

Updates of MHI KM CDR Process™

PCCC-8
16-18th September 2025
Masaya Sakaida

Mitsubishi Heavy Industries, Ltd.



Mitsubishi Heavy Industries Group Profile



1884 Foundation
140 years history



77,778 Employees
(Consolidated: As of Mar.,2025)



259 Group Companies
(Consolidated: As of Mar.,2025)



Diverse Products
on Land, at Sea, in the Sky, in Space



6,684.0 bil. yen
Order Received
(FY2024, Consolidated)



4,657.1 bil. yen
Revenue
(FY2024, Consolidated)

Mitsubishi Heavy Industries, LTD. – GX(Green Transformation) Solutions Segment



Business content

- Promote energy transition business
- Engineering solutions and after-sales service for carbon capture plant, chemical plant and transportation system



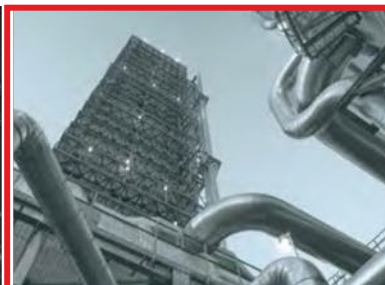
H-IIA Launch Vehicle



Fighter



Turbocharger



Carbon Capture Plant
(Proprietary Technology)



