ASIA CLEAN ENERGY FORUM 2025

Empowering the Future: Clean Energy Innovations,
Regional Cooperation and Integration, and Financing Solutions

2–6 June | ADB Headquarters, Manila

ADB

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HYUNDAI ENGINEERING & CONSTRUCTION

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Technology Innovation for Sustainable Energy Transition: Hybrid Carbon Capture and Offshore Storage Solutions

4 June 2025

HYUNDAI ENGINEERING & CONSTRUCTION

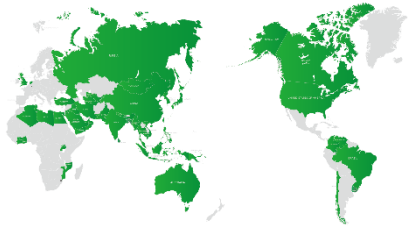
WHO WE ARE

ABOUT HYUNDAI E&C

HYUNDAI MOTOR GROUP

Main construction company in Hyundai Motor Group

4 business areas:
Infra& Environment
Building
Plant, Power & Energy



889 projects in 62 countries

ENR

12th Largest Contractor

MEMBER OF
Dow Jones Sustainability Indices
In Collaboration with RobecoSAM

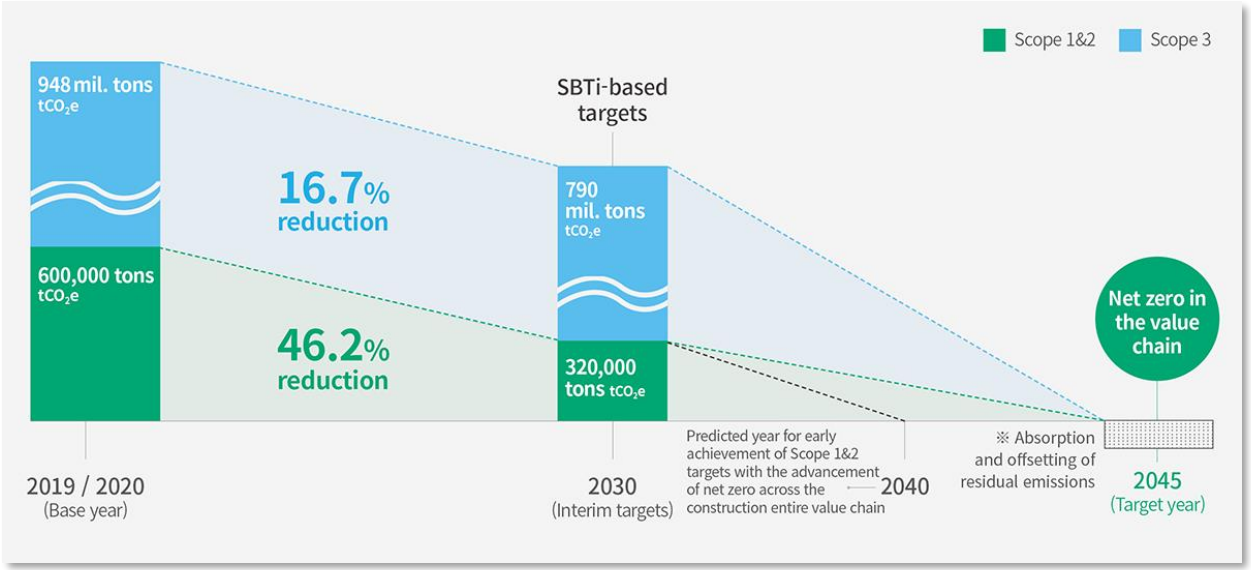
World Index for sustainability

(15 consecutive years)

Hyundai E&C has set out the target of

Net Zero by 2045, reflecting the criteria of SBTi

VISION : Global Green One Pioneer



GLOBAL ENERGY TRANSITION FORCAST

Clean Energy Market Growth, Hydrogen Expansion, and the Rising Importance of CCUS

- Global energy demand continues to rise, but fossil fuel demand is expected to peak before 2030.
- In 2022, energy import costs surpassed $100 trillion,
  highlighting the urgency of energy security and the need for clean energy investment.
- Clean and low-carbon hydrogen production is expected to scale up,
  with CCUS playing a crucial supporting role in this transition.

*Source : World Energy Outlook 2024

CONTENTS

- [CCU] CO_2 Capture & Liquefaction
  for Blue Hydrogen Production (SMR)

