO_2 injection was achieved, and injection was terminated.
- From JFY2016: Monitoring of CO_2 (*), being continued after termination of injection
- From JFY2021 to JFY2024: Study/preparation of the interoperation of CCS and CCU

(*) Monitoring the behavior (migration, distribution) of the injected CO_2, continuous monitoring of micro-seismicity and natural earthquakes, marine environmental monitoring to detect for possible CO_2 leakage/seepage are being conducted.

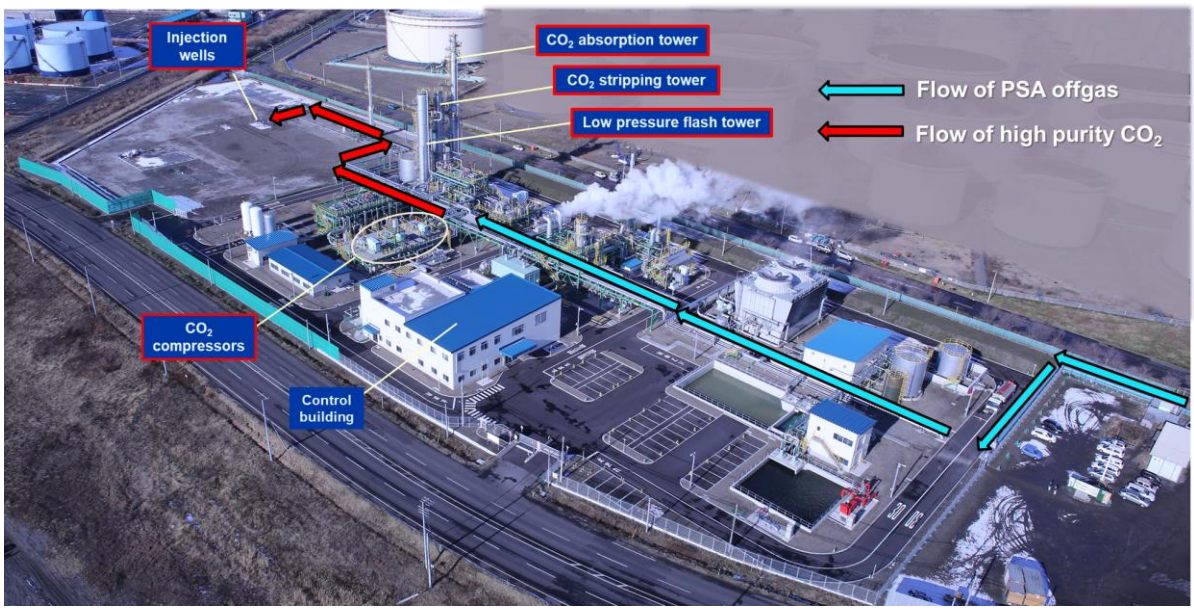


※ Years are in Japanese Fiscal Years (JFY: April of calendar year to March of following year)

Main Features

- First full cycle CCS system deployed in Japan
- Low energy CO_2 capture process → Page 4
- First case of deviated CO_2 injection wells drilled offshore from onshore site → Page 5, 6
  - Cost reduction of drilling, operation and maintenance compared to offshore drilling
  - No disturbance on marine environment and harbor operation
- Extensive monitoring system → Page 7
  - Confirm safety and stability of CCS system
  - Remove concerns about earthquakes
- CO_2 storage governed by Act on Prevention of Marine Pollution & Maritime Disaster (Japanese law reflecting London Protocol) → Page 8
- First case of CCS near urban area; extensive public outreach activities engaging local government, residents and industry → Page 10

