

Update to the Development of CO₂ Capture Technologies in Far East Asia

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IEA Greenhouse Gas R&D Programme

CCS Opportunities in CCOP Region

CCOP-EEPM Workshop (Indonesia)

September 2012



Presentation Outline

- ***Development of CO₂ Capture Technologies in the Far East Asia***
 - Japanese
 - South Korea
 - China
- ***CO₂ Capture Technologies***
 - Pre-Combustion
 - Post-Combustion
 - Oxyfuel Combustion
 - Industrial CCS



JAPAN'S DEVELOPMENT OF CO₂ CAPTURE TECHNOLOGIES

Strategy of CCS in Japan



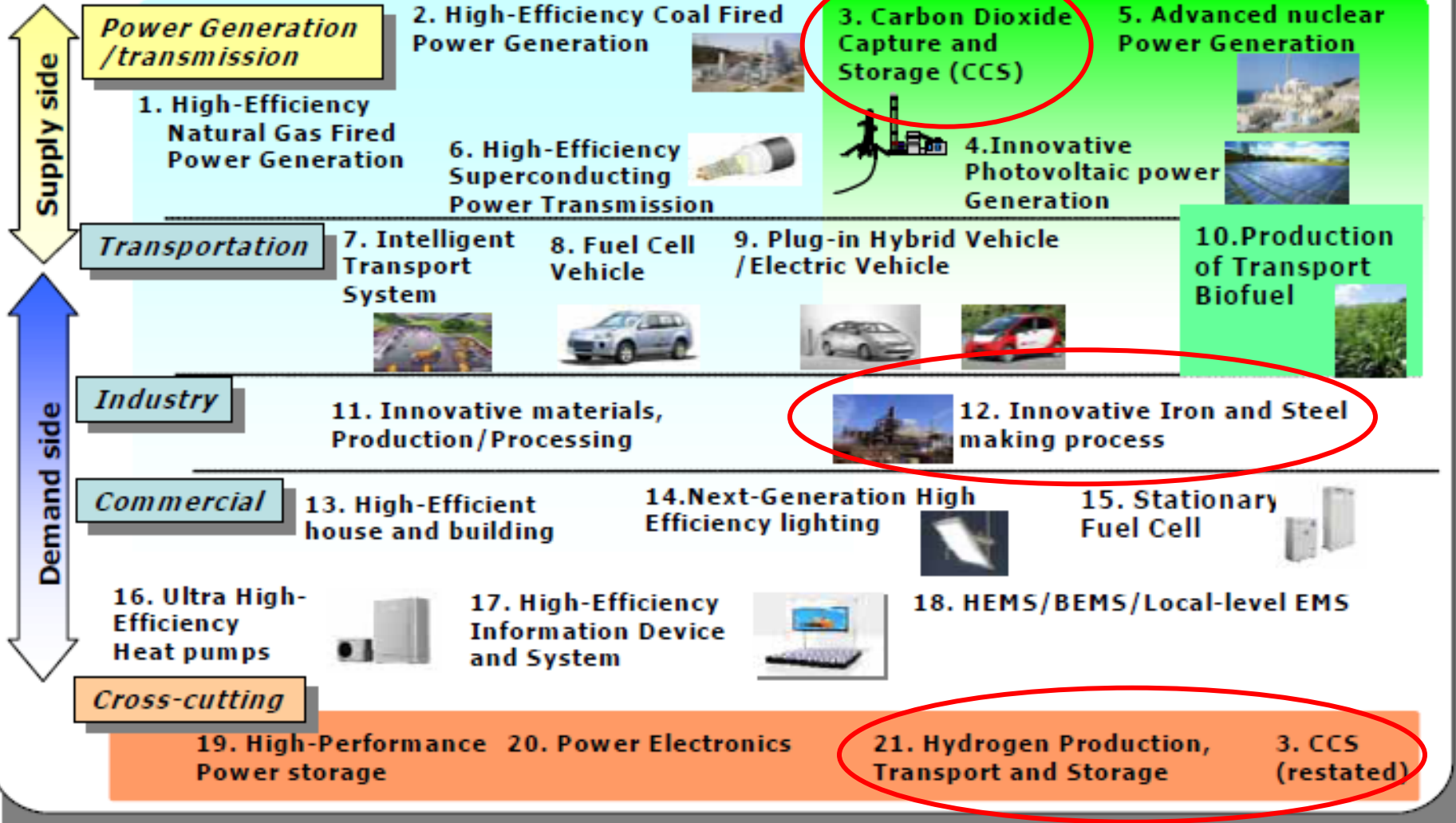
- ***CCS under the Japanese Strategic Energy Plan***
 - Plan enacted in 2003, revised in 2007 and 2010 by Japanese Government
 - Direction of the energy policy based on the 3E principles, **Energy** security, **Environment**, and **Economy**
 - CCS is an important part of this strategic plan
- ***Target is to commercialize CCS by 2020***
 - conduct large-scale CCS demonstration projects
 - conduct R&D on reducing the capture cost of CO₂

Cool Earth Innovative Energy Technology Program

- "21" Technologies to be Prioritized -

Efficiency improvement

Low carbonization



* EMS: Energy Management System, HEMS: House Energy Management System, BEMS: Building Energy Management System

CCS Development Target



- ***Current Cost:***

- 4,200 JPY (USD 52.5) /t-CO₂ was estimated for new pulverized coal fired power plant

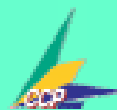
- ***Target Cost:***

- 2,000s JPY (USD 25) /t-CO₂ by around 2015
- 1,000s JPY (USD 12.5) /t-CO₂ by the 2020s

- ***Technologies:***

- Pre Combustion: physical and chemical absorption (JPOWER, JGC etc.), membrane (RITE)
- Post Combustion: chemical absorption (MHI, RITE, Toshiba etc.)
- Oxy Fuel: Callide A in Australia (JPOWER, IHI etc.)

Development history of air-blown IGCC in Japan



Shareholders of CCP are
10 major Utilities in Japan

Demonstration plant

CCP R&D Co.,Ltd.

1700t/d 250MW (2007-2010)



Pilot plant

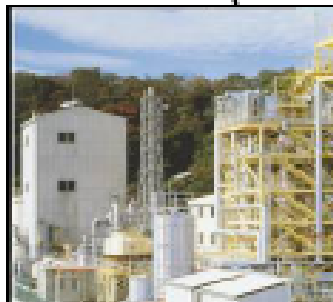
IGC Research Association

200t/d Equivalent to 25MW (1991-1996)



Process development unit

CRIEPI-MHI 2t/d(1983-1995)



Confirmation test plant

MHI Nagasaki 24t/d (1998-2002)