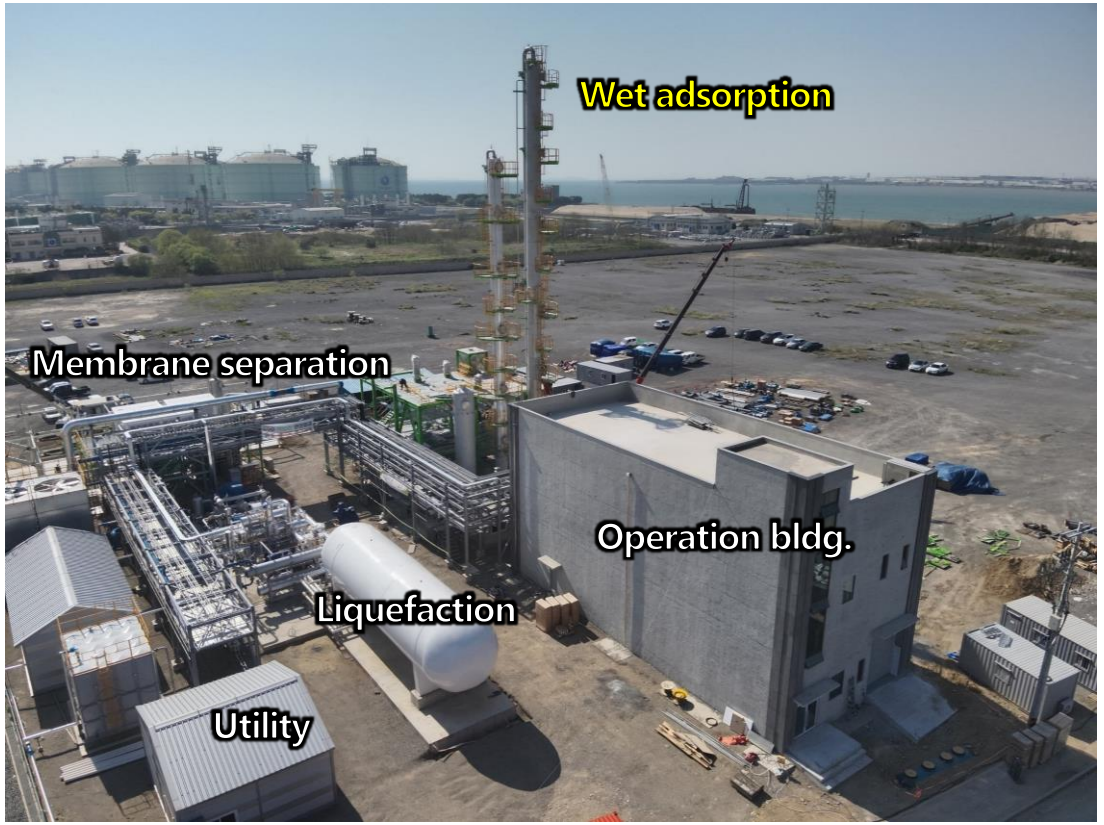
- [CCS] Optimal Storage Design and Facility Conversion Technology
  for CCS Using Depleted Gas Fields

DEMONSTRATION PROJECT IN COMMERCIAL SCALE PLANT

CO_2 CAPTURE & LIQUIFACTION FOR BLUE HYDROGEN PRODUCTION (SMR)

- Project Period : '22.05 ~ '25.10 (41month)
- Amount : USD 25.6 Mil (USD 14 Mil, government fund)
- Research target :
  - Commercial-scale demo to optimize CO2 capture in SMR
  - **Capacity** : 81 tCO_2/d design of commercial scale
  - **Capture** : 90 %↑,
  - **CO2 purity** : 95 % ↑
- Main process :
  - Hybrid capture (wet/membrane/VSA)
  - Liquefaction & Storage
- Remark : Commercial operation planned after R&D project

Challenge in new business utilizing government-Supported R&D Programs



DEMONSTRATION PROJECT IN COMMERCIAL SCALE PLANT

SITE LOCATION : LINKED TO NATIONAL INDUSTRIAL HYDROGEN COMPLEX

【Status of the Pyeongtaek Hydrogen Production Complex 】

① Kogastech SMR
- 7t-H_2/d, CO_2 capture unit X
- Operation from July '22
  ▶ Target of our project

