A summary of CCT/CCS Developments Worldwide

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IEA Greenhouse Gas R&D Programme

JCOAL CCT Seminar

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Tokyo, Japan

Outline

- Brief introduction of my organisation
- Summarise active developments on CCT/CCS worldwide
  - Cover; Canada, USA, Europe, Korea and China
  - Summarise Japanese activities
  - Cover developments in both power and industrial sectors
- Concluding remarks

IEA Greenhouse Gas R&D Programme

- A collaborative international research programme founded in 1991
- Aim: To provide information on the role that technology can play in reducing greenhouse gas emissions from use of fossil fuels.
- Focus is on Carbon Dioxide Capture and Storage (CCS)
- Producing information that is:
  - Objective, trustworthy, independent
  - Policy relevant but NOT policy prescriptive
  - Reviewed by external Expert Reviewers
- Activities: Studies and reports (>250); International Research Networks: **Risk, Monitoring, Modelling, Wells, Oxy, Capture, Social Research, Solid Looping**; GHGT conferences; IJGGC; facilitating R&D and demonstrations eg Weyburn; Summer School; peer reviews.


BG GROUP
bp
CEZ GROUP
Chevron
eni
TOTAL
EPRI
ALSTOM
ExxonMobil
CIAB
Schlumberger
ConocoPhillips
DOOSAN
Doosan Babcock
SCOTTISHPOWER
EnBW
REPSOL YPF
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Evaluating technology options to mitigate greenhouse gas emissions
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Masdar CARBON
INSTITUTO DE INVESTIGACIONES ELECTRICAS
B&W power generation group
Enel L'ENERGIA CHE TI ASCOLTA.
GLOBAL CCS INSTITUTE
JGC
RWE The energy to lead
Statoil

Global Developments in CCS

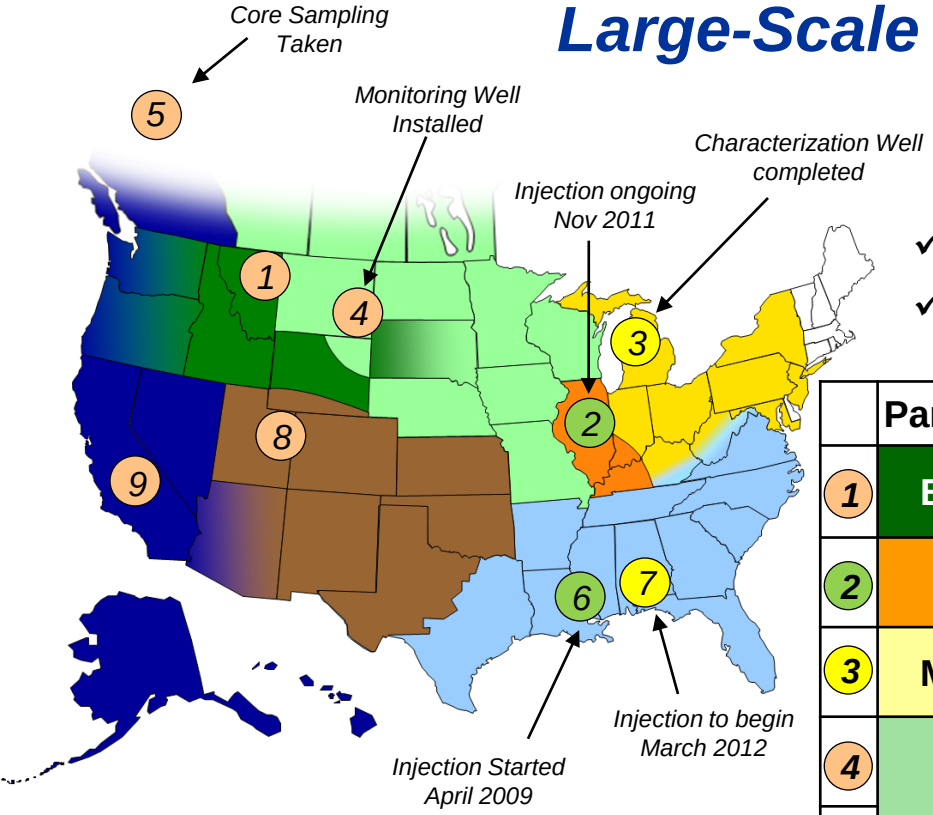
- Significant R&D and Deployment Activity
  - USA, Canada, China, Korea, Japan
  - Gulf States, Europe (UK, Spain, Netherlands) & Norway
- Significant R&D but Deployment Stalled
  - Australia, Germany
- Significant R&D Underway
  - Brazil, Mexico
- R&D Programmes Developing
  - India, South Africa

CCT/CCS Developments in USA

- Major R,D,D activity on CCT and CCS
- Emphasis on CCUS
  - "U" means CO2-EOR
  - Used as means to make CCS projects financially secure
- Large industry CCS component
  - Worlds first Bio-CCS project

RCSP Phase III: Development Phase

Large-Scale Geologic Tests



- *Injection Ongoing*
- *2012 Injection Scheduled*
- *Injection Scheduled 2013-2015*

Note: Some locations presented on map may differ from final injection location

- ✓ *Injection Targets - minimum planned volumes*
- ✓ *Two ongoing RCSP Injection Projects*

	Partnership	Geologic Province	Storage Type
1	Big Sky	Sweetgrass Arch-Duperow Formation	Saline
2	MGSC	Illinois Basin-Mt. Simon Sandstone	Saline
3	MRCSP	Michigan Basin-St Peter SS or Niagaran Reef	Saline/Oil
4	PCOR	Powder River Basin-Muddy Formation	Oil Bearing
5		Alