

EIGHTH ANNUAL CONFERENCE ON
Carbon Capture & Sequestration

Pittsburgh, PA May 2009

Determining the Technologies & System Components for Commercially Viable CCS

IEA GHG – What Have We Learned From Large-Scale CCS Projects?

**KM-CDR Post-Combustion CO₂ Capture
with KS-1™ Advanced Solvent**



Mitsubishi Heavy Industries, America Inc.

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Development History

LABORATORY

MHI Hiroshima R&D Center
Kansai Environmental Research Center
1983-present

Kansai Environmental Research Center
1991-present

BENCH SCALE



PILOT PLANTS

MHI Hiroshima R&D Center
1 MTPD

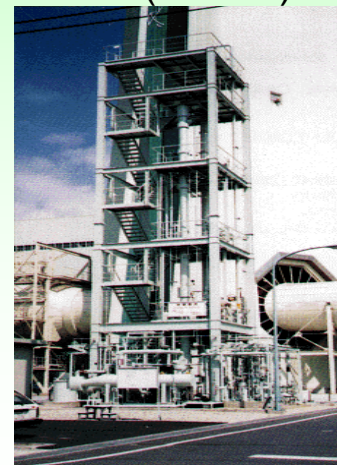
Validation of the
process on Natural
Gas and Coal flue
gas

2002-present



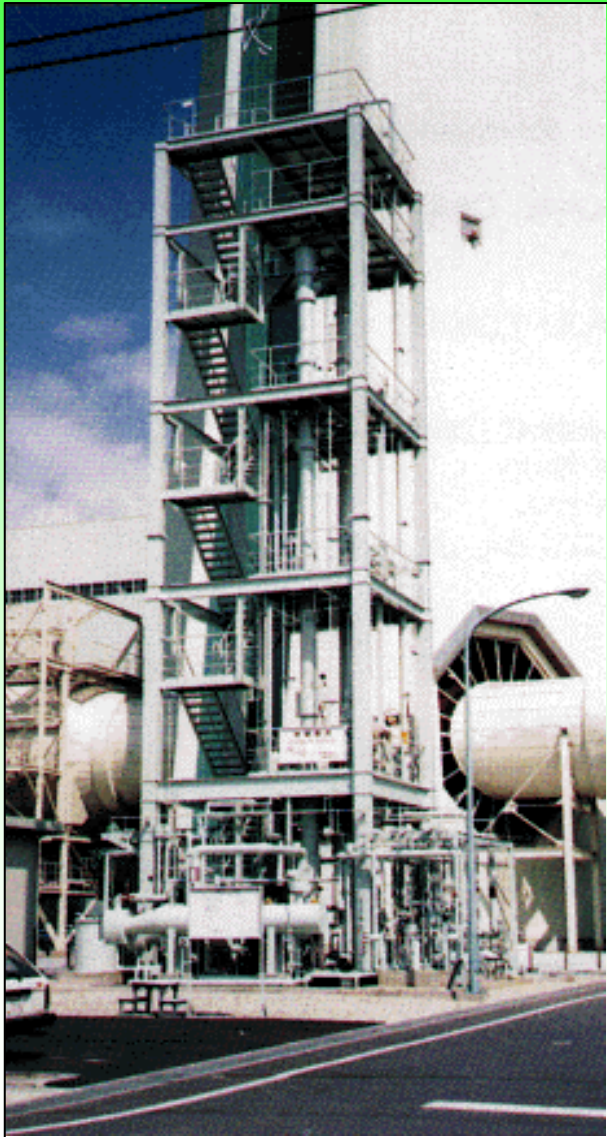
Kansai Environmental Research Center
KANSAI (Nanko) Pilot Plant - 2 MTPD

1991-present



Nanko Pilot Plant

Solvent & Process Development



Location : Nanko Power Plant, Osaka, Japan

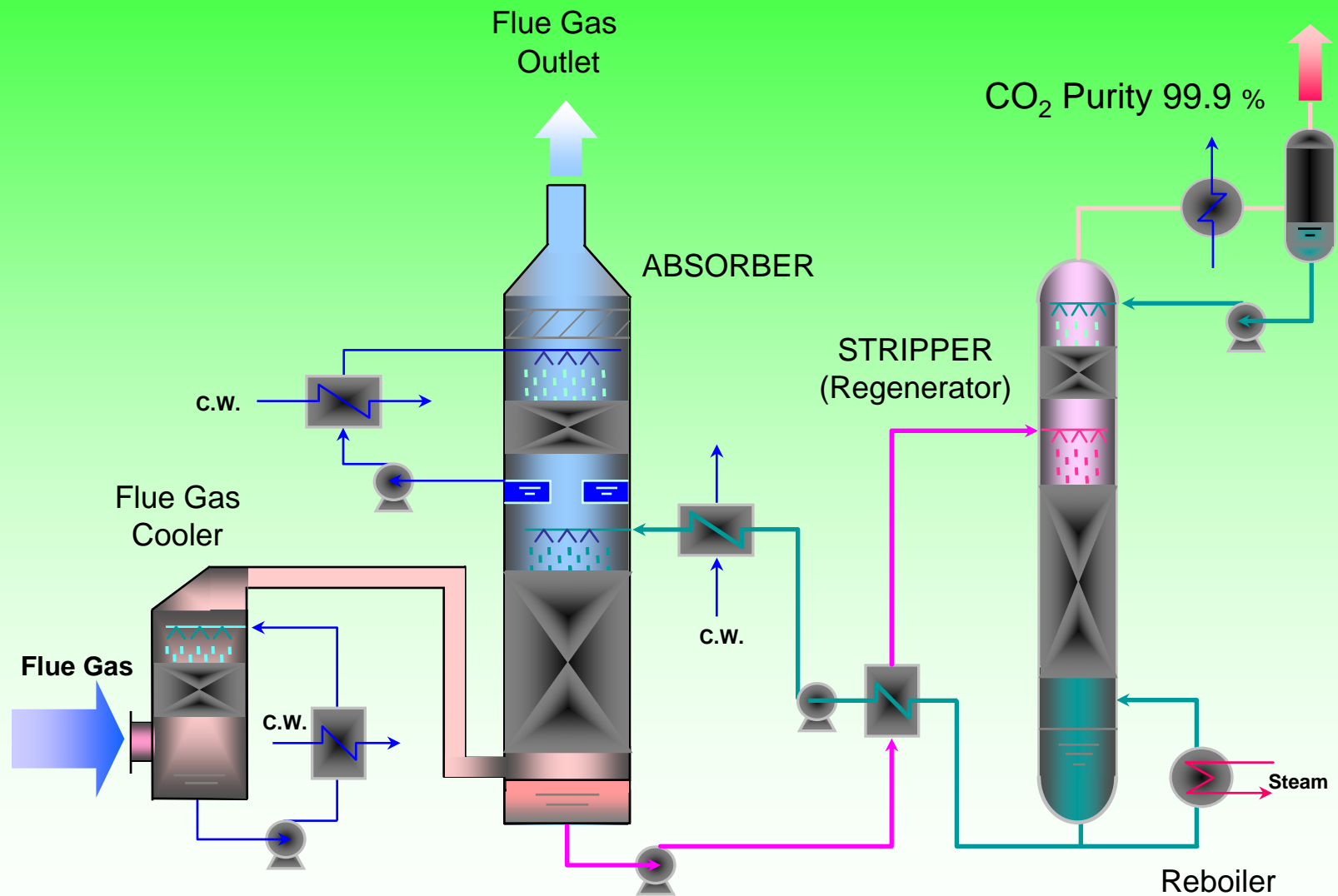
Capacity : 2 TPD

Start Up : 1991

Feed Gas : Natural gas fired boiler

- Over 200 solvents tested – lots of data
- New Solvent KS-1™ was developed.
- KS-1™ alone can reduce steam consumption by about 20% compared to standard MEA.
- Energy efficient steam systems developed.
- Ongoing process testing and solvent development

