CSLF Technology Workshop in Seoul Korea

Hadong and Boryeong 10 MW Pilot Projects

Landscape of KEPCO RI

Dr. Chong Kul Ryu (ckryu@kepri.re.kr)

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Contents

I KEPCO & KEPCO RI

Monopoly in Korea (as of 2012)

84%	100%	100%
		
Generation	Transmission	Distribution

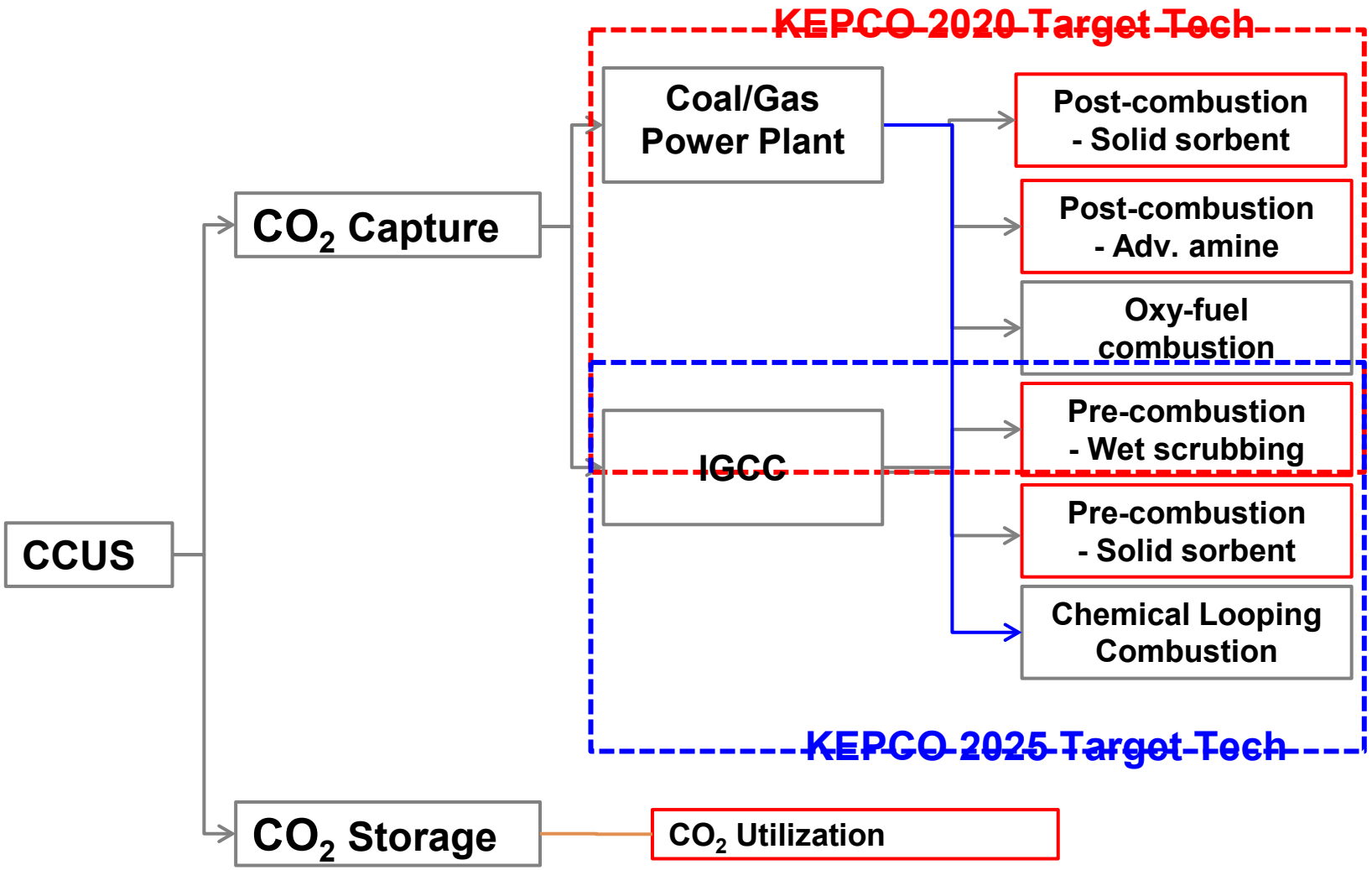
Assets	**137 B USD**
Sales	**46 B USD**
Generation Capacity	**68.848 GW (82.296 GW incl. IPP)**
Power Generation	**448.517 TWh (509.574 TWh incl. IPP)**
Customers	**20.050 M households**
Employees	**19,278**
Price	**USD 82/ MWh**

KEPCO Research Institute

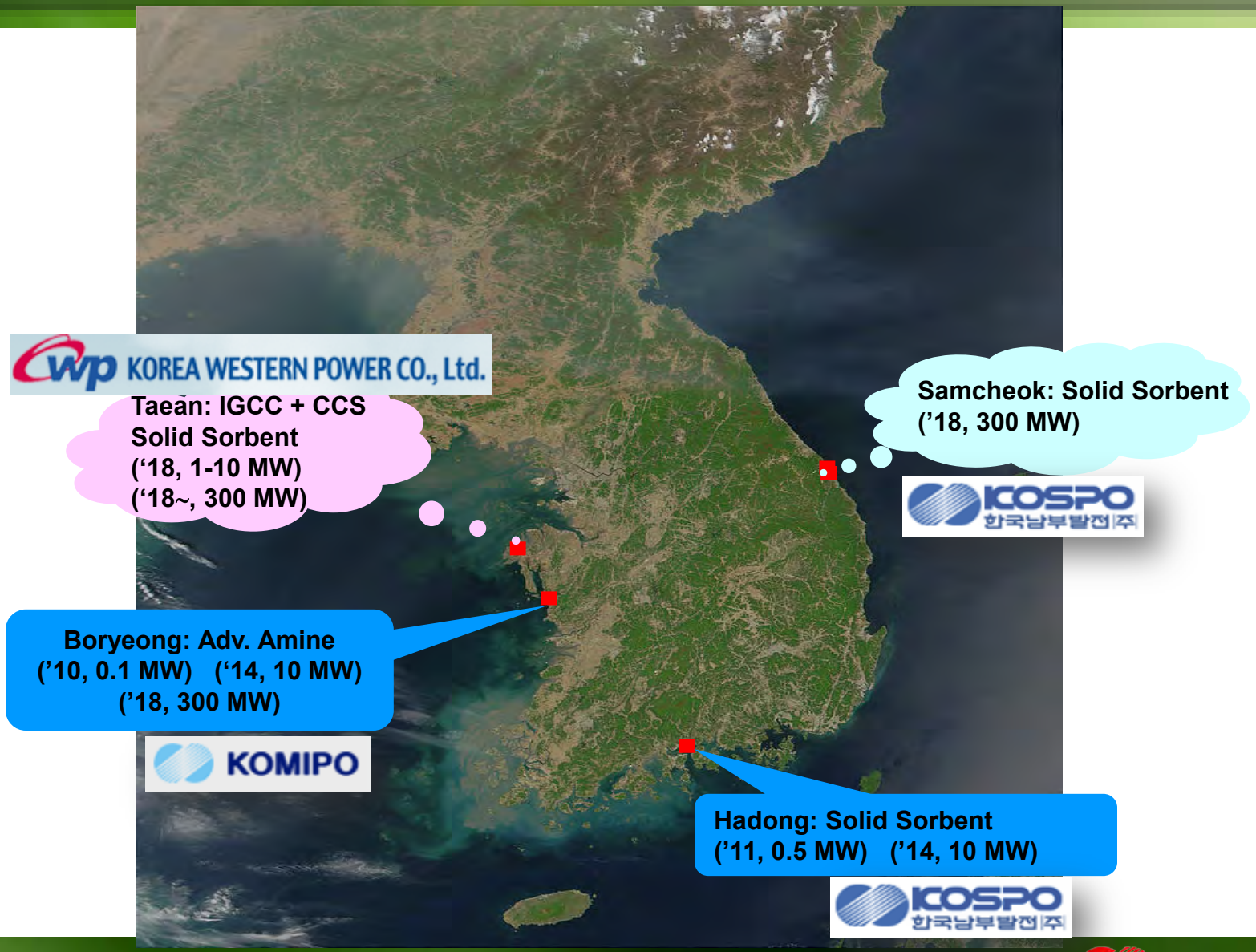
Research Center for Electric Power Industry

We are providing the technology and leading the business

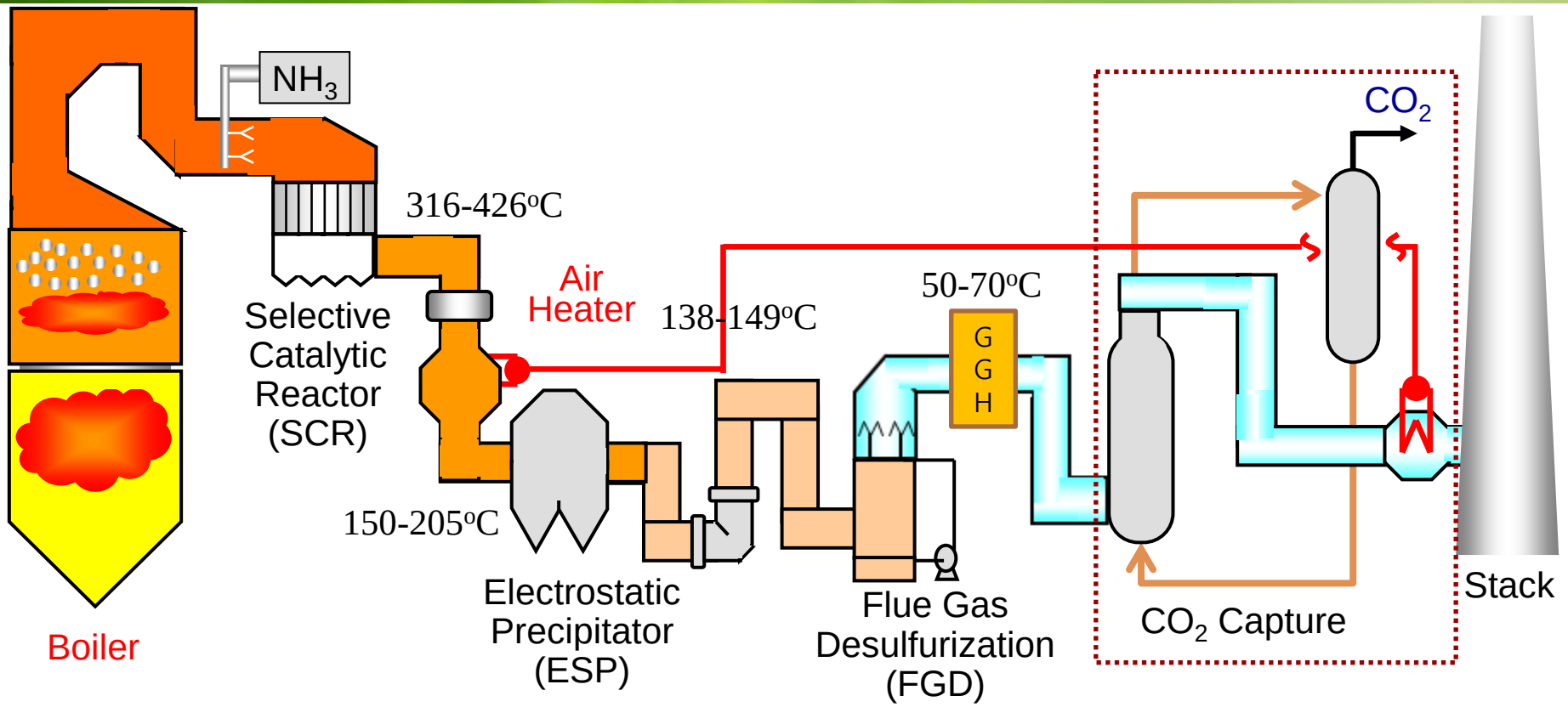
KEPCO's CCS R&DD Strategies



Large CO_2 Capture Plant Sites in Korea

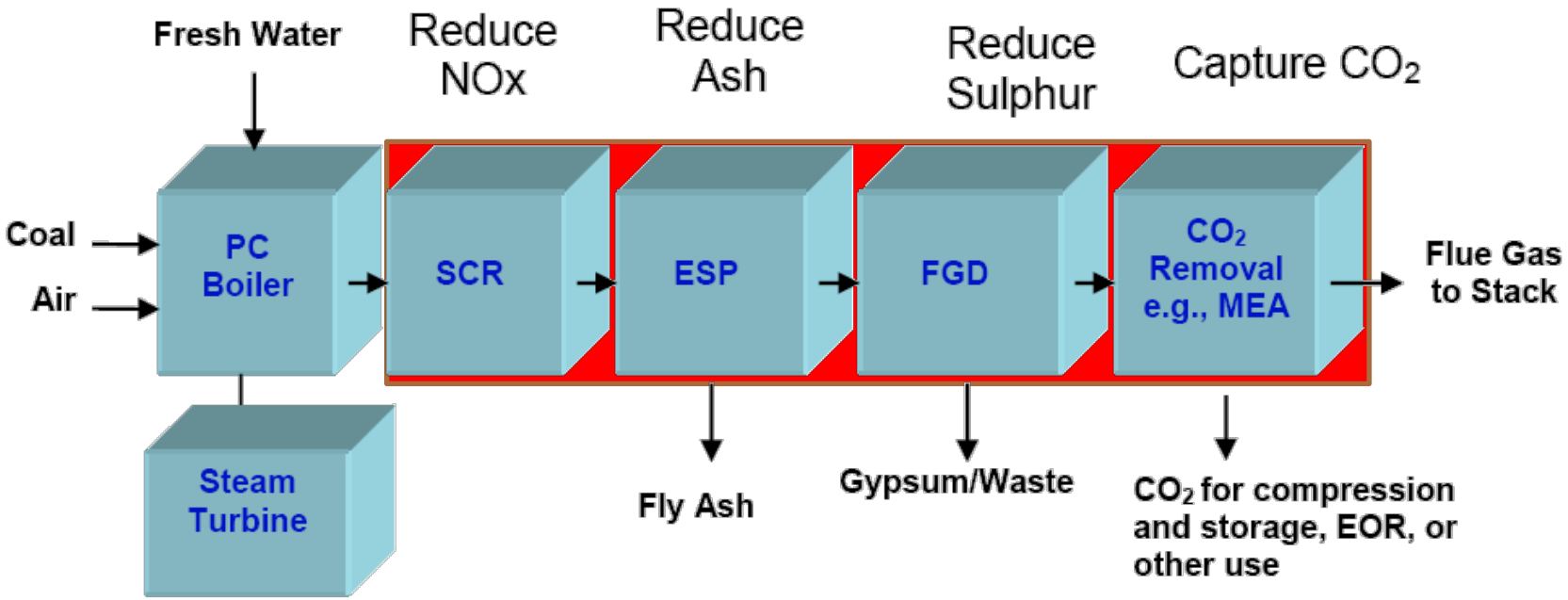


CO_2 Capture System in PC



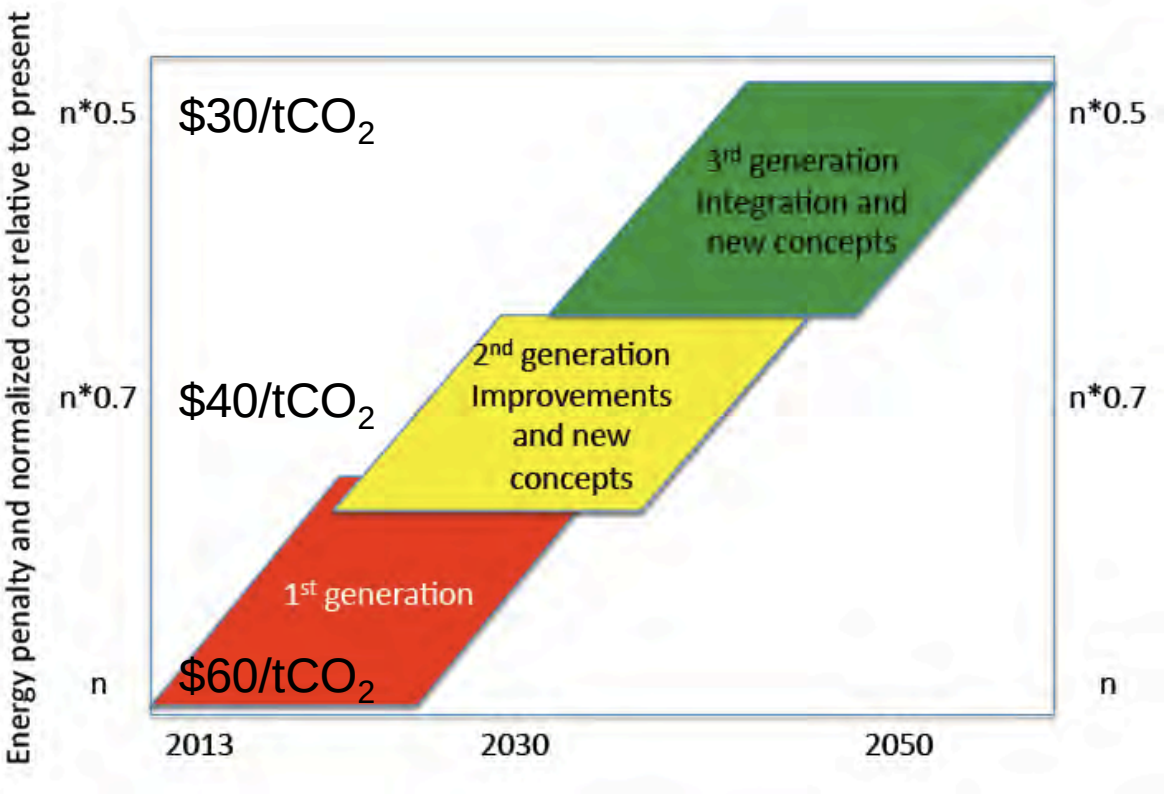
SCPC: 246 bar/538℃/538℃(500 MW)
SCPC: 246 bar/566℃/566℃(800 MW)
USCPC: 246 bar/566℃/593℃(500/800 MW)
USCPC: 265 bar/610℃/621℃[1000 MW]