Bird's Eye View of Tomakomai Capture/Injection Facilities



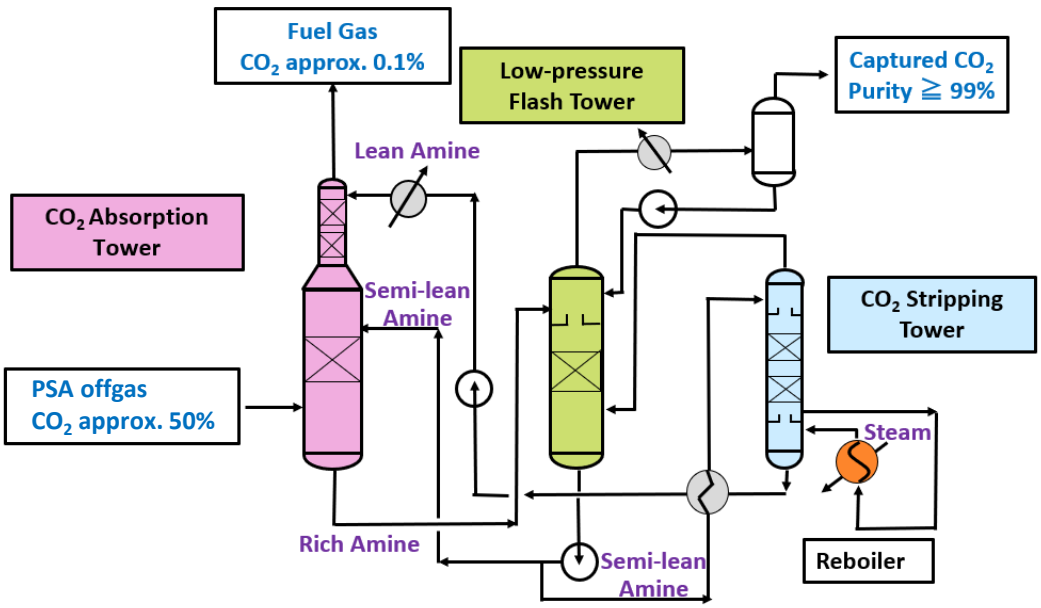
CO_2 Capture Process

Two-stage Absorption System with Low-pressure Flash Tower

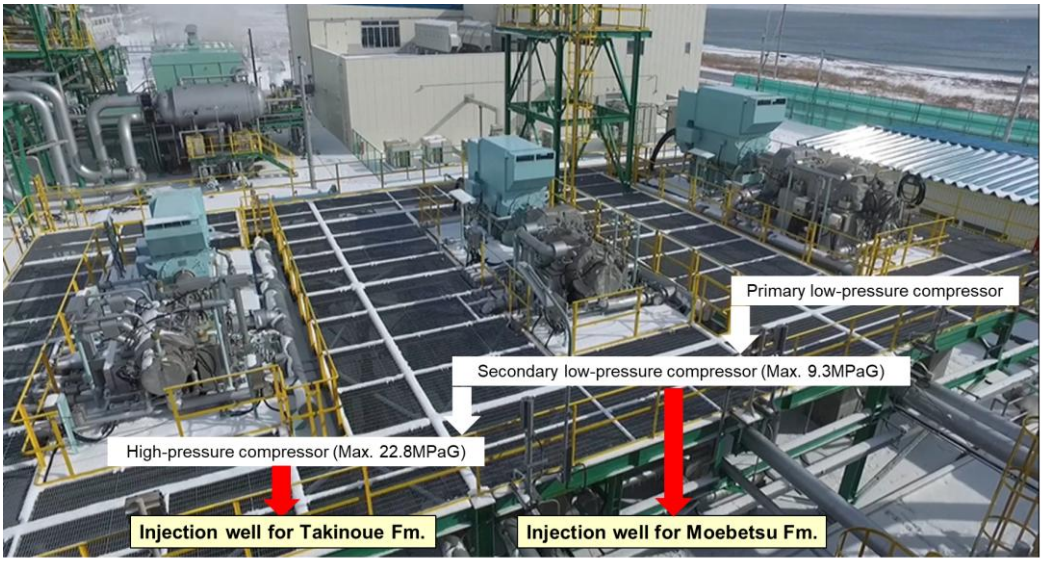
- Depressurization in Low Pressure Flash Tower strips substantial portion of CO_2
- Energy consumption is 1/2 to 1/3 of conventional CO_2 capture process

The CO_2 source is a hydrogen production unit (HPU) of an adjacent oil refinery, which supplies off gas containing approximately 50% CO_2 from a Pressure Swing Adsorption (PSA) hydrogen purification unit. In the capture facility, gaseous CO_2 of 99% purity or more is recovered by a commercially proven amine scrubbing process. A two-stage absorption system including a low-pressure flash tower reduces the amine reboiler duty in the capture system, and achieved a reboiler duty of 0.882 - 0.923GJ/t-CO_2 which is 1/2 to 1/3 of a conventional one stage absorption process.