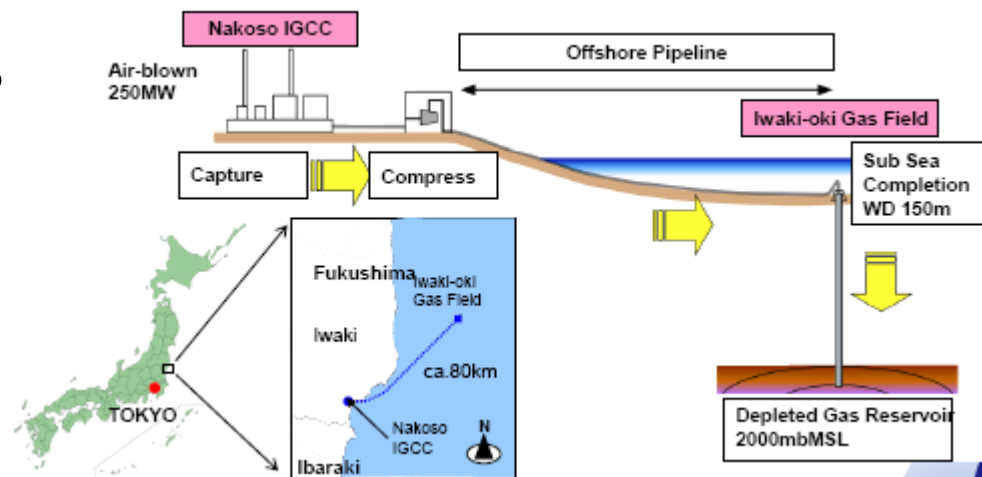
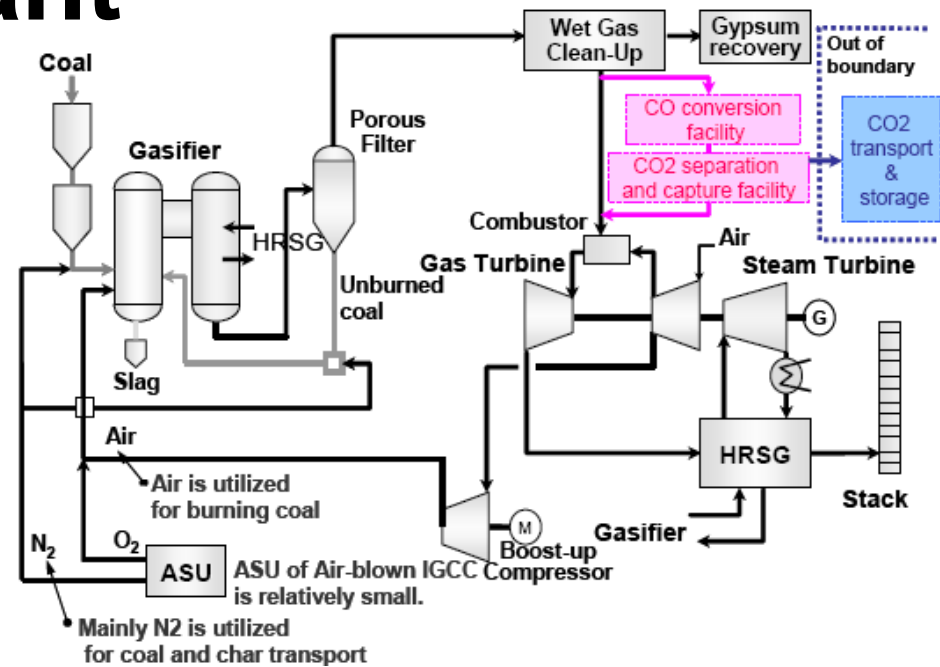


CRIEPI: Central Research Institute of Electric Power Industry

Consideration for CCS at Nakoso IGCC Plant



- Japanese government funded a feasibility study on possibility of capturing CO₂ from Nakoso IGCC (owned by CCP R&D Co. Ltd.) and transported to Iwaki-Oki Depleted Gas Field (owned by INPEX)
- Study funded by NEDO



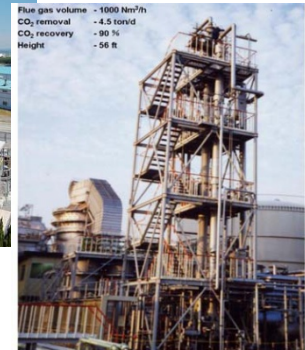
Post-Combustion Capture Development in Japan



- ***Development led by Major Engineering Companies and Research Organisations...***

- Mitsubishi, Hitachi, Toshiba, RITE, etc...

~3000 tpy pilot plant (Toshiba)



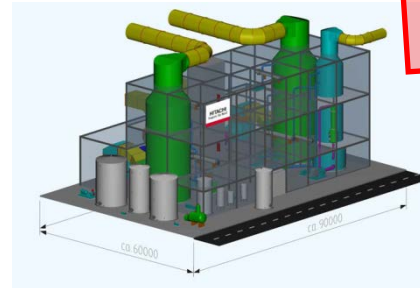
~1200 tpy pilot plant (Hitachi)

- ***Development for:***

- Retrofit
- New Build

- ***Focus:***

- Energy Efficiency
- Cost Improvement



Post-Combustion Capture Development in Japan



(Scaling Up Projects – MHI Experience of CO₂ Capture from Coal Fired Flue Gas)

Alabama, USA

2011: 500 tpd (~150,000tpy)



Nagasaki, Japan

2006: 10 tpd (~3,000tpy)



Hiroshima, Japan

2003: 1 tpd (~300tpy)



Oxyfuel Project at Callide A Power Station

(Showcase for Australian-Japanese Collaboration)



Callide A Project – would be the world's 1st oxyfuel retrofitted power station.

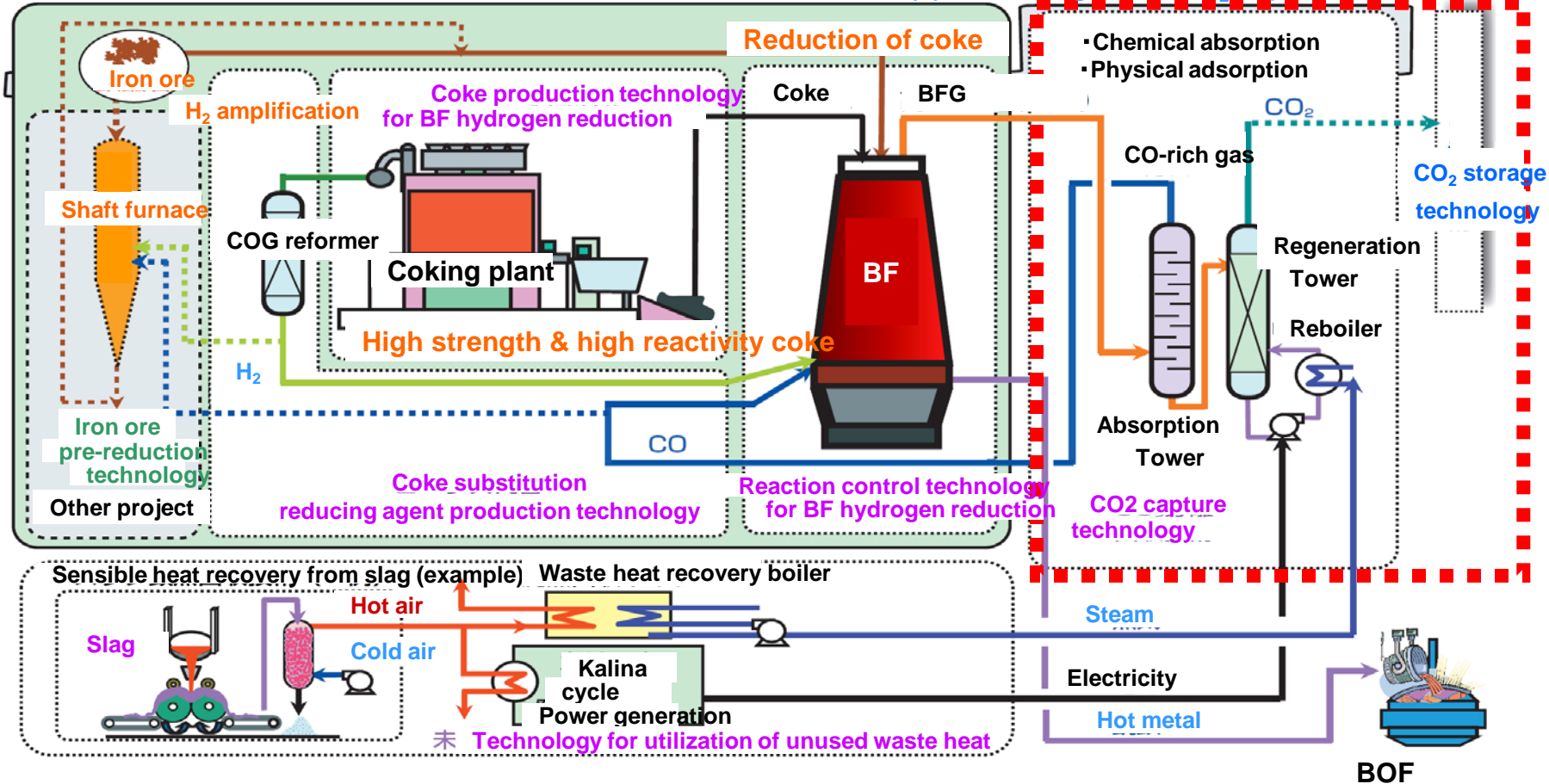
- 1st oxyfuel and world's largest pilot plant that will actually produce electricity.
- 2 ASU (330 tpd each)
- 1 CPU - Capturing ~22,000 t/y CO₂
- Installation of 2 new Wall Fired Burners
 - A unique position to provide information related to the burner – burner interaction



