

A low-angle photograph of the Tomakomai CCS Demonstration Project, showing three tall, silver-colored industrial towers with complex piping and yellow safety railings against a clear blue sky. The towers are connected by a network of pipes and ladders, with some green structural elements visible.

Tomakomai CCS Demonstration Project — Results and Lessons Learned

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Tomakomai CCS Demonstration Project – Results and Lessons Learned

Part I Yoshihiro Sawada

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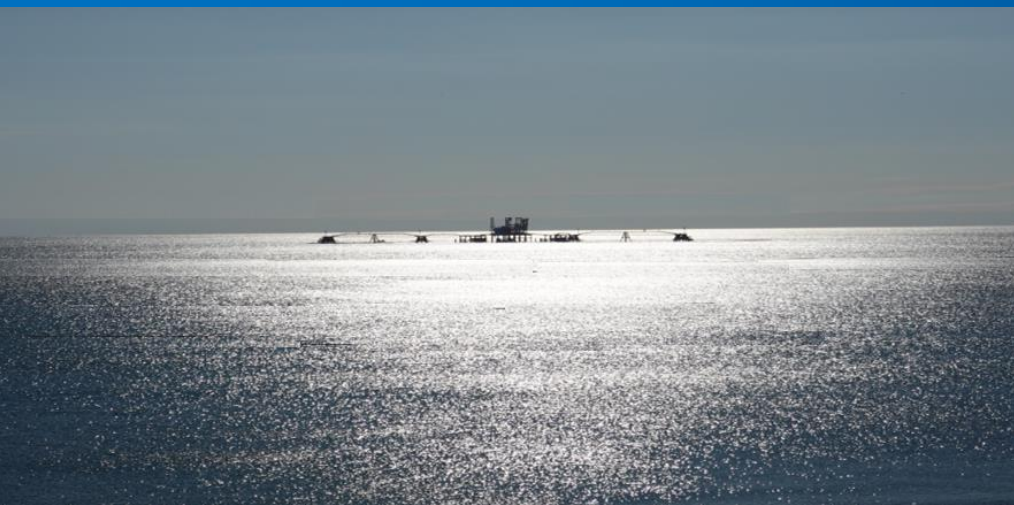
Part I Yoshihiro Sawada

Overview of Tomakomai CCS Demonstration Project

Key Results of Tomakomai Project

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Overview of Tomakomai CCS Demonstration Project

Project Overview

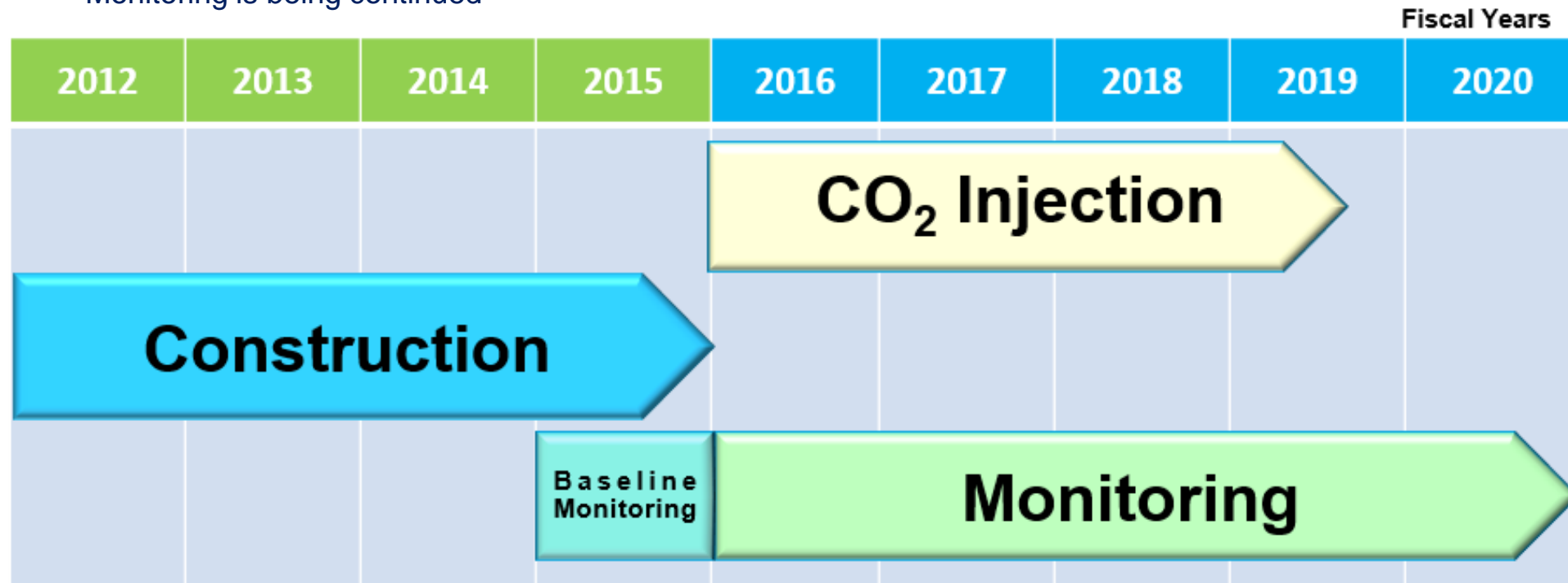
- **First large-scale CCS demonstration project in Japan**
- **Location: Tomakomai City, Hokkaido Prefecture**
- **Commissioned by: METI, NEDO**
- **Contractor: JCCS**



Tomakomai CCS Demonstration Center, Tomakomai City, Hokkaido

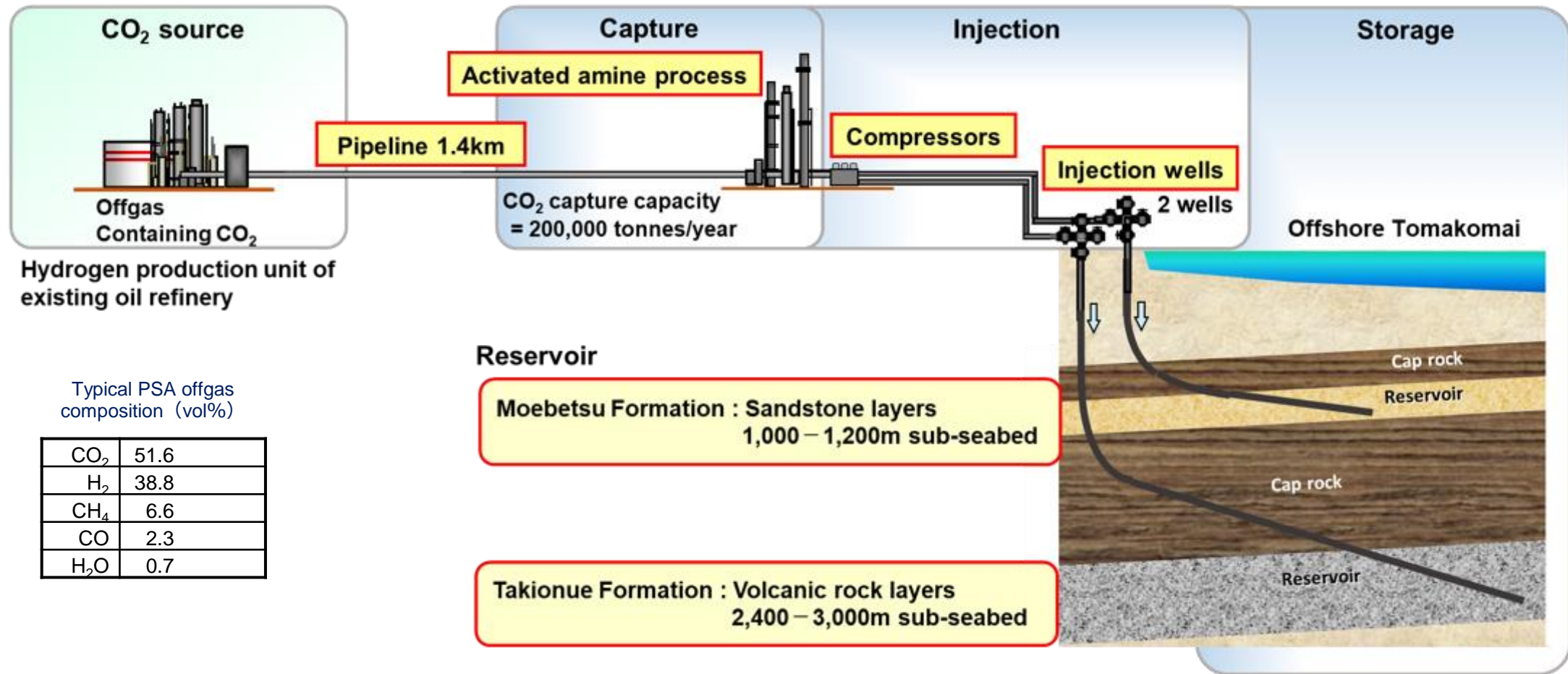
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- Constructed demonstration facilities **from FY2012 to 2015**
- Started injection **at scale of 100 thousand tonnes** per annum **from April 2016**
- Achieved initial target of **300 thousand tonnes cumulative injection on November 22, 2019**
- Monitoring is being continued

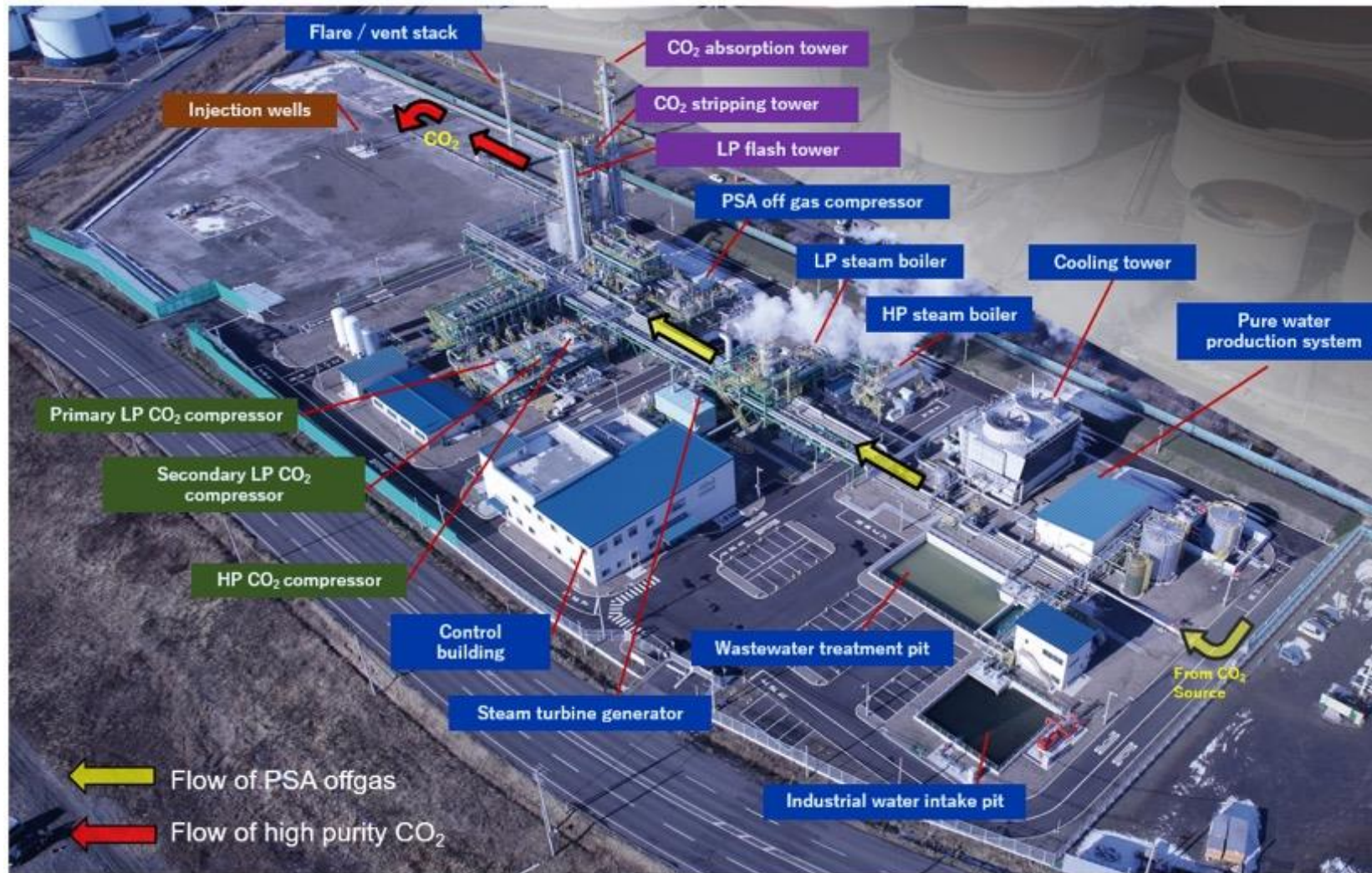


Project Scheme

- A portion of PSA (Pressure Swing Adsorption) offgas containing approximately 52% CO₂ generated by a hydrogen production unit in adjacent refinery is transported by 1.4km pipeline to Tomakomai Project capture facilities.

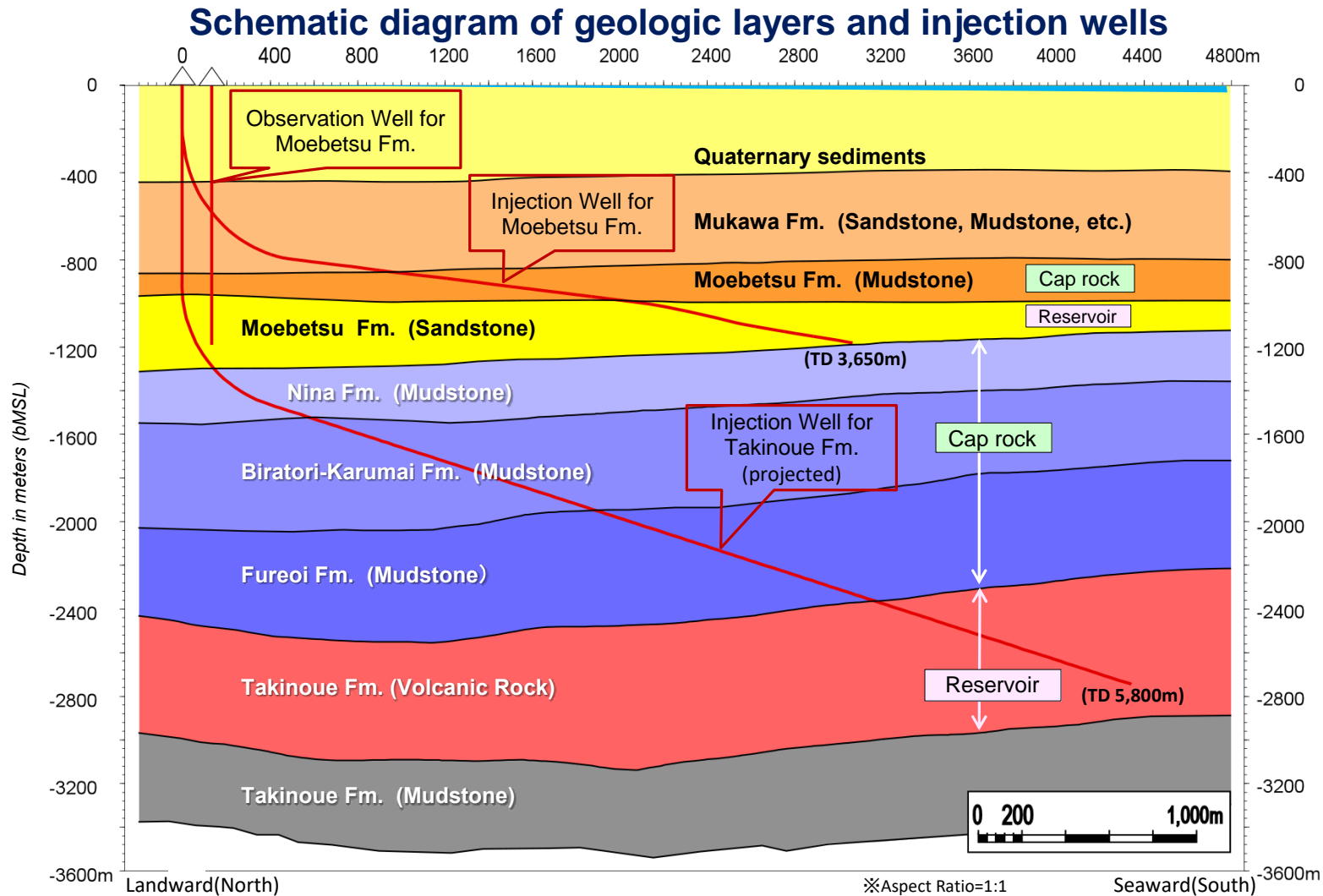


Bird's Eye View of Tomakomai Capture/Injection Facilities



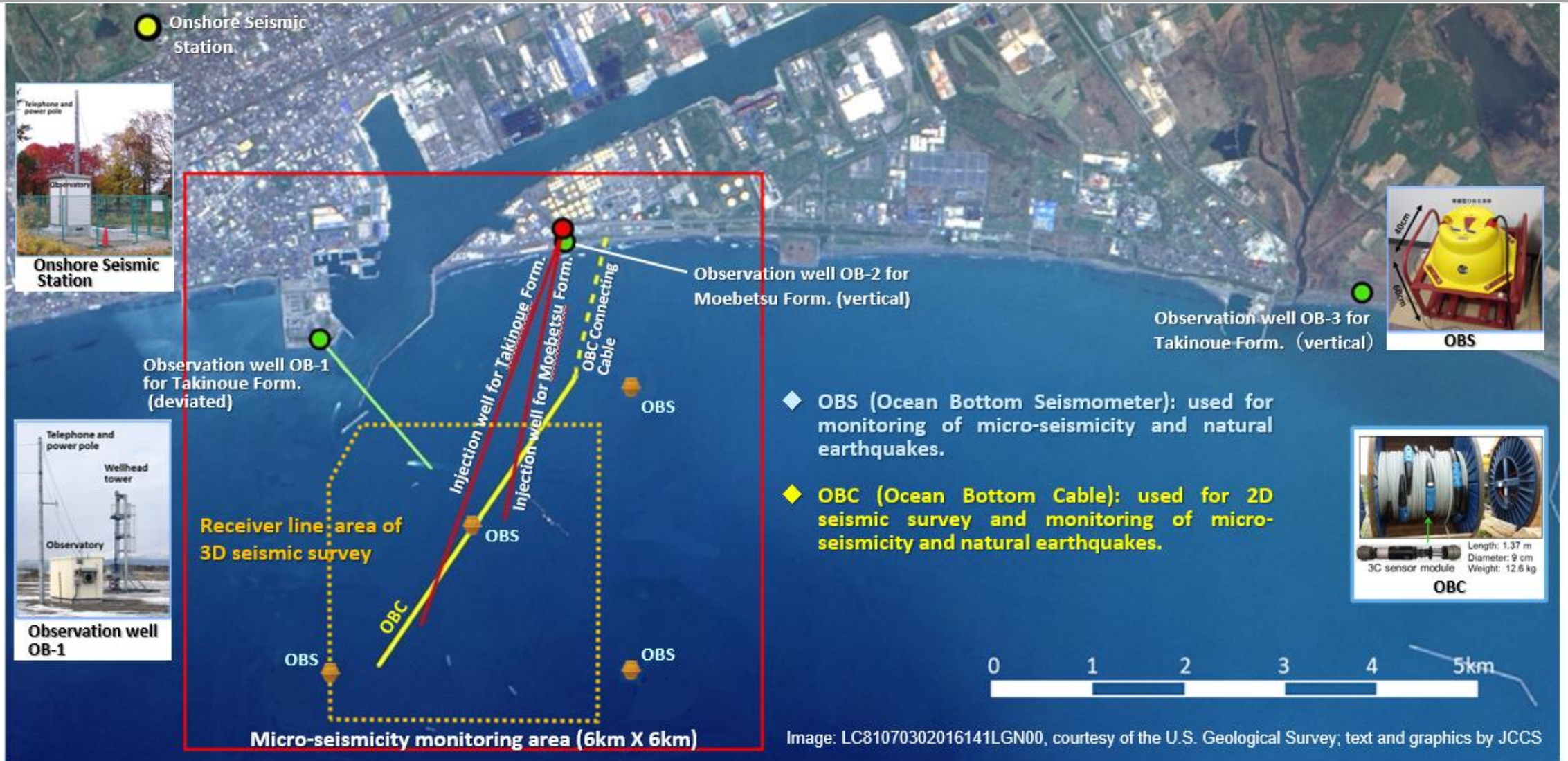
- CO₂ rich gas from refinery is sent to the CO₂ absorption tower
- Captured CO₂ is compressed and sent to injection wells

CO₂ Injection and Storage



- The captured CO₂ is compressed and stored 3-4km offshore in two sub-seabed reservoirs at different depths – Moebetsu and Takinoue formations by two independent injection wells.
- Deviated CO₂ injection wells drilled from onshore to offshore sub-seabed
 - Cost reduction of drilling, operation and maintenance
 - No disturbance on marine environment and harbor operation

