CCUS and Hydrogen Symposium

Current update on CO2 capture and transport study in Sustainable CCS Project by the Ministry of Environment Japan

CO2 Transport Demonstration

Feb. 20th,2020

HARUO OKOCHI

JGC JAPAN CORPORATION

AGENDA

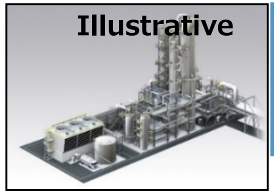
1. Sustainable CCS Project by MOE

The project demonstrates the capturing of the most of the emitted CO_2 at an existing coal power plant. It also identifies a smooth deployment methodology by taking the demo results into consideration.

CCS project overview

Separation and capture

Toshiba Energy Systems & Solutions
Mizuho Information & Research Institute



CO_2 capture: 500tCO_2/day

Evaluating the operation of the thermal power plant with large-scale CO_2 capturing plant etc.

Transport

Uyeno Transtech
JGC JAPAN Corp.
Chiyoda Corp.
University of Tokyo
Taisei Corp.

Consideration of CO_2 transport method suitable for Japanese condition

*** Officially launched in FY2018**

Storage (Monitoring etc.)

Mitsubishi Materials
Taisei Corp.
CRIEPI
INPEX
Mitsubishi Corporation Exploration
JANUS
AIST
University of Tokyo
DIA Consultant
Kyushu University

Storage planning for the candidate sites, following the suitable site identification

Monitoring planning for the candidate sites, following the suitable site identification

Developing a smooth deployment methodology of CCS

QJ Science
JANUS
Mizuho Information & Research Institute
Kyushu University
Taiheiyo Cement
JCOAL

- **Examination and assessment of CCS deployment path**
- **Assessment of the relevant technologies via working groups and expert interviews**
- **Organizing an international symposium etc.**

Project Organization

Project leader

Dr. Makoto Akai

Ministry of the Environment

Representative party

TOSHIBA

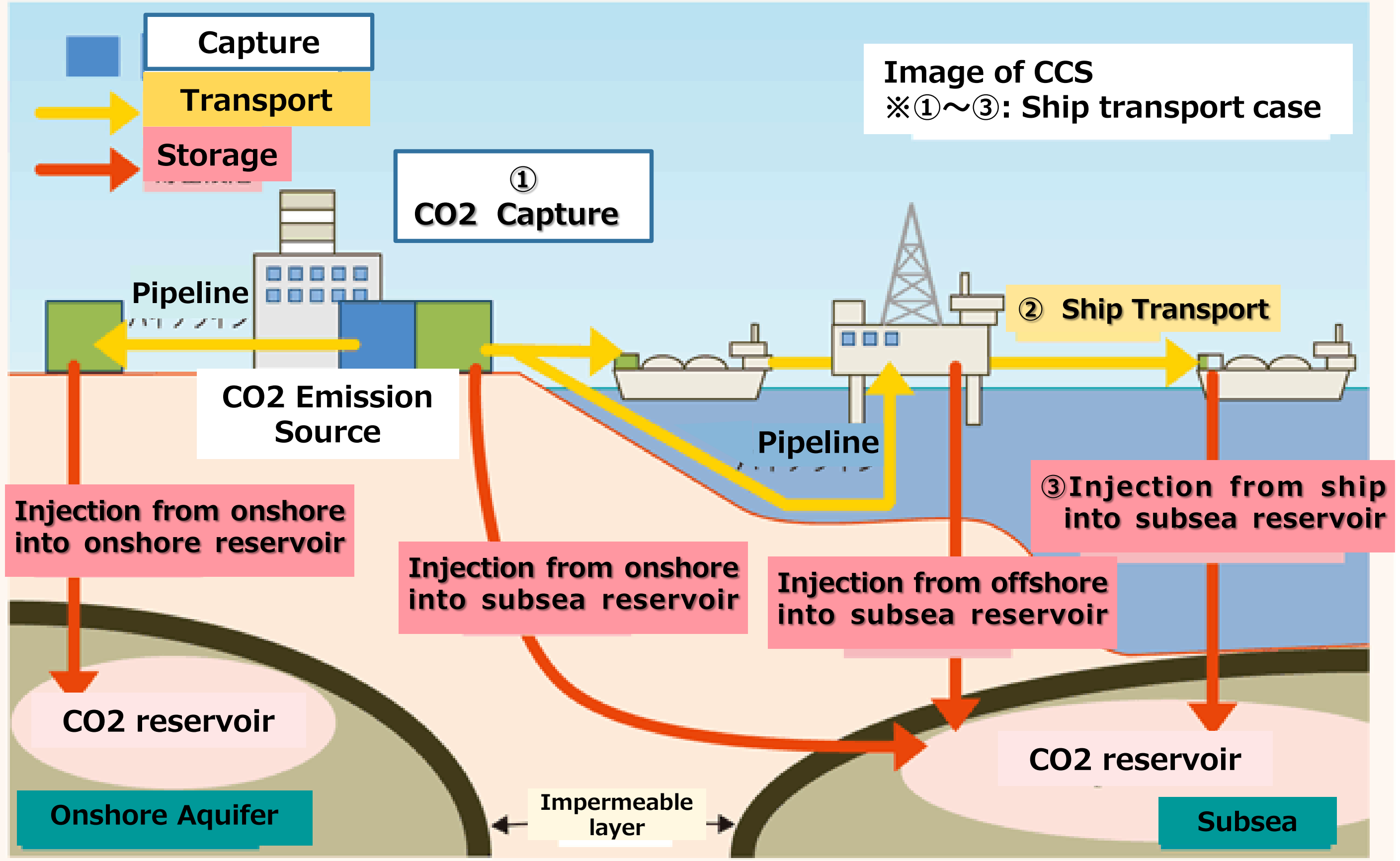
Participating parties

MIZUHO (Administrator)

- UYENO
- JGC 日揮株式会社
- CHIYODA CORPORATION
- MITSUBISHI MATERIALS
- TAISEI For a Lively World
- 電力中央研究所 (Central Research Institute of Electric Power Industry)
- INPEX INPEX CORPORATION
- Mitsubishi Corporation Exploration
- DIA CONSULTANTS
- KYUSHU UNIVERSITY I²CNER
- THE UNIVERSITY OF TOKYO
- JANUS JAPAN NUS CO., LTD.
- AIST
- JCOAL Japan Coal Energy Center
- QJ Science
- TAIHEIYO CEMENT

2. CO2 Transport

CCS Flow



SOURCE: English translation of Ministry of Environment Japan's material

- ◆ Need to transport the CO2 captured from CO2 emission sources
- ◆ Select transport methods considering the locational relationship between CO2 emission sources and storage sites, existing infrastructures and transport capacity, etc.
- ◆ Onshore transport ;
  Pipeline, Tank Lorry (truck) and Railway
- ◆ Offshore transport ;
  Ship transport, Subsea Pipe line
- ◆ CO2 physical property at transport;
  Gas, Liquid, Solid
- ◆ In offshore ship transport, higher transport efficiency by the volume reduction with compression and liquefaction

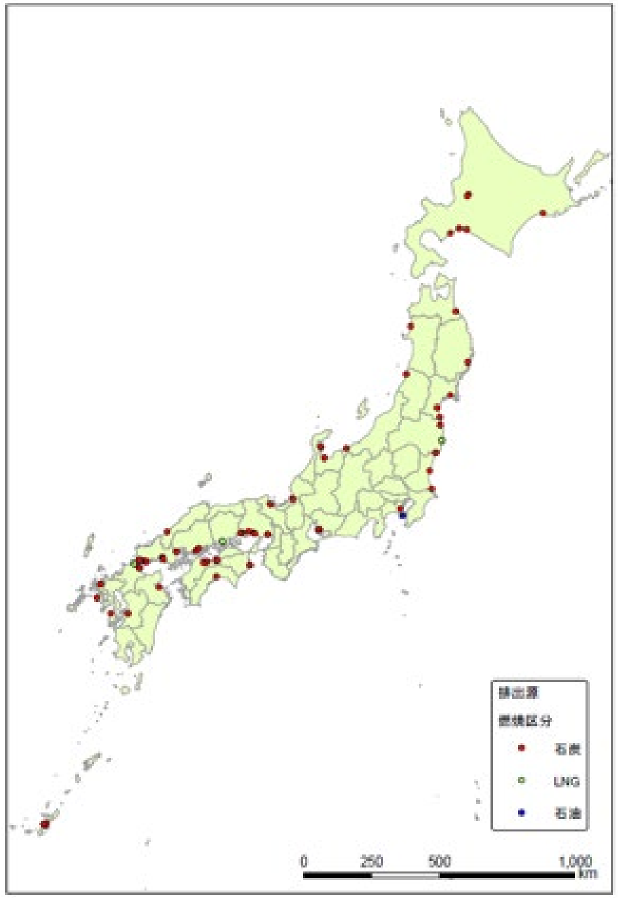
Standard Condition（Gas）2.0 kg/m3
（0℃, 1 bar）