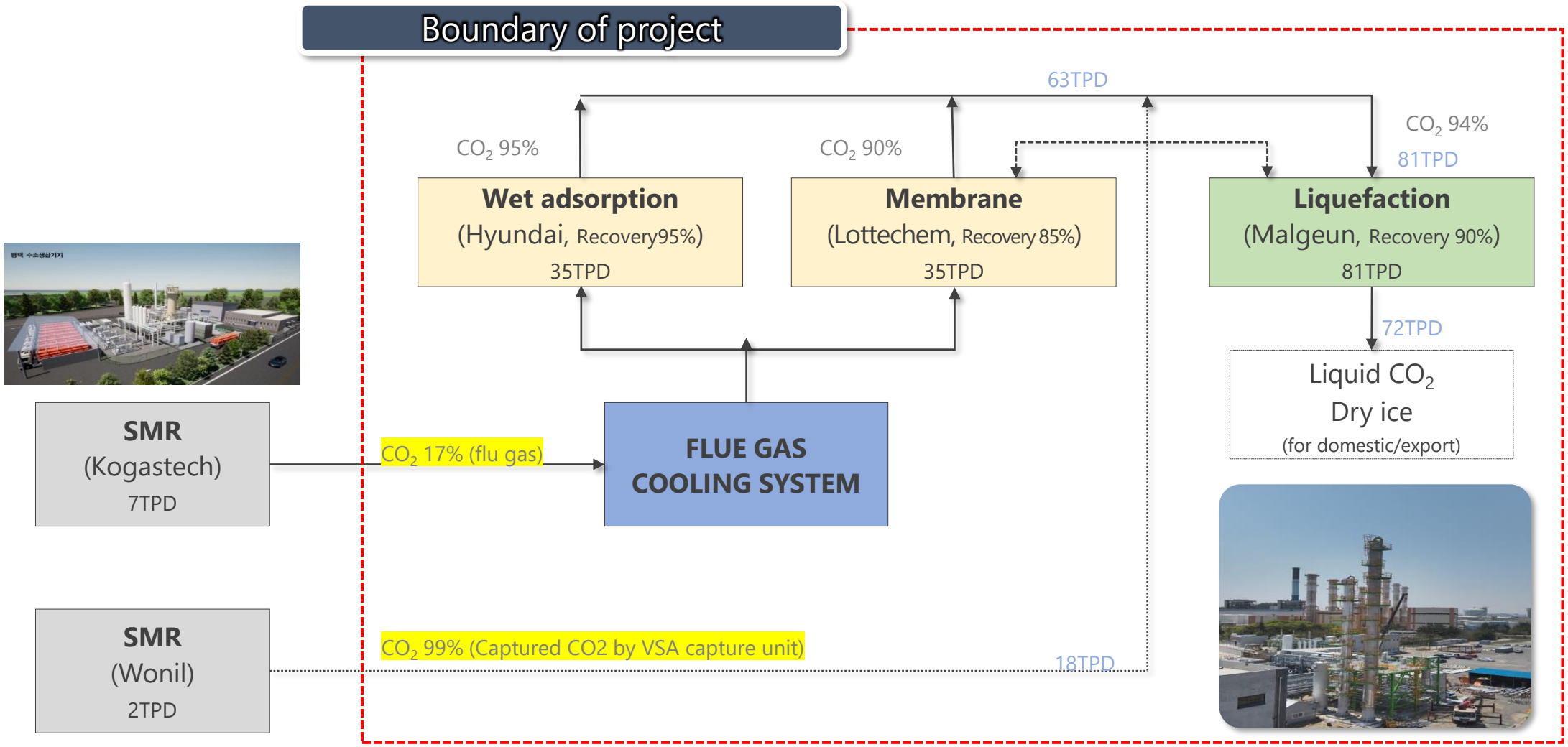
② Kogas SMR
- 15t-H_2/d, CO_2 capture unit X
- Under construction from April '25

③ Wonil T&I SMR
- 2t-H_2/d, CO_2 vspyutr O /liquefaction X
- Operation from May ' 25
  ▶ Target of our project

④ Hyundai consortium CCU
- 81.5t-CO_2/d capture/liquefaction
- Commissioning from **July '25년**

CONSTRUCTION OF PLANT

PROJECT FLOW



CONSTRUCTION OF PLANT

TECHNIQUES FOR CO_2 CAPTURE

	Wet adsorption	Membrane separation	Vacuum swing adsorption
Principle	▪ Gas-liquid contact ▪ physical/chemical absorption	▪ Separation using CO_2 permeability through membrane	▪ Selective adsorption onto solid adsorbents ▪ Regeneration under vacuum
Advantages	▪ Most widely used in industry ▪ High removal efficiency for large-scale	▪ Simple process, easy to expansion ▪ Compact and modularized equipment	▪ Simple design, easy operation ▪ Highly modular equipment
Disadvantages	▪ Corrosive absorbents ▪ Handling of circulation is complex	▪ High cost of replacing membranes ▪ Not suitable for large-scale gases	▪ Performance may decrease due to catalyst impurities and by-products
Main element	▪ Aqueous Absorbent (Amine)	▪ Membrane (polymer, ceramic)	▪ Solid absorbent (MoF[1)], zeolite,etc)
Remark	▪ **Variable cost factor must be considered in feasibility assessment (including pre- and post-treatment, purification, liquefaction, etc**		

[1)] MoF (Metal Organic Framework)

CONSTRUCTION OF PLANT

PILOT PLANT

OVERALL PLANT

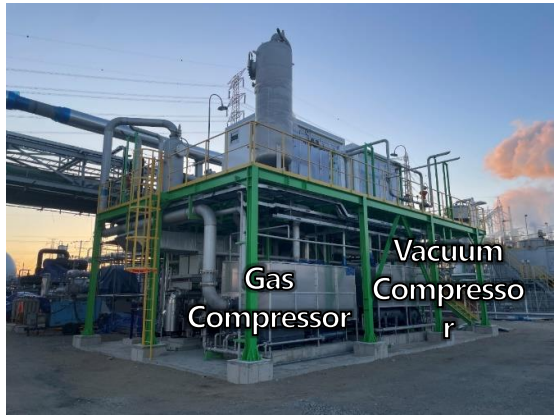
- CAPTURE UNIT : WET, MEMBRANE)
- LIQUEFACTION UNIT
- UTILITY UNIT : QUENCHER, WWT, etc
- OPERATION BUILDING