Project Outline

(1) Technologies to reduce CO₂ emissions from blast furnace

(2) Technologies for CO₂ capture



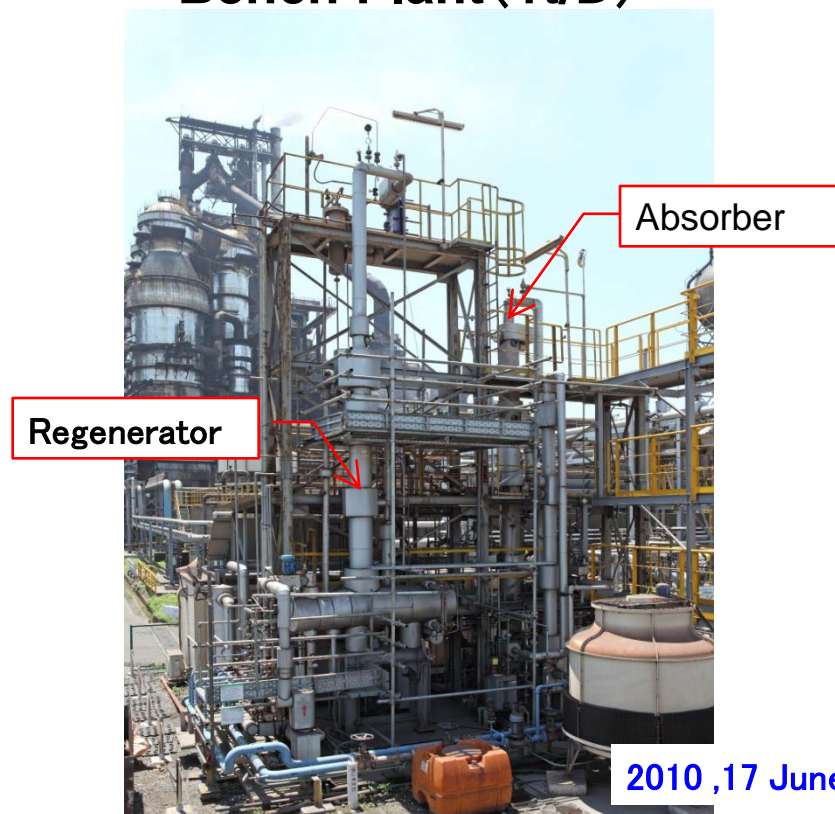
Development of the chemical absorption process

Test Equipment: Process Evaluation Plant (30t/D)



Nippon Steel Kimitsu Works No. 4BF

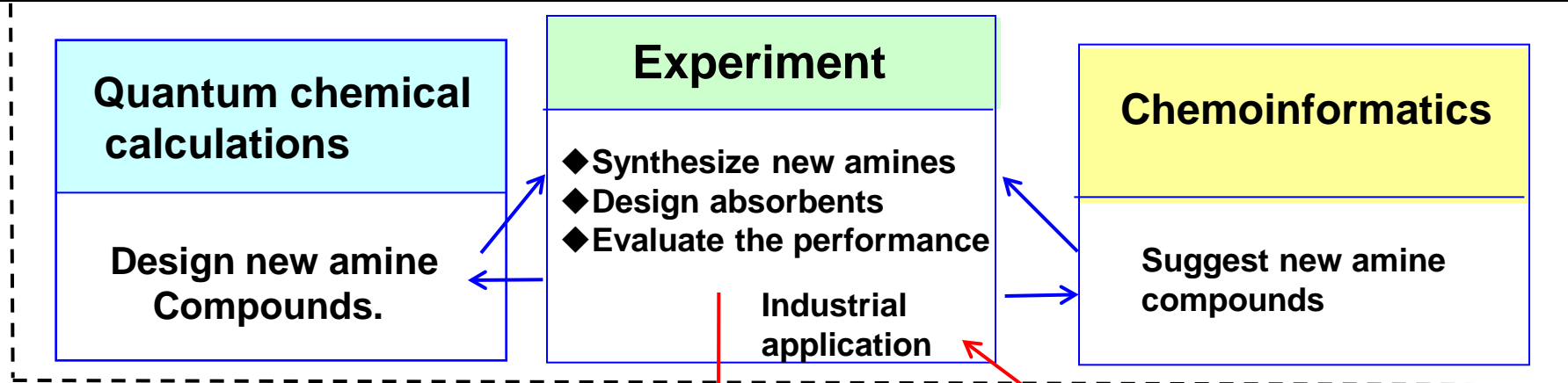
Bench Plant (1t/D)



2010, 17 June

Collaboration Scheme to Develop New Chemical Absorbents

Development of new chemical absorbents (NSC + RITE + Univ. of Tokyo)

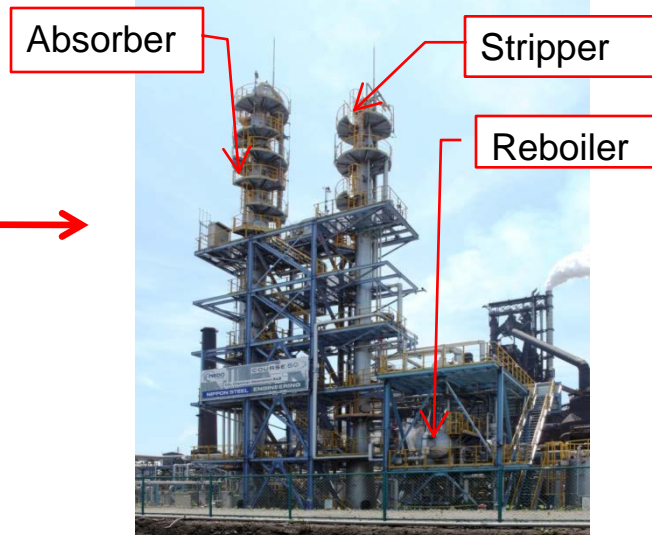


Evaluation with test plants (NSEC)

CAT1 (1t-CO₂/d)



CAT30 (30t-CO₂/d)



Development of New Absorbents		
Projects	Absorbents	Development Status
* COCS (2004-2008)	RITE-5C (NO. 1)	<ul style="list-style-type: none"> ◆ 2-component absorbent ◆ Under investigation for practical use
COURSE50 (2008 - 2012)	RN-1 (NO. 2)	<ul style="list-style-type: none"> ◆ Single-component absorbent ◆ Results evaluation of plant tests at CAT1 & CAT30
	RN-2	<ul style="list-style-type: none"> ◆ 2-component absorbent ◆ Under plant test at CAT1
	RN-3	<ul style="list-style-type: none"> ◆ Under exploration

P16 * Cost-saving CO₂ Capture System



SOUTH KOREA'S DEVELOPMENT OF CO₂ CAPTURE TECHNOLOGIES

National CCS Master Plan

(Information obtained from KEPRI)



- **Overview of the National CCS Master Plan**

- Comprehensive action plan for CCS Demonstration in Korea, released on July 13, 2010
- Planned and issued by Presidential Committee on Green Growth and Relevant Ministries
- 2.3 Trillion KRW(1.7B USD) in 2010-2019(52% by the Government)

- **Background**

- Recognizing the increasing importance of CCS as a practical solution to reduce GHG emissions
- Should need to accelerate the development and competition of the CCS market
- Development in GHG Reduction Technologies as New Growth Engine