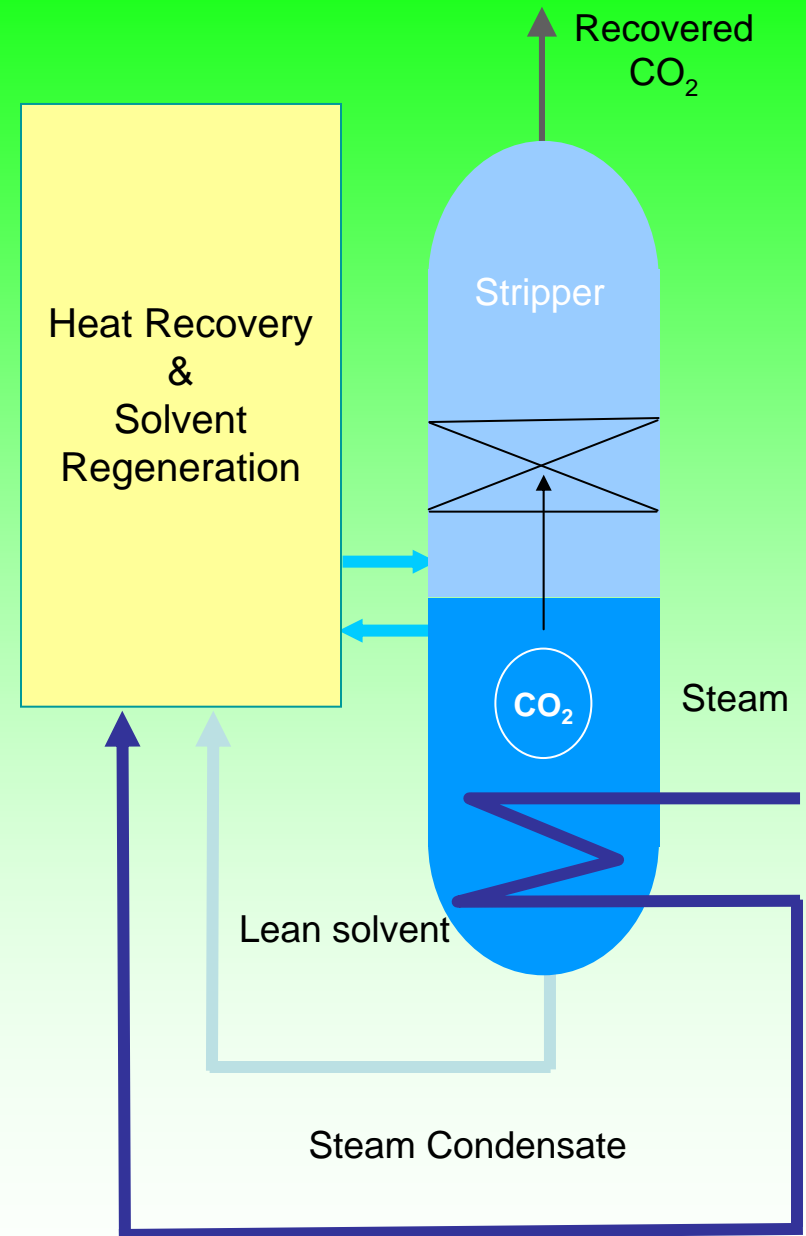
Basic Process Flow Diagram



Process Improvements

- 15% reduction in steam consumption over MHI's conventional process
- Advanced process demonstrated at MHI's Nanko Pilot Plant and other commercial plants
- Process Features
 - Utilize lean solvent and steam condensate heat for regeneration inside the stripper
- Performance
 - Steam Consumption: <math><1.30 \text{ Ton Steam/ Ton CO}_2</math> (660 Kcal/ Kg CO₂)

Note: Steam = 3 BarG Saturated



Patent Application submitted in various countries

KEY ADVANTAGES

compared to MEA

KS-1™ solvent

- Higher CO₂ Loading
- More Efficient Regeneration
- Lower Circulation Rate
- Lower Solvent Degradation
- Low Corrosion – no solvent inhibitor

KM-CDR Process

- Lower Utility & Solvent Consumption
- Atmospheric process – safe and easy operation & Maintenance

MHI's Commercial Achievements

Five Large Commercial PCC plants in operation

(from Natural Gas flue gas)



200 tpd Malaysia
1999



330 tpd Japan
2005



450 tpd India
2006



450 tpd India
2006



450 tpd India
2009

Construction on 4 additional commercial plants continues;

- UAE 400 tpd (2009)
- Bahrain 450 tpd (2009)
- Pakistan 340 tpd (2010)
- Vietnam 280 tpd (2010)

Several other contracts under negotiation

MHI's Commercial Achievements

What have we learned?



More than 17 years of cumulative operational experience of these large scale plants has allowed us to:

- Refine certain aspects of the process
- Confirm material selection for key components
- Confirm utility & solvent consumption
- Develop and incorporate countermeasures against impacts of impurities

- Develop a commercial contracting structure for delivery of CO2 capture equipment together with our partners

- Prove operation of the KM-CDR process at a sufficient scale for us to be confident to move ahead with scale-up of a single train design

CO₂ Recovery from Natural Gas Flue Gas

– MHI is ready to go!!

- MHI has learned from these large commercial plant experiences
- Design of a 3,000 tpd single train PCC Plant is complete
- Being offered on a commercial basis