CAPTURE (WET)

- CAPACITY : 35 TPD
- ADSORPTION TOWER
- STRIPPER
- ABSORBENT DRUM

CAPTURE (MEMBRANE)

- CAPACITY : 35 TPD
- MEMBRANE (POLYMER)
- COMPRESSOR
- DRYER



CO2 CAPTURE

- CAPACITY : 81 TPD
- COMPRESSOR
- CHILLER
- STORAGE TANK

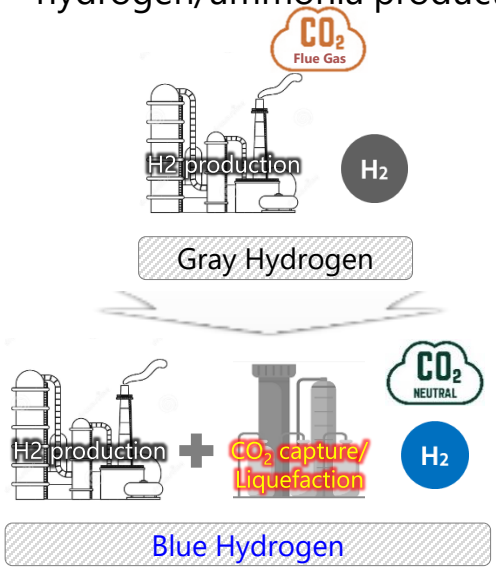
FUTURE PLAN

EXPANSION WITH GLOBAL COOPERATION

- [Similar application] Commercial-scale blue hydrogen / blue ammonia plant project
- [Expansion of target] Expansion to CO_2 capture and utilization at high-emission sites (incinerators, landfills, biogas, etc)
- [Constrains & Suggestions] Boost CCUS fund and carbon market, Relax regulations, Unite certification standard

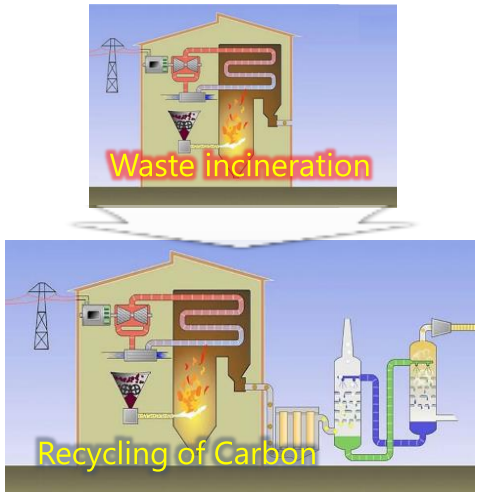
Blue Hydrogen Value Chain Project

- CO_2 capture and utilization in hydrogen/ammonia production plants



Expansion of target project

- Eco-friendly transformation of incinerator / emission facility



Suggestions based on global cooperation

- Ensure economic feasibility by boosting carbon markets and CCUS funds
- Relax rules on international transfer of CCUS and related products, and unify certification standards
- Create CCUS laws to support cooperation between Asian countries

HYUNDAI ENGINEERING & CONSTRUCTION

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CONNECT GLOBAL,
ACHIEVE NET ZERO,
DESIGN OUR FUTURE

CONTENTS

- [CCU] CO_2 Capture & Liquefaction
  for Blue Hydrogen Production (SMR)

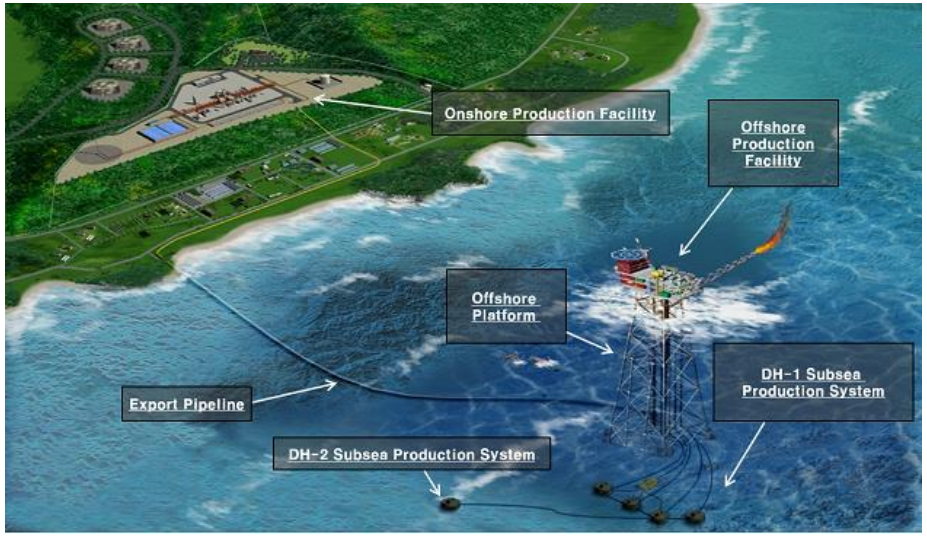
- **[CCS] Optimal Storage Design and Facility Conversion Technology**
  for CCS Using Depleted Gas Fields

Optimal Storage Design and Facility Conversion Technology for CCS Using Depleted Gas Fields

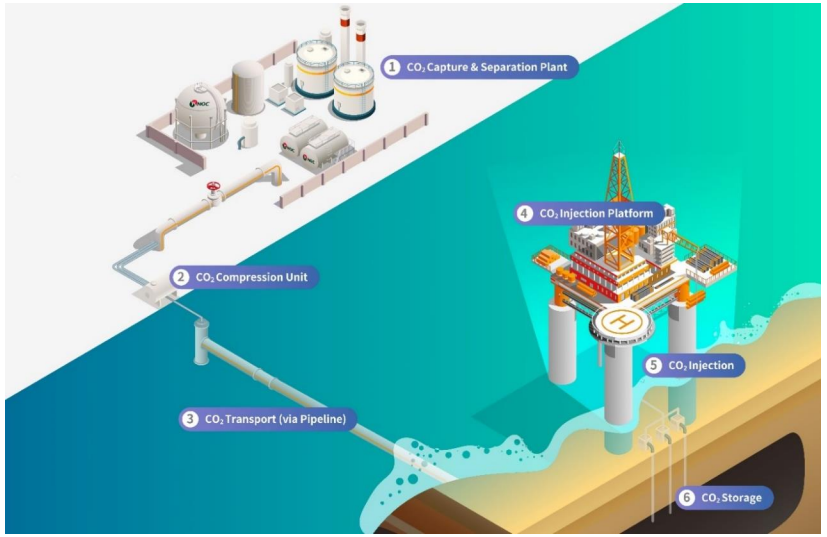
- Opportunity: Utilization of depleted offshore gas fields

- East Sea Gas Field:
  Construction of the East Sea Gas Field production facility began in March 2002.
  Gas production began in July 2004, and gas production ended on December 31, 2021.

- Donghae CCS Project:
  The pre-FEED ordered by the Korea National Oil Corporation (KNOC) in 2023 was carried out.



< Overview of the facility layout for the East Sear Gas Field project, source by KNOC >



< Overview of the facility layout for the depleted East Sea CCS project, source by KNOC >

Porthos Project in Netherlands

Porthos (Port Of Rotterdam CO_2 Transport Hub and Offshore Storage)

- Location : Rotterdam / North Sea
- CO_2 captured by several companies
- CO_2 transport via pipeline from Rotterdam
- 30km onshore pipeline
- Compressor Station
- 20km offshore pipeline
- Existing offshore platform converted for reuse
- Capacity : 2.5 Mt/y for 15 years, Total 37 Mt
- FID : October 2023
- EPC Start : Early 2024
- Operation : 2026

International joint research (Government-Funded)

TNO; Toegepast Natuurwetenschappelijk Onderzoek

Netherlands Organization for Applied Scientific Research

Source : https://www.porthosco2.nl/en/

Porthos Project in Netherlands

Composition of Transported Fluid

- The CO_2 fluid for transportation was designed with CO_2 at a minimum concentration of 95 mol% and H2O at a maximum concentration of 70 ppmv, based on the information collected and analyzed from fluids used in CCS projects worldwide.

CO_2 specifications

Component	Mole Base
CO_2	≥ 95%
H_2O	≤ 70 ppm
Sum [H_2+N_2+Ar+CH_4+CO+O_2]	≤ 4%
H_2	≤ 0.75%
N_2	≤ 2.4%
Ar	≤ 0.4%
CH_4	≤ 1%
CO	≤ 750 ppm
O_2	≤ 40 ppm
Total sulfur-contained compounds (COS, DMS, H_2S, SOx, Mercaptan)	≤ 20 ppm Of which H_2S ≤ 5 ppm
Total NOx	≤ 5 ppm
Total aliphatic hydrocarbons (C2 to C10)[i]	≤ 1200 ppm
Total aromatic hydrocarbons (C6 to C10, incl. BTEX)[i]	≤ 0.1 ppm
Total volatile organic compounds[ii] (excl. methane, total aliphatic HC (C2 to C10), methanol, ethanol, and aldehydes)	≤ 10 ppm
Total aldehyde compounds	≤ 10 ppm
Ethanol	≤ 20 ppm
Methanol	≤ 620 ppm
Hydrogen cyanide (HCN)	≤ 2 ppm
Total amine compounds	≤ 1 ppm
Total glycol compounds	Follow dew point specification
Ammonia (NH_3)	≤ 3 ppm
Total carboxylic acid and amide compounds	≤ 1 ppm
Total phosphorus-contained compounds	≤ 1 ppm
Toxic compounds[iii]	
Dew point limit value measurement (for all liquids, i.e. for complete CO_2 composition)	< -10 °C (at 20 bara)

Note i: Specification values are molecular based
Note ii: VOC definition according to Dutch policy
Note iii: Toxic compounds: although CO_2 and other gases like i.e. H_2 and N_2 can form a risk of asphyxiation, Porthos would like to know other components within the stream which impose a risk on personal safety to be taken into account in Porthos HSE policy

< the CO_2 specifications for storage in the Netherlands PORTHOS CCS project, Source : https://www.porthosco2.nl/en/ >

Porthos Project in Netherlands

Capacity Design

- The conditions of CO_2 entering the CCS onshore compression facility and the conditions of CO_2 being transported through the subsea pipeline after compression are as follows and were used as key boundary conditions for this study.
- The average CO_2 output through the compression facility is 2.5 Mtons of CO_2 per year.
- Considering an annual operation of 8,000 hours and a margin rate of 10%, the maximum hourly output is 343.8 tons of CO_2 per hour.

[Table - Boundary Conditions]

Location	Boundary Conditions
Onshore Plant Inlet	30℃, 35 barg, 343.8 ton-CO_2/h
Onshore Plant Outlet	80℃, 130 barg, 343.8 ton-CO_2/h
Offshore Platform Inlet	80℃, 130 barg, 343.8 ton-CO_2/h (temperature and pressure drops in the offshore pipeline are ignored, using maximum values for this study)
Offshore Platform Outlet	343.8 ton-CO_2/h

Porthos Project in Netherlands

Onshore Equipment List

- The onshore facilities are the core process systems for CO_2 transport, designed to discharge CO_2 at 150 barg and 80°C through two-stage compression and cooling configured in three trains.
- Impurities are separated through an inlet filter separator, and the required temperature and pressure are adjusted through suction and discharge drums and CO_2 coolers.
- Other items are assumed to consist of generally necessary equipment.

Inlet filter separator
1st Stage Compressor Suction Drum
2nd Stage Compressor Suction Drum
2nd Stage Compressor discharge drum
1st Stage CO2 Compressor
2nd Stage CO2 Compressor
Motor for CO2 compressor
1st Stage CO2 Cooler
2nd Stage CO2 Cooler
Metering unit
Pig Launcher

Porthos Project in Netherlands

Offshore Equipment List

- The offshore platform is designed to inject CO_2 into depleted gas fields or saline aquifers, with compressed CO_2 transported from the onshore facility via a 16-inch, 21 km subsea pipeline.
- It includes choke and safety valves, control systems, a manifold connected to four risers for injection, and an umbilical for subsea operations.
- A pig receiver is also installed for pipeline maintenance.
- Additionally, space is allocated for future installations of booster pumps, an electric heater, and control systems for potential subsea operations.

Inlet Choke Valve and Accessories
Safety Valve and Accessories
Outlet Manifold and Accessories
Pig Receiver
Solar Panel
Wind Turbine
Battery Pack
Diesel Engine Generator
Electrical Distribution System
Metering Unit