Two-stage absorption process



CO_2 Compressors

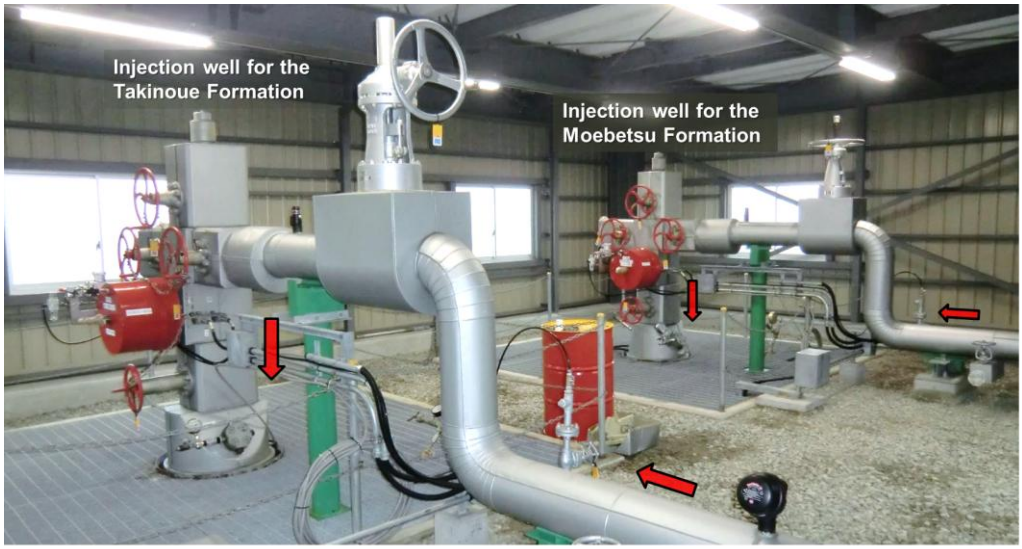


Injecting from Onshore to Offshore

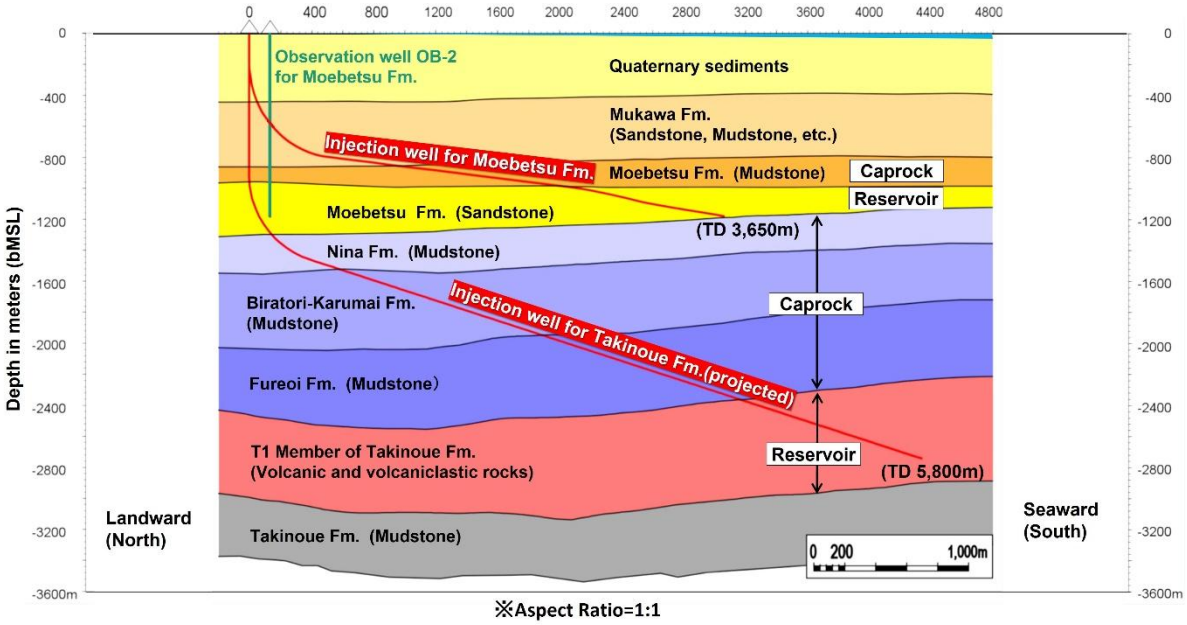
- Deviated wells from onshore to offshore
  - Cost reduction of drilling, operation and maintenance compared to offshore drilling
  - No disturbance on marine environment and harbor operation

At the onshore injection facility, the CO_2 is compressed and injected into two different offshore reservoirs by two separate deviated wells. The storage points are located 3 to 4km offshore. The shallow reservoir (**Moebetsu Formation**), a saline aquifer mainly composed of sandstone located approximately 1,000m below the seabed, was reached by an extended reach drilling (ERD) well with a maximum inclination of 83 degrees, vertical depth of 1,188m and horizontal reach of 3,058m. A perforated liner covered by sand control screens was set over the injection interval of almost 1,200m in length in order to minimize sand flow back into the well. The deep reservoir (**Takinoue Formation**) is a saline aquifer composed of volcanic and volcaniclastic rocks located approximately 2,500m below the seabed. The deep injection well has a maximum inclination of 72 degrees, vertical depth of 2,753m and horizontal reach of 4,346m.