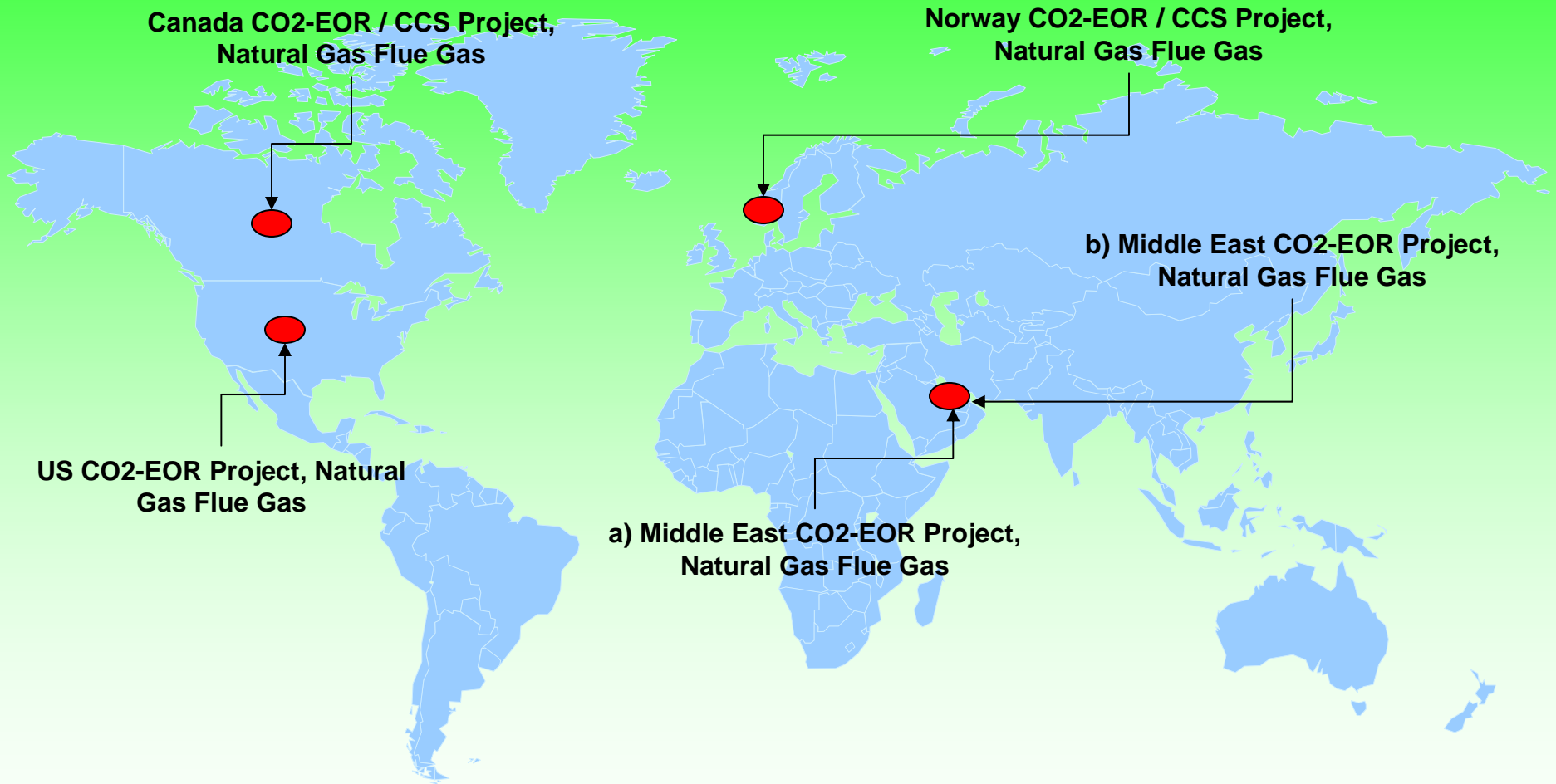


Gas Boiler



Gas Turbine

MHI's Global Natural Gas Fired CO₂-EOR/CCS Project Work under Negotiation



Coal Fired Long Term Demonstration Plant



Plant Outline

Solvent: KS-1

Capacity: 10 tpd

Feed Gas: Coal Fired Boiler

Start-up: July, 2006

Location: J-POWER Matsushima Power Station, Nagasaki, Japan

Objective

Demonstrate long term CO₂ recovery from coal fired boiler flue gas.

Note:

Project funding support from RITE (50%) and cooperation from J-Power

Coal Fired Long Term 10 tpd Demonstration

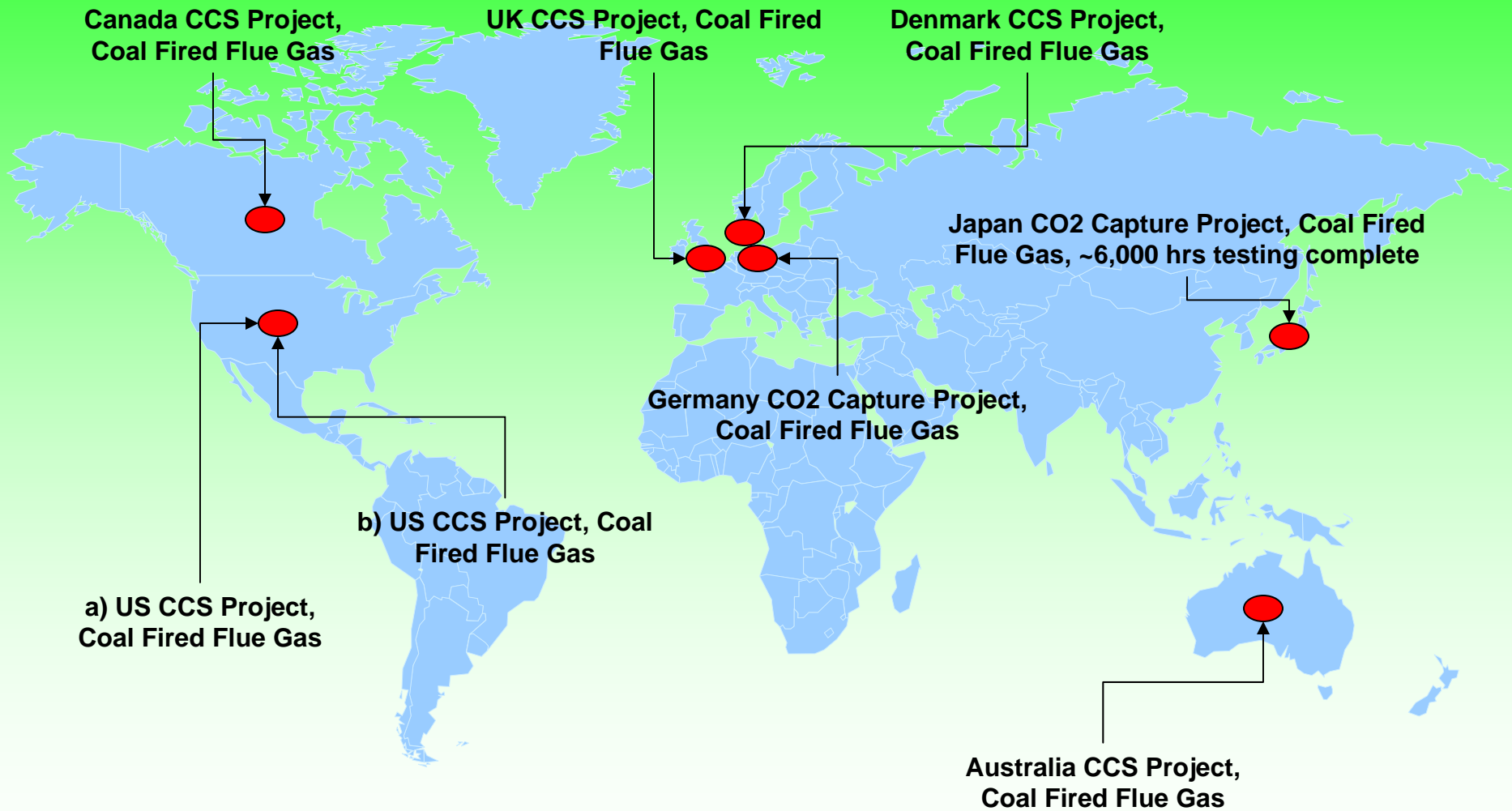
What have we learned?



~6,000 hours of operation

- 1) Increased understanding of the effects of impurities on the system and solvent (SO_x, NO_x, Dust, etc.).
 - SO₂ and NO₂ in the flue gas were absorbed by the solvent and generated heat stable salts. If maintained at low levels do not cause operational problems
 - By maintaining the dust levels at or below 10mg/kg concentration in the solvent, no flooding occurs
 - Solvent loss as predicted
 - Incorporated countermeasures for the impurities where necessary.
- 2) The operational experience and lessons learned are helping us to facilitate scale-up of KM-CDR process for CO₂ capture from coal fired boilers.

MHI's Global Coal Fired CCS Project Work in Various Study & Test Phases



Coal Fired CO₂ Capture Plant Scale-up

From Pilot to Full Scale

From what have we learned, how do we get there?

Phased approach

Pilot
1's TPD
Scale



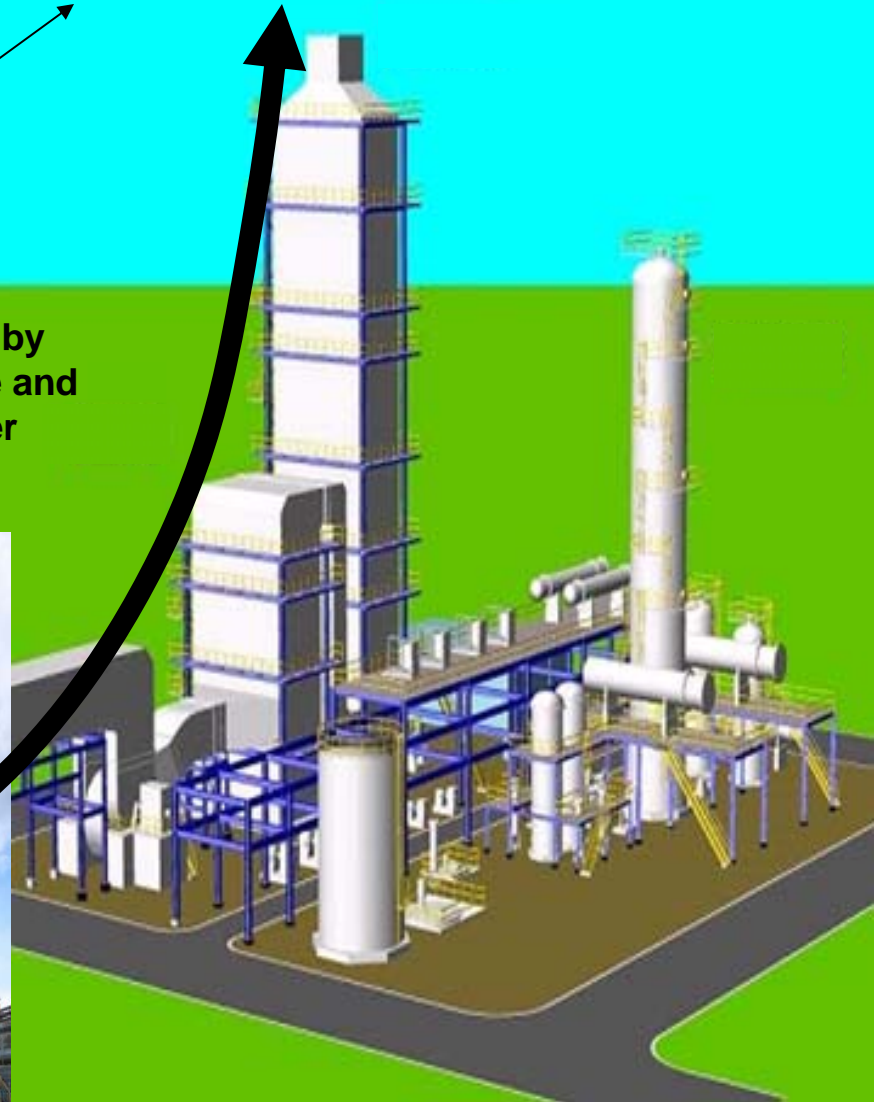
Small Scale
Demonstration
10's TPD Scale



Next Step: Large Scale
Demonstration backed by
commercial experience and
lessons learned in other
industries
100's TPD Scale



1,000's TPD Large Scale



CO₂ Capture Plant Scale-up Development

Flue gas CO₂ recovery scale-up – MHI's experiences.

5 times

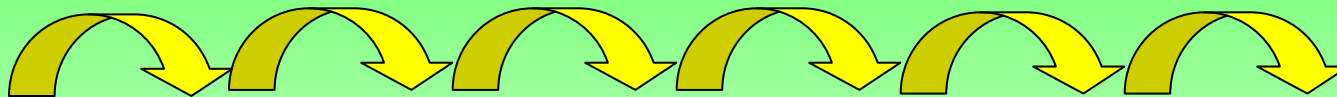
20 times

1.65 times

1.5 times

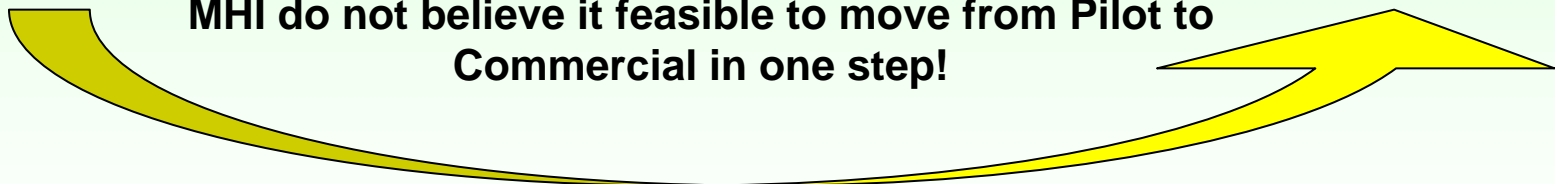
1.1 times

6 times



	Japan Nanko Pilot plant	Japan Coal-Fired demo plant	Malaysia Commercial plant	Japan Commercial plant	India Commercial plant	TBA Coal Fired Demo plant	TBA Coal Fired project
CO ₂ recovery capacity	2 TPD	10 TPD	200 TPD	330 TPD	450 TPD	500 TPD	3,000 TPD

MHI do not believe it feasible to move from Pilot to Commercial in one step!



Coal Fired CO₂ Capture Plant Scale-up

With scale-up there are some issues to consider

Pilot



1,000's TPD Large Scale



Current Commercial Plant - Cylindrical Absorber Tower



Large Scale CO₂ Capture Plant - Rectangular Absorber Tower



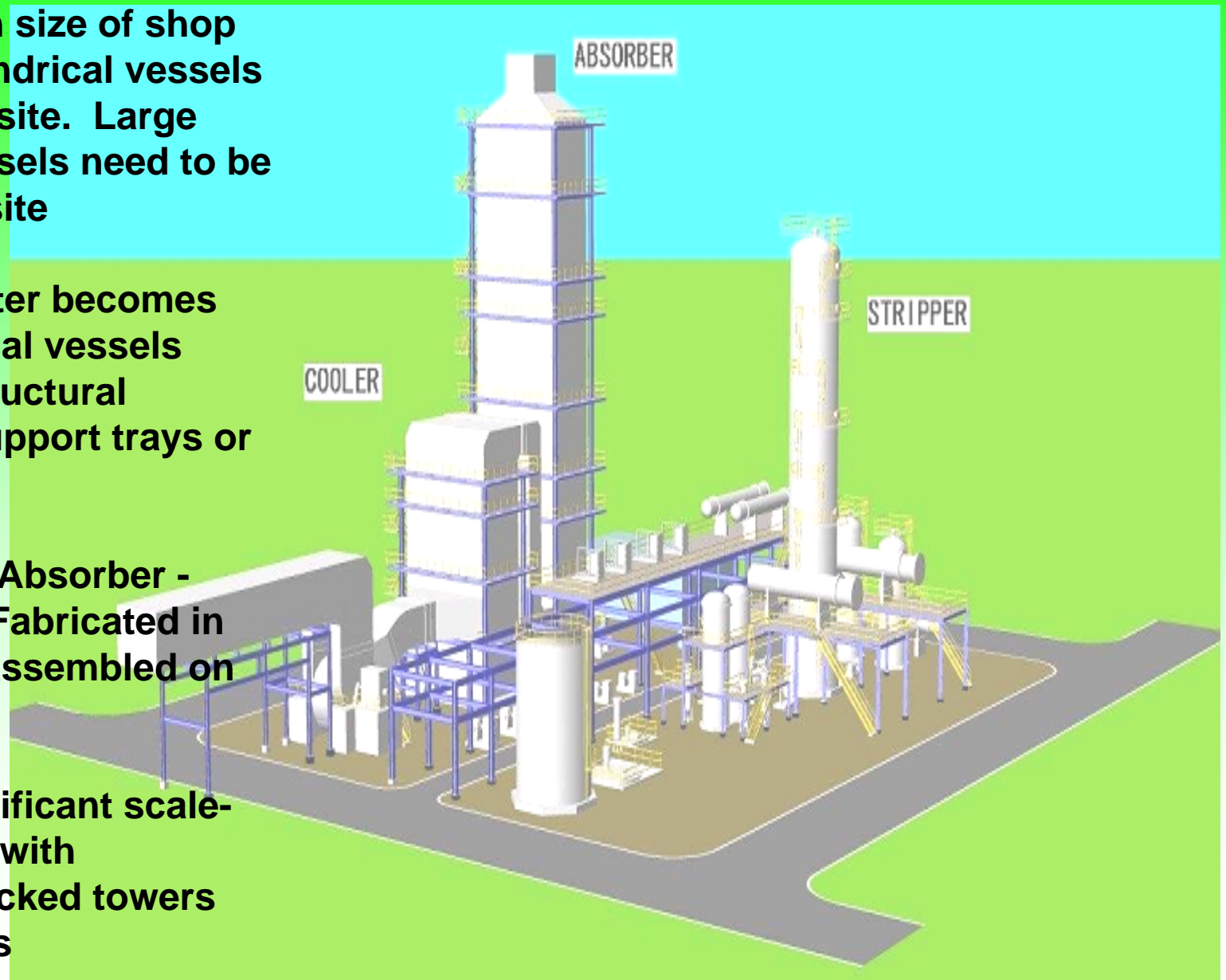
Large Scale CO₂ Capture Plant - Rectangular Absorber Tower

- Limitation on size of shop fabricated cylindrical vessels for delivery to site. Large cylindrical vessels need to be fabricated on site

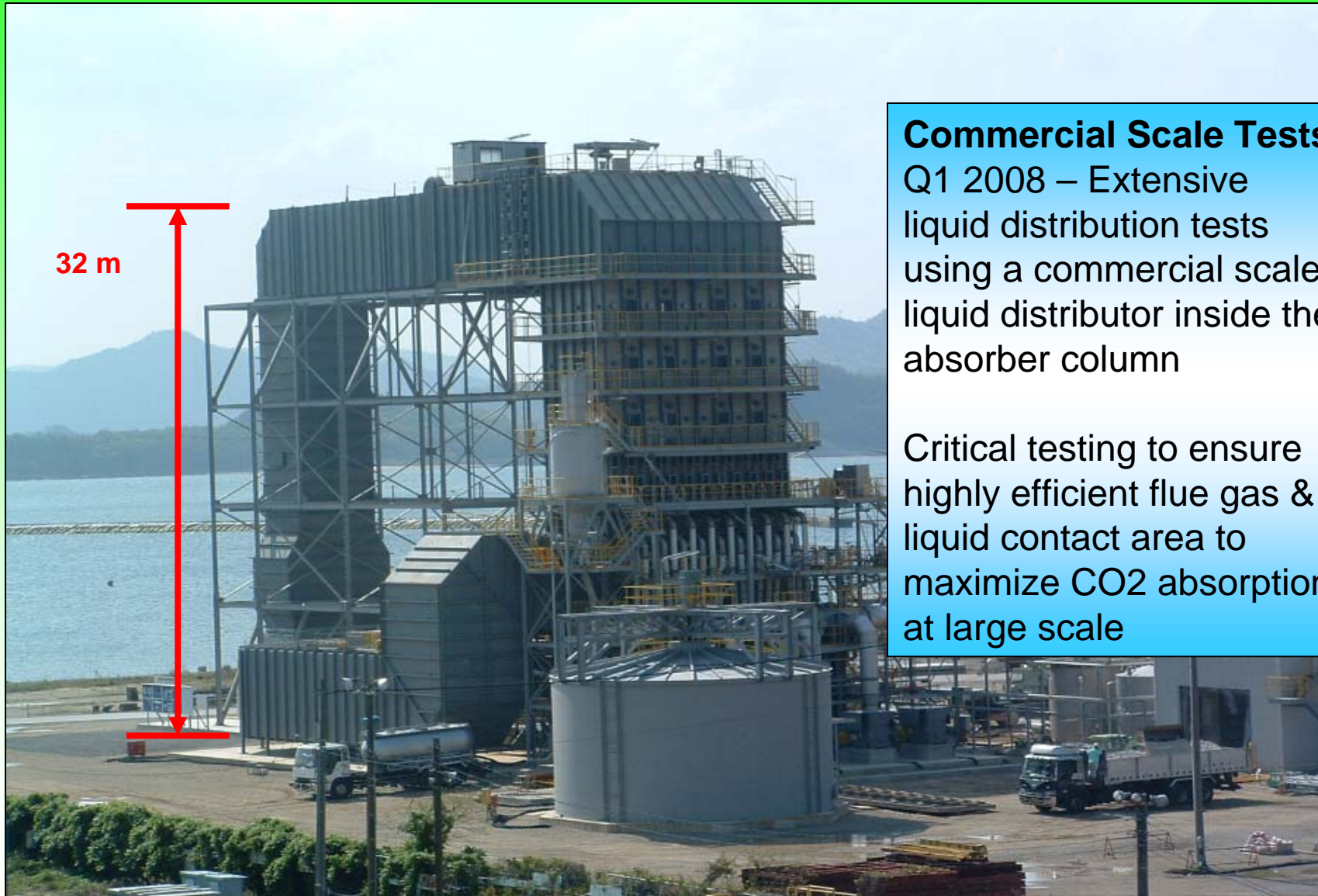
- As the diameter becomes large, cylindrical vessels need heavy structural members to support trays or packing

- Rectangular Absorber - panel design. Fabricated in the shop and assembled on site

- MHI has significant scale-up experience with rectangular packed towers - FGD business



Largest Multi-Pollutant Test Plant in the world (FGD & CO2 Capture) Absorber Test Facility (400 MW equivalent)



Commercial Scale Tests
Q1 2008 – Extensive liquid distribution tests using a commercial scale liquid distributor inside the absorber column

Critical testing to ensure highly efficient flue gas & liquid contact area to maximize CO2 absorption at large scale

MHI's Risk Mitigation with Scale-Up

Commercial Experience to date



~6,000 hrs experience with CO2 capture from coal fired flue gas (10 tpd scale)

Commercial scale (400MW equiv.) liquid distribution tests at Mihara test plant

3,000 tpd Plant Basic Design Complete (Nat. gas)



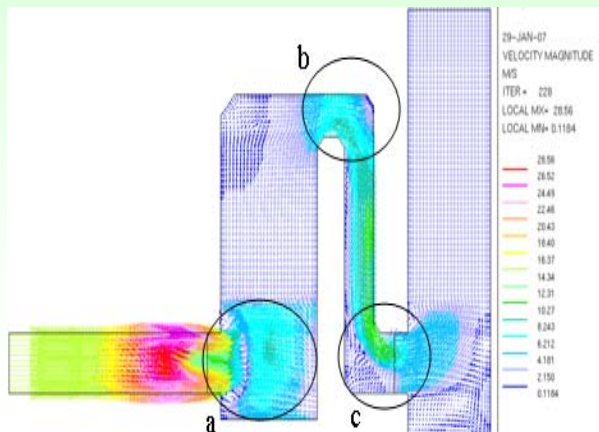
Application of Advanced Computational Flow Dynamics (CFD) Technology