Chemical Plant



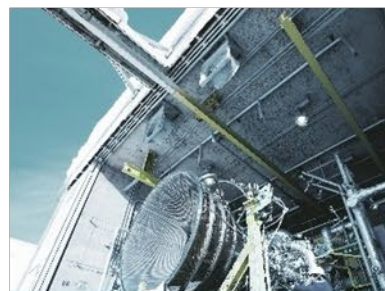
Transportation System



Gas Turbine



Compressor



LE-7A Engine



Aero Engine



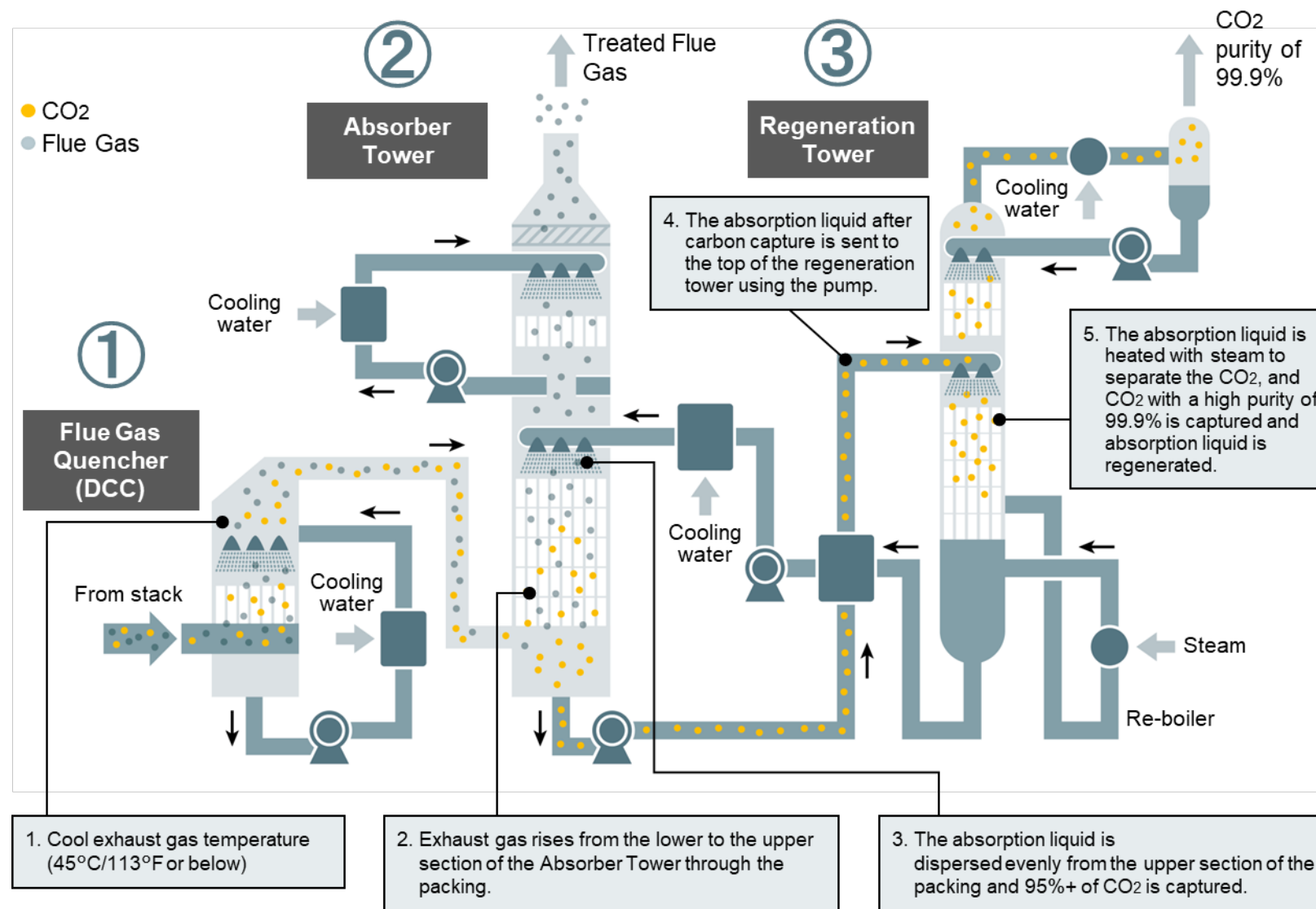
Waste-to-Energy



Metal Machinery

KM CDR Process™

- KM CDR Process™ = **Kansai Mitsubishi Carbon Dioxide Recovery Process**
- Amine-based technology
- Capable of capturing 95+% CO₂ from combustion gas (depending on source)
- Automatic load adjustment control (ALAC)
- Amine filtration and purification systems
- Tower design capability for even gas/liquid distribution



Unique features of KM CDR Process™

Three (3) primary technology of KM CDR Process™

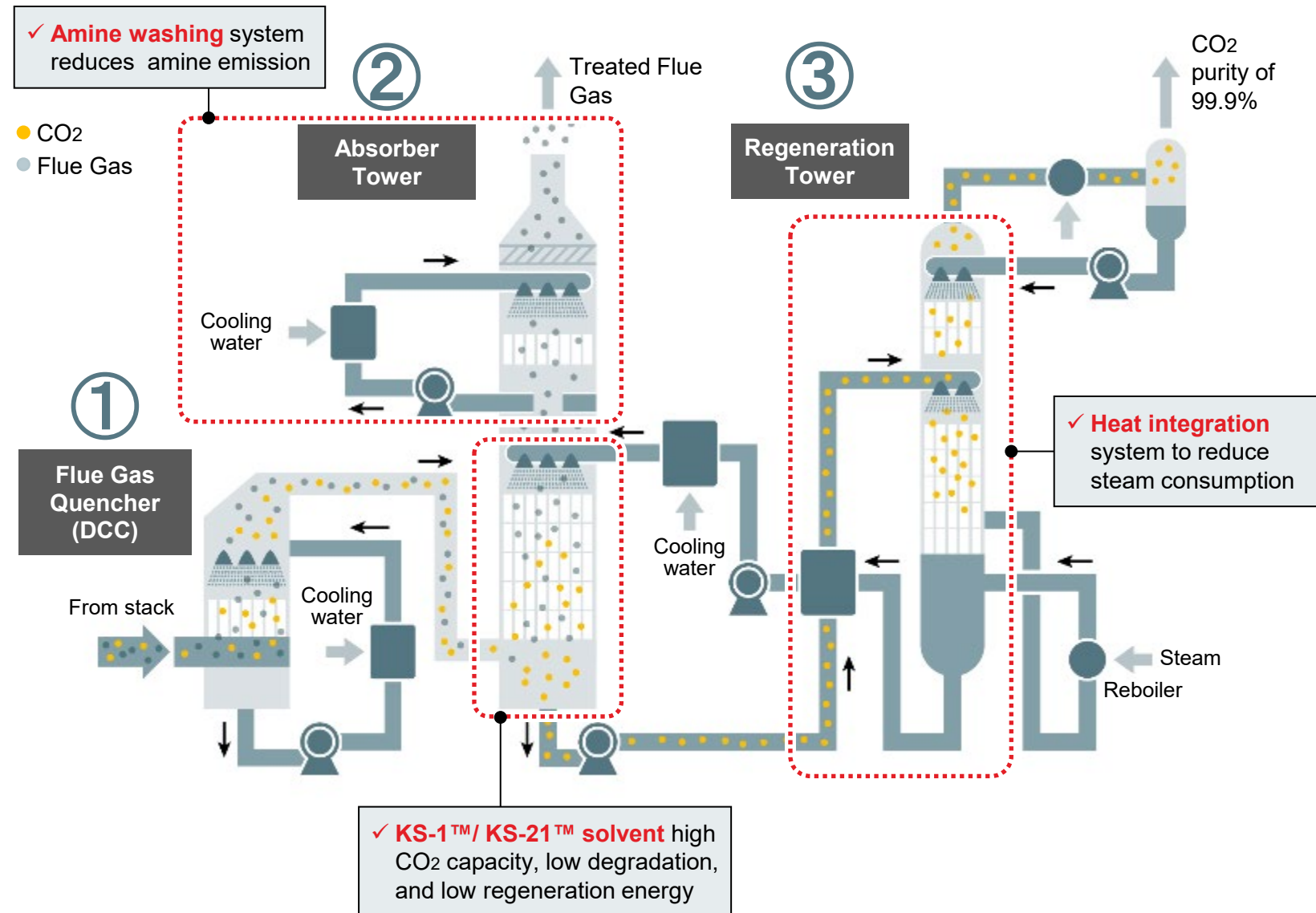
- Proprietary solvent; **KS-1™ / KS-21™**
- **Amine washing** system reduces amine emission
- **Heat integration** system to reduce steam consumption

Low OPEX

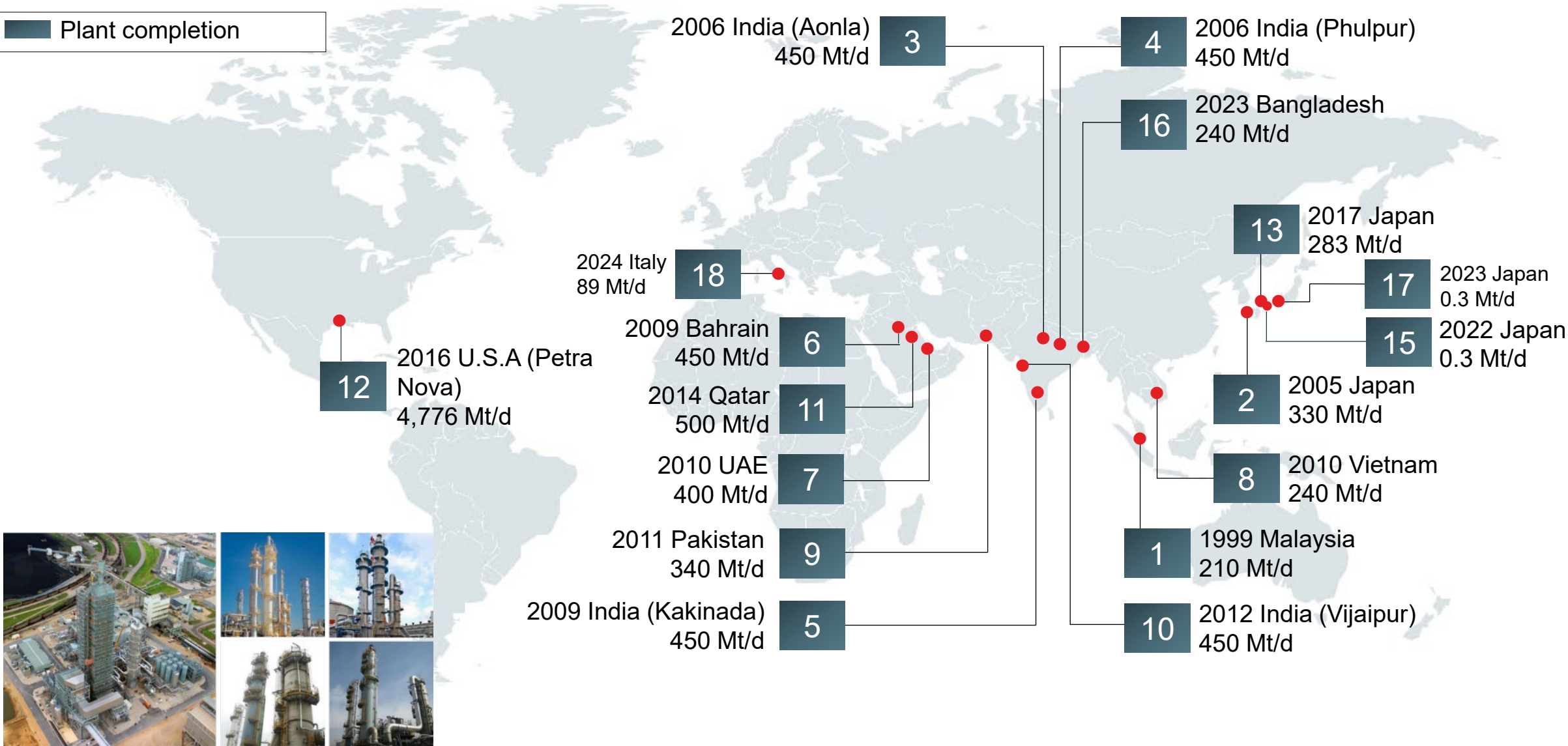
- Low solvent make up frequency
- Low steam volume & electricity consumption