Post-combustion process and flue gas composition



Gas constituent	Coal (ST	Natural gas (GT)
Nitrogen (N_2)	70-75%	73-76%
Carbon dioxide (CO_2)	10-15% (13-14%)	4-5%
Water vapor (H_2O)	8-15% (10-12%)	8-10%
Oxygen (O_2)	3-4% (3-6%)	12-15%
Trace gases (SO_x, NO_x, others)	<1% (<100 ppm)	<1% (<10 ppm)

Priorities for CCS technology development



CSLF CCS TRM, 2013 (www.cslforum.org)

Current CO_2 Capture Cost: USD 60/tCO_2 (IEA 2011, GCCSI 2013)

I Boryeong 10 MW CO_2 Capture Project

Advanced Amine CO_2 Capture Technology

- CO_2 Capture plan Plant

- R&D strategies

KCCP project

" Development of a wet CO_2 capture technology to be more efficient and cheaper by novel absorbent and advanced process with heat integration"

Novel absorbent	Process
· Low regeneration energy · High capture efficiency · Fast kinetics · Low thermal degradation · Low corrosion · Low volatility/foaming	· Heat integration · Improved absorber · Advanced reclaimer · Energy saving system

*KCCP : KoSol CO_2 Capture Process

KEPCO RI's R&D Progress of Wet Scrubbing

0.1 MW CO_2 Test-bed
Seoul Thermal
Power Plant (NG flue gas)

0.1 MW CO_2 Test-bed ($ 8 M)
Boryeong Thermal Power Plant
(Coal flue gas)

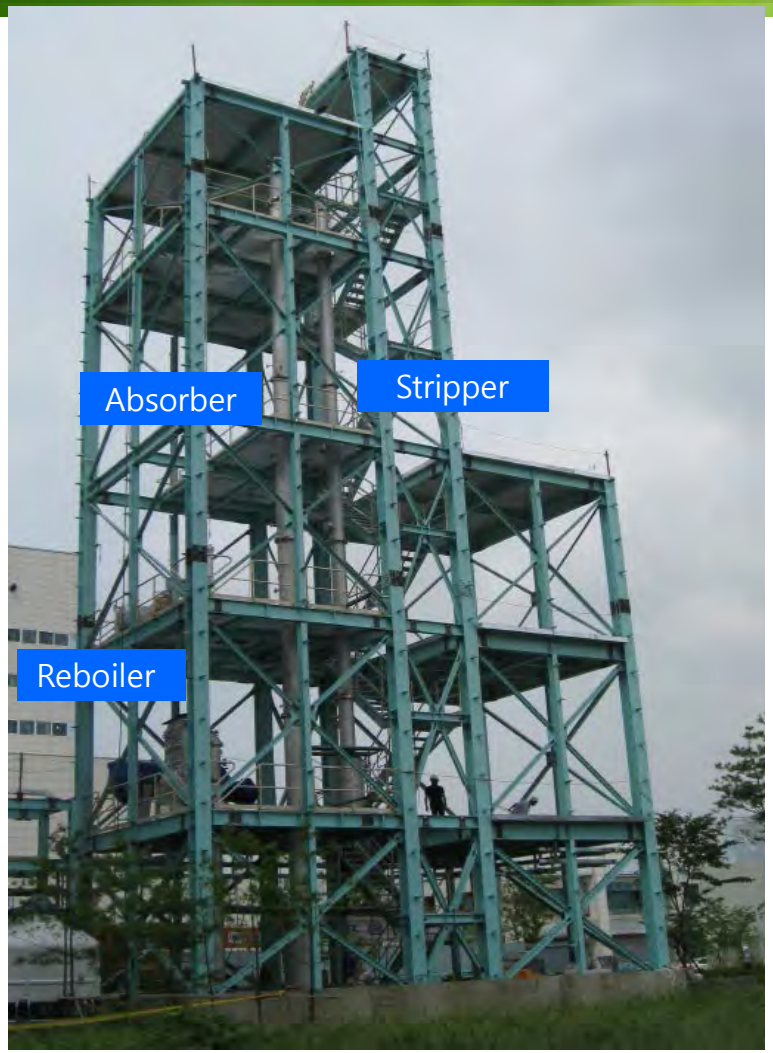
10 MW CO_2 Pilot plant ($ 42 M)
Boryeong Thermal Power Plant (Coal
flue gas)

Phase 1('00.1~'06.09)
Technology Introduction(ABB)

Phase 2('08.11~'11.06)
Advanced Amine technology

Phase 3('10.11~'14.09)
Process Scale-up & Demonstration

0.1 MW Test bed, Advanced amine



0.1MW Test-bed at Boryeong coal-fired power plant

- **Scale: 0.1 MW slip-streamed from 500 MW coal-fired power plant(SC)**
- **Capacity: 2 tCO_2/d**
- **Flue gas: coal-fired boiler**
- **Solvent: KoSol-3 & 4***
  - **> 90% CO_2 capture**
  - **> 99% CO_2 product purity**
  - **3.0~3.1 GJ/tCO_2 regeneration energy (> 3000 hrs continuous campaign)**
- **Plot area: LxWxH =12m x 7m x 25m**
- **Startup: Oct, 2010**
- **Location: City of Boryeong, Korea. KOMIPO's Boryeong Thermal Power Station (unit #8)**