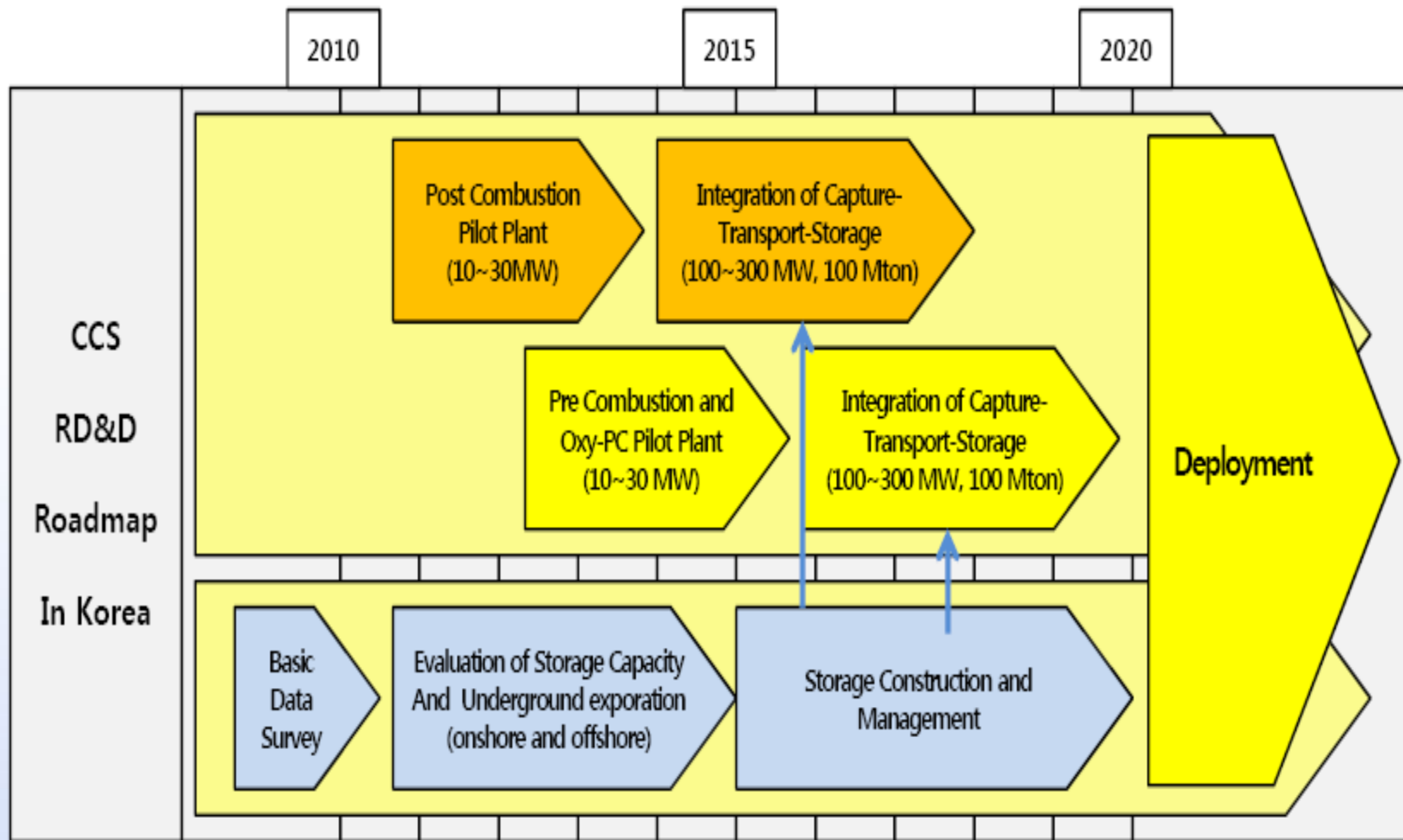
- **Vision and Objective**

- Vision: Growing into the leading countries to supply CCS technology
- Objective: To Secure Plant Commercialization and Technical Competitiveness by 2020
- Verification of Integrated Capture-Transport-Storage System of 1MtCO₂/yr
- Cost target at \$30/tCO₂ (\$20 for capture, \$10 for storage)

- **Benefits/Expectation**

- CO₂ reduction up to 32 MtCO₂ by 2030, contributing 10% of the total domestic CO₂ reduction amount.
- CCS business opens 100 Trillion KRW (cumulative) market by 2030.

National CCS Roadmap of S. Korea



Project Goal

Demonstration of 100MWe Class Oxy-PC Power Plant

Conceptual Design

Basic Design

Detail Design & Construction

Conceptual Design & Test Bed Construction

- Development of Process Analysis Tool
- Development of key technology of Oxy-PC Combustor
- Construction of Test Bed

Basic Design of Oxy-PC Plant

- Feasibility Study of Plant Retrofit
- Development of key technology of Process Control & Operation
- Optimization of Process Analysis Tool
- Basic Design Oxy-PC Power system

Detailed Design & Construction of Demo. Plant

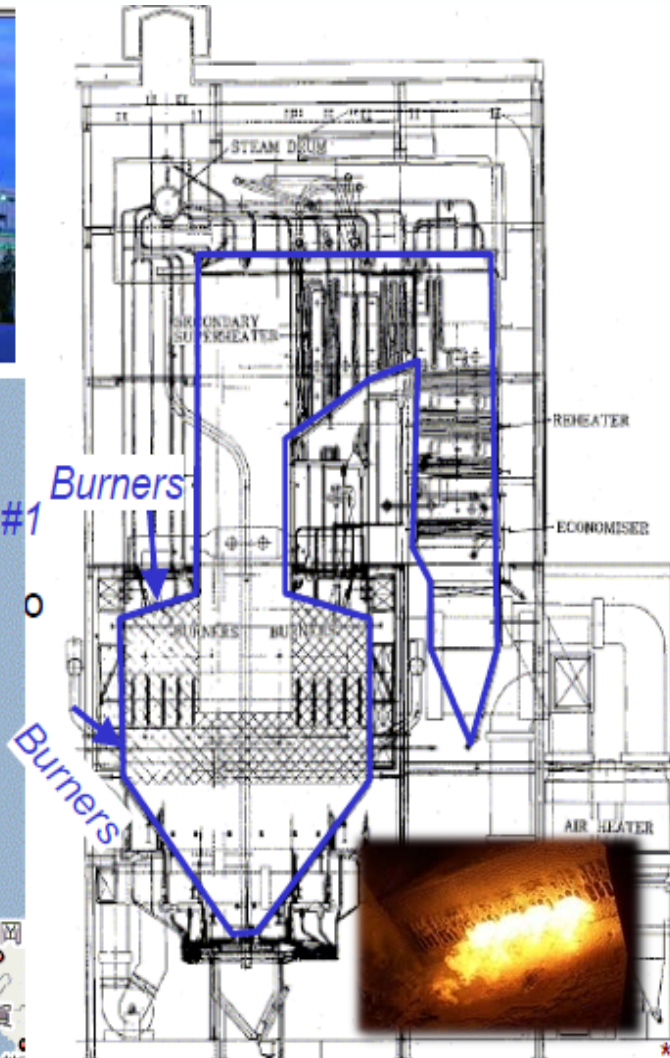
- Construction of Demo. Plant
- Detailed Design
- Test Running

Phase I (2007 ~ 2010)

Phase II (2010 ~ 2012)

Phase III (2012 ~ 2015)

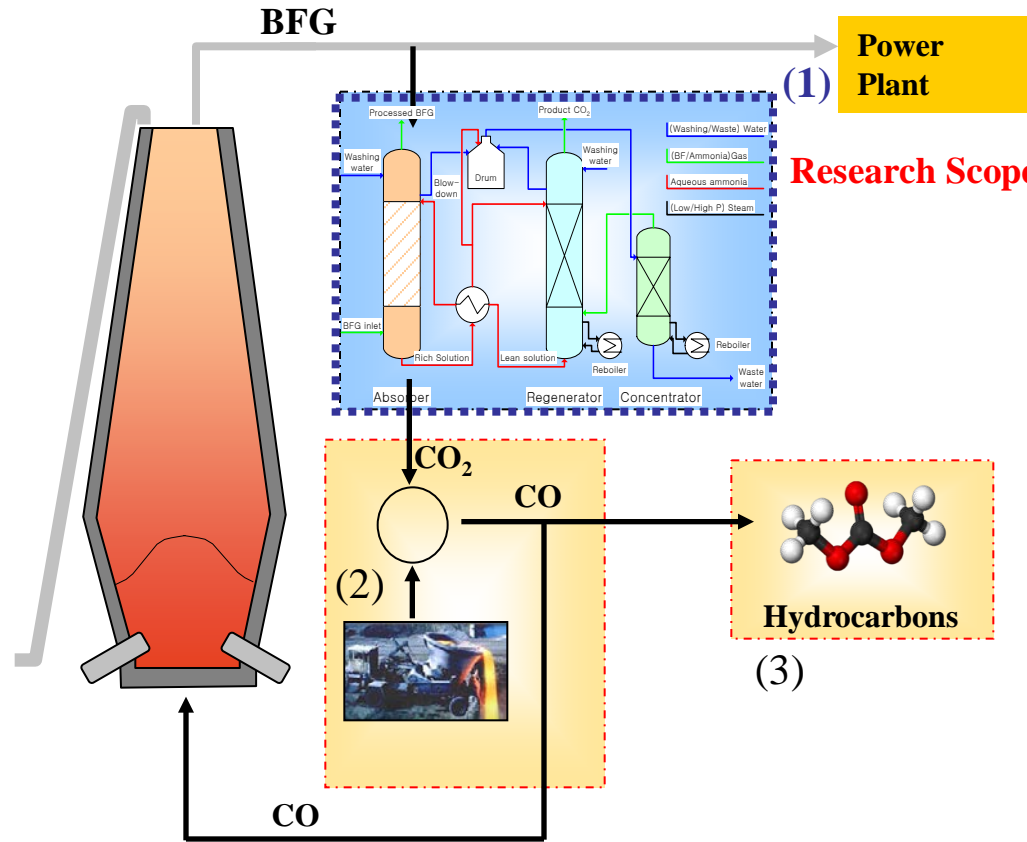
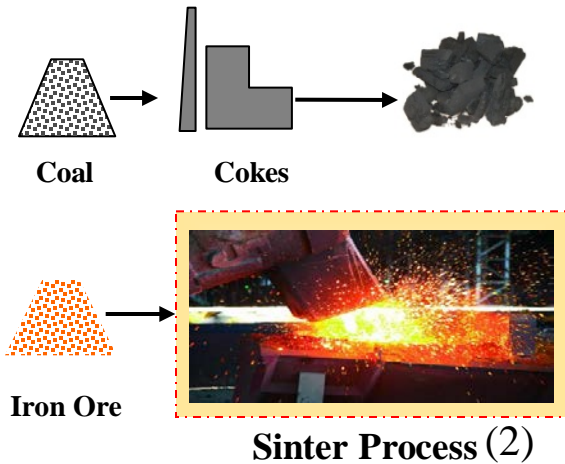
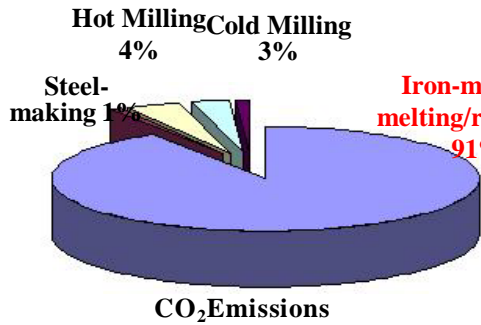
Tentative Demo. Site (Youngdong TPP)