The volume of CO2 is reduced to about 1/550 by liquefaction →

Liquefaction（Liquid） 1,030 kg/m3
（-20℃, 20 bar）

3. Significance of CO_2 Ship Transport

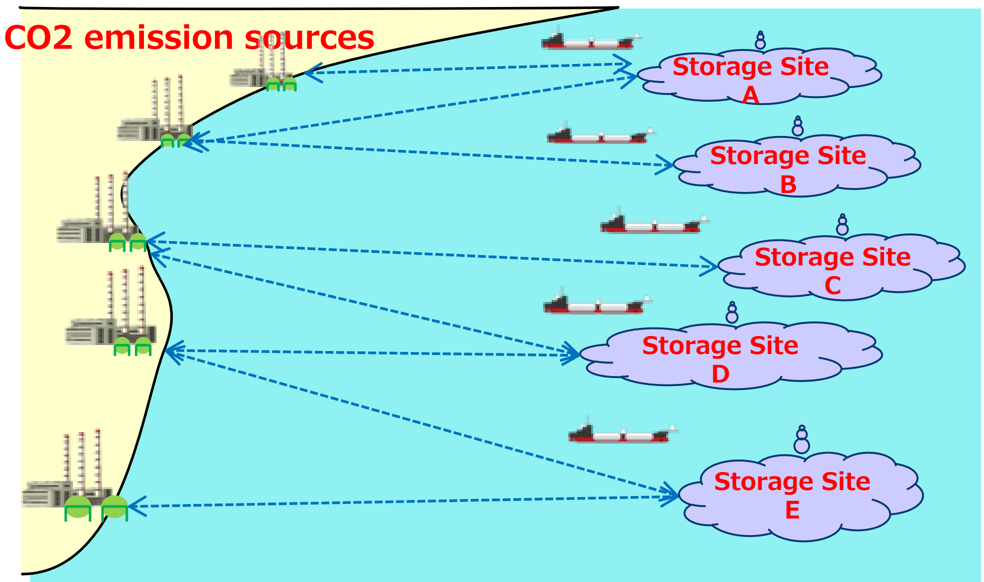
- When CCS acts as a tool for GHG reduction, **it is necessary to identify reservoirs with sufficient to stably storage CO_2** together with efforts to reduce the generation of CO_2 itself and effectively utilize generated CO_2.
- However in Japan, the storage potential for CO_2 is **small on land**, while it is **large in the surrounding sea area**. In addition, **most major CO_2 emission sources are located in coastal areas.** **Therefore, from transportability point of view, CO_2 storage in sea areas are considered as a reasonable option.**
- When the storage site is offshore far from CO_2 emission sources, a series of system of CO_2 liquefaction, CO_2 ship transport and CO_2 on-board injection is required.
- A series of CCS systems from transport to injection (**CCS integrated system) has not been proven in Japan**. Therefore, **Demonstration Testing at practical scale needs to be conducted** from the viewpoint of establishing technical feasibility, safety and economy before reaching the commercial stage in the future.
- Under the Basic Energy Plan, etc., research and development aimed at commercializing CCUS technology in around 2020 are being promoted, and for that purpose, **it is necessary to urgently establish CO_2 maritime transportation technology**.

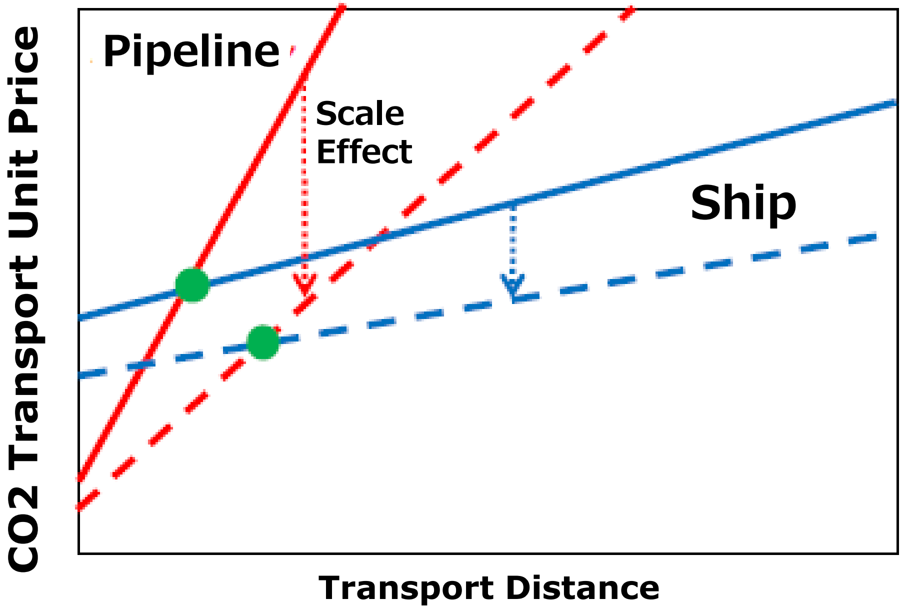


Location distribution of thermal power plants in Japan

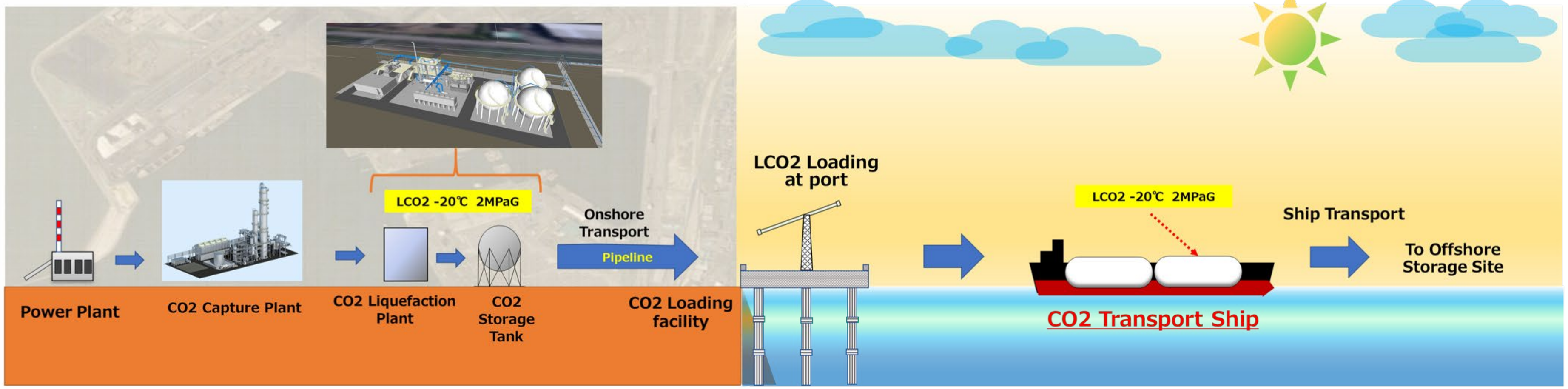
4. Features of Ship Transport

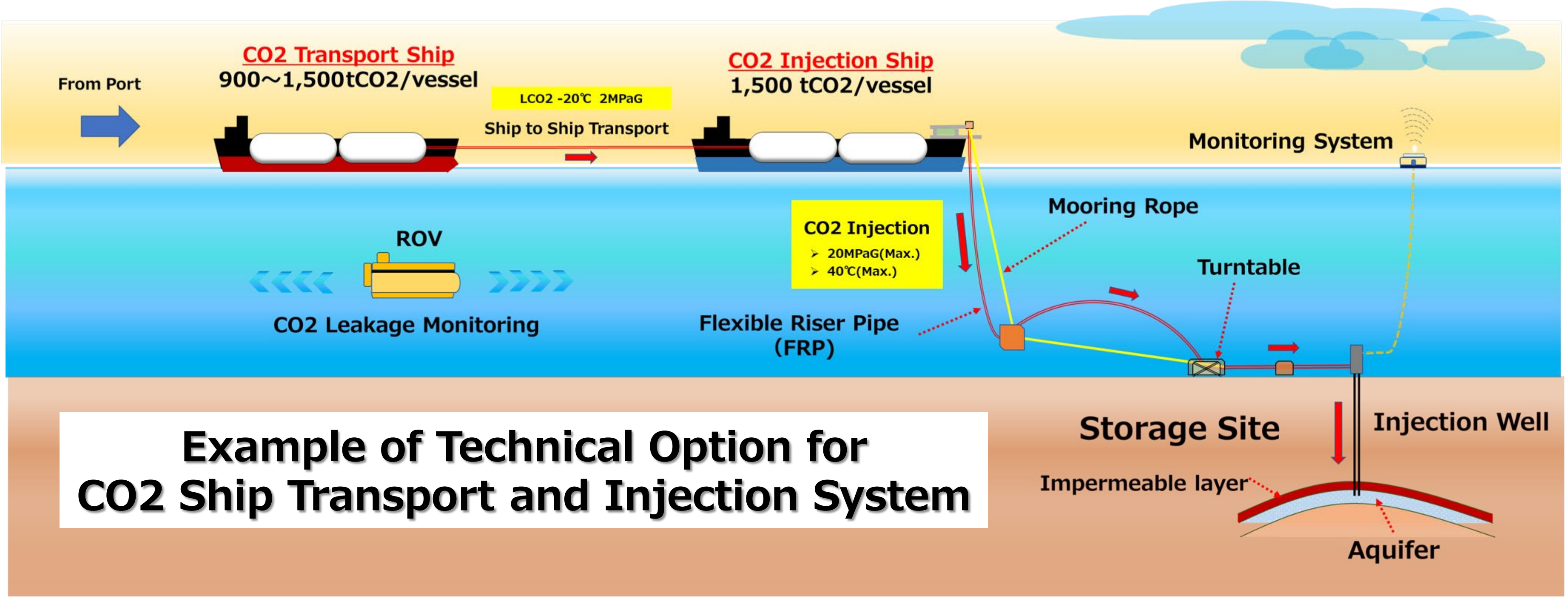
- Less subject to transport distance and water depth changes
- High flexibility in changing transport routes, phase to phase expansion and scale changes of the project
- High degree of freedom in connecting emission sources and storage sites
- Solution against the difficulty of constructing medium- or long-distance pipelines onshore/offshore.
- As a result of preliminary economic analysis for the combination of various sources and storage sites in this project, ship transport was superior to pipeline transport in 2/3 of the cases, and the effectiveness of CO2 ship transport in Japan was confirmed.