CO_2 injection wells



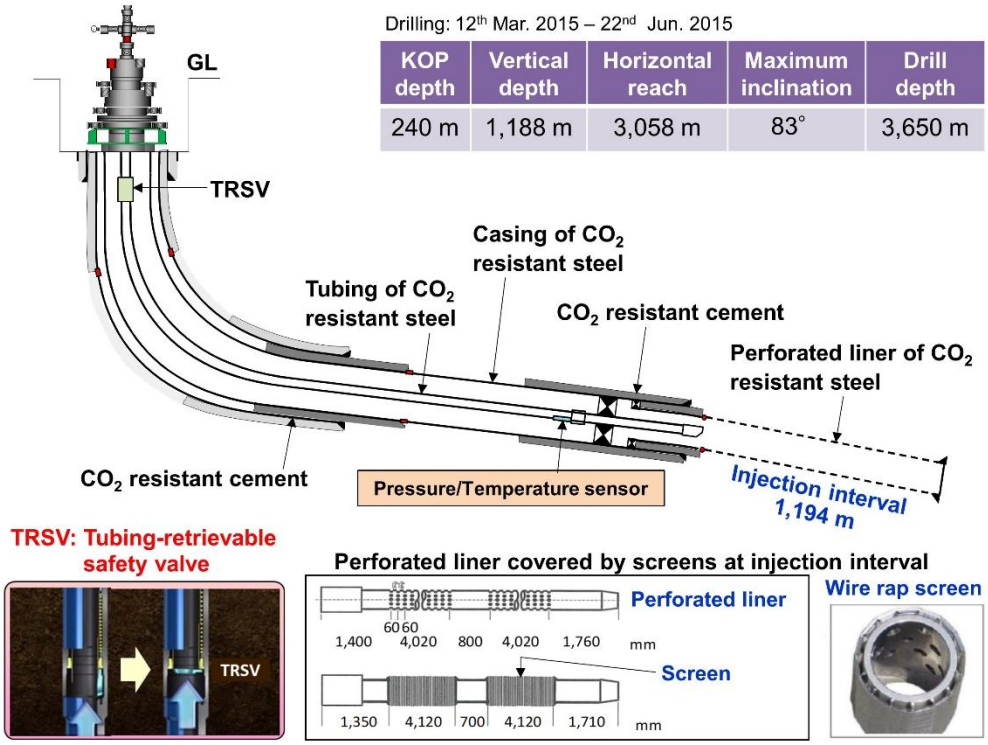
Geological cross section



※Aspect Ratio=1:1

Schematic Diagram of Injection Wells

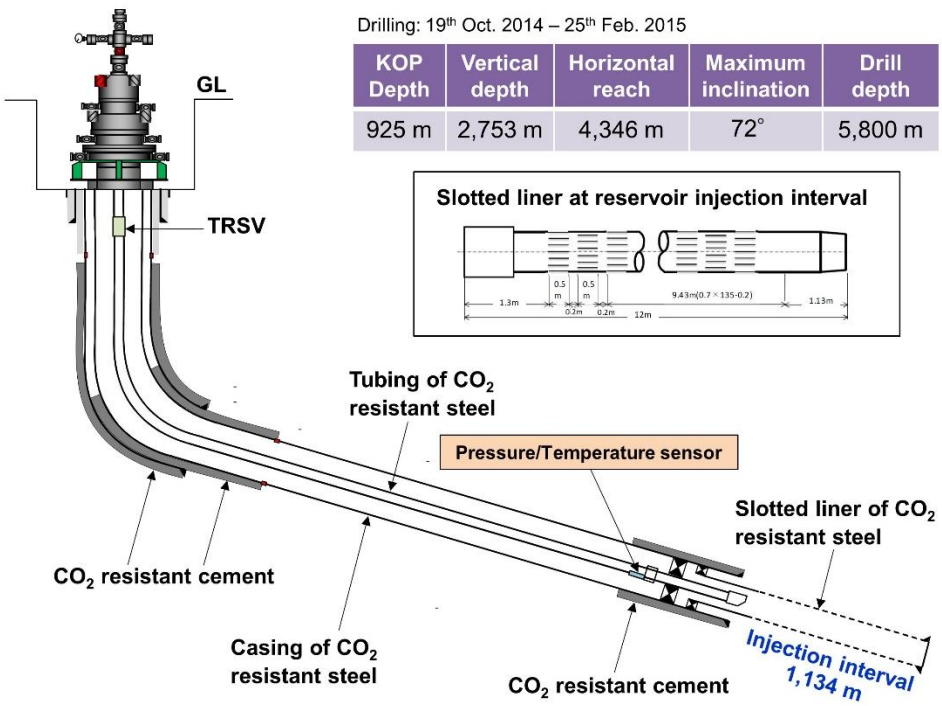
Injection Well for Moebetsu Formation



Drilling: 12th Mar. 2015 – 22nd Jun. 2015

KOP depth	Vertical depth	Horizontal reach	Maximum inclination	Drill depth
240 m	1,188 m	3,058 m	83°	3,650 m

Injection Well for Takinoue Formation



Drilling: 19th Oct. 2014 – 25th Feb. 2015

KOP Depth	Vertical depth	Horizontal reach	Maximum inclination	Drill depth
925 m	2,753 m	4,346 m	72°	5,800 m

Objectives of Monitoring and Verification

- Confirm the safety and stability of CO_2 injection
  - The CO_2 behavior in the reservoirs is being monitored continuously to detect for any CO_2 leakage.
  - Seismic surveys to delineate the subsurface CO_2 distribution, and monitoring of the injected CO_2 volume, formation pressure and temperature are being conducted.
  - Baseline seismic surveys were conducted during the site survey and preparation phases, and time lapse 2D and 3D seismic surveys are being conducted.
  - The monitoring is being used to update a simulation model to predict CO_2 behavior.
- Verify that natural earthquakes do not affect the stored CO_2, and that CO_2 injection does not cause any perceptible tremors
  - Monitoring of natural earthquakes and micro-seismicity is being conducted.
- Monitor the marine environment
  - Marine environmental surveys are being conducted on ocean currents, water quality, seabed mud, marine organisms, etc., in accordance with the “Act on Prevention of Marine Pollution and Maritime Disaster”.

