Quantitative Comparison of CCS Value Chain with LCO_2 three modes (LP/MP/EP)

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Disclaimer

- CAPEX/OPEX/any other cost information are indications provided by potential suppliers and/or based on inhouse date through previous studies.

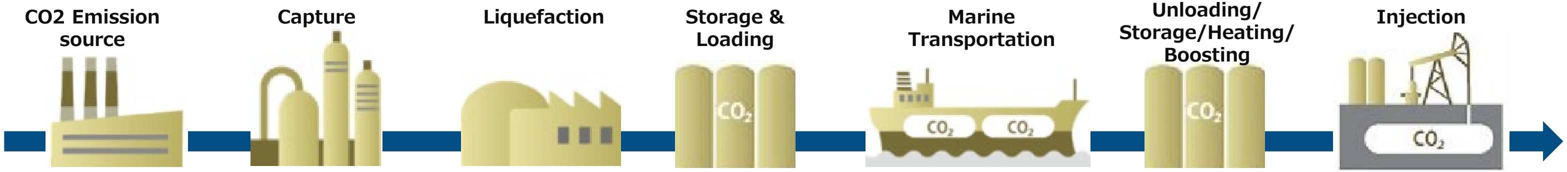
- The information provided does not impose any legal commitment nor obligation on Chiyoda/NYK/KNCC or any of its affiliates in any respect.

Agenda

1. Background

Scope:

CCS value chain with large scale transport by liquefied CO_2 (LCO_2)



Purpose:

Verify the feasibility of 3 modes (LP/MP/EP) in CCS Value chain by investigating the Pros/Cons of each mode in each system and comprehensive evaluation of their suitability in CCS Value chain

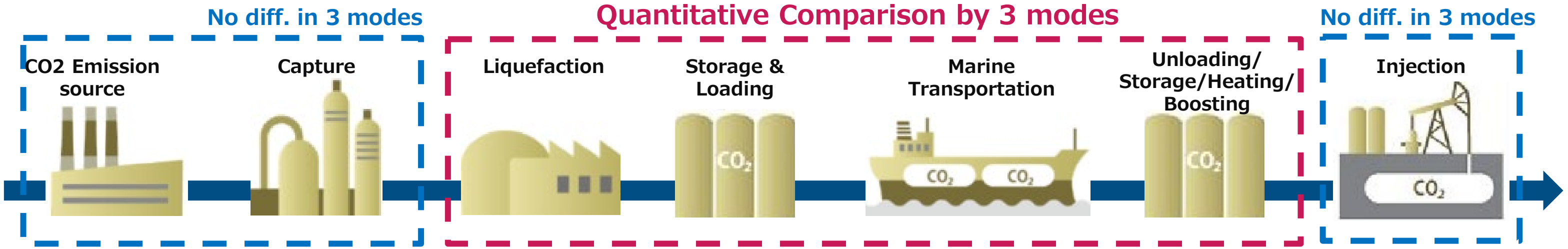
Evaluation Items:

- ✓ CAPEX/OPEX relative comparison for each facility
- ✓ Outstanding Actions for Social Implementation

2. Basis of Study

- Post Combution CO_2 capture by chemical solvent (no differences among 3 modes)
- Liquefaction Capacity : 2MTPA CO_2 recovery and liquefaction
- Liquefaction Technology : Propane Refrigerant Cycle
- LCO_2 Transport (Capacity, Loading/Unloading Port) :

  Japan Domestic : 20,000 m^3, Osaka to Hokkaido (1,550 km)
  Oversea : 40,000 m^3 and 50,000 m^3, Japan to Australia (5,600 km)
- CO_2 delivery conditions at well head : 10 MPaG, 20degC



2. Basis of Study

Study Case

	MP Medium Pressure		LP Low Pressure		EP Elevated Pressure	
CO_2 Capacity	2 MTPA		2 MTPA		2 MTPA	
LCO_2 Product Conditions	1.3 MPaG/-30°C		0.6 MPaG/-50°C		3.4 MPaG/0°C	
LCO_2 density	1,000 kg/m3		1,150 kg/m3		930 kg/m3	
Study Case	**Domestic**	**Overseas(*2)**	**Domestic**	**Overseas**	**Domestic(*3)**	**Overseas(*4)**
LCO_2 onshore storage capacity(*1)	22,000 m3	-	22,000 m3	44,000 m3	24,200 m3	55,000 m3
LCO_2 carrier capacity	20,000 m3	-	20,000 m3	40,000 m3	22,000 m3	50,000 m3
Number of shipping vessels	2	-	2	3	2	3

(*1): 10% margin by LCO2 carrier capacity
(*2): Exclude Overseas case considering low feasibility of oversea transportation by MP carrier
(*3): 110% capacity of volume than MP/LP considering mass density gap between MP and EP
(*4): 125% capacity of volume than LP considering mass density gap between LP and EP

2. Basis of Study

Basis of Unit Cost

The cost is shown in Unit Cost [USD/t-CO_2] calculated by dividing the total cost with the annual volume of CO_2.

$$\text{Unit Cost} = \frac{\text{(CAPEX or OPEX)}}{\text{Annual } CO_2 \text{ tons}}$$

Basis of Onshore CAPEX for Liquefaction, Storage & Loading and Receiving Terminal

CAPEX = Equipment Cost (incl. Material cost) + Construction Cost (AACE Class 5)

Basis of Onshore OPEX for Liquefaction, Storage & Loading and Receiving Terminal

OPEX = Electricity cost (0.17 USD/kWh)
(Compressor, Pump, Cooling tower, Electrical Heater etc.)
(excluding other utility since there is no difference among 3 modes)

2. Basis of Study

Basis of CAPEX/OPEX for Marine Transportation

CAPEX (Fixed cost)	**Vessel Price**	Vessel price
OPEX (Semi-fixed cost)	**Crew expense**	labor costs of crews on board (number of crews depends on the size & operation of vessel)
	Vessel stores	cost of equipment and supplies to maintain vessel quality
	Lubrication	cost of lubricating oil for vessels' main engines and generators
	Dock cost	reserve for regular repair (twice in every five years)
	H&M insurance	physical damage protection for the vessels.
	P&I insurance	covers ship owner's third-party risks for damage caused to cargo during carriage and risks of environmental damage such as oil spills and pollution.
	Ship management	ship management commissioning fees
	Port cost	fees charged when vessel calls ports. Incl. harbor dues/agency fees, assisting tugs, pilotages etc.
	Fuel cost	Dual Fuel basis (LNG and MGO) in this case

Vessel Conditions:
- LNG/MGO dual fueled new built vessel
- Fuel Price: LNG 900 USD/MT、MGO 700 USD/MT
- Sailing Speed: adjusted to most optimal speed between 11.5 – 14 knots
- Port Cost: 30,000 – 50,000 USD/Call subject to to vessel size
- Others: Reasonable allowance (bad weather, delay,etc) is taken into consideration.

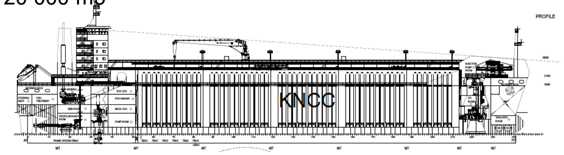
2. Basis of Study Vessel dimension

Vessel Type	Tank Volume (m^3)	Loa (m)	Beam (m)	draft(m)
LP / Type C	20,000	180	27	9.5
MP / Type C	20,000	188	28	9.3
EP / CTC	22,000	190	30	9.5
LP / Type C	40,000	230	35.3	11.4
EP / CTC	50,000	265	42.6	11.4

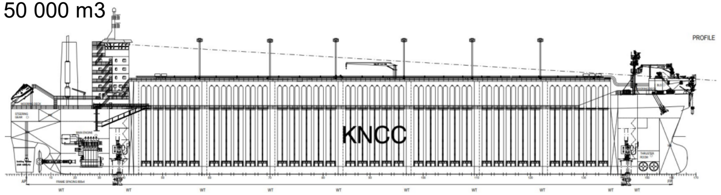
Domestic Transportation

Overseas Transportation

20 000 m3

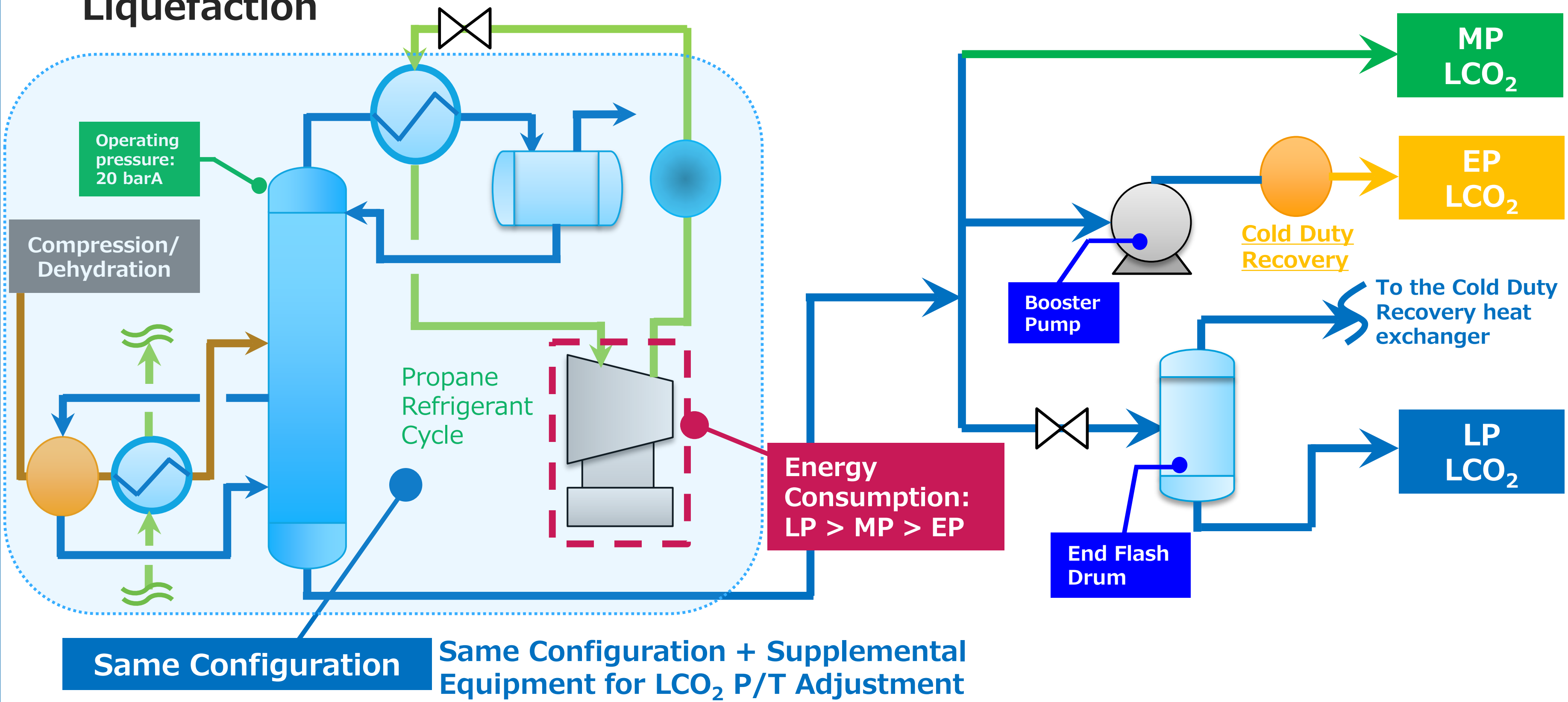


50 000 m3



3. System Description in CCS Value chain

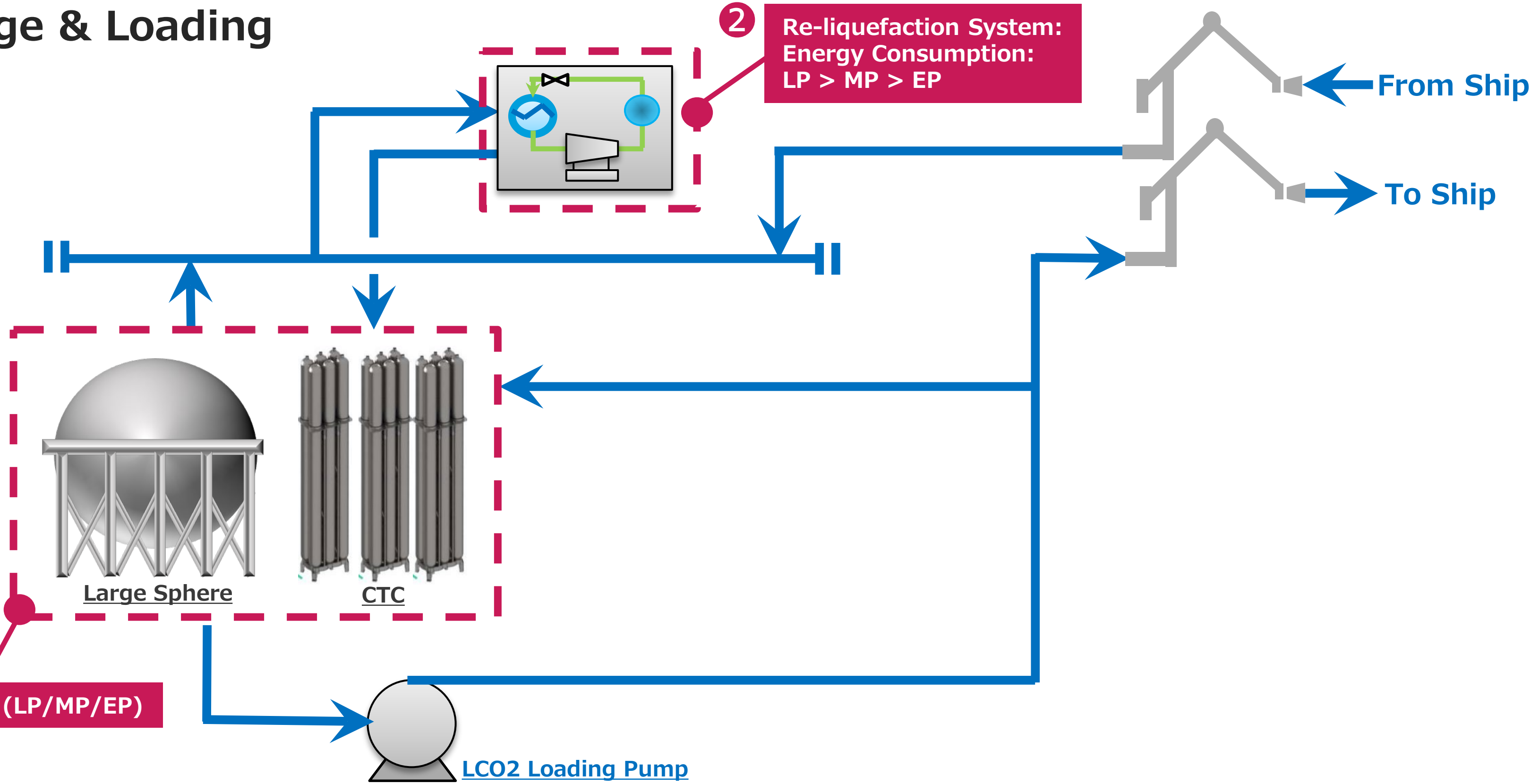
Liquefaction



Same Configuration + Supplemental Equipment for LCO_2 P/T Adjustment

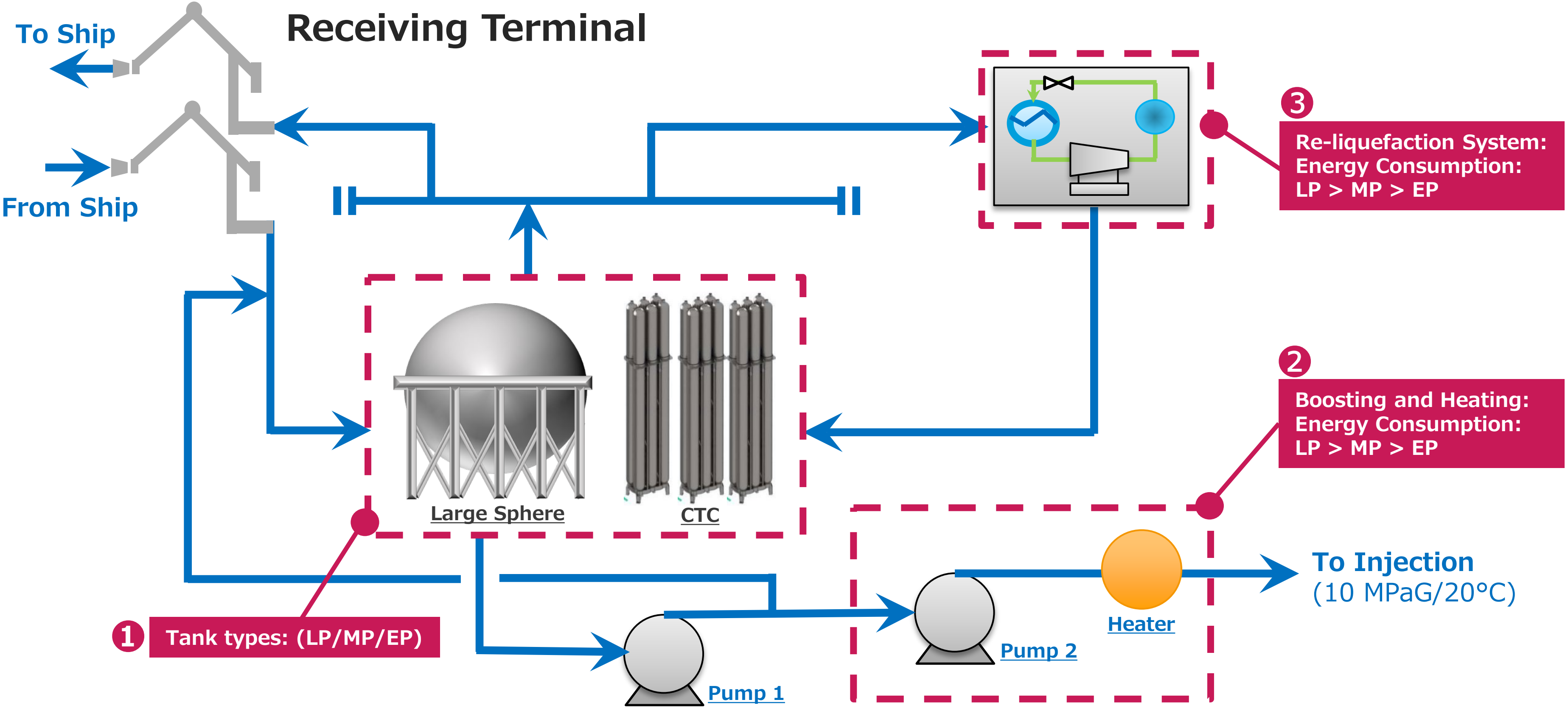
3. System Description in CCS Value chain

Storage & Loading



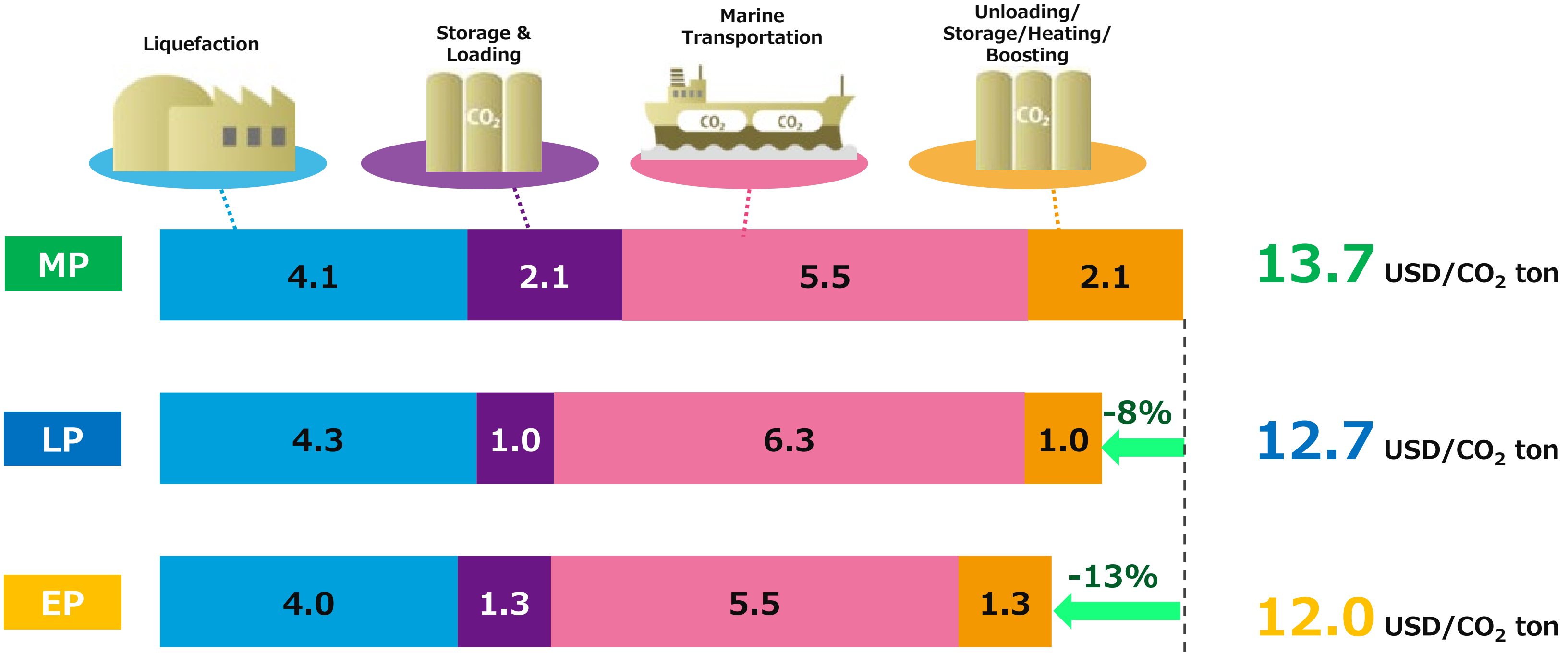
1 Tank types: (LP/MP/EP)

3. System Description in CCS Value chain



4-1. Quantitative Comparison for Domestic Case

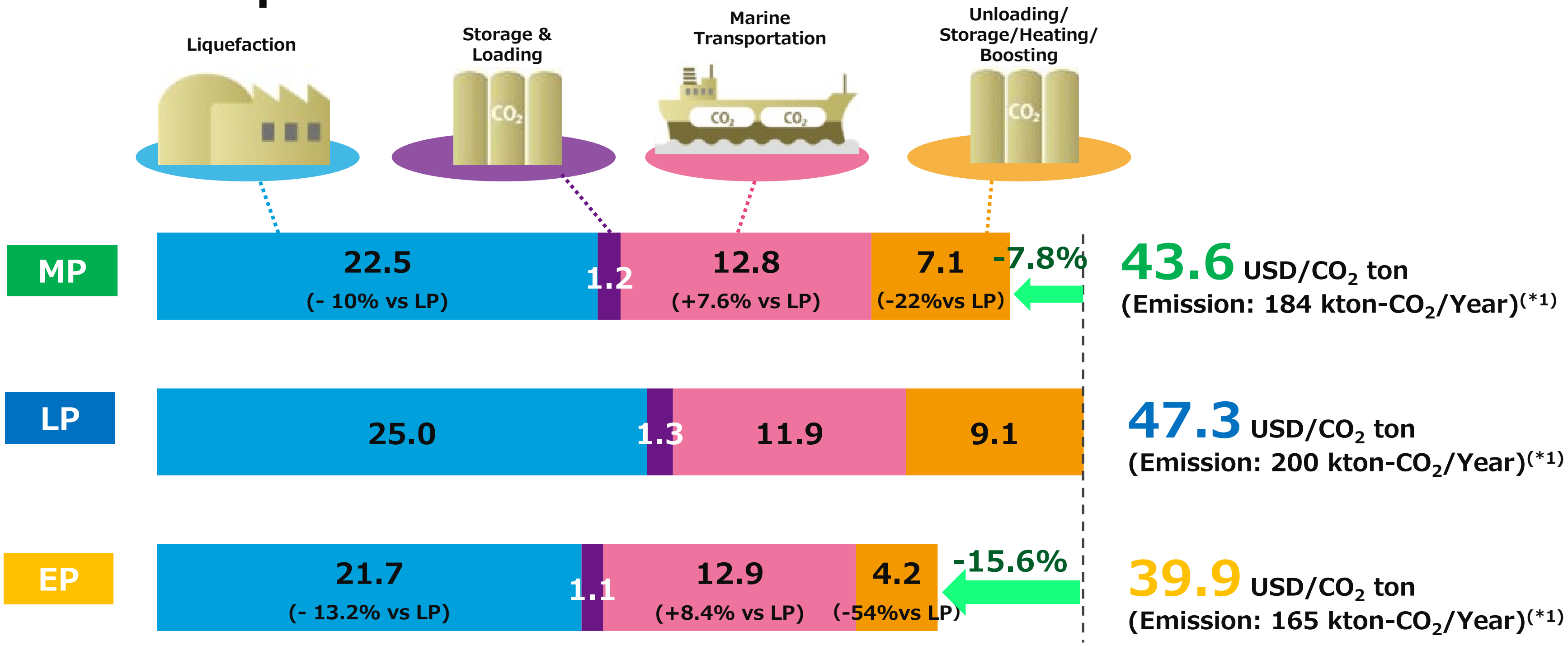
CAPEX Comparison



- 120JPY/USD
- Indication only
- CAPEX : excluding financing and miscellaneous cost

4-1. Quantitative Comparison for Domestic Case

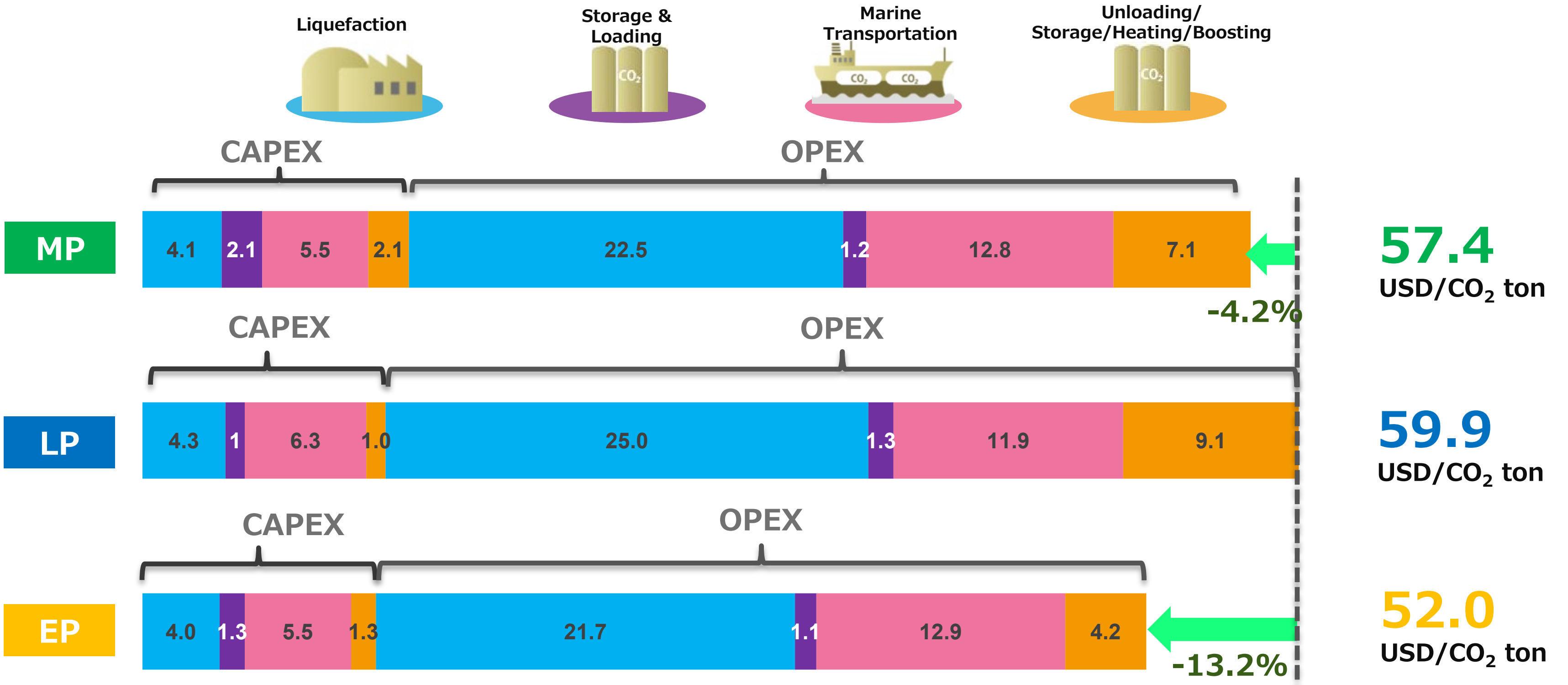
OPEX Comparison



(*1): Assumed all energy is fed by LNG (LNG thermal Power, LNG fueled ship)

- 120JPY/USD
- Indication only
- OPEX onshore : Electricity only (excluding labor cost /maintenance cost etc…)
- OPEX marine : all inclusive (fuel/port/crew/insurance/dock/R&M etc)

4-1. Quantitative Comparison for Domestic Case



- Unit cost is not covering all cost aspects. Costs assumed to be similar among the three modes is excluded regardless OPEX consists majority of CCS VC cost
- EP CAPEX is more or less similar while big difference in OPEX cost among the three modes.

- 120JPY/USD
- Indication only
- CAPEX : excluding financing and miscellaneous cost
- OPEX onshore : Electricity only (excluding labor cost /maintenance cost etc…)
- OPEX marine : all inclusive (fuel/port/crew/insurance/dock/R&M etc)

4-1. Quantitative Comparison for Domestic Case

<u>LCO_2 Storage Tank - Breakdown</u>

LP/MP; Spherical tank ≒ 22,000 m^3, EP; CTC tank ≒ 24,200 m^3

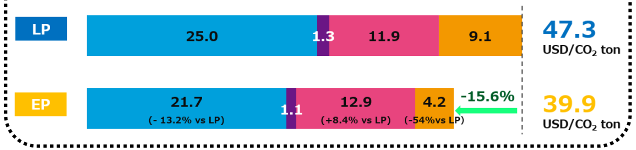
	MP Medium Pressure	**LP** Low Pressure	**EP** Elevated Pressure
Tank Type	Spherical (ID 11,980 mm×32 mm)	Spherical (ID 21,500 mm×37.9 mm)	CTC
Nameplate capacity	900 m^3/base	5,000 m^3/base	240 m^3/set
Total empty weight	4,200 tons/28 units (150 tons/unit)	3,350 tons/5 units (670 tons/unit)	10,200 tons/102 sets (100 tons/set)
Material	Aluminum-killed steel (SPV490)	Aluminum-killed steel (SLA325A)	API 5L X70
Construction cost Ratio	**100**	**50**	**60**
Construction Schedule	**77 months ~** <u>EPC sequence (2 crew case)</u> Eng.(10) Civil (12) Fabrication (55)	**48 ~ 74 months** <u>EPC sequence (2 crew case)</u> Eng.(10) Civil (12) Fabrication (26)	**appx 32 months** <u>EPC sequence</u> Eng.(10) Civil (12) Installation (4) Building (6) CTC Manufacturing (6)
Outline Footprint	Approx. 9,000 m^2	Approx. 4,700 m^2	Approx. 3,200 m^2

4-2. Quantitative Comparison for Overseas Case

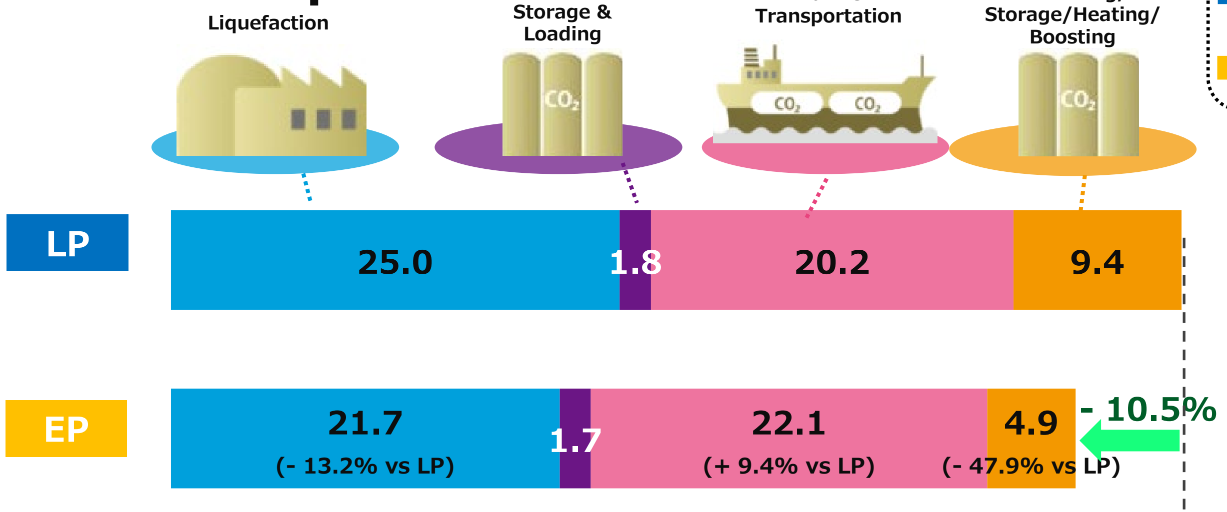
- Compare LP and EP LCO_2 transport from Japan to Australia
- Scope in Japan domestic part is the same regardless LCO_2 operating mode
- CAPEX is assumed to be in the same order as the domestic case.

  →Focus on entire OPEX evaluation

Domestic OPEX Case



OPEX Comparison

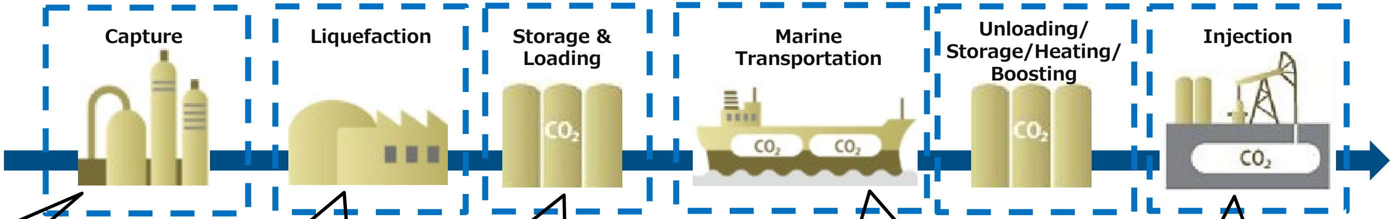


- 120JPY/USD
- Indication only
- OPEX onshore : Electricity only (excluding labor cost /maintenance cost etc…)
- OPEX marine : all inclusive (fuel/port/crew/insurance/dock/R&M etc)

5. Outstanding Actions for Social Implementation

CCS VC utilize existing materials and technologies, and it has less technical uncertainty.

On the other hand, the operation, safety, and maintenance philosophies of each facility should be developed in the execution phase of each project, and will be an action item



Commercial operation of CO_2 recovery system from combustion exhaust gas

The scale up is necessary to increase the size but it is composed by proven technologies

Technology of tank and loading system can be referred the existing technologies

No technical bottleneck as it is composed by proven technologies

Track record of EOR, CO_2 sequestration

Outstanding Actions for Social Implementation

<table>
<tr><th></th><th>MP
Medium Pressure</th><th>LP
Low Pressure</th><th>EP
Elevated Pressure</th></tr>
<tr><td>Storage/ Loading/ Unloading</td><td colspan="2">- Require large number of spherical tanks and capacity

- Longer construction schedule, manpower for construction of spherical tank

- Pressure vessel type tank option

-Development of operating procedure for LCO_2 loading</td><td rowspan="2">- Development of Operation, Maintainane and Safety Philosophies for CTC tank

- Development of Annual inspection method

- Establishment of CTC Supply Chain at scale including mill maker, fabrication yard and transportation</td></tr>
<tr><td>Marine Transportation</td><td>- Technical limiataion of upsizing MP tanks
- Economic Difficulty in upscaling MP vessels</td><td>- Prevention of possible dryice formation during voyage
- Material development for cost optimization</td></tr>
</table>

6. Summary

- **Domestic Comparison**: The study compares three modes of LCO_2 liquefaction and transport based on domestic transport in Japan. The CAPEX is equivalent for LP/EP, but relatively high for MP due to the large number of tanks. In terms of OPEX, EP<MP<LP, indicating differences in energy efficiency during liquefaction and injection.

- **Overseas Comparison**: LP has advantage in terms of the energy efficiency for ship transport. However, when considering the entire value chain including liquefaction and injection, it is confirmed that EP has an advantage under the conditions of the study.

- **Challenges in the value chain**: The study recognizes that temporary storage is the most challenging aspect of the value chain due to the prolonged construction period. This should be addressed with plant owners and suppliers to optimize delivery schedules.