5. CCS Integrated System for Offshore Storage Sites
(1) CO2 Ship Transport and Injection System

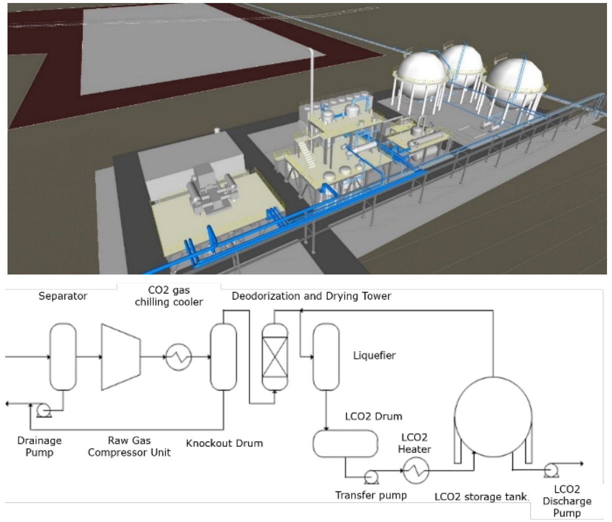




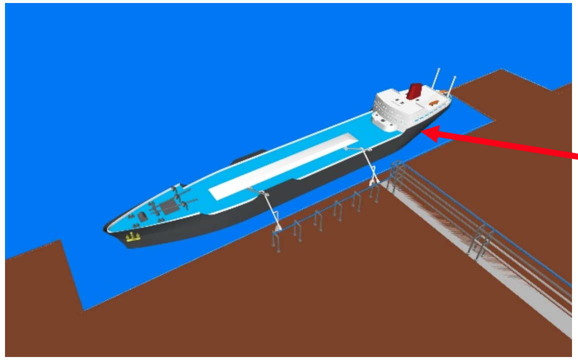
Example of Technical Option for CO2 Ship Transport and Injection System

5. CCS Integrated System for Offshore Storage Sites
(2) Overview of Main Facilities and Equipment

Compression, Liquefaction and Storage

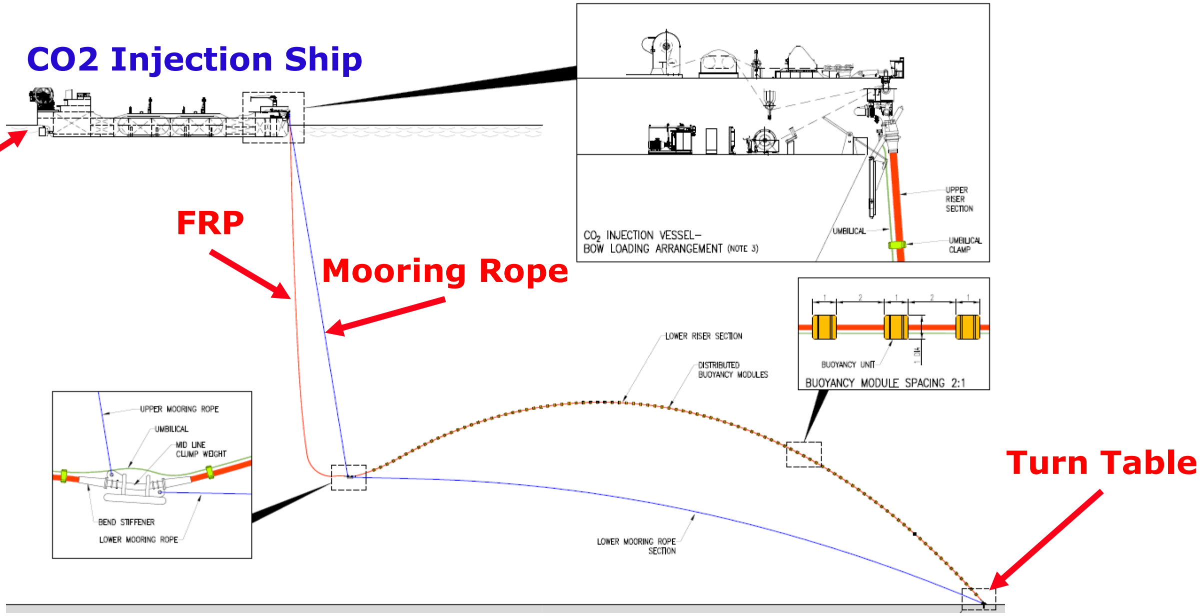


CO2 Loading at Port



CO2 Transport Ship

CO2 Injection Ship



5. CCS Integrated System for Offshore Storage Sites
(3) Steps for establishing CCS Integrated System

Fiscal 2016	2017	2018	2019	2020
Study for technical issues related to CO2 transport and countermeasures		Concretizing the demonstration test plan		
	Confirming prospect of technical feasibility of each component technology	Comparative study of multiple transport scenarios ◆Various Options ・Onshore capacity ・Transport capacity ・Transport distance ・Sea depth at storage site ・Port conditions ・Injection/mooring methods	Screening of Scenarios ・Optimization of whole system ・Screening of technical options ・Cost reduction	Basic Concept for Demonstration of CCS integrated system
Study for the combination of sources & sinks and selection of the candidate transport models		Study for the future commercial phase		
Economic analysis of optimal transport method considering the combination of various emission sources & storage sites		Transport model rationalization and countermeasure proposal Study and demonstration on component and elemental technology applicable to commercial phase		Transport model concept for future commercial phase

6. Transport Scenario Study
(1) Multiple Transport Scenarios

Facilities/Locations	Onshore Facilities (Compression, Liquefaction and Storage)	Port facilities	Transport/Injection Ship	Storage Site Location
Typical Variable Factors (Parameters)	Installation Capacity	Pier Location	Cargo Tank Capacity	・Marine Transport Distance ・Sea Depth ・Marine/Weather Conditions
Options	Maximum (600tCO2/day) ↕ **Variations** Minimum (<600tCO2/day)	◆Pier 1 (※) → ◆Pier 2 (※) ◆Pier 3 (※)	1,500t~3,000 tCO2/vessel (Pier 1) 900 tCO2/vessel (Pier 2, Pier 3) Available Ship Size depends on conditions of each pier.	◆ Storage Site A (※) ◆ Storage Site B (※) ◆ Storage Site C (※)

(※) **Candidate Location**

- ◆**Define representative multiple transport scenarios (13 cases) considering the combination of options**
- ◆**Cost Estimate of each transport scenario**

6. Transport Scenario Study
(2) Improvement Points for Cost Reduction

◆For the pier, using "pier-1" rather than "pier -3" can increase the size of the transport vessel and increase the total amount of injection, but pier 1 is expensive to remove the existing facilities and build a new pier.

➡ Reduce cost by modifying and reusing the existing pier-1

◆The capacity of onshore facilities is more reasonable in terms of cost if it is matched to the transportable amount.

➡The capacity of onshore facilities will be determined in consideration of transport and injection efficiency (= total amount of CO_2 injection÷total amount of liquefied CO_2 production) to optimize the overall cost.

[Ship capacity x transport distance ⇒ transportable capacity ⇒ onshore facilities capacity]

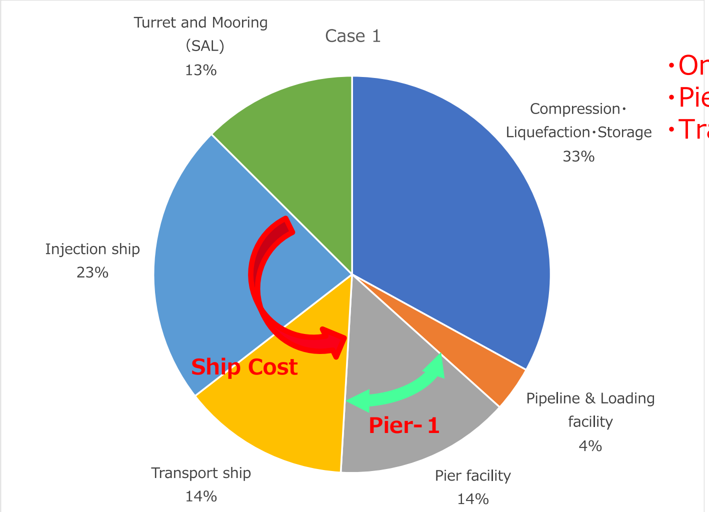
◆The shorter the transport distance and the larger the ship transport capacity, the greater the total CO_2 injection can be.

➡ Maximize total CO_2 injection amount by increasing ship capacity within an acceptable budget range

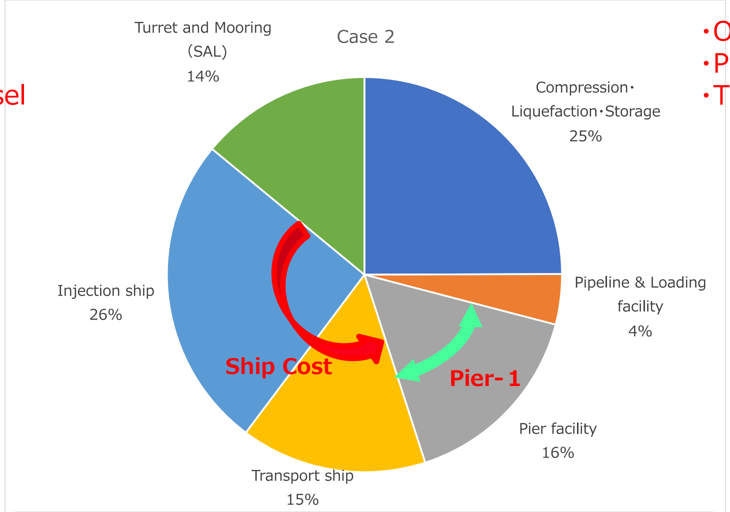
◆The proportion of ship costs for transport and injection ships of total cost is large.

➡ Pursue improvement measures to reduce ship costs

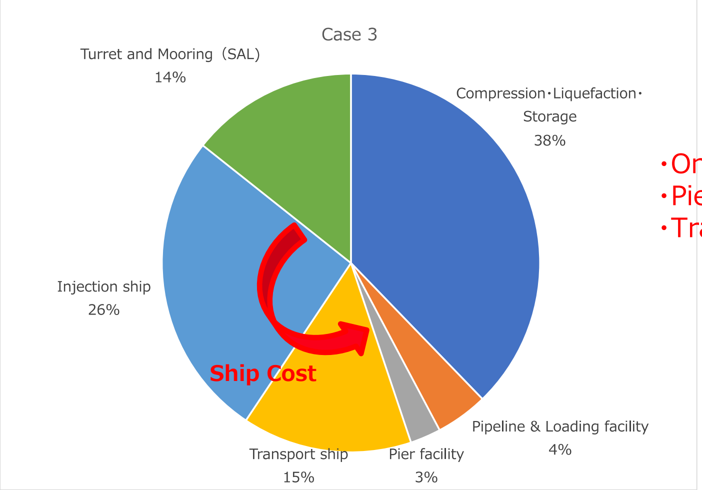
Construction cost composition ratio (Storage Site A, Transport Distance:~1,300km)



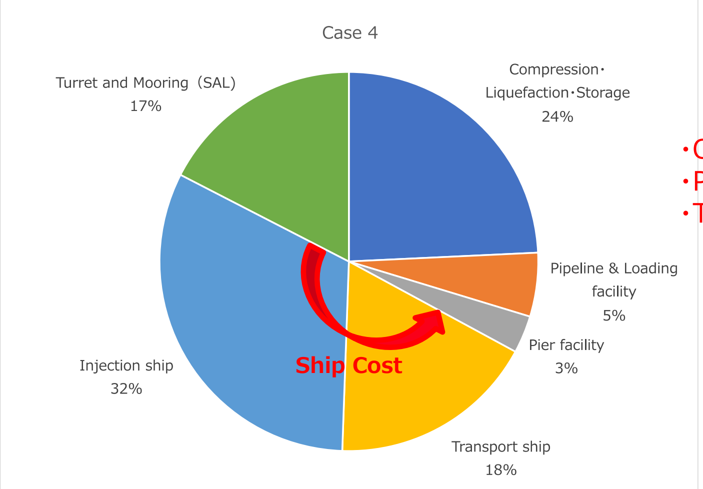
Case 1
・Onshore Capacity : 600tCO_2/d
・Pier : Pier-1
・Transport Ship : 1,500tCO_2/vessel



Case 2
・Onshore Capacity : 200tCO_2/d
・Pier : Pier-1
・Transport Ship : 1,500tCO_2/vessel