Monitoring System

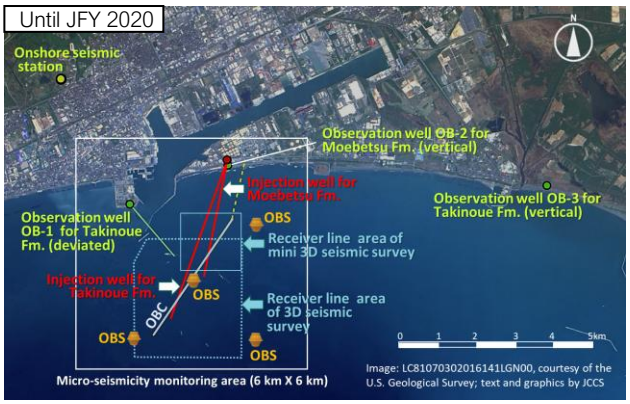
An extensive monitoring system comprising 3 observation wells, 4 ocean bottom seismometers, 1 ocean bottom cable, wellbore temperature/pressure, and flow meters was established to continuously measure the temperature and pressure of the reservoirs, the flow of CO_2 into the reservoirs, and to monitor natural earthquakes and micro-seismicity.

Based on the results of an optimization study of the micro-seismicity monitoring system, the operation of the onshore seismic station and ocean bottom seismometers (OBS) was suspended in FY2021, and the operation of the permanent OBC was suspended in FY2025. Micro-seismicity monitoring is currently being continued by the observation wells.

Monitoring equipment/work and monitored items

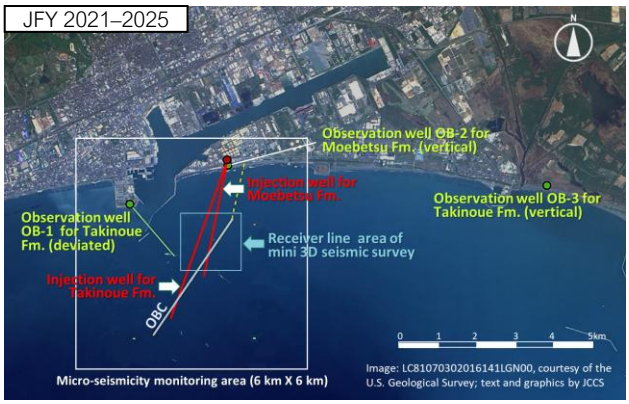
Equipment/Work	Monitored Items
Sensors in injection facility Injection wells • Well head pressure gauge • Downhole pressure/temperature sensor	Temperature, pressure, injection rate Pressure Pressure, temperature
Observation wells • Downhole pressure/temperature sensor • Seismic sensor	Pressure, temperature Seismicity
Ocean bottom cable (OBC)	Seismicity, receiver for 2D seismic survey
Ocean bottom seismometer (OBS)	Seismicity
Onshore seismic station	Seismicity
2D seismic survey 3D seismic survey 2D seismic survey plus mini-3D survey Mini-3D survey	Distribution of CO_2 in reservoir
Marine environmental survey	Marine data (physical and chemical properties, biological habitat, etc.)