>200 Commercial FGD Plants deployed – significant experience with flue gas absorber towers using rectangular vessels (max capacity >1000 MW single tower)



Commercial Ammonia Plant Synthesizes Gas 2,559 T/D CO2 recovery plant – experience with large cylindrical CO2 stripper vessels

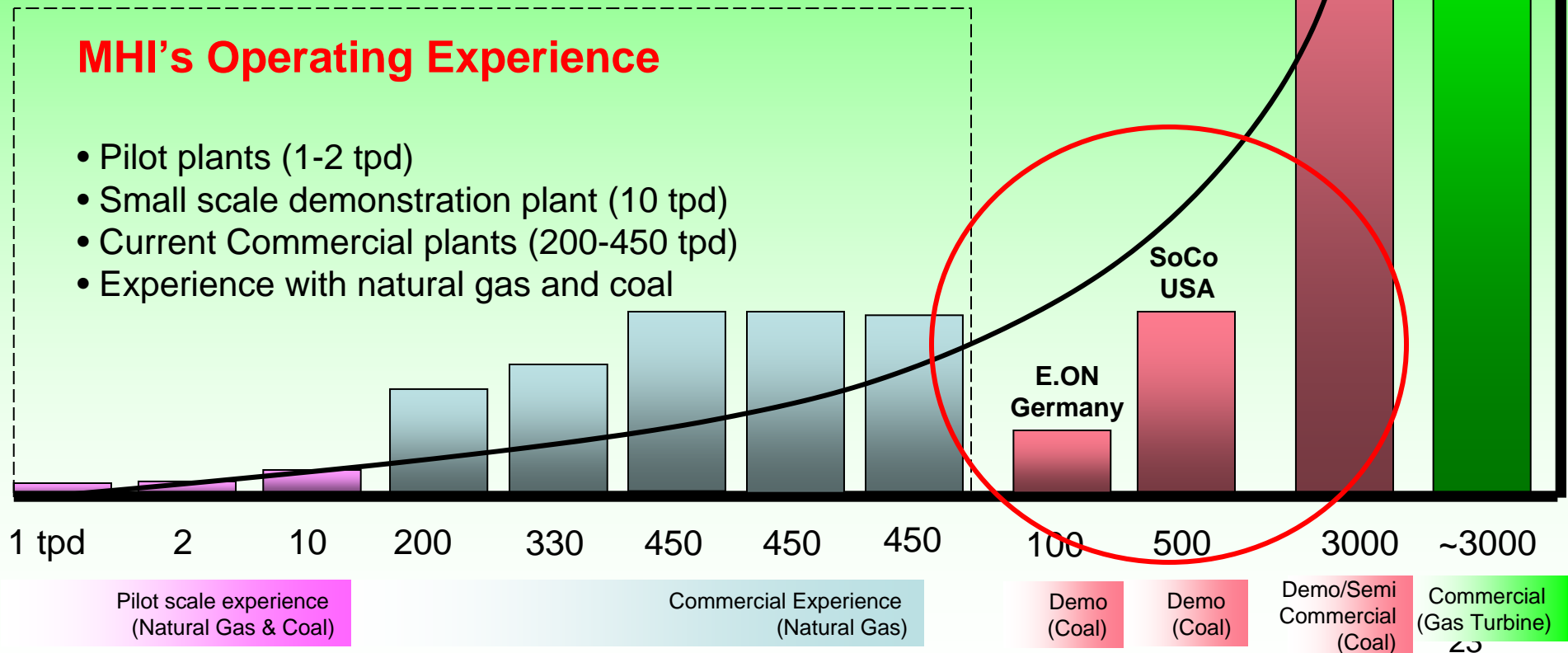


MHI's roadmap to commercialization for coal fired boilers

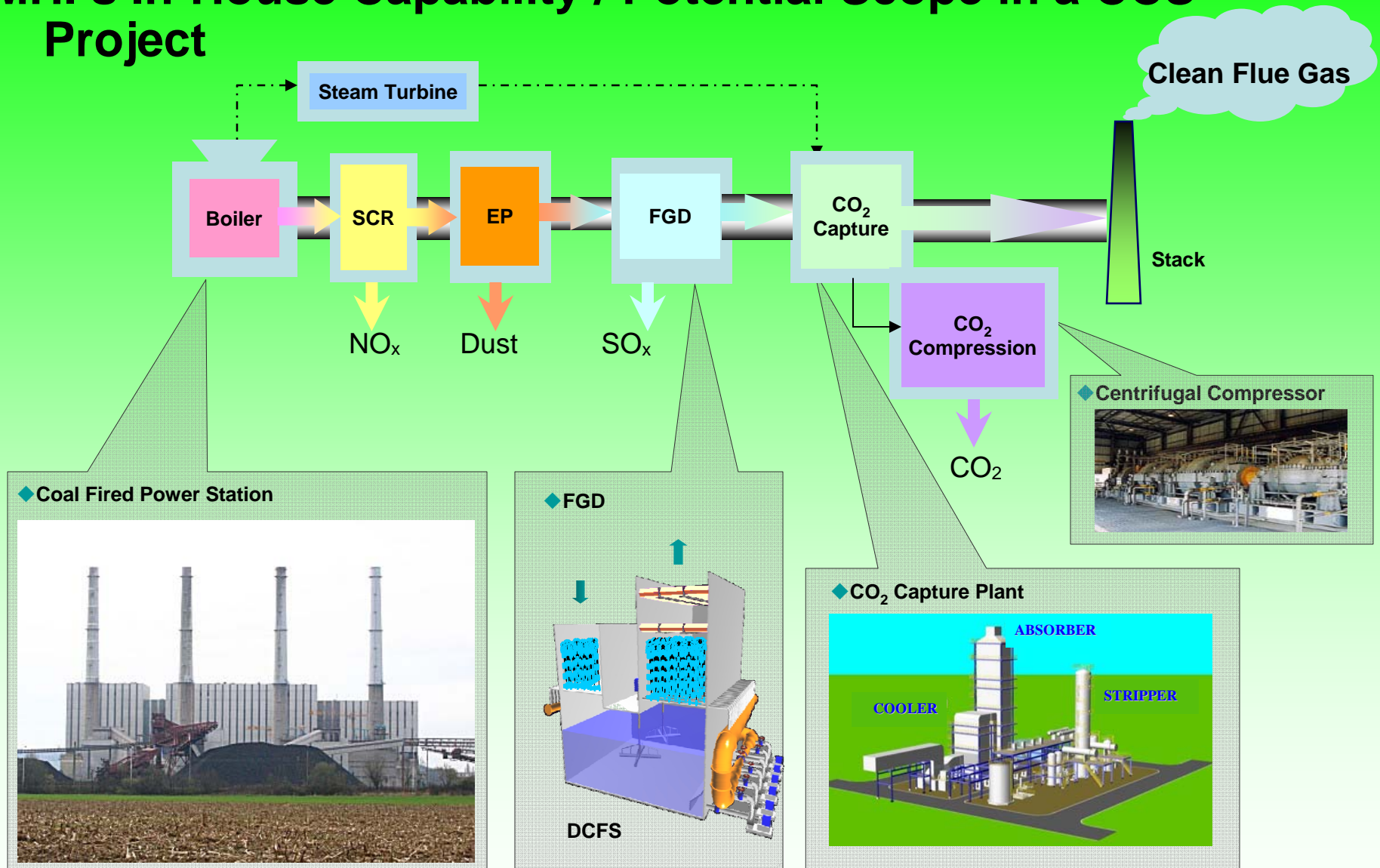
Important next step is to operate the process at a scale large enough to ensure trouble-free operation at commercial scale