Low CAPEX

- Related equipment capacity such as reboiler and pump is smaller



Plant completion



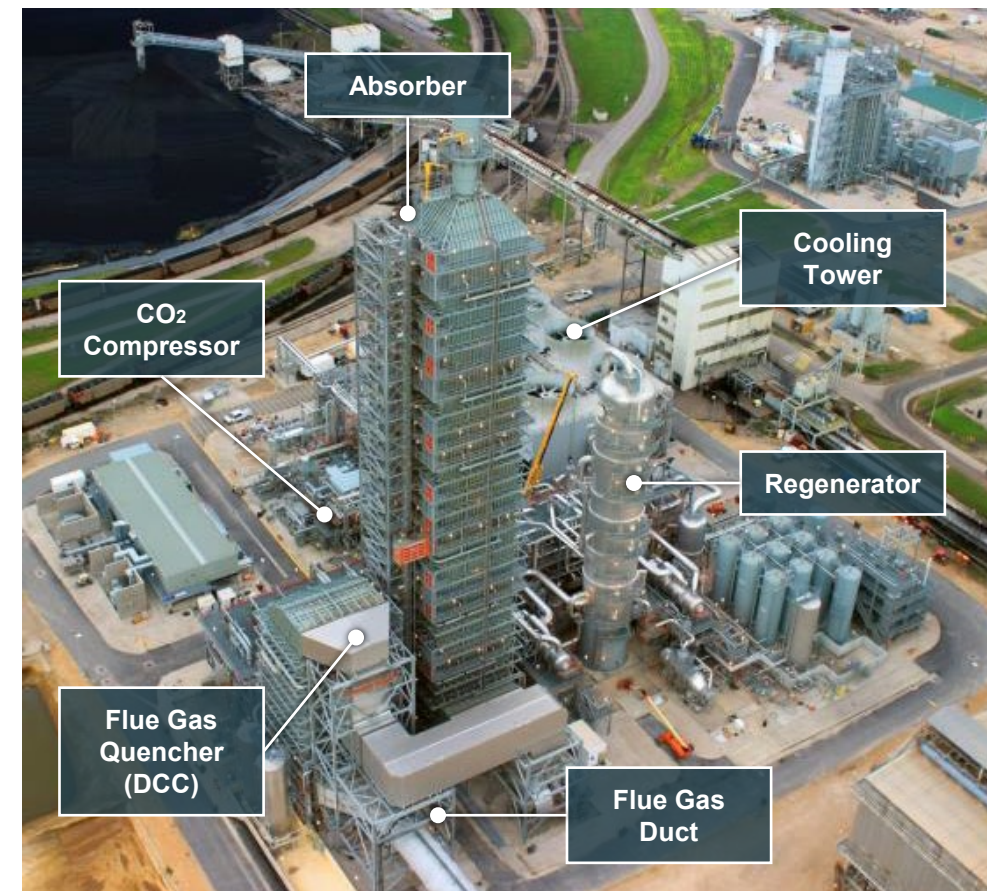
Petra Nova Project

The World's Largest Post-Combustion Carbon Capture Plant

EPC full turnkey project

- ✓ MHI has provided the world's largest carbon capture plant on coal-fired flue gas delivered in December 2016 for Petra Nova Project
- ✓ Supported by DOE (U.S. Department of Energy) grant program (CCPI* Round 3) and Japanese government finance (JBIC / NEXI)

Project Formation	• Consortium of MHI / Kiewit / The Industrial Company (TIC) • MHI: Engineering and Procurement for Carbon Capture Plant • Kiewit: Utility and balance of plant • TIC: Construction
Plant location	NRG WA Parish Power Plant (Thompsons, TX)
Project owner	Petra Nova - partnership between NRG Energy and JX Nippon Oil&Gas Since 2022, full ownership under JX Nippon Oil&Gas
Plant scale	240 MW _{eq}
CO ₂ capacity	4,776 Mt/d (1.4 MMt/y)