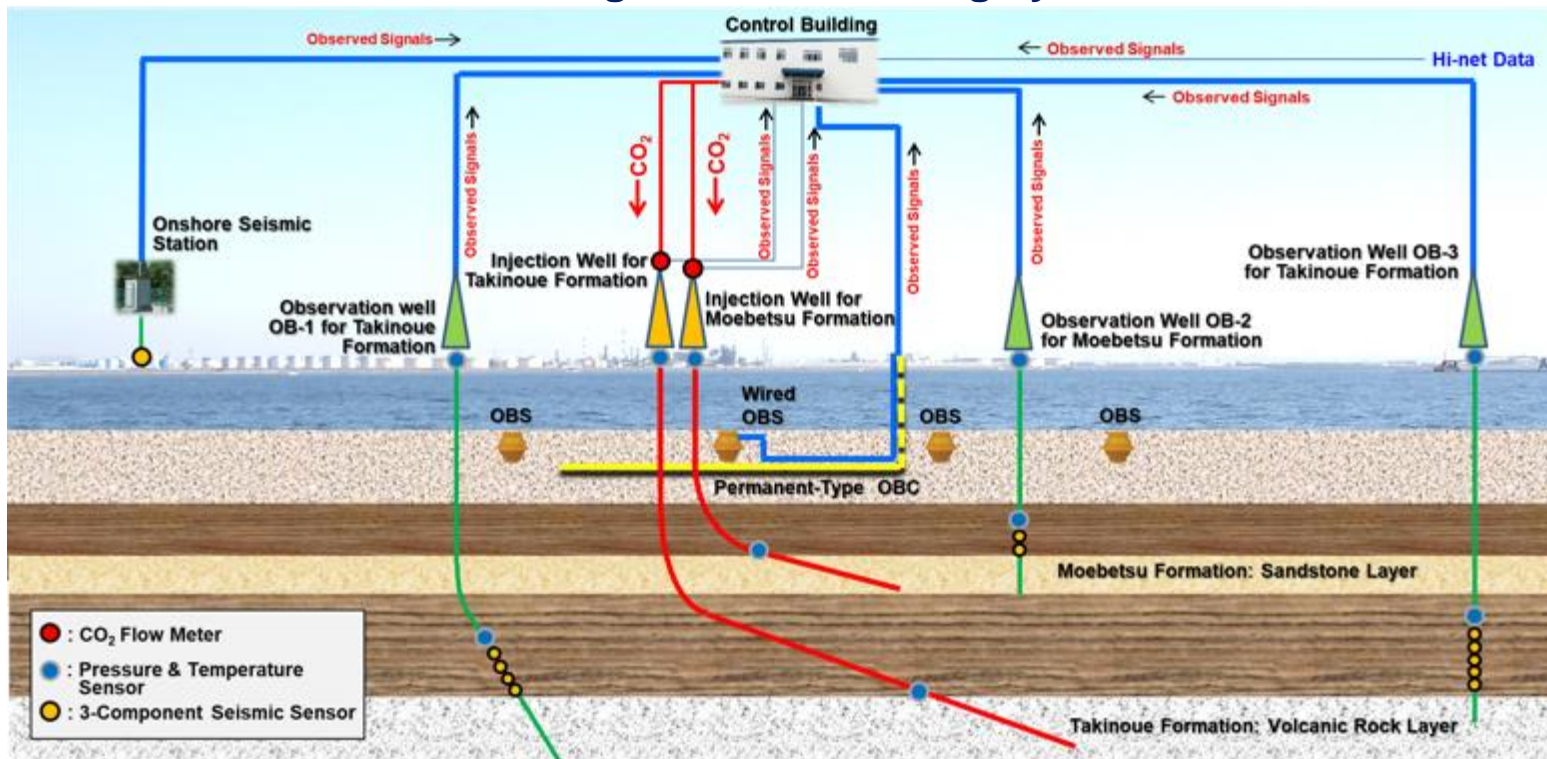
Location of Monitoring Facilities



Schematic Diagram of Monitoring System / Monitored Items

- Offshore CO₂ storage in Japan is conducted in accordance with Act on Prevention of Marine Pollution and Maritime Disaster, with a storage permit issued by Minister of Environment. Permit holder (METI in this project) is required to conduct monitoring in accordance with “Monitoring Plan” submitted in permit application and confirm CCS is being conducted safely as planned.
- In accordance with Tomakomai Project “Monitoring Plan”, observation of reservoir temperature and pressure, and seismic surveys to grasp CO₂ distribution, quarterly (seasonal) marine environmental surveys are being conducted.

Schematic diagram of monitoring system

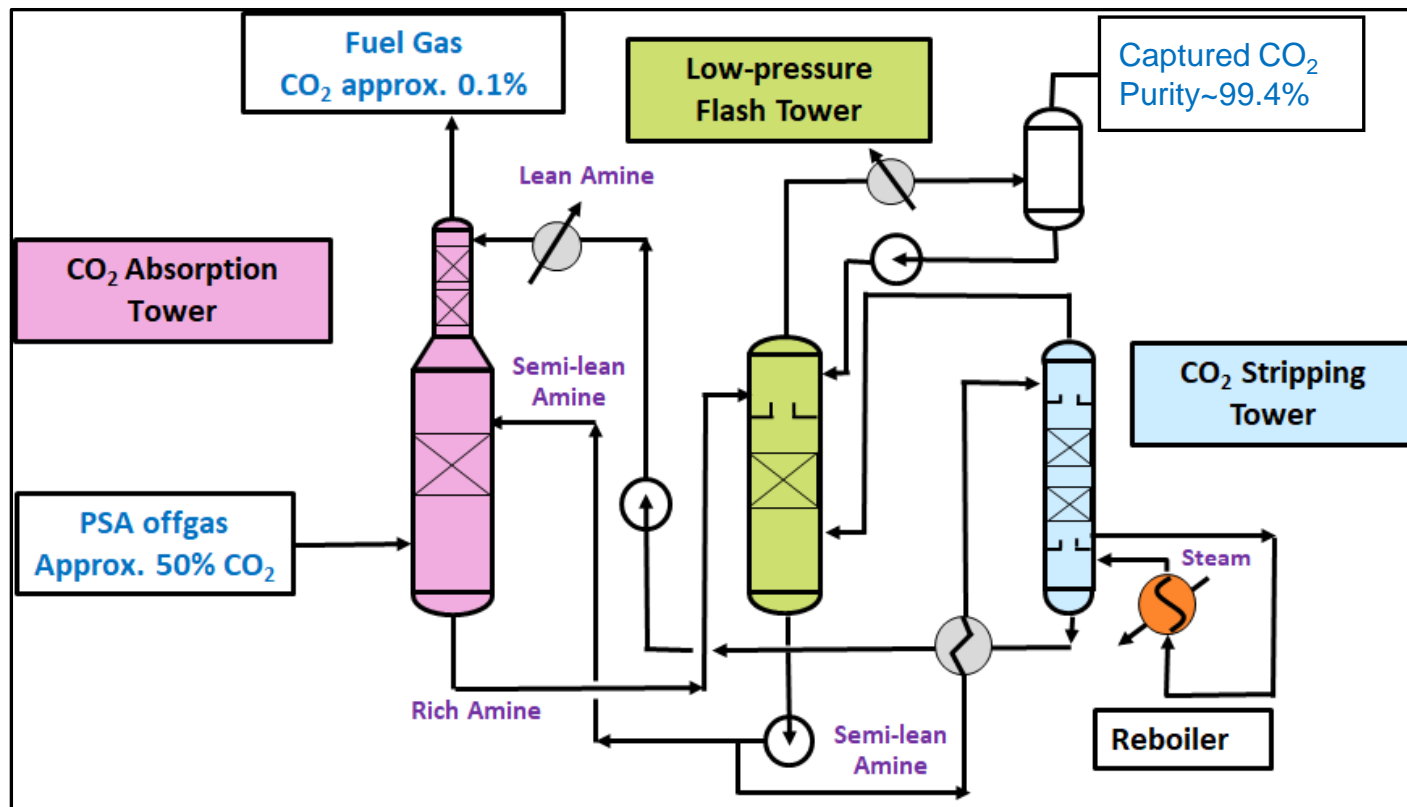


Monitored Items

Equipment/Work	Monitored Items
Injection wells, facilities	Downhole: temperature, pressure Wellhead: injection temperature, pressure, CO ₂ injection amount
Observation wells	Downhole: temperature, pressure, micro-seismicity, natural earthquakes
Ocean Bottom Cable (OBC)	Micro-seismicity, natural earthquakes, recording of 2D seismic surveys
Ocean Bottom Seismometers (OBS)	Micro-seismicity, natural earthquakes
Onshore seismometer	Micro-seismicity, natural earthquakes
2D seismic survey	Distribution of CO ₂ in reservoir
3D seismic survey	Distribution of CO ₂ in reservoir
Marine environmental survey	Marine data (physical, chemical properties, biological habitat, etc.)