** KoSol: KEPCO's proprietary solvent*

Progress of 10 MW Pilot Plant

Project start

'10.11

Details Design

'12.6

Foundation

Column construction

'12.8

'12.11

Process piping & Panel installation

Test run & Trouble Shooting

'13.1

'13.2

Cooling tower

Completing Construction

'13.3

'13.4

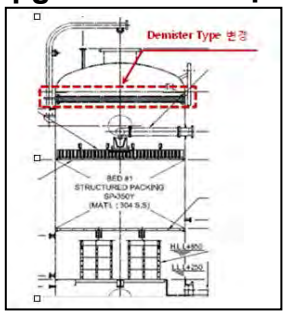
Absorbent filling

Commissioning ceremony

'13.5

'14.1

Process upgrade



Start of Long-term operation

'14.3

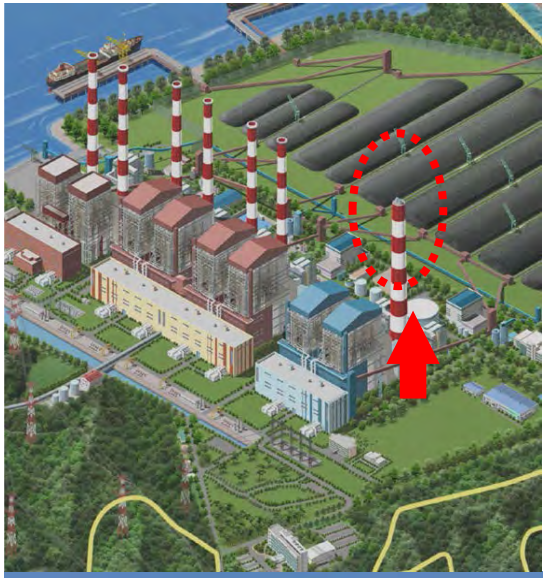
'14.6

End of long-term opeontion

Project end

'14.9

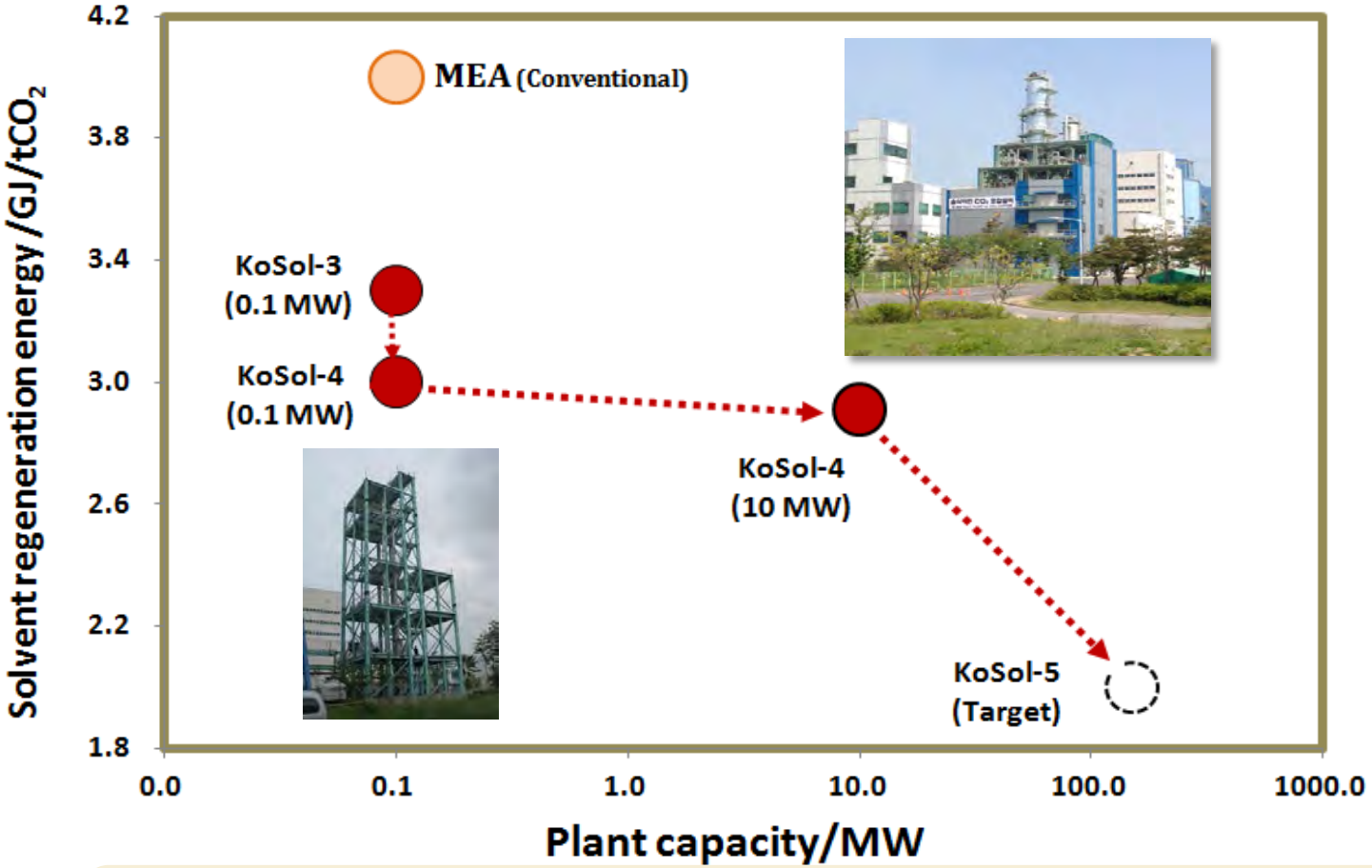
10 MW Pilot Plant, Advanced amine



- Scale: 10 MW slip-streamed from 500 MW coal-fired power plant(SC)
- Capacity: 200 tCO_2/d
- Flue gas: coal-fired boiler
- Solvent: KoSol-4 *
  - > 90% CO_2 capture rate
  - > 99% CO_2 product purity
  - 3.0~3.1 GJ/tCO_2 regeneration energy (Early test results)
- Startup: May, 2013
- Plot area: LxWxH = 31m x 31m x 48m
- Location: City of Boryeong, Korea. KOMIPO's Boryeong Thermal Power Station (unit #8)