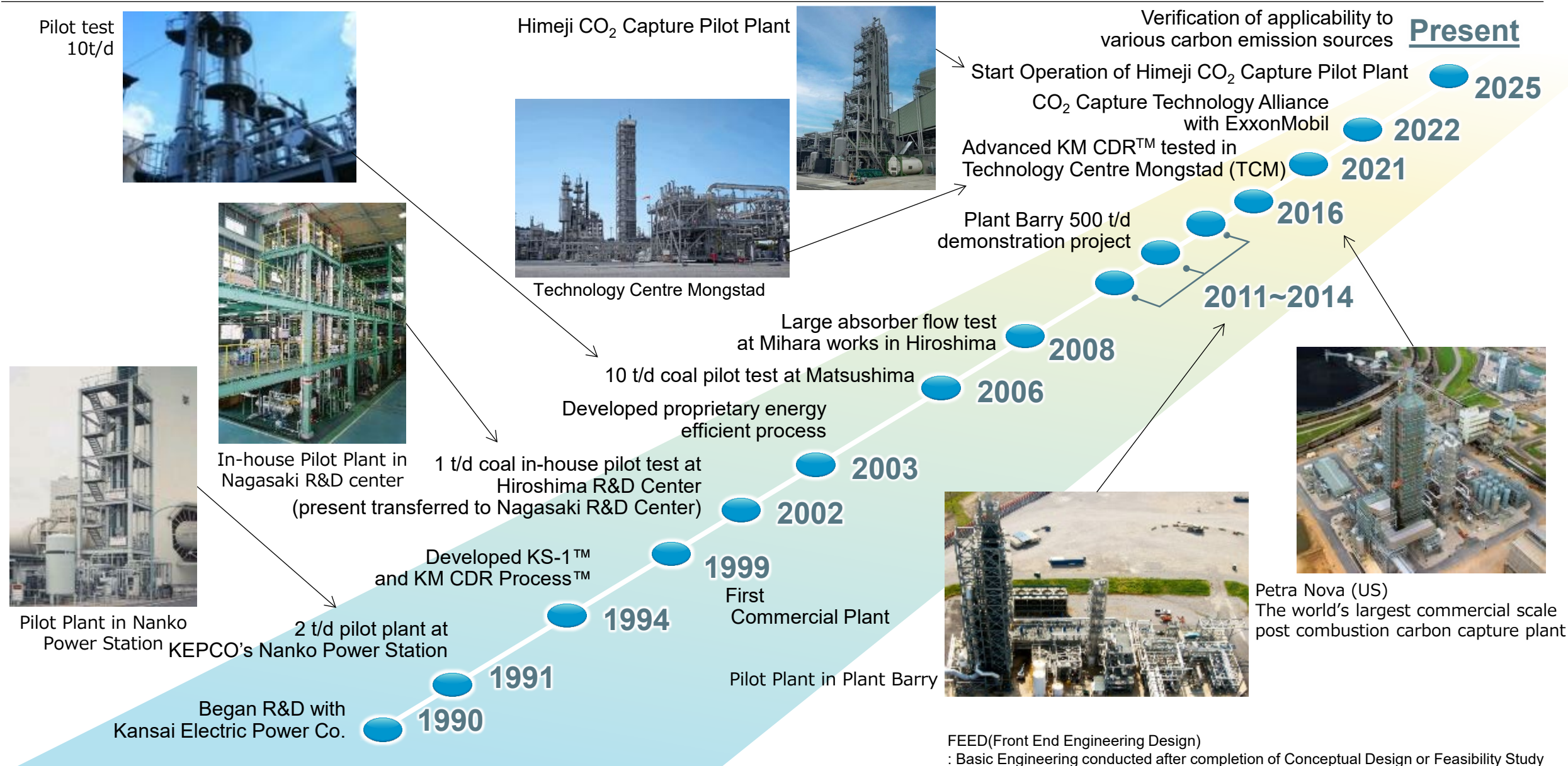
Carbon Capture Plant

*Clean Coal Power Initiative

*U.S. Department of Energy "W.A. Parish Post-Combustion CO₂ Capture and Sequestration Project Final Environmental Impact Statement Volume I" (Feb, 2013), DOE/EIS-0473

Released by MHI

History of carbon capture technology development and up-scaling



Advanced KM CDR Process™

- MHI has developed upgraded process **Advanced KM CDR Process™** and upgraded solvent **KS-21™**.

KS-21™ solvent features (vs. original KS-1™)

- MHI demonstrated at Technology Centre Mongstad (TCM) carbon capture facility in Norway in 2021 and conformed the following features.
 - ✓ Lower degradation rate, longer solvent health.
 - ✓ Lower volatility, applicable to the strict European environmental regulation.
 - ✓ Lower energy consumption of CO₂ compressor.



Technology Centre Mongstad

KS-21™



Parameters	KS-1™	KS-21™
Volatility	100	50-60
Thermal degradation rate	100	30-50
Oxidation rate	100	70
Heat of absorption	100	85



Medium to large scale carbon capture plant

- Capacity: 200 t/d ~
- Leadtime: 24 ~ 36 months up to the capacity
- Order-made design for the customer's request
- Modular construction to minimize construction period
- Capability for up-scaling of carbon capture amount



CO₂MPACT™ Series

- Capacity: 0.3 ~ 200 or more t/d
- Leadtime: 12 ~ 24 months up to the capacity
- Standardized design optimized for small scale emission
- Compact design and short lead time
- Capability for verification with actual gas and small to medium scale carbon capture plant
- Established two lineups, “CO₂MPACT™ Full-Module” and “CO₂MPACT™ Mobile,” to meet customer needs

Applicability to various carbon emission sources

- We are further expanding the number of applications for carbon capture based on our core technology.
- CO₂MPACT™ will be modularized and digitized to meet the challenges and needs of customers.

As a leading company in Carbon capture, we offer a wide range of Carbon capture technologies.