CO₂ Capture

Two-stage absorption process



CO₂ Capture facilities



Key Results of Tomakomai Project

CO₂ Capture Results

- Achieved following results in capture/injection facilities demonstration:
 - ① Designated capture amount (25.3t/h), recovery rate ($\geq 99.9\%$), purity ($\geq 99\%$), capture energy ($\leq 1.22\text{GJ/t-CO}_2$)
 - ② Complete automation of CO₂ compressor control system (simultaneous injection into two different reservoir types).
- Adopted two-stage absorption process employing activated amine for capture process. Achieved capture energy (consumption) target of less than 1.22GJ/t-CO₂**

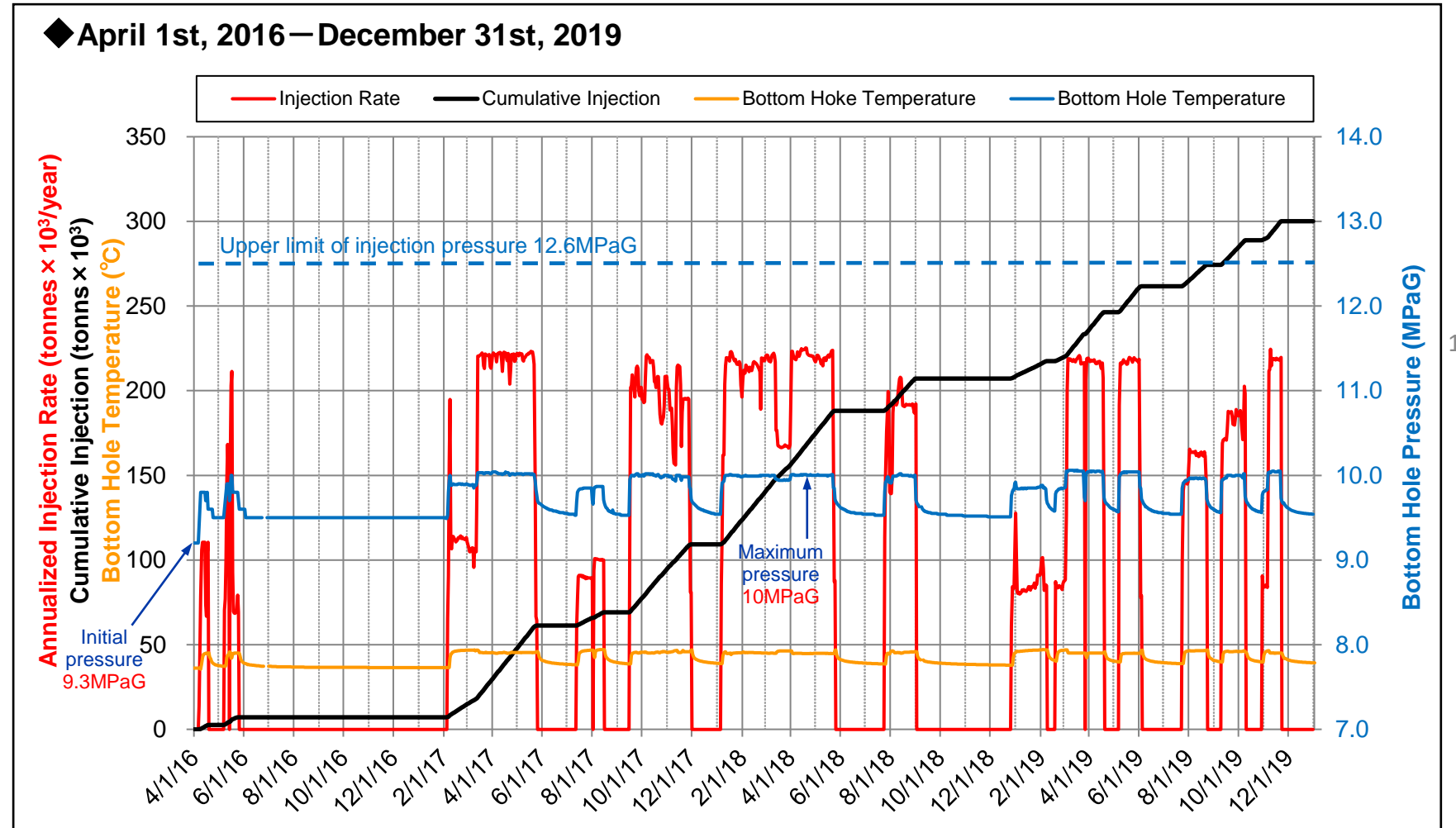
• Capture energy = reboiler duty/boiler efficiency
 + pump electricity x heat conversion coefficient/power efficiency;
 Example for FY2016: $0.923/0.9 + 19.8 \times 0.0036/0.42 = 1.20 \text{ GJ/t-CO}_2$

		FY2016	FY2017	FY2019	Designated Value
CO ₂ recovery	t/h	25.3	24.3	26.4	25.3
Reboiler duty	GJ/t-CO ₂	0.923	0.882	0.915	0.949
Pump electricity	kWh/t	19.8	21.0	18.8	19.2
Capture energy	GJ/t-CO ₂	1.20	1.16	1.18	Target:1.22