MHI's Operating Experience

- Pilot plants (1-2 tpd)
- Small scale demonstration plant (10 tpd)
- Current Commercial plants (200-450 tpd)
- Experience with natural gas and coal



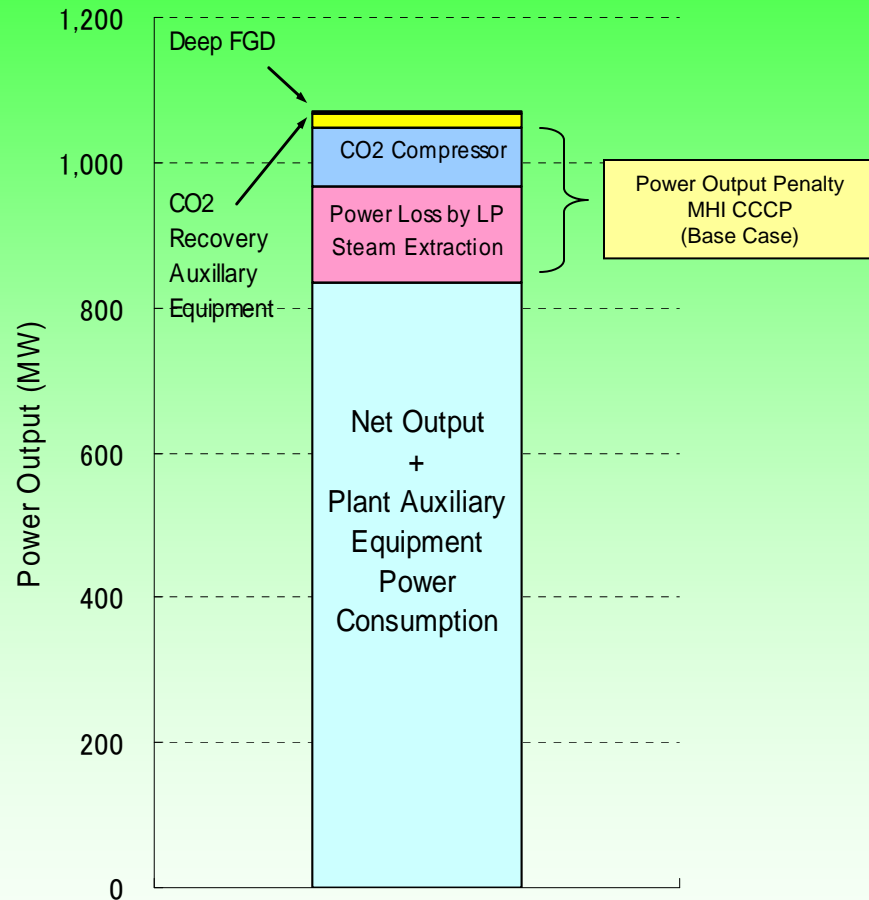
MHI's In-House Capability / Potential Scope in a CCS Project