Main Results : Pilot plant test results

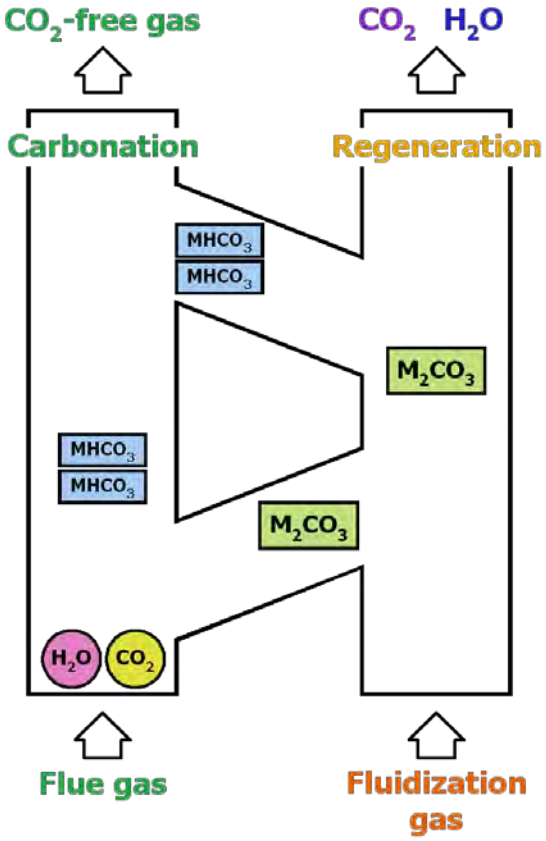
- Performance of CO_2 capture absorbent (KoSol*)

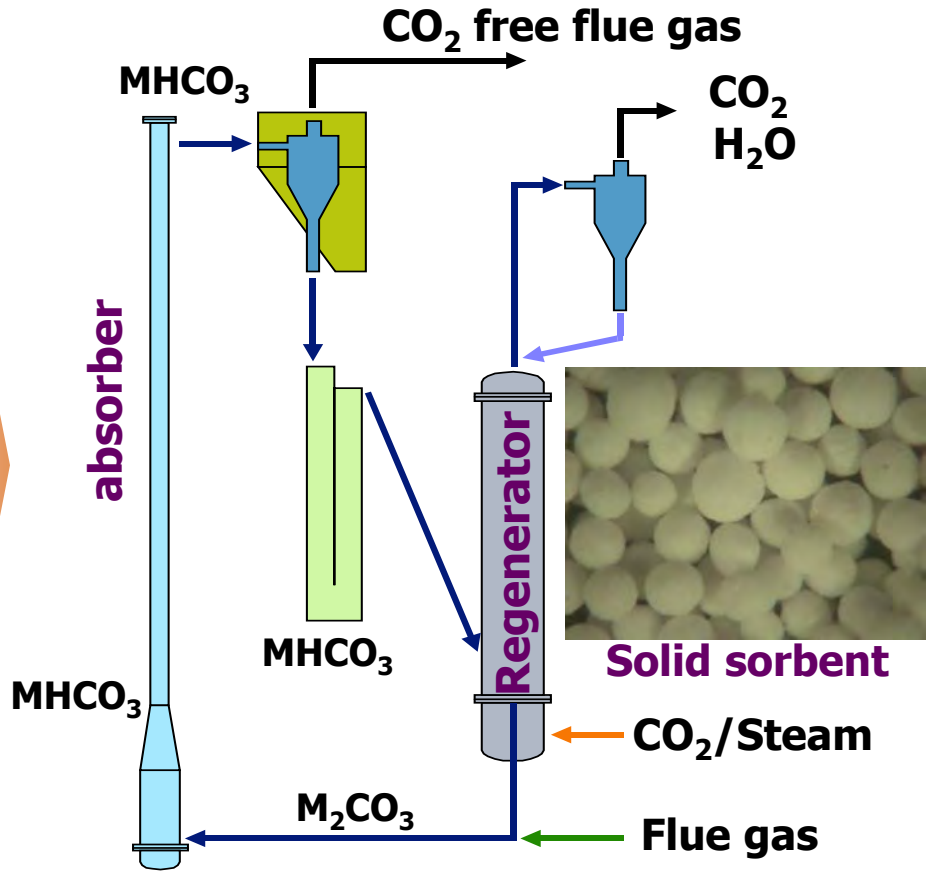


KoSol series showed ① lower regeneration energy than MEA by 20%
② higher durability than MEA by 85% ③ less corrosion than MEA by 93%

III Hadong 10 MW CO_2 Capture Project

Dry CO_2 Capture Technology





- First Cost Reduction Strategies
  - Dual Fluidized-bed Process
  - Solid Sorbents

Characteristics of Dry CO_2 Capture Technology

Carbonation

$K_2CO_3(s)+CO_2(g)+H_2O(g) \rightarrow 2KHCO_3(s)$

$\Delta H = -3.25\ GJ/tCO_2$

$K_2CO_3 \cdot 1.5H_2O(s) + CO_2(g) \rightarrow 2KHCO_3(s) + 0.5\ H_2O(g),\ \Delta H = -1.0\ GJ/tCO_2$

Operating temperature: 40-90°C

- High sorption capacity (ΔL)
- Less influence of water & pollutants
- Less side reaction w/support

- Little Corrosion & No volatiles
- No waste water

- Easy to control heat for exothermic reaction

Regeneration

$2KHCO_3(s) \rightarrow K_2CO_3(s)+CO_2(g)+H_2O(g)$

$\Delta H = 3.25\ GJ/tCO_2$

$2KHCO_3(s) + 0.5\ H_2O(g)) \rightarrow K_2CO_3 \cdot 1.5H_2O(s) + CO_2(g),\ \Delta H = 1.0\ GJ/tCO_2$

Operating temperature: 140-200°C

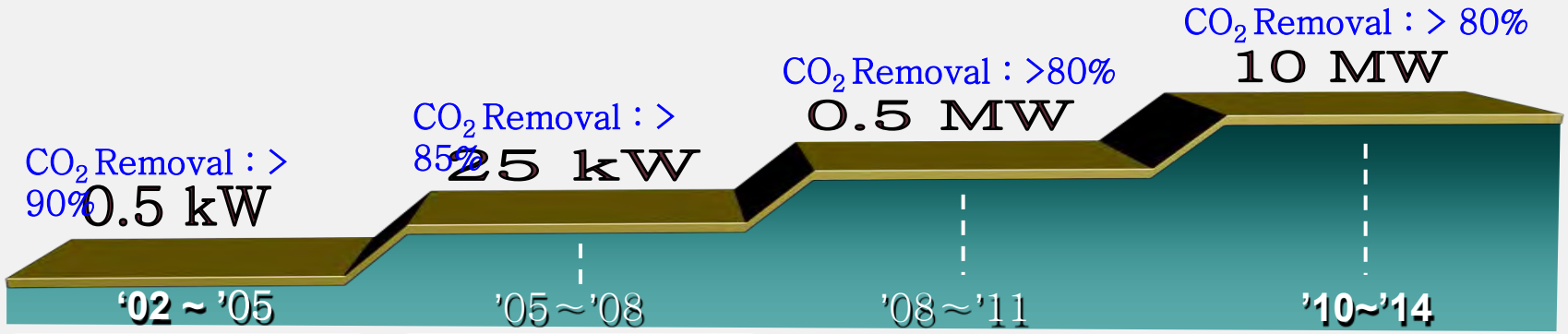
- Good Regenerablity (ΔL)
- Low C_p
- Low ΔH

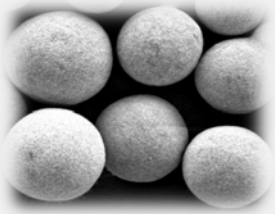
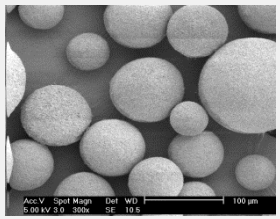
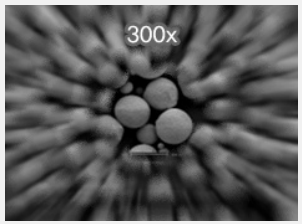
- Recover high-concentrated CO_2 after condensing H_2O

- Use waste heat, steam for endothermic reaction

- Fast kinetics with reasonable reaction temperature (40~200℃) & ΔT~60 ℃
- Fluidized-bed reactor (mechanical strength (AI), density, size, shape)
- Maintaining integrity of sorbent during multi-cycles

Scale-up (X 20,000/10y)



NX30	KX35	KEP-CO2P1	KEP-CO2P2
			

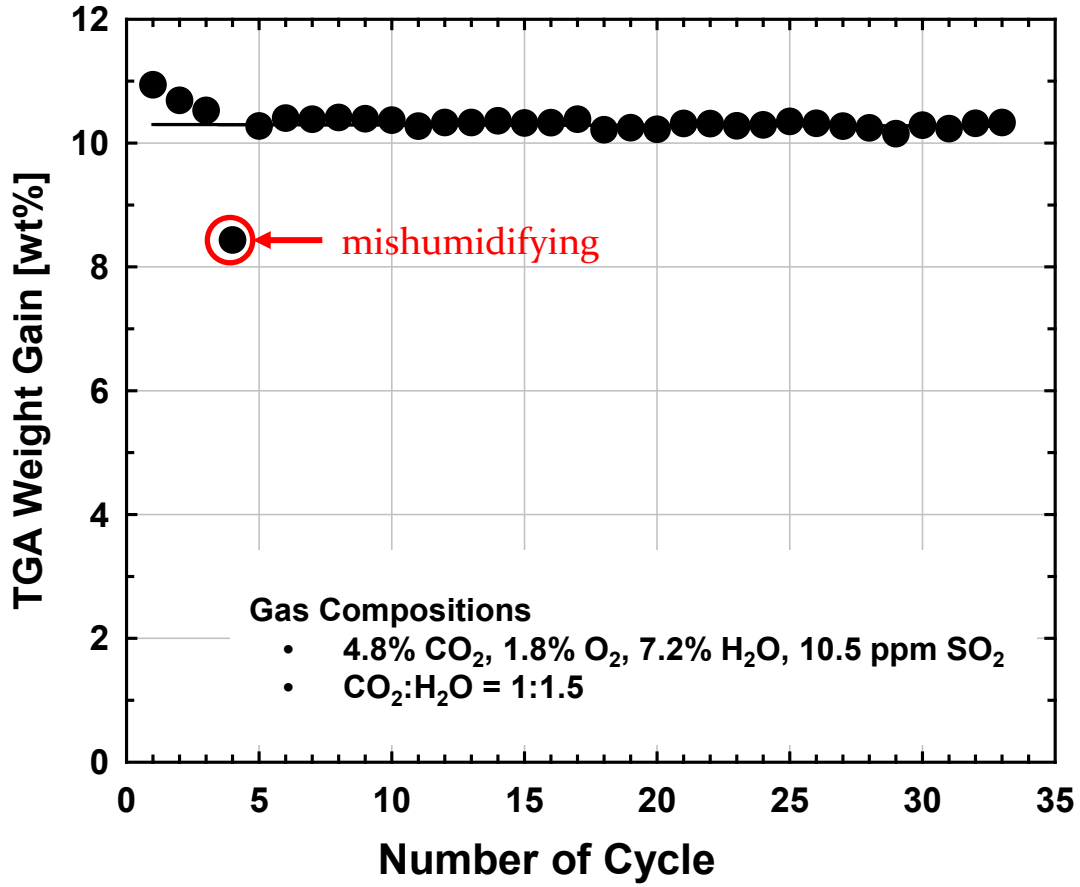



0.5 MW test-bed: Dry regenerable sorbent

0.5 MW test-bed at KOSPO's Hadong coal-fired power plant, Unit # 3

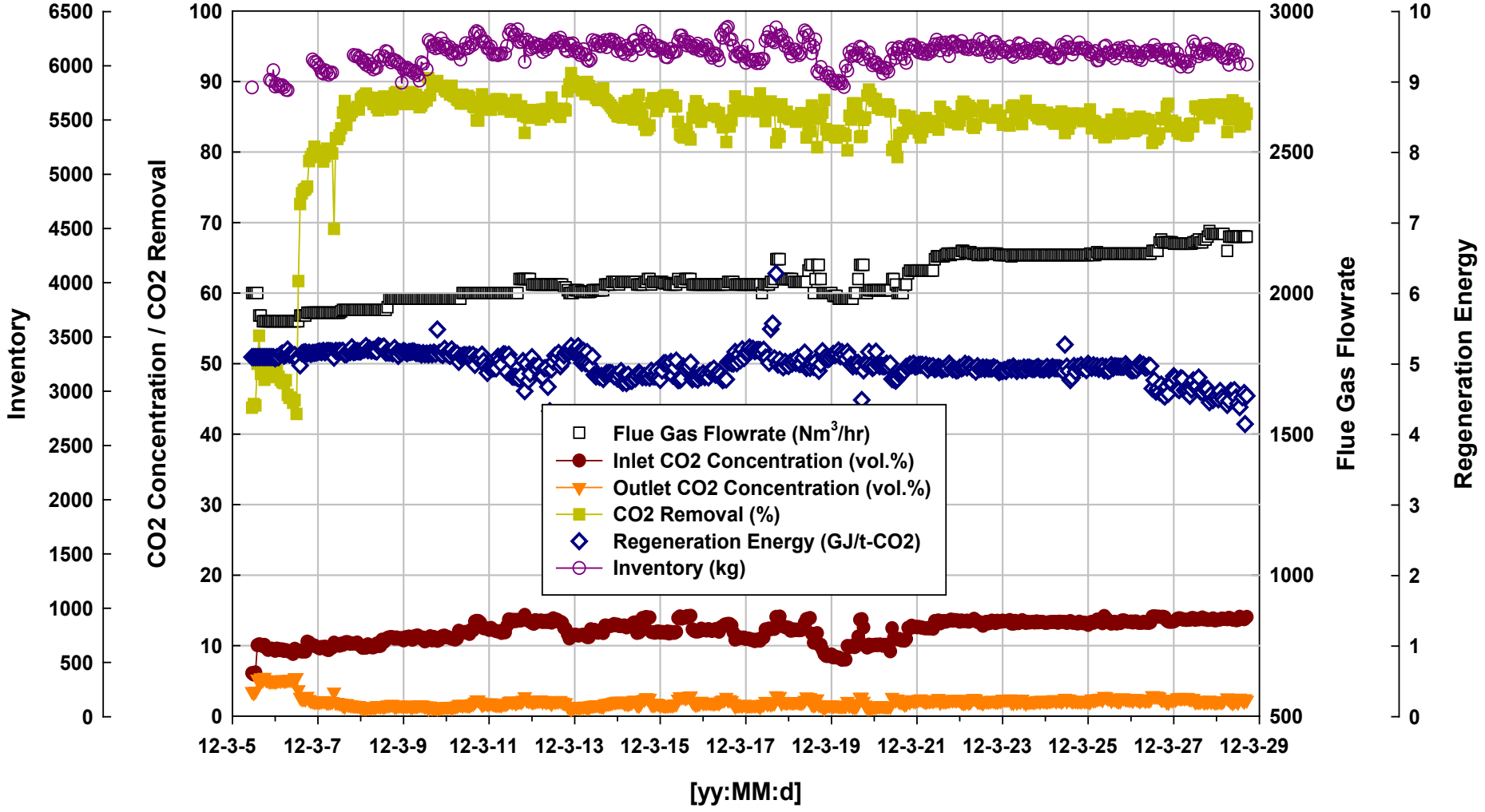
- Scale: 0.5 MW slip-streamed from 500 MW coal-fired power plant(SC)
- Capacity: 10 tCO_2/d
- Flue gas: coal-fired boiler
- Process: KIER's Fluidized-bed Process
- Sorbent: KEP-CO2P2 or P3
  - 85±5% CO_2 capture rate
  - > 90% CO_2 product purity
- Startup: 2010.03.
- Plot area: 10x6x24(H) m
- Location: Hadong, Korea. KOSPO's Hadong Thermal Power Station (unit #3)

Sulfur influence of KEP-CO2P2 sorbent



❍ **Maintaining the sorption capacity of sorbent during 33 cycle TGA test**

30-day Campaign of 0.5 MW Test-bed



Performance of 0.5 MW Test-bed

Items	1st year('11)	2nd & 3rd year('12-'13)	
	KEP-CO2P1	KEP-CO2P2	KEP-CO2P3
Flow rate of flue gas /Nm^3/h ([CO_2]/%)	1600-1800 (10)	2050 ± 150 (13.5)	1900±100 (13.5)
Absorption/Regeneration Tem/℃	70/180	70/165~180	70/170~180
Dynamic sorption capacity/wt%	2.2 ~ 3.0	5.4 ± 0.2	5.6(4.0~7.2)
CO_2 removal rate/%	80 (50 h)	80~85 (~680h)	85~90 (>40h)
Regeneration energy/GJ/tCO_2	5.6	4.7± 0.3	4.7± 0.3
Attrition resistance AI/%	6	5	3