Plant output	125MWe
Boiler type	Single-drum radiant heat type
Operation start	1973
Maker	Boiler : BHK T/G : Hitachi
Main steam	Flow rate : 420t/h Temp. : 541deg-C Pressure : 12.85MPa
Burner type	Circular type x 16 Bent type x 12
Mill type	Tube type x 6 (Standby x 1)
Fuel	Anthracite(FR [*] =14)
Efficiency	36%

* Fuel Ratio = Fixed Carbon/Volatile

Ideas/Projects for CO₂ Reduction

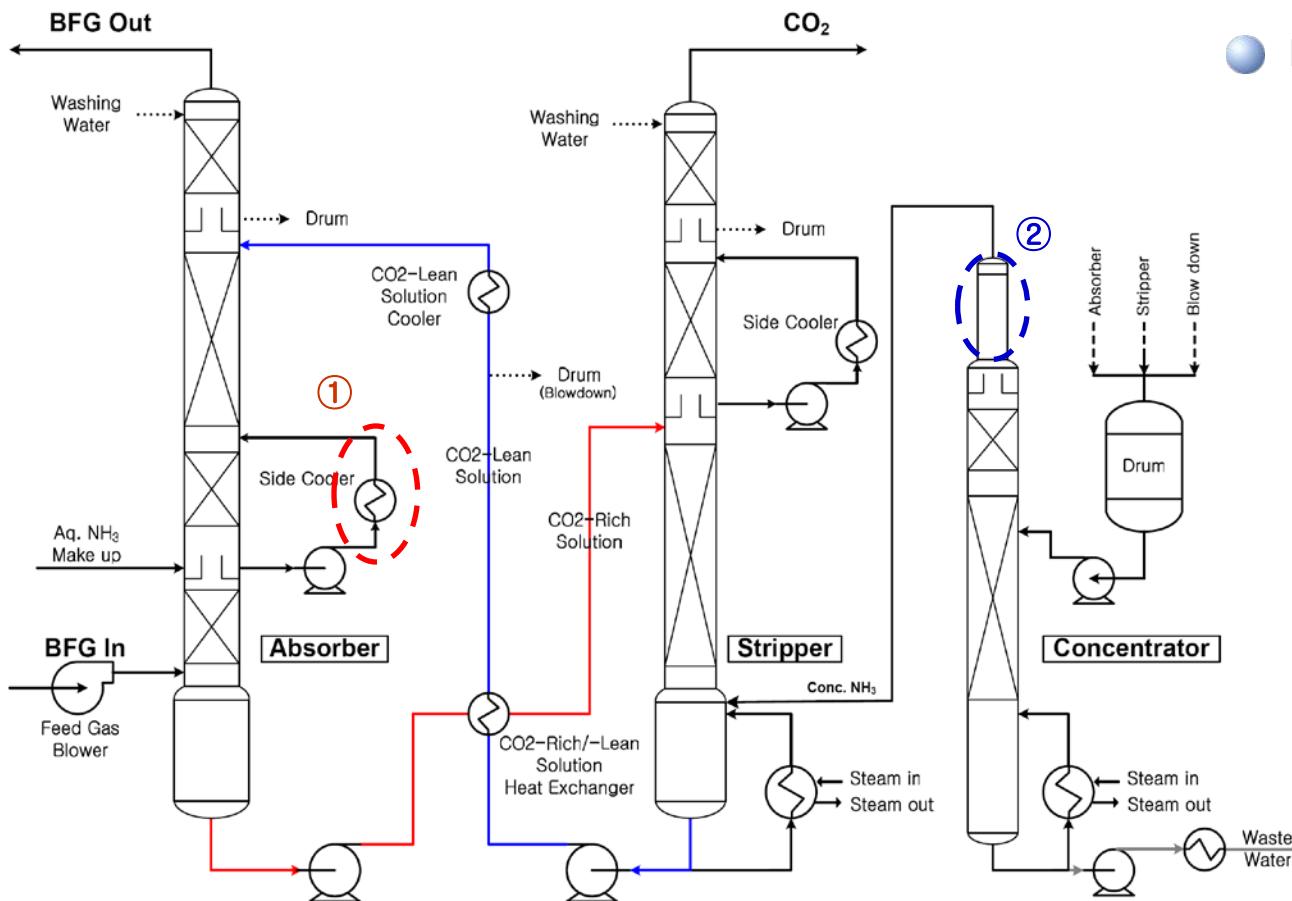


Research Activities of CO₂ Project in RIST

- (1) CO₂ Capture from BFG stream using aqueous ammonia
- (2) Waste heat recovery from molten slag and hot sinter
- (3) CO₂ utilization

1st stage pilot plant (1/2)

Process improvement

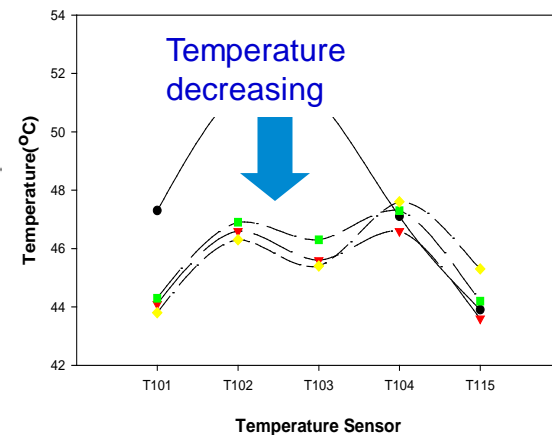


Removal of condenser at the top of the concentrator

- Improvement of heat efficiency in the stripper and concentrator
- Prevent clogging of the pipe line

Side stream in the absorber

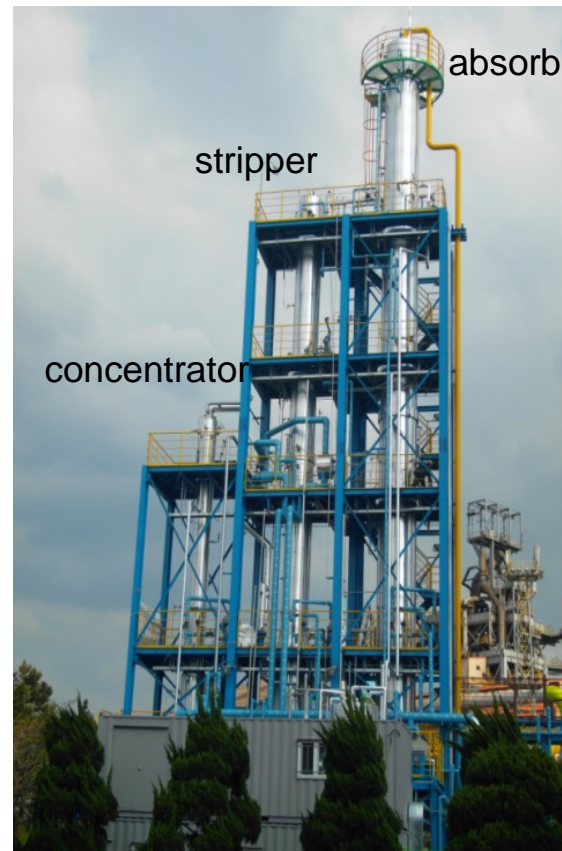
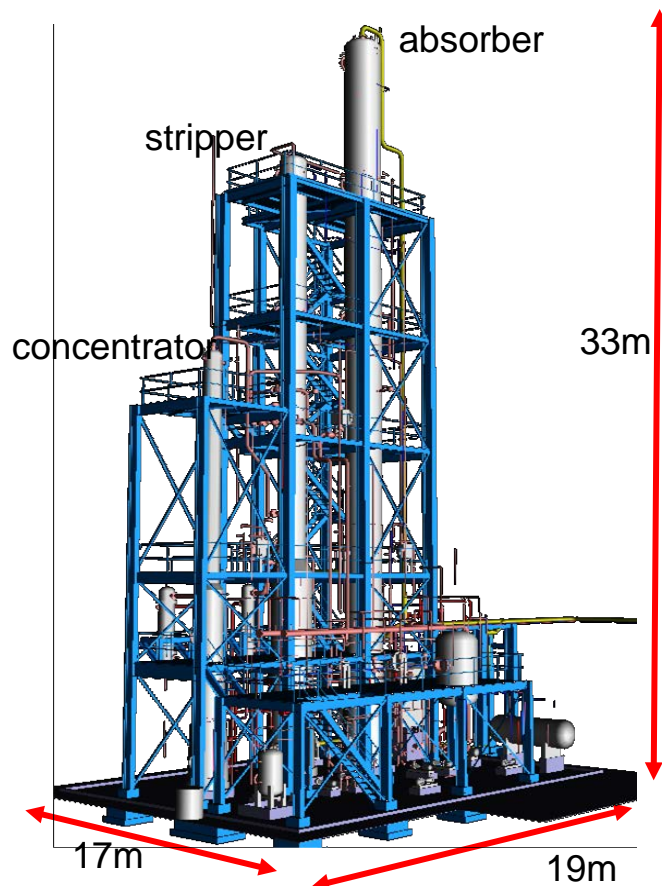
- Temperature decrement in the middle of the absorber
- Improvement of absorption efficiency
- Suppression of ammonia vaporization



2nd Stage pilot plant

● Operation of 2nd stage pilot plant (May. 2011~)

- **Development of CO₂ capture process** for commercialization using aqueous ammonia in iron & steelmaking
 - Utilizing the waste heats at low and mid-temperature waste heat as regeneration energy
 - Ultimate goal: CO₂ removal > 90%, CO₂ purity > 95%, energy requirement < 2.0 GJ/ton-CO₂



- Dimensions
 - : Absorber
 - D 1.4m, H 27m
 - : Stripper
 - D 0.9m, H 20.6m
 - : Concentrator
 - D 0.5m, H 11.7m

- Capacities
 - : 1000 Nm³-BFG/hr
 - as 0.5 MW
 - (CO₂ conc: 20~25%)



CHINA'S CO₂ CAPTURE AND UTILISATION DEVELOPMENT

CCS Development in China



- Does not feature in the economic goals of 12th FYP but is included as a high technological priority within the R&D programme
- MOST supports both fundamental research (Programme 973) and technology development (Programme 863) while the National Science Foundation focuses on fundamental and generic research.
- Significant activities initiated by SOE – where CO₂ Utilisation (i.e. for supply of Food Grade CO₂ or EOR application) is the major driver.

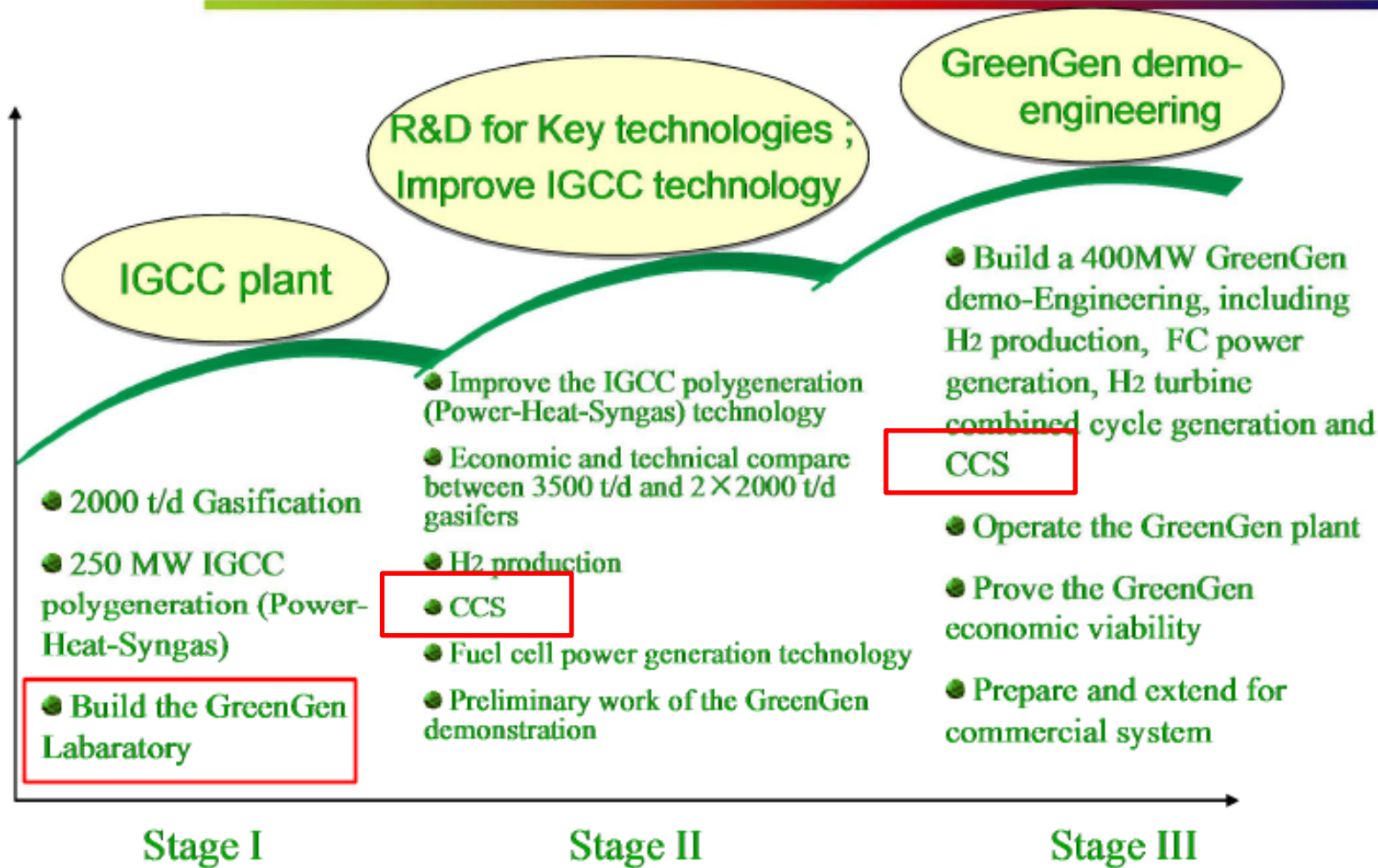
GREENGEN Project – Near Zero Emissions IGCC