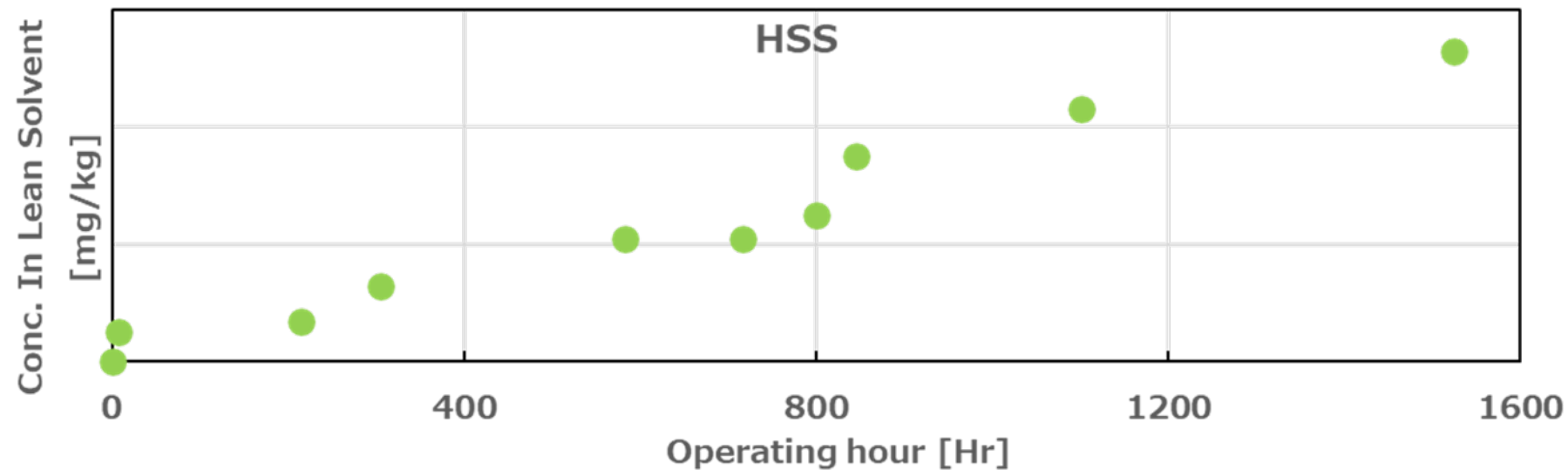
	Power generation	World's largest carbon capture plant (as of 2023)
	Biomass	License granted for first BECCS project of its kind in Europe
	LNG liquefaction	Feasibility Study/PDP for low-carbon production of LNG production
	Refinery	Basic design package for the UK's first low-carbon refinery
	Cement	Feasibility Study/ FEED awarded at the UK and Canada
	Steel	Technology verification on multiple emission sources in ironmaking process in Belgium and North America
	Shipping	Onboard carbon capture system verified in field (on an actual voyage)
	Waste-to-Energy	Technology verification on emission from WtE process
	Gas Engines	Technology verification on CO ₂ capturing from internal Gas Engines and liquefaction
	Ceramic	World's first application in the ceramic manufacturing process
	Hydrogen	CO ₂ capture at the UK's largest blue H ₂ plant

Pilot Test Experiences of KM CDR Process™ / Advanced KM CDR Process™



No.	Year of Delivery	Country	Flue Gas Source	CO ₂ Capacity (t/d)	Purpose	Status
1	1991	Japan	Power Plant	2	Annual Test Campaign	On-going
2	2006	Japan	Power Plant	10	Impurity/Dust behavior	Done
3	2007	Japan	Natural gas fired flue gas	2	Long term operation with artificial gas turbine flue gas	Done
4	2008	Japan	Cement furnace flue gas	1	Verification for cement flue gas	Done
5	2010	USA	Power Plant	1	Verification for SO ₃ and emission	Done
6	2011	USA	Power Plant	500	Long term operation / Geological Sequestration	Done
7	2012	Italy	Power Plant	56	Verification for coal flue gas	Done
8	2012	Japan	Natural gas fired flue gas	2	Long term operation	Done
9	2018	USA	Power Plant	1	Solvent testing	Done
10	2020	USA	Power Plant	1	Solvent testing	Done
11	2021	Norway	Natural gas fired flue gas	100	KS-21™ demonstration test	Done
12	2021	UK	Biomass flue gas	0.3	Verification for Biomass flue gas	Done
13	2022	Japan	Waste to Energy plant flue gas	0.3	Verification for WtE flue gas	On-going
14	2022	Japan	Cement kiln flue gas	0.3	Verification for cement flue gas	Done
15	2022	Japan	Gas engine generator flue gas	0.3	Verification for gas engine flue gas	Done
16	2023	Canada	Cement kiln flue gas	0.3	Verification for cement flue gas	On-going
17	2023	USA	Biomass flue gas	0.3	Verification for Biomass flue gas	Done
18	2024	Belgium	Steel plant flue gas	0.3	Verification for steel plant flue gas	On-going
19	2024	Japan	Chemical recovery boilers at paper mills	0.3	Verification for Pulp and Paper Industry flue gas	On-going