Donghae CCS Project

CCS demonstration project using the Donghae-1 depleted gas reservoirs

- Location : Ulsan / East Sea

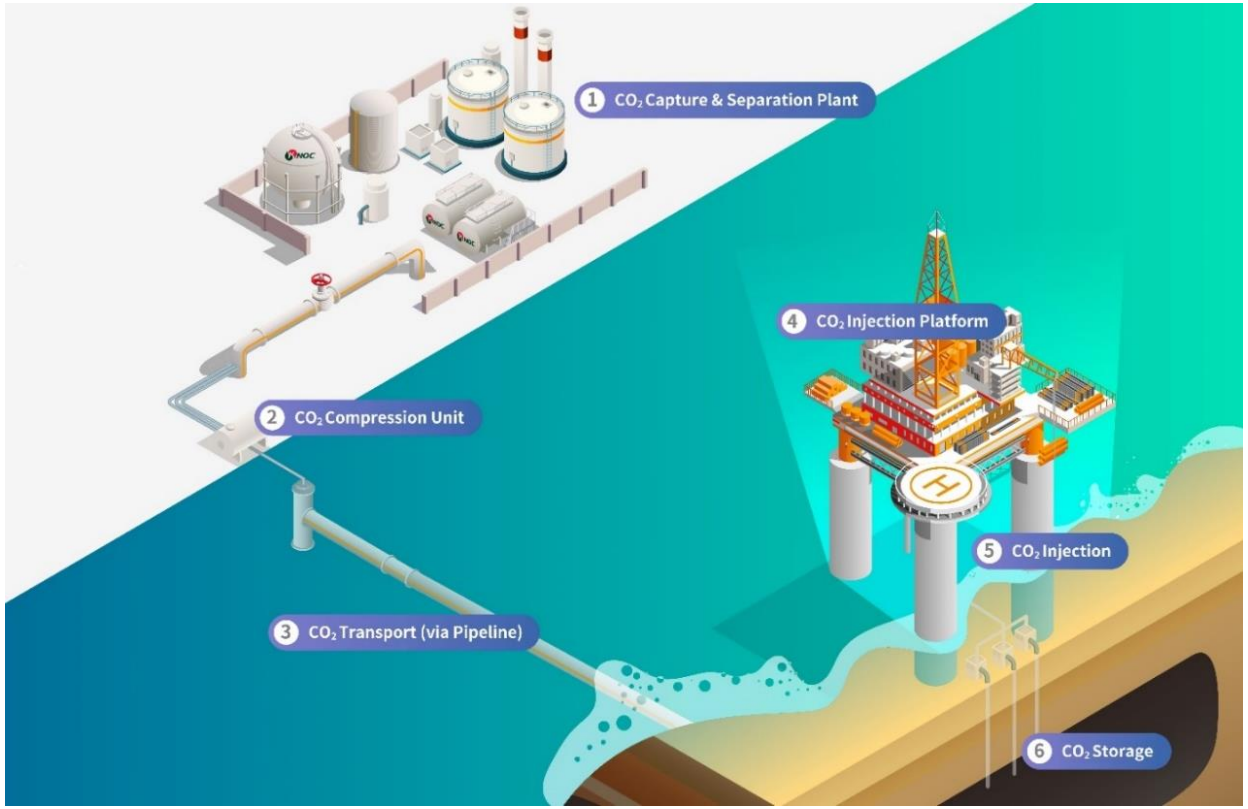
- CO_2 captured by several companies

- CO_2 transport via pipeline from Ulsan
- Onshore Hub Terminal
- Approx. 60km offshore pipeline

- Existing offshore platform converted for reuse
- Reuse of production wells

- Capacity : 1.2 Mtpa for 10 years

- Expected FID : 3Q 2025
- Expected EPC Start : Early 2026
- Expected Operation : After 2028



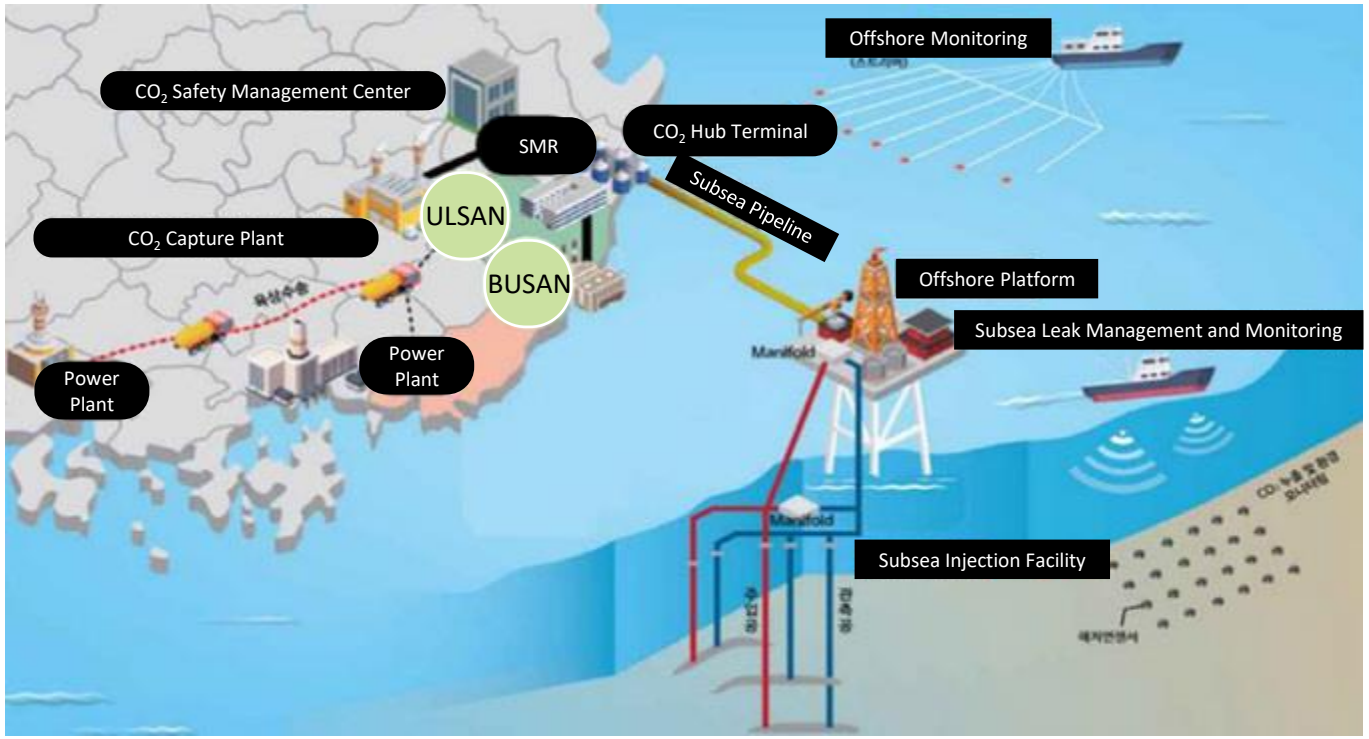
Donghae CCS Project

Composition of Transported Fluid

- The CO_2 stored at the East Sea Gas Field comprises emissions from Steam Methane Reforming (SMR) processes for hydrogen production and flue gases from nearby thermal power plants. As shown in below Table, the stored CO_2 has a purity level of 99.26%.