Current rather high regeneration energy could be overcome by optimization of operation condition as well as improvement of sorbent and process since estimate range of RE is 2.8-5.9 GJ/tCO_2

Construction Progress of 10 MW PP

KOSPO

10 MW Landscape

Ground breaking

Steel-Frame work

Completing Construction

End of Project
(300 MW FEED)

Start of Project

'10.11

'12.3

One-month campaign
(KEP-CO2P2),
removal : 85±5%)

'12.5

'12.8

'12.12

Bulk prod.

'13.3

1st field test
(0.5 MW)

'13.4

Bulk prod.

'13.6

2nd field test
(0.5 MW)
Sorbent selection

'13.9

Shakedown test

'13.10

Bulk sorbent Delivery

'14.9

KEPCO RI & KIER

10 MW Pilot plant: Dry regenerable sorbent

10 MW Pilot Plant at KOSPO's Hadong coal-fired power plant, Unit # 8

- Scale: 10 MW slip-streamed from 500 MW coal-fired power plant(SC)
- Capacity: 200 tCO_2/d
- Flue gas: coal-fired boiler
- Sorbent: KEP-CO2P2 or P3
- Targets:
  - > 80% CO_2 capture rate
  - > 95% CO_2 purity
  - > 1000 h continuous operation
  - US$ 30/tCO_2
- Startup: October, 2013
- Main plot area: 34 (L) x 15 (W) x 59 m(H)
- Location: Hadong, Korea. KOSPO's Hadong Thermal Power Station (unit #8)

IV. Summary

- For energy security and climate change, KEPCO offers the comprehensible portfolio of CO_2 capture technology.
- Two 10 MW pilot plants (dry sorbent and adv. amine) scaled-up based on the results from 0.1- 0.5 MW test-beds are under operation mode, aiming to bring at least one commercial demo project online by 2015~2018.
- KEPCOs with MOTIE's support is moving big steps forwarding to commercialize CCS technology by 2020.
- Looking for funding, strategic partners and opportunities to demonstrate our technologies in Korea

Thank You

Hadong Project

Boryeong Project