Until JFY 2020



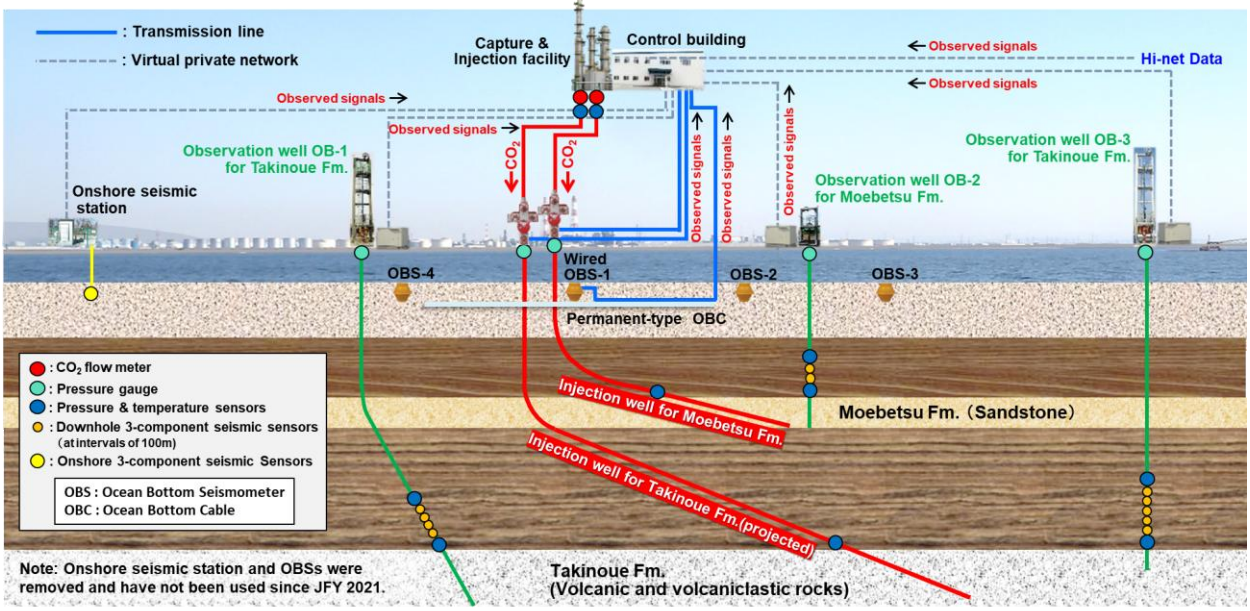
- Onshore seismic station
- Three observation wells
- OBC
- Four OBSs
- Combination of 2D, 3D and 2D + mini-3D seismic survey

JFY 2021–2025



- Three observation wells
- OBC
- Mini-3D seismic survey

Schematic Diagram of Sensors Deployed for Monitoring



Marine Environmental Surveys

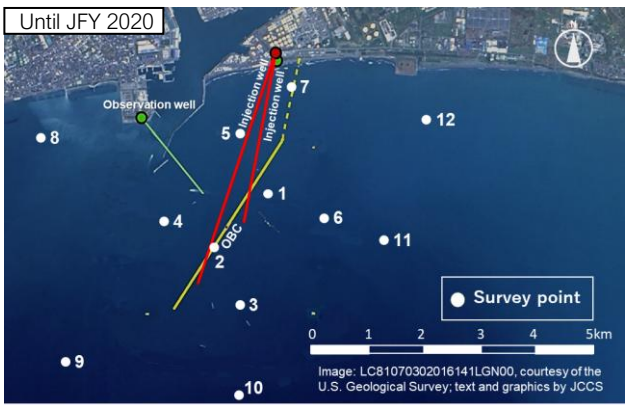
Subsea CO_2 geological storage is regulated by the "Act on Prevention of Marine Pollution and Maritime Disaster", enforced to reflect the London 1996 Protocol. Marine environmental surveys were conducted in FY2013 and FY2014; from FY2016, seasonal surveys are being conducted quarterly.