Results of CO₂ Injection

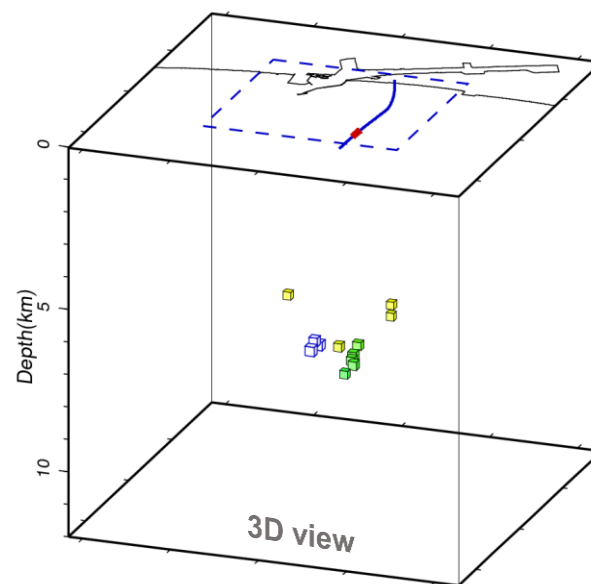
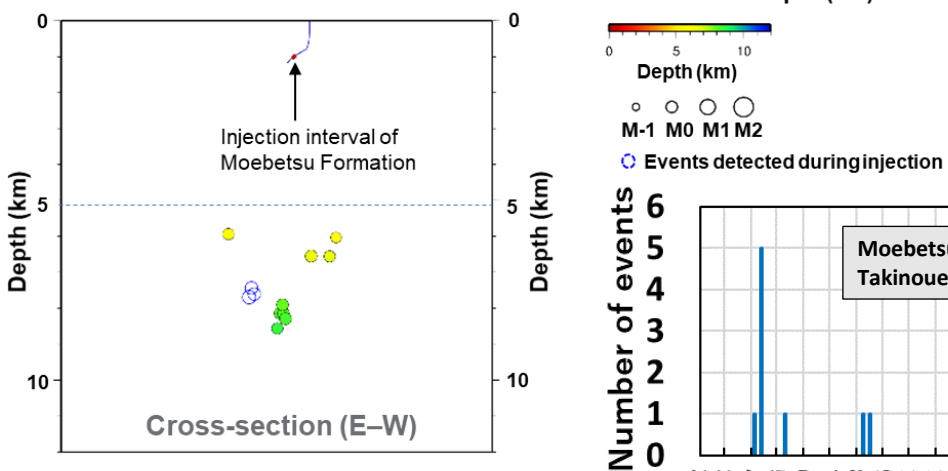
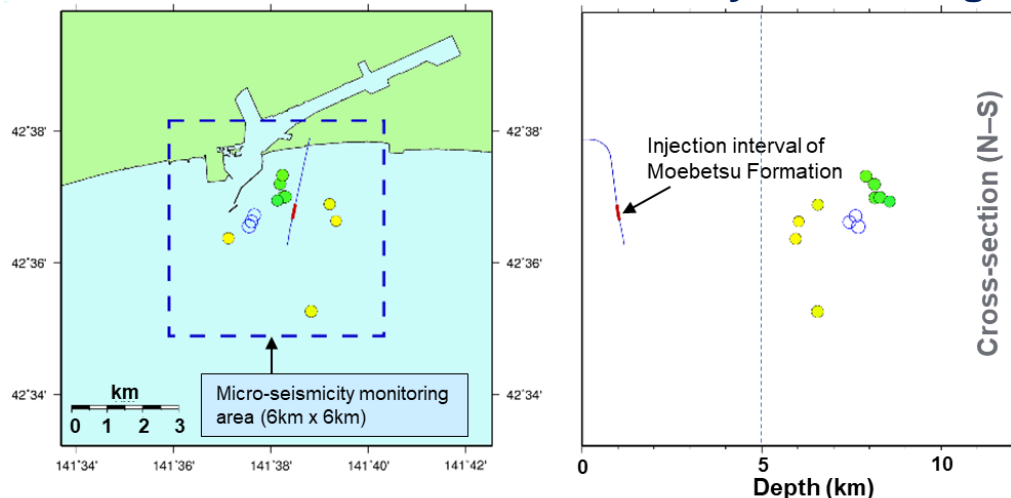
- Achieved 300,110 tonnes cumulative CO₂ injection into 2 reservoirs at different depths (Moebetsu Formation – 300,012 tonnes, Takinoue Formation – 98 tonnes).
- Maximum values recorded by PT sensors (pressure, temperature sensors set close to reservoir) during injection were sufficiently lower than the upper limits set to avoid destruction of cap rock of each reservoir.

Injection record of Moebetsu Formation



Results of Micro-seismicity Monitoring

Events detected in micro-seismicity monitoring area

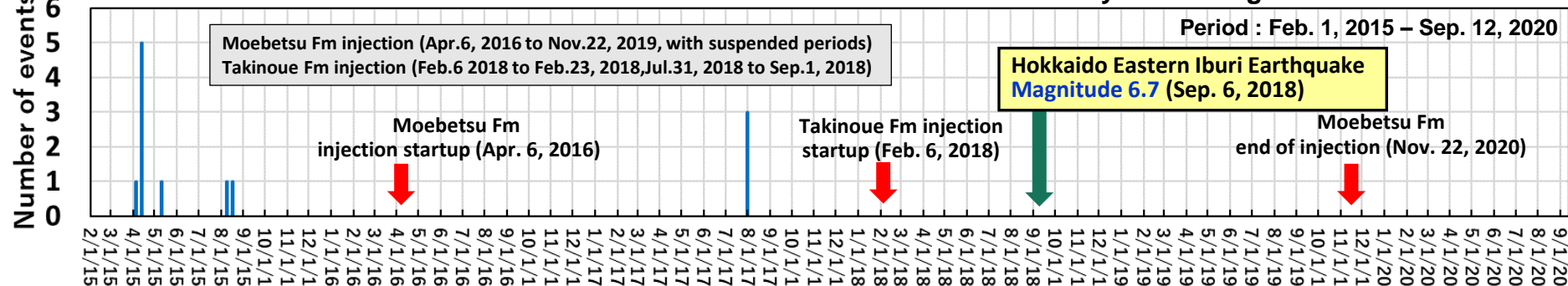


- No micro-seismicity or natural earthquakes attributable to CO₂ injection were detected in vicinity of injection area between startup of injection and December 2019, including before and after 2018 Hokkaido Eastern Iburī Earthquake.

※ Detectability: $M_w > -0.5$

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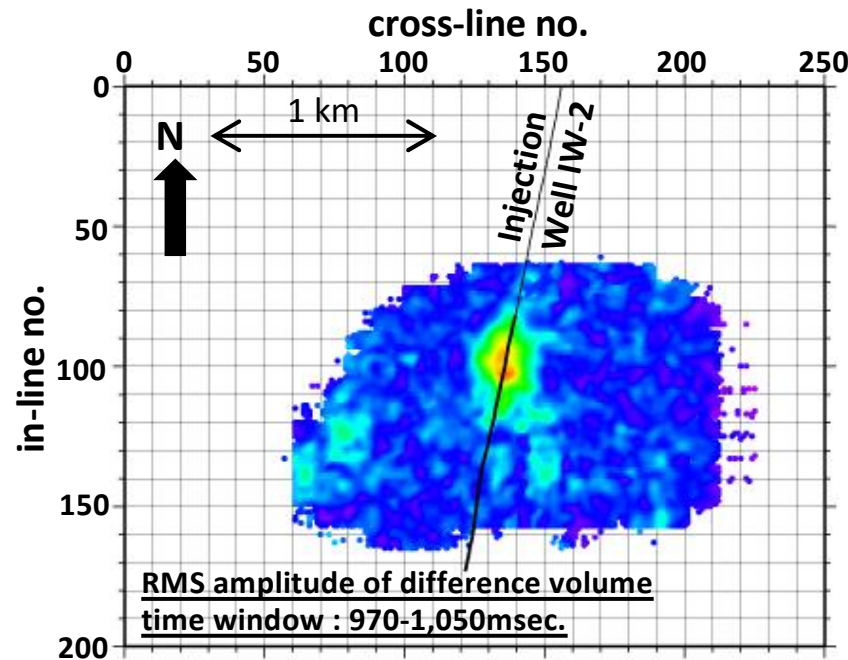
Micro-seismic events detected in the micro-seismicity monitoring area



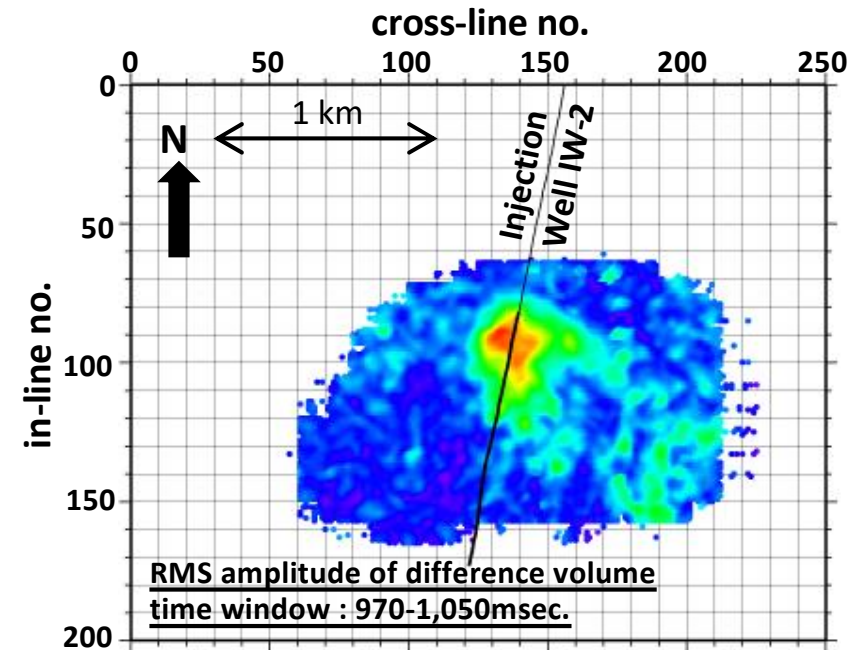
Seismic Survey Results - 2nd & 3rd Monitor Surveys -

- Distribution of CO₂ in Moebetsu Formation confirmed by seismic surveys since FY2017. Injected CO₂ is limited to upper portion of reservoir in correspondence with predictions made in advance, and not believed to have behaved abnormally.