[Table – Specification of CO_2 Fluid]

Component	Mol (%)
CO_2	99.26
CO	0.01
H_2	0.6
CH_4	0.12
H_2O	0.01



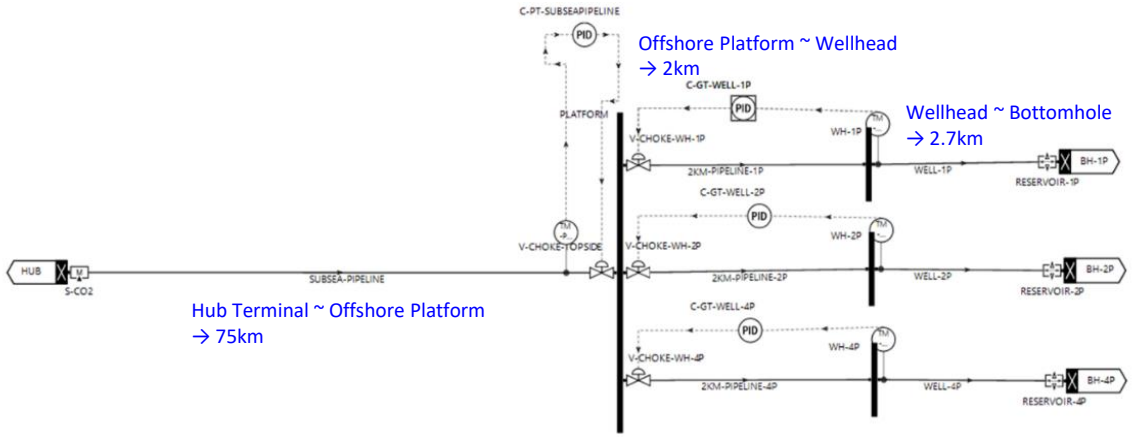
Donghae CCS Project

Capacity Design

- The Korean government is preparing a 1.2 MTPA CCS project
- On the platform, the CO_2 passes through choke valves that regulate flow to three wells
- Well 2P, the depleted gas well with the lowest pressure. Production continued until this well reached a very low pressure of 33 bar, a significant decrease from the initial production pressure of 248 bar.

[Table – Reservoir condition of East Sea Gas Field (Well 2P)]

Contents	Value
Pressure (Depleted, After production)	33 bar
Pressure (Initial, Before production)	248 bar
Temperature	104 ℃
Depth	2600 ~ 2800 m



[OLGA simulation model for 1.2 mil ton/yr CO_2 injection]

Donghae CCS Project

Onshore Equipment List

- The facility is capable of processing 1.2 MTPA of CO_2, handling 1.1 MTPA of gaseous CO_2 and 0.1MTPA of liquid CO_2 annually.
- It consists of CO_2 Inlet, Dehydration, Compression, Liquefaction, Storage, and Export infrastructures.

CO_2 Inlet	Inlet Separator
	CO_2 Gas Metering Package
	Pig Receiver
CO_2 Dehydration	CO_2 Dryer
	Regeneration Gas Heater
	Regeneration Gas Cooler
	Regeneration Gas K.O Drum

LCO_2 Compression· Liquefaction	CO_2 Booster Compressor Suction Drum
	CO_2 Booster Compressor
	CO_2 Booster Compressor Inter Cooler
	Interstage KO Drum
	CO_2 Booster Compressor After Cooler
	After-stage KO Drum
	Chiller
	Refrigerant Compressor
	Refrigerant Condenser
	Refrigerant Receiver
	Compressor Suction KO Drum
LCO_2 Storage· Export	LCO_2 Storage Tank
	LCO_2 Unloading Pump
	LCO_2 Truck Weighing Gauge
	LCO_2 Export Pump
	LCO_2 Metering Package
	Pig Launcher
	Chemical Injection Package

Donghae CCS Project

Offshore Equipment List

- To be designed to inject LCO_2, transported via pipeline from the CO_2 terminal to the offshore platform, into reservoirs through injection wells using LCO_2 injection pumps.
- Pigging operation facilities for connecting LCO_2 transported from the onshore CO_2 terminal to the injection system on the offshore platform, and for cleaning and maintaining the subsea pipeline.
- Equipment for transferring liquefied CO_2, which conditions the fluid to the required temperature and pressure for final injection into the subsea reservoir and facilitates LCO_2 injection.

Inlet	CO_2 Import Pig Receiver
Injection	CO_2 Injection Filters
	CO_2 Buffer Vessel
	CO_2 Buffer Vessel Pressure Build-up Unit
	CO_2 Injection Pump
	CO_2 Metering Skid

Conclusion : Comparison

Summary

Contents	Porthos	Donghae
Stage	EPC	FID
CO_2 Phase	Gas	Liquid
Onshore Facilities	Compression	Dehydration & Liquefaction
Offshore Platform Power Source	Green	From Shore
Reuse Existing Facilities	Offshore Platform, Injection Well	Offshore Platform, Injection Well, Subsea Pipeline
Subsea pipeline	New : CCS Injection Existing : Gas production	Existing : CCS Injection