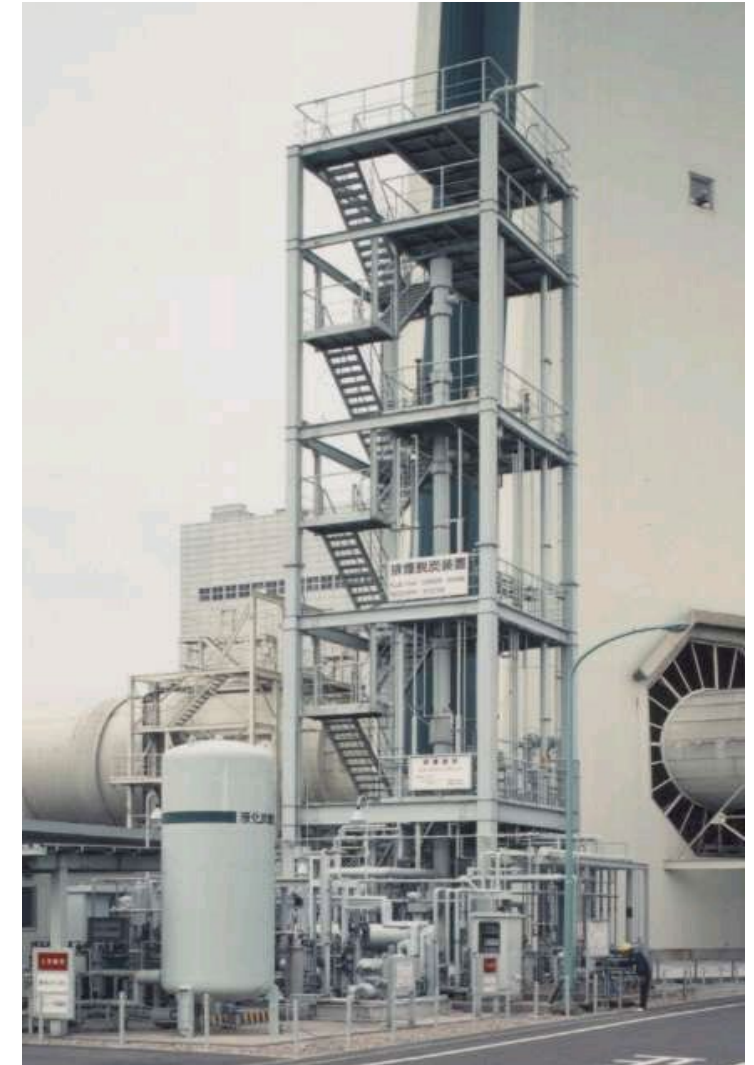
- ✓ MHI had conducted the mobile test for verification for cement flue gas
- ✓ Total 4000 hours of operation using actual cement exhaust gas was achieved
- ✓ The accumulation of HSS was observed. The validity of our calculation was confirmed from the result of accumulation rate.



Accumulation of Heat Stable Salts during mobile test

- ✓ MHI had conducted the Pilot Tests at the pilot plant installed at the Nanko Power Station since 1991
- ✓ Evaluated the CO₂ capture performance and emissions for KS-1™ and KS-21™ solvent
- ✓ The results were well validated with in-house process simulator

Site	Nanko, The Kansai Electric Power Co.
CO ₂ Source	Natural Gas Boiler
Start up year	1991
Solvent	KS-1™ / KS-21™ Solvent
Flue gas CO ₂ content	Adjustable
CO ₂ Capture Rate	Adjustable



Nanko Pilot Plant

- ✓ MHI has completed the demonstration test for CCGT flue gas and RFCC flue gas at Technology Centre Mongstad's carbon capture facility in Norway
- ✓ Achieved capture rate of around 95% for each flue gas
- ✓ Maintained at 95% CO₂ capture rate for each flue gas during the campaign

CO ₂ Source	CCGT, RFCC flue gas
Solvent	KS-1 TM / KS-21 TM Solvent
Flue gas flow rate	30,400 - 55,000 Sm ³ /h
Flue gas CO ₂ content	CCGT : 4 vol%, RFCC : 14 vol%
Regenerator pressure	0.30 - 1.58 barG
CO ₂ Capture Rate	More than 95%



Photograph courtesy of Technology Centre Mongstad

Start Operation of Himeji CO₂ Capture Pilot Plant at KEPCO Himeji No.2 Power Station

- ✓ The new pilot plant was installed for R&D of CO₂ capture technology and will use flue gas from the gas turbine at Himeji No.2 Power Station and start operation in 2025.
- ✓ By demonstrating the next-generation CO₂ capture technology, the plant will accelerate R&D aimed at reducing environmental impact and costs, and further strengthen its competitiveness.