2nd monitor survey (61,239 - 69,070 tonnes; JFY2017)



3rd monitor survey (207,209 tonnes; JFY2018)



※ S/N ratio and accuracy of difference calculation is low due to the limited area of the data utilized for calculation.

Part II Jiro Tanaka

Public Engagement

Summary

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Public Engagement

Public Outreach Activities

Voice of Tomakomai Citizens

1. Information Disclosure

Thorough disclosure should be made

2. Safety/CO₂ leakage

Want more detailed information on risk of CO₂ leakage

Monitoring & Disclosure Plan

3. Dissemination to Young Generation

Should consider efforts to involve young generation

Outreach Activities

- ① Panel Exhibitions
- ② Forum for Tomakomai Citizens
- ③ Site Tours
- ④ Information Disclosure System

- ⑤ Mini seminars for students
- ⑥ Kids' lab classes/site tours

Outreach Activities (JFY2019)

Site Visitors: 2168 people
(401 from overseas)

Mini seminars: 27 times

Panel Exhibitions: 8 times

Kids' lab classes: 3 times

Booth in Environmental exhibitions: 11 times

CCS Forum: 600 people



Project being conducted with understanding and support of local community

Outreach Activities:



Panel Exhibition in Tomakomai



Kids' lab class



Site Tours

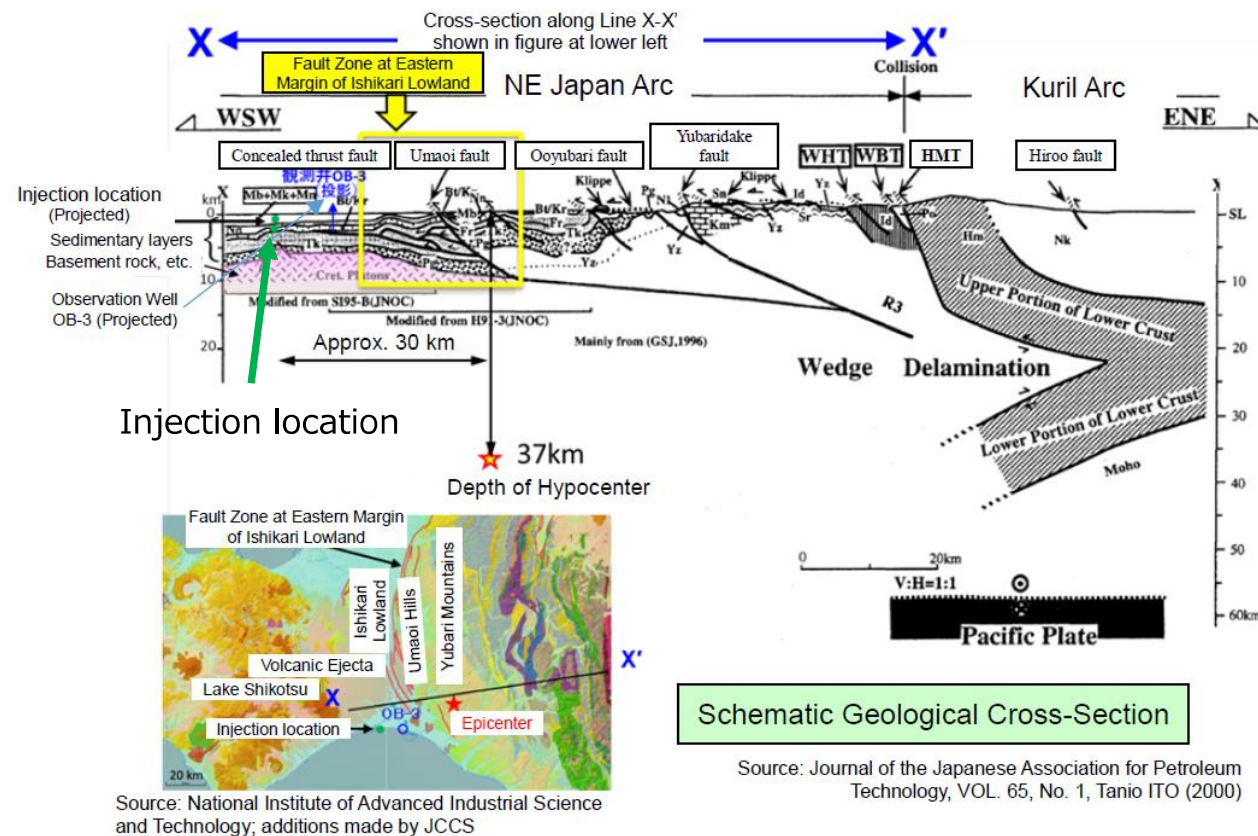


Information disclosure system in Tomakomai City Hall

2018 Hokkaido Eastern Iburi Earthquake

- At 3:07am Sept. 6, 2018, a magnitude 6.7 earthquake at 37km depth occurred in central eastern part of Iburi region of Hokkaido. Tomakomai CCS demonstration site recorded seismic intensity of lower 5.