Marine environmental surveys have been conducted under the five-year injection permit (FY2016–2020 and FY2021–2025) from Ministry of the Environment (MOE) which requires the implementation of a "monitoring plan" approved by MOE.

After evaluating the performance and effectiveness of the marine environmental survey results, the implementation items were reduced with the approval of the Ministry of the Environment.

Four survey points shallower than 10 m water depth were excluded because their chemical properties are very unstable by vertical mixing of sea water and atmosphere, and the number of survey points was reduced from 12 to 8. Chemical measurements of sea bottom sediments and benthos observation were changed from mandatory to when necessary.

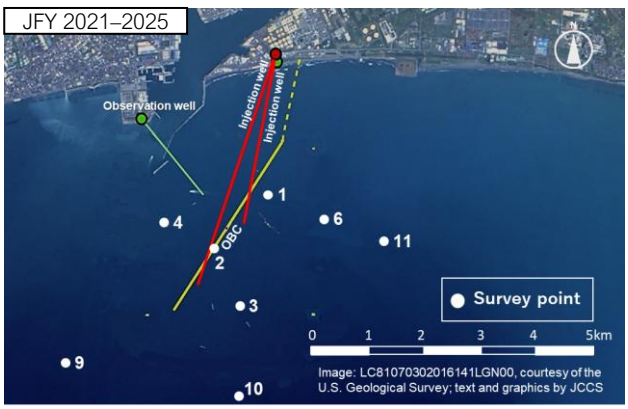
Until JFY 2020



- Seasonal survey at 12 survey points
- Chemical measurements of seawater
- Chemical measurements of sea bottom sediments

- Plankton observation
- Benthos observation
- Seismic survey (once a year)
- Pressure and temperature at the injection wells and the observation wells

JFY 2021–2025

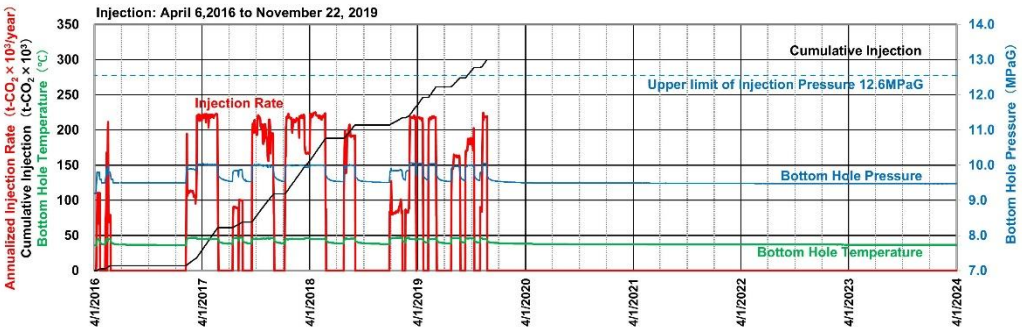


- Seasonal survey at 8 survey points
- Chemical measurements of seawater
- Chemical measurements of sea bottom sediments (conducted as needed)
- Plankton observation
- Benthos observation (conducted as needed)
- Seismic survey (twice in 5 years)
- Pressure and temperature at the injection wells and the observation wells

Results of CO_2 Injection

- Achieved 300,110 tonnes cumulative CO_2 injection into 2 reservoirs at different depths (Moebetsu Formation – 300,012 tonnes, Takinoue Formation – 98 tonnes).
- The maximum bottomhole pressures recorded during injection in the Moebetsu Formation were much lower than the upper limit set to avoid destruction of the overlying cap rock.

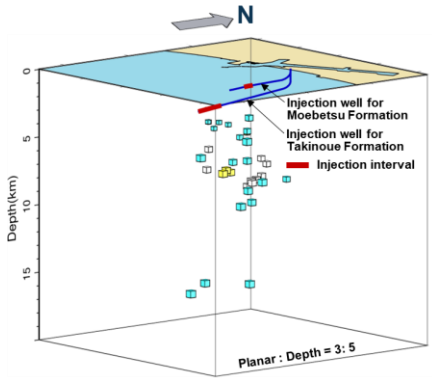
Injection record of Moebetsu Formation



Results of Micro-seismicity Monitoring

- No micro-seismicity or natural earthquakes attributable to CO_2 injection were detected in vicinity of injection area.