- ***Research and Development Project led by Huaneng Group***
 - Project Initiated in 2006 (~US\$ 1 Billion)
 - Supported by the State Council, NDRC, MOST and MOF
 - Consortium of 8 Energy Enterprises and 1 US Company
- ***Project Goal:***
 - To establish a high-efficiency, coal-based IGCC poly-generation plant with efficient reduction of pollutants and near-zero emissions of CO₂.
- ***Project Components (Phase 1 & 2)***
 - R&DD on 2000t/d HCERI (formerly from TPRI) coal gasifier and 250MW IGCC power plant (Syngas production integrated to the Siemens GT Technology)
 - R&DD on coal-based hydrogen production, hydrogen power generation and CO₂ Capture
 - To verify key technologies, system integration, availability and reliability of key components consisting of the “GreenGen” technology



Three Stages of the GreenGen Programme



GREENGEN IGCC Laboratory

(Under Commission and Fully Operational by 2012)



- Power: 265MW
- Net eff. 41%
- SO₂ : <1.4mg/Nm³
- NO_x: 52mg/Nm³
- PM: <1mg/Nm³
- Start to operate in Dec. 2011

- Gasifier: HCERI
- GT: SIEMENS
- ASU: Kai Feng Air Separation
- ST: Shanghai Electric
- HRSG: Hangzhou Boiler
- Engineering: HCERI, SINOPEC, NWEPTDI



GREENGEN Project:

CO₂ Capture Component



- ***SynGas slip stream (6000 Nm³/h or ~15 MW_t) to demonstrate***
 - the delivery of high purity H₂ from coal based IGCC for Fuel Cell application; and
 - CO₂ capture of ~60,000 Mt/y for EOR trials
- ***Asia Development Bank (ADB) Financing***
 - Provided US\$135 Million in Loan and US\$ 5 Million in Grant
 - Grant is aimed to develop CDM documentation

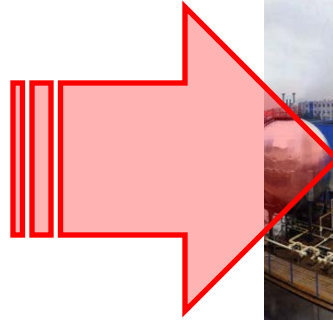
Post-Combustion Capture Development in China



~3000 t/y CO₂



~120,000 t/y CO₂



- Cooperation between CSIRO and China Huaneng Group – CHNG
- CO₂ captured from flue gas slip stream of 800MWe Gaobeidian Coal Fired CHP (Beijing)
- Operation started July 2008

- Project led by Huaneng and TPRI
- CO₂ captured from the flue gas slip stream of 660MWe USC Shidongkou (No. 2) Power Plant (Shanghai)
- Operation started in December 2010
- Total Investment: US\$ 14.6 Million
- **Total CO₂ capture cost of < 200RMB/t (US\$ 30-35/t) incl. processing to food grade.**

Roadmap for Oxy-fuel R&D in China (SKLCC Draft)



300kWt small pilot study
Burner development
Data collection and Optimization
Thermal Design

Fundamental Study

1995



2005



2010



3MWt large pilot study
7000T/a full chain validation
ASU-CPU coupling
FGC and drying



2014

35MWt pilot plant
0.1 million ton capture
ASU-CPU-power generation integration and optimization



2020

200-600MWe full demo.
Millions ton CCS-EOR

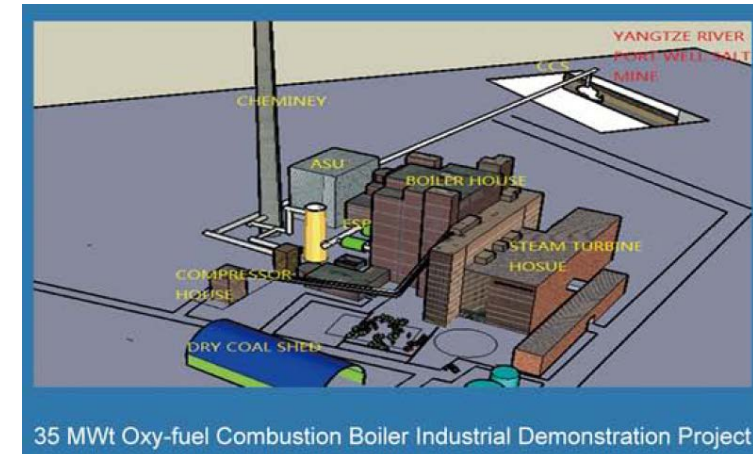
Development of Oxyfuel Combustion in China is now geared toward full scale demonstration of the technology...

Consequence of shelving of Janschwalde Project means that Europe could lose grounds in the development of oxyfuel combustion

Oxyfuel Combustion R&D Development – HUST



- Features of the 35MWt Oxyfuel Pilot Plant
- Supported granted under MOST 863 Programme
- Project led by Huazhong University of S&T and Others.
- Goal:
 - To set up a full demonstration plant combining carbon capture, storage and utilization
- Scale:
 - 35 MWt oxy-fuel combustion boiler with 100,000 t/a CO₂ storage
- Location: Yingcheng, Hubei Province
- Technology:
 - Oxy-fuel combustion + storage in salt mines
- Status: Expected Start Up - 2014



Datang Oxyfuel Demo Project

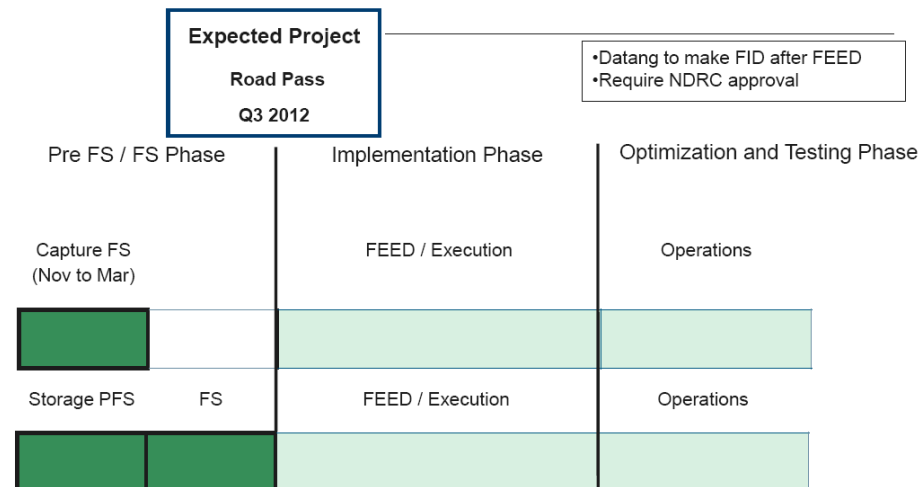


- Daqing 350MWe Project
- Full size Oxyfuel Combustion CO₂ Capture
- Cogeneration of Heat and Power based on SC PC Boiler using lignite
- Location: Daqing, Heilongjiang province
- EOR and CO₂ storage: adjacent to PetroChina's Daqing oil field for EOR, near Songliao basin for geological sequestration

Anticipated Project Interface

		
CO2 Capture	CO2 Storage	EOR
- Alstom - Datang - NEPDI	- Datang - Wuhan Rock & Soil - PetroChina's Drilling Institute	- PetroChina

Daqing Demo Project Timeline



SIEG Oxyfuel Demo Project

- ***Shanxi SIEG Project is based on 350MWe Power Plant (To capture ~2 MTPY CO₂)***
 - Project Based on Joint US-China Fossil Energy Protocol
 - Pre-feasibility Study Completed
 - Partnership with Shanxi International Energy Group (SIEG)
 - Key Technology Partners:
 - B&W – providing technology for boiler and environmental island
 - APCI – providing ASU and CPU
 - WVU – providing support for CO₂ storage

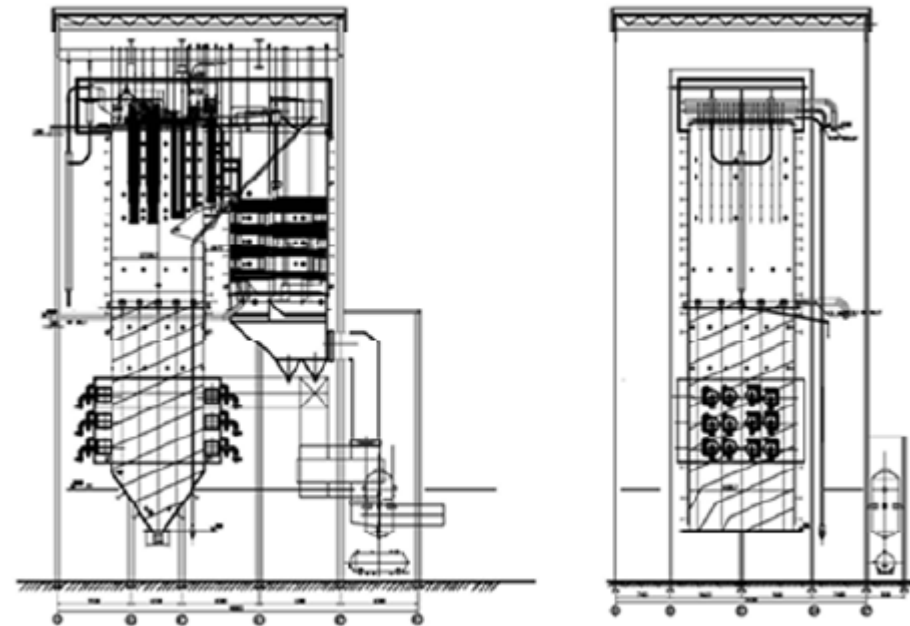
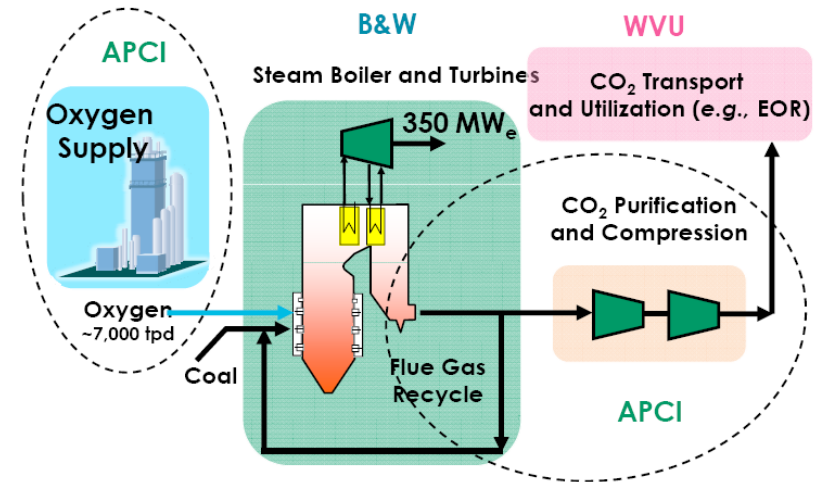


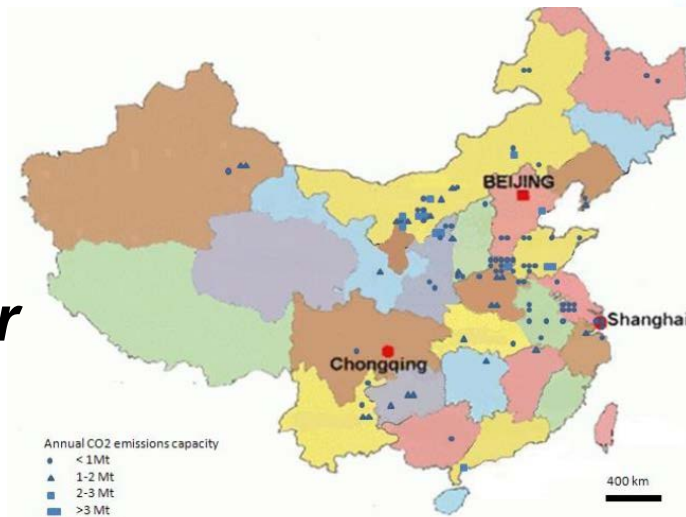
Fig. 6 SIEG boiler side and front views.

Potential for Coal to Chemical with CO₂ Capture Demonstration



(Data from IEA CCC)

- **Significant growth in scale and extent of application in the coal to chemicals sector**
- **Opportunity to capture, at relatively low cost, concentrated streams of CO₂.**
- **Early opportunities of CO₂ storage demonstration in the likes of EOR application**



Supplier	Coal gasification projects		
	Operational	Design/construct	Total
GE	27	10	37
Shell	14	5	19
Siemens	1	2	3
Sasol Lurgi	3	3	6
GTI U-Gas	1	1	2
ECUST	8	9	17
TPRI	-	3	3
CACG	3	15	18
Tsinghua U	3	5	8
ICC-CAS	3	-	3
Total	63	53	116

Direct CTL with CCS Demonstration



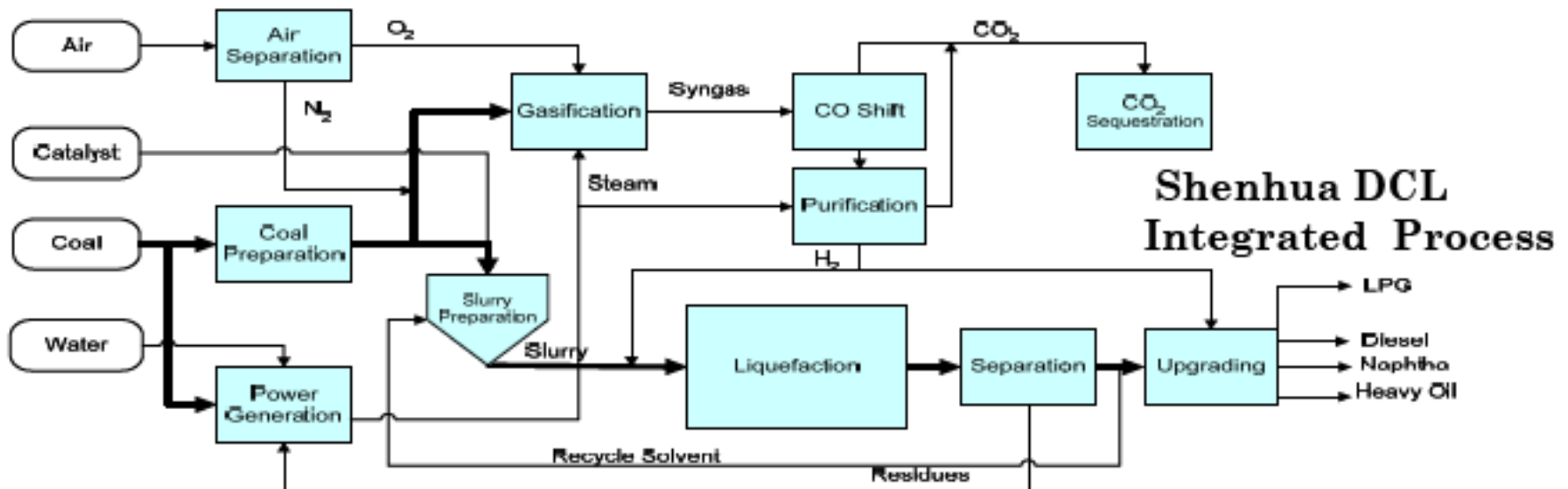
- ***Shenhua CTL (Ordos, Inner Mongolia) – operational since 2008***
 - Sub-Bit. Coal from Inner Mongolia ~ 3.5 MPTY
 - ~1.08 MMTPY of Oil Products
 - LPG
 - Naptha
 - Diesel
 - Phenol
 - CO₂ Emission: ~3.5MPTY





DCL – Overview...

- **2 x Shell Gasifiers (@ ~315 TPD H₂)**
- **Solvent Based DCL Facility**
 - Chinese owned developed catalyst
 - Reactor build by Chinese Heavy Industry
- **Slip stream CO₂ Capture**



Shenhua's CTL Demonstration (CO₂ Storage Component)



Shenhua CCS project 2007 - 2011

- ◆ Technical research on CO₂ purification
- ◆ Analysis on the Ordos Basin storage potential.
- ◆ Select location
- ◆ CCS demonstration project of 100,000 ton level

CO₂ Storage Demonstration started in 2011!



Concluding Remarks



- Far East Asian countries has established their CCS programme to address their target for greenhouse gas emissions reduction .
- CCS development in the Far East has been led by Japan since the 1990's. Now in position to provide commercial offering and demonstration of their technology.
- China is a latecomer to the CCS. Nonetheless, they have catch up and now in position to lead in the demonstration of this technology – particularly in the area of CO₂ utilisation and EOR application.
- CCS application to industry should play an important role to the global reduction of GHG emissions. Far East Asia is currently one of the leaders in this area of development.