Schematic cross section of hypocenter and injection location



Positional relationship between injection area and epicenter

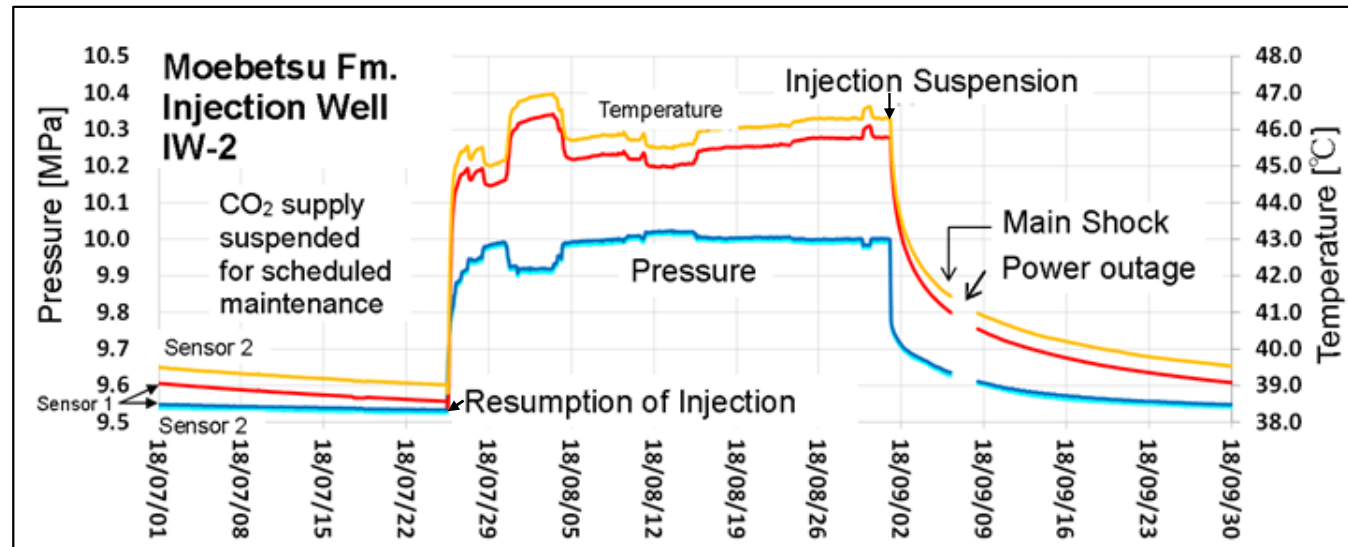


2018 Hokkaido Eastern Iburi Earthquake

- No indication of CO₂ leakage was confirmed in the reservoir pressure and temperature data. No detection of events by micro-seismic monitoring conducted continuously in injection area.
- Stress variation caused by CO₂ injection at hypocenter of Eastern Iburi Earthquake was found to be about 1/1,000th of pressure change in earth's crust caused by earth's tidal force.
- On Oct. 19, 2018, review meeting including experts in seismology reached common understanding: 1) No CO₂ leakage caused by the earthquake, 2) No data suggesting a connection between CO₂ storage and earthquake. Report summarizing conclusions was posted on JCCS homepage (https://www.japanccs.com/wp/wp-content/uploads/2019/09/Research-Report-on-Impacts-of-Hokkaido-Eastern-Iburi-Earthquake-on-CO2-Reservoir_2nd-edition.pdf)

Bottom hole pressures, temperatures of Moebetsu Formation injection well before/after earthquake

(measured by downhole pressure and temperature sensors set close to the reservoir)



Measures taken by JCCS after the Hokkaido Eastern Iburi Earthquake

- 6th Sept. 2018: Magnitude 6.7 earthquake occurred
- 12th Sept 2018: Posted JCCS's views on HP
- 19th Oct. 2018: Convened an expert review meeting
- 21st Nov. 2018: Posted summary of review meeting on HP
- 21st Feb. 2019: Magnitude 5.8 aftershock occurred
- 26th Feb. 2019: Posted JCCS's views on HP

Key points on JCCS HP:

1. No relationship between CO₂ injection and earthquake
2. No CO₂ leakage

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Key principles to minimize concerns of local community and general public:

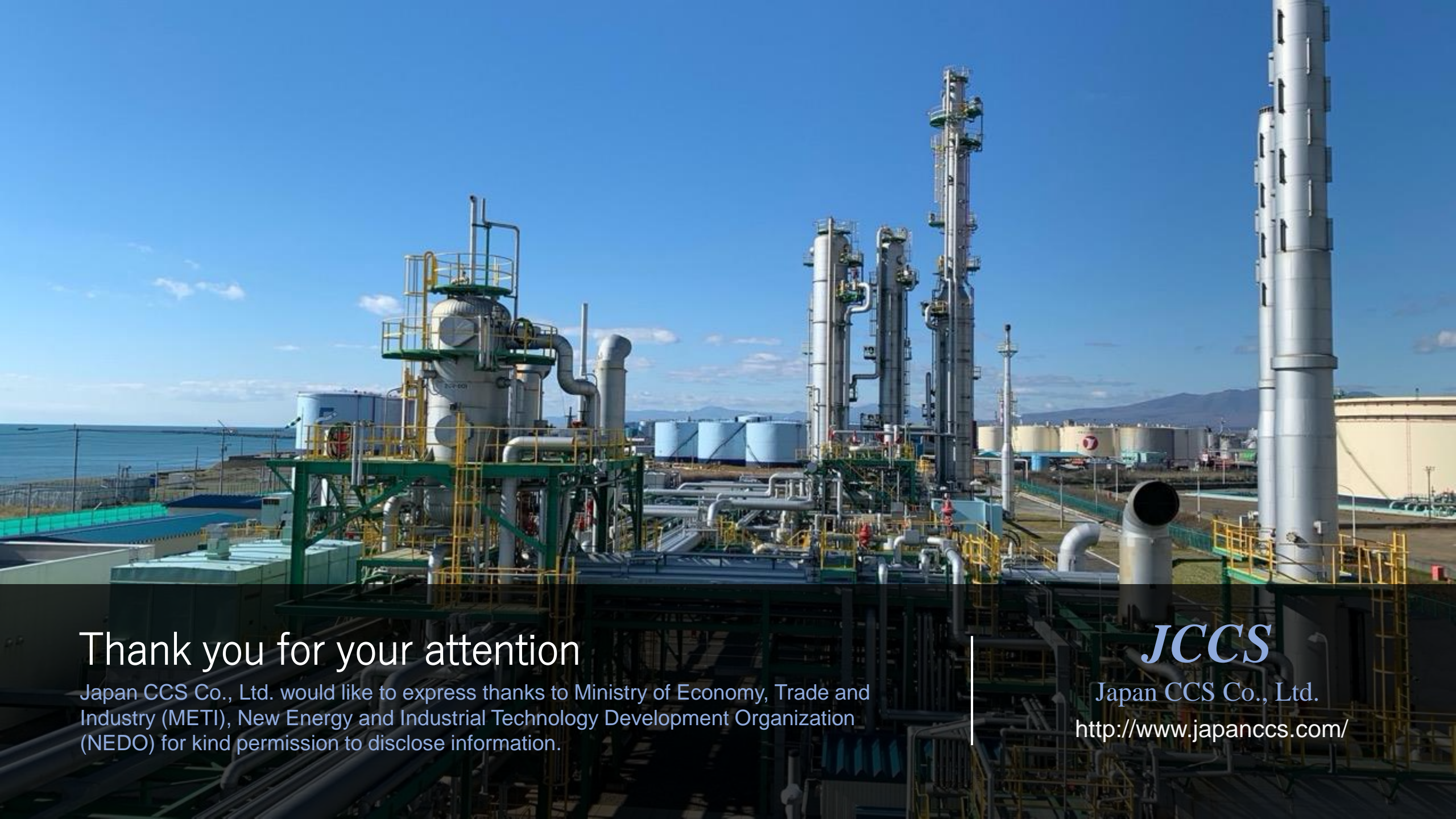
- *Respond quickly*
- *Include technical explanation*



Summary

Results and Lessons Learned

- Operation of **full chain CCS system from capture to storage conducted successfully, target of 300,000 tonnes of CO₂ injection achieved.** Monitoring operations being continued.
- CO₂ capture process comprising a two-stage absorption system with low pressure flash tower achieved **significantly lower capture energy than conventional system**
- Deviated injection wells from onshore site into offshore reservoirs saved drilling cost, avoided disturbance of marine environment and harbor operation
- Safety and reliability of CCS system demonstrated
- Concerns about **earthquakes and induced seismicity** addressed
 - Natural earthquakes have not caused damage to reservoirs; no data suggesting connection between CO₂ storage and earthquakes
 - Important to respond as quickly as possible, and to include technical data to minimize concerns.
- Project being conducted with **understanding and support of local community**
 - Importance of information disclosure and diligent efforts to secure understanding of local stakeholders



Thank you for your attention

Japan CCS Co., Ltd. would like to express thanks to Ministry of Economy, Trade and Industry (METI), New Energy and Industrial Technology Development Organization (NEDO) for kind permission to disclose information.

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