3D view of hypocenters of events



※Detectability: Mw ≥ - 0.5

List of events (February 2015 – December 2026)

Pre-injection events

No.	Date	Estimated Depth	Mw
1	4/09/2015 15:03	6.64 km	0.14
2	4/13/2015 14:00	5.97 km	0.14
3	4/17/2015 07:06	8.17 km	0.20
4	4/17/2015 07:09	8.19 km	0.19
5	4/17/2015 07:13	8.33 km	0.28
6	4/17/2015 07:18	7.57 km	0.17
7	5/10/2015 08:27	8.59 km	-0.04
8	8/10/2015 19:08	6.76 km	0.23
9	8/20/2015 23:20	8.18 km	0.44

Events during injection

No.	Date	Estimated Depth	Mw
10	8/02/2017 13:35	7.80 km	0.50
11	8/02/2017 13:36	7.78 km	0.33
12	8/02/2017 13:55	7.70 km	0.33

Post-injection events

No.	Date	Estimated Depth	Mw
13	9/24/2020 11:53	5.86 km	0.59
14	4/01/2021 04:23	7.45 km	0.23
15	8/24/2021 16:03	6.50 km	0.13
16	9/18/2022 14:04	4.35 km	0.12
17	3/22/2023 10:26	8.37 km	0.43
18	3/20/2024 22:43	5.15 km	0.59
19	5/27/2024 23:04	5.73 km	- 0.35
20	10/15/2024 7:25	5.02 km	-0.05
21	10/24/2024 17:20	15.83 km	0.56
22	11/4/2024 2:05	9.55 km	0.62
23	2/12/2025 12:00	8.72 km	0.56
24	6/29/2025 7:12	9.87 km	0.33
25	7/28/2025 22:52	15.70 km	0.65
26	8/6/2025 1:53	16.28 km	0.74
27	11/2/2025 2:42	8.09 km	-0.11

Pre-injection events
Events during injection
Post-injection events

3D seismic survey results

- 3D seismic surveys at cumulative CO_2 injection of approx. 65,000, 207,000 and 300,000 tonnes into the Moebetsu Formation detected anomalies, indicating evolution of the CO_2 plume.

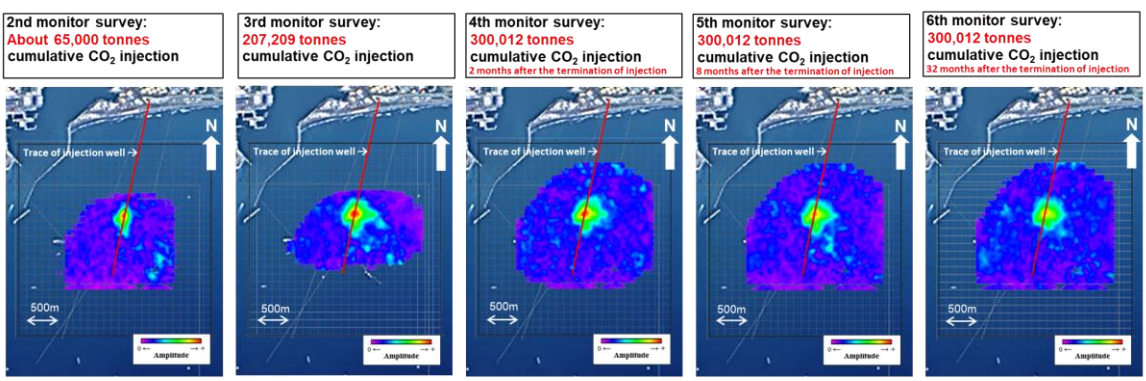


Image: LC81070302016141LGN00, courtesy of the U.S. Geological Survey; text and graphics by JCCS

RMS (Root Mean Square) amplitude of difference of monitor survey and baseline survey at the depth of the reservoir (970 to 1050 msec)

In Tomakomai City

Tomakomai City has a population of 164,000 and as the operation is taking place in the port area, intensive stakeholder engagement has been implemented since FY2011. Securing the strong support of the Tomakomai government, a wide range of activities; providing information on JCCS's website, exhibitions and forums for residents, receiving site visits, engaging in consultation and collaboration with government officials and fishery cooperatives, conducting interviews with local and national media, etc., are being carried out.

Tomakomai CCUS/Zero Carbon Promotion Association

- Activities
  - Attraction of CCS Demonstration Project to Tomakomai
  - Information communication to Tomakomai citizens on CCS, etc.
- Chairman : Tomakomai City Mayor
- Secretariat : Tomakomai City
- Members : All major corporations in Tomakomai and industrial associations including Tomakomai Fishery Cooperative

Association Meeting

Newsletters

Various activities for local communities

Panel Exhibitions

CCS Forums

Site tours & lectures

CCS courses for senior citizens

Science classes & site tours for schoolchildren