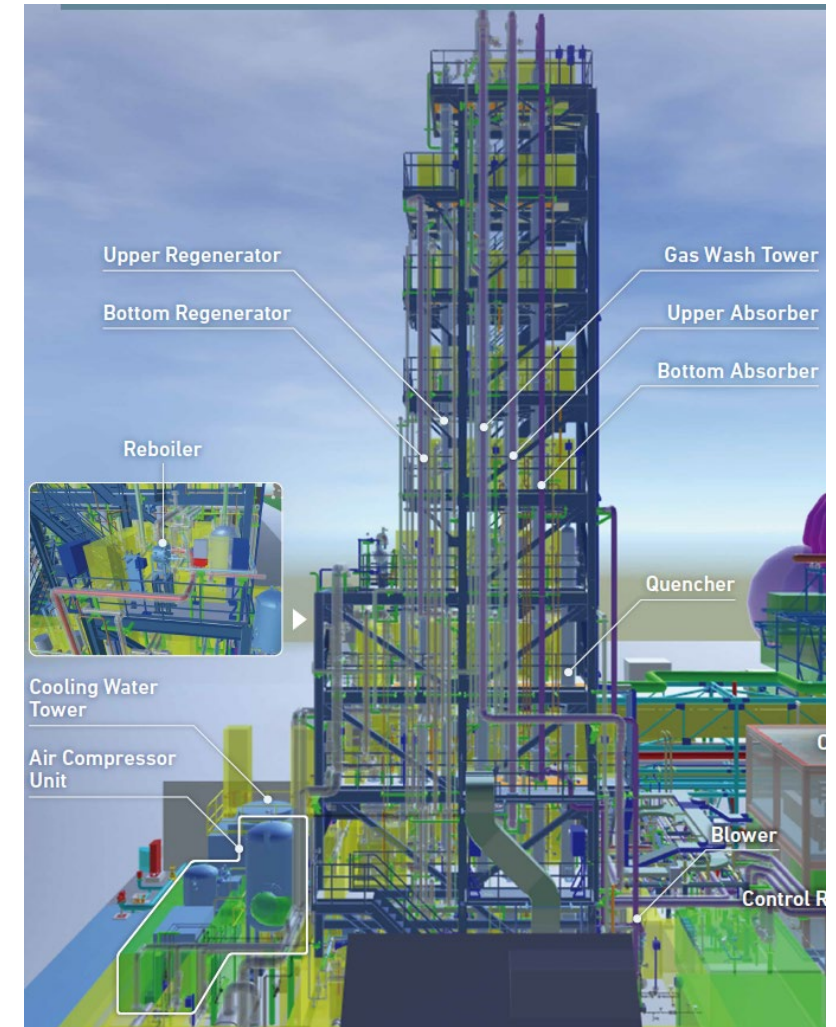


Himeji CO₂ Capture Pilot Plant

Features of Himeji CO₂ Capture Pilot Plant at KEPCO Himeji No.2 Power Station

- ✓ Inlet CO₂ concentration can be adjusted by recycling captured CO₂
- ✓ Solvent Reclaiming System is installed
- ✓ Absorber packing height can be changed

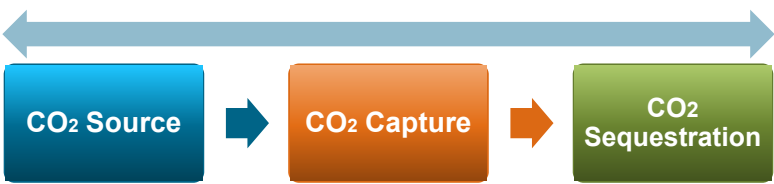
CO ₂ Source	CCGT flue gas
Start up year	2025
Solvent	KS-21 TM Solvent
Flue gas CO ₂ content	Adjustable (5% -)
Regenerator pressure	Adjustable (- 1.5 barG)
CO ₂ Capture Rate	Adjustable



Himeji CO₂ Capture Pilot Plant

ENI Ravenna CCS Project, Phase 1

Europe's First Post-Combustion Carbon Capture Plant with full value chain till storage starts Operation at ENI, Italy with MHI Technology



Project Formation	- Carbon Capture plant is installed at ENI's Casalborgseti natural gas plant near Ravenna, Italy - MHI is working in partnership with NEXTCHEM, MAIRE's subsidiary dedicated to the energy transition,
Key Feature	- Plant captures CO2 from flue gas with the lowest concentration < 3% > 95% capture rate. - First complete end to end solution from capture to storage.
CO2 Source of Emissions	Gas Turbine
CO2 capacity	89 t/d (25,000 tpa is envisaged to be injected into a depleted offshore gas field owned by ENI)



Carbon capture plant for Ravenna CCS (photo courtesy of Eni S.P.A)

BCIC Ghorasal Project

Largest fertilizer plant in Bangladesh with Advanced KM CDR Process™ for enhance urea production

Project Formation	- Working together with China National Chemical Engineering No7 Construction Co., Ltd., to install a fertilizer plant including carbon capture unit. - Carbon Capture plant is installed at Ghorasal Polash Urea Fertilizer Project - MHI uses its Advanced KM CDR Process™ using its new KS-21™ solvent.
Plant Location	Bangladesh Chemical Industries Corporation (BCIC) plant located at Polash, Narsingdi, Bangladesh
CO2 Source / Key Features	- SMR (Steam Methane Reforming) First commercial plant with KS-21™ solvent
CO2 capacity	240 t/d >90% capture rate



Carbon capture plant for BCIC

Parameters Relative to KS-1™	KS-1™	KS-21™
Volatility	100	50-60
Thermal degradation	100	30-50
Oxydative degradation	100	70
Heat of reaction	100	85

- ✓ MHI developed Advanced KM CDR Process™ and new solvent KS-21™
- ✓ MHI is offering the process to various industrial flue gas sources, including Refinery, LNG plant, cement/steel/ceramic making, hydrogen, etc.
- ✓ MHI evaluated the applicability to various industrial flue gas by conducting mobile test
- ✓ KS-1™ / KS-21™ solvent have been evaluated by Nanko pilot & TCM demonstration test
- ✓ Start Operation of Himeji CO₂ Capture Pilot Plant
- ✓ Start Operation of first commercial plant with KS-21™ solvent

MOVE THE WORLD FORWARD

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HEAVY
INDUSTRIES
GROUP**