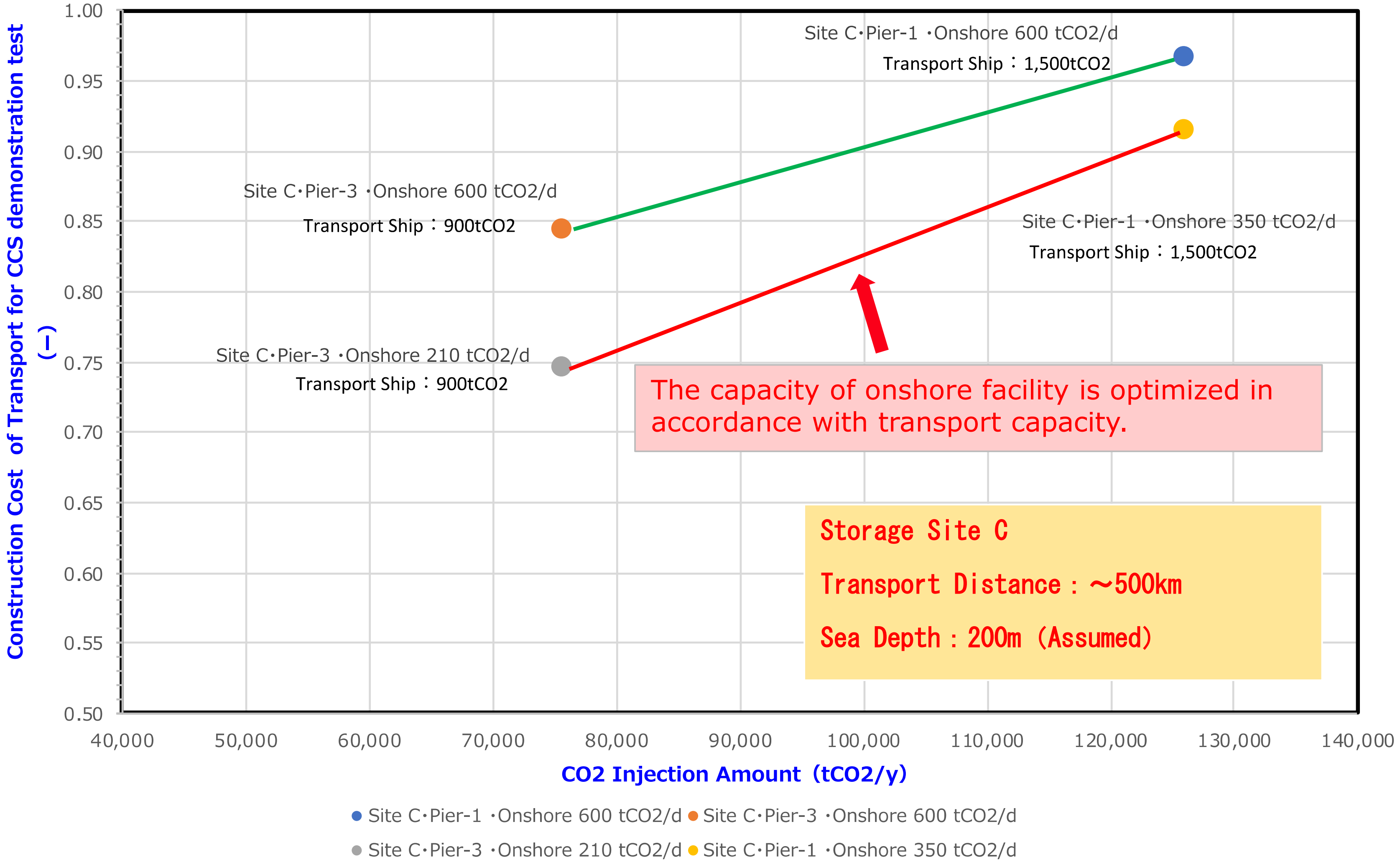


Case 3
・Onshore Capacity : 600tCO_2/d
・Pier : Pier-3
・Transport Ship : 900tCO_2/vessel



Case 4
・Onshore Capacity : 120tCO_2/d
・Pier : Pier-3
・Transport Ship : 900tCO_2/vessel

Construction Cost vs CO2 Injection



Next Steps for Optimization of Transport System by Quantitative Indexes (Under evaluation at present)

Screening an advantageous transportation scenario for each storage site from the viewpoints of transport and injection efficiency, cost, and energy efficiency considering improvement points

① Index of Transport and Injection efficiencies (-)

Annual CO_2 Injection Amount (tCO_2/y) ÷ Liquefied CO_2 Production Amount（tCO_2/y at Liquefaction Plant）

This index includes all efficiencies such as transportation efficiency, berthing time at the port, Ship to Ship transportation time, and injection time. If the liquefaction facility produces liquefied CO_2 that exceeds transportable amount, this index will be small, and the utilization rate will be poor.

② Index of Cost (JPY/tCO_2)

Lifetime cost of the facilities from liquefaction to Injection (JPY) ÷ Total injected CO_2 for plant life (tCO_2)

Lifetime cost includes OPEX during whole operation period as well as CAPEX.

③ Index of Energy Efficiency (kWh/tCO_2)

Annual Power Consumption（kWh/y） ÷ Annual CO_2 Injection Amount (tCO_2/y)

For example, in case of liquefaction facility, this index represents consumed energy (electric power) per the amount of CO_2 processed.

7. Summary

- The **CCS integrated system** is composed of various sub-systems, such as onshore facilities (capture, liquefaction, storage) , port facilities, CO_2 transport/injection ship, injection systems (Flexible Riser Pipe, mooring), monitoring system.

- Since several pre-conditions are not determined at present, **multiple transport scenarios** are defined, and their cost were provisionally evaluated.
  As a result, **several cost reduction measures were identified.**

- In next phase, considering such measures, the **screening of the transport scenarios** will be carried out by using **quantitative indexes** from the point of view of cost, transport efficiency and energy efficiency.

8. Target and Prospects

Target of this project up to fiscal 2020

◆Implement **detailed study of ship transportation technology** to efficiently transport and inject CO2 recovered from the large-scale CO2 capture plant

◆Establish **basic concepts** to fully start optimization, detailed design, and construction for demonstration tests

Future Prospects

Aim to rapidly establish **CO2 maritime transportation technology**, which is one of the important components of this technology toward the practical application of CCS technology around 2020

Although some conditions for system design, such as pre-conditions related to storage site, are not determined at present, **the concept of the transport system for the demonstration test** is expected to be established by broadly evaluating multiple transport scenarios in term of technical and economic aspects.

Continually study and demonstrate the integrated systems and elemental technologies applied to the **commercial phase**, in order to deploy CCS as one of the global warming countermeasures