MHI Fully Integrated Environmental Solutions

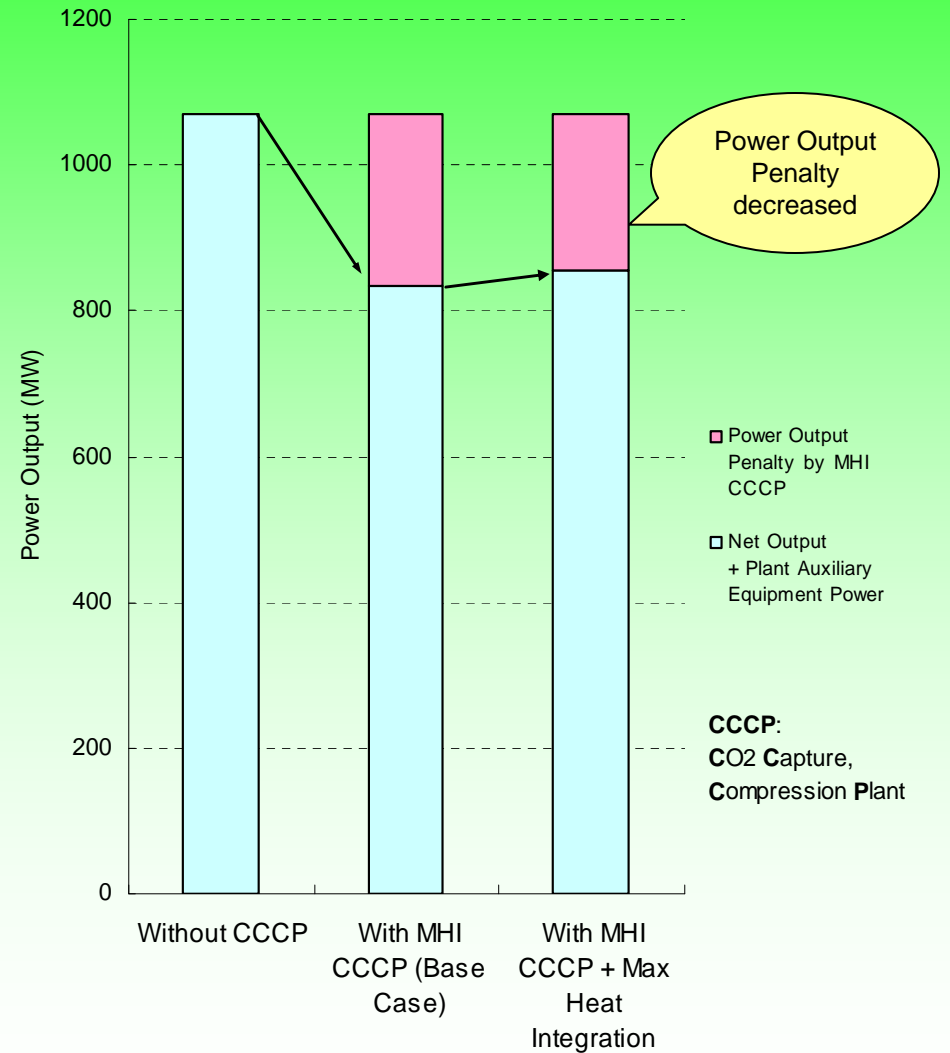
Energy Penalty

Power output penalty of CO2 capture and compression without heat integration

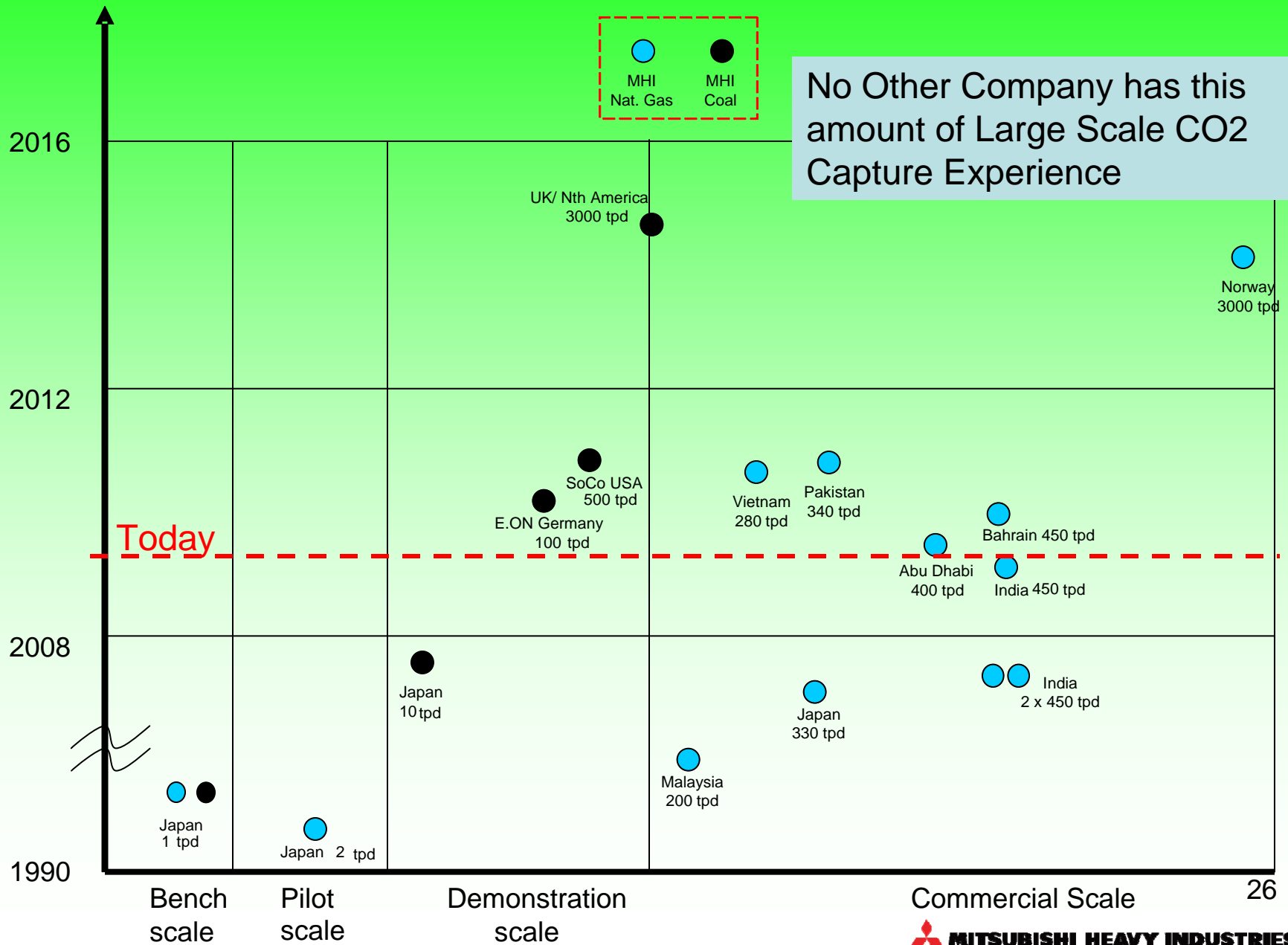


1,070MW (Gross) Supercritical Pulverized Coal Power Plant; Bituminus Coal Case

Net output improvement with heat integration



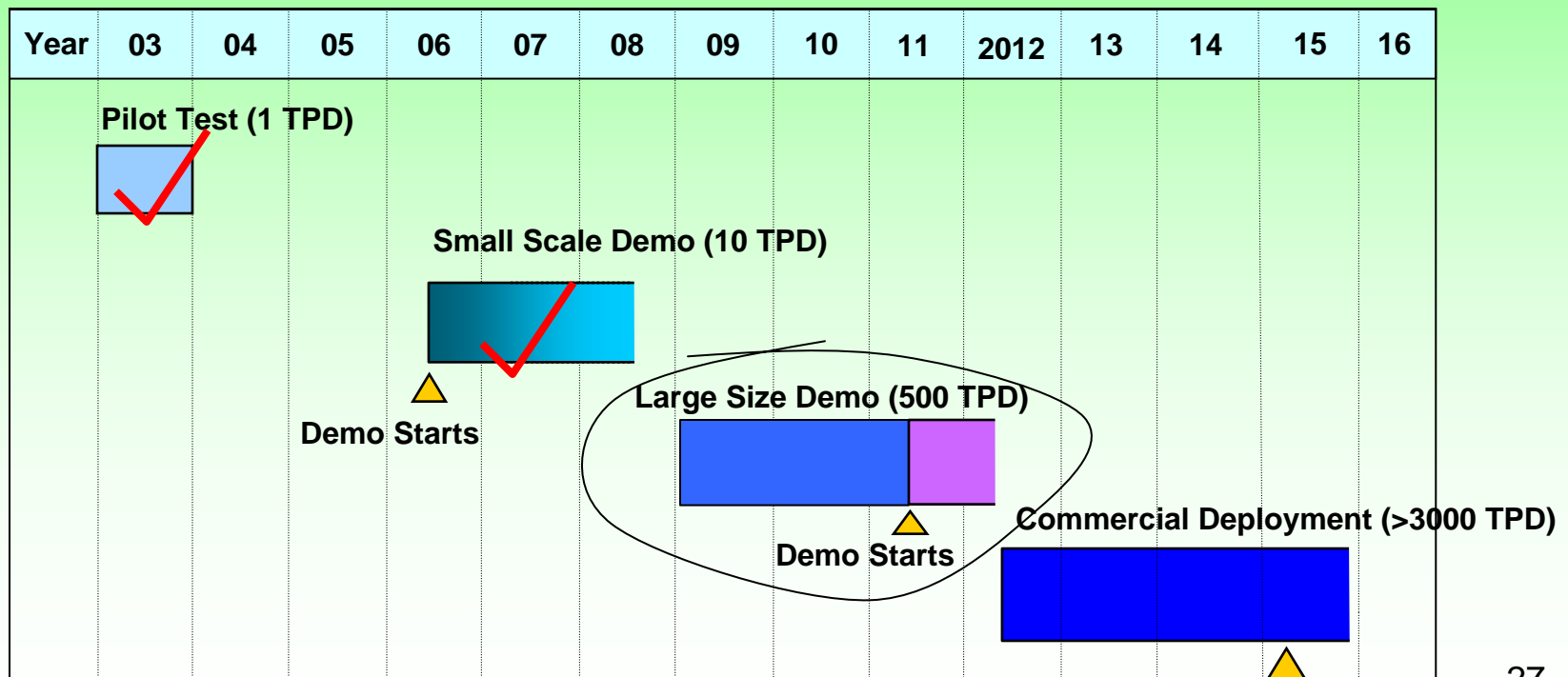
MHI's combined know how from global CO2 Capture projects



Path Forward with Lessons Learned

- Large Scale Coal Fired Demonstration

- MHI has completed pilot and small scale demonstration testing and has learned from those experiences
- MHI is now taking the critical next step which will lead to the rapid commercialization of coal fired flue gas CO₂ capture technology
- Following 1 year of operation we will offer this product on a full guarantee basis – a real solution to address CO₂ emissions is here!



Summary

- The KM-CDR Post combustion CO₂ capture process is commercially available for Natural Gas fired applications
- The KM-CDR process is close to demonstration at large scale as a solution for Coal fired applications
- **Be aware...there are lessons to be learned when it comes to CO₂ capture from Coal Flue gas**
- **You need to ‘learn to walk before you can run’
- there are no short cuts**
- MHI is one technology provider that has gone through the learning curve, that has significant large scale CO₂ capture experience and is taking the next step on the path to making post combustion CO₂ capture from Coal Fired applications a reality

**For further information please stop by the
MHI Exhibit Booth and meet the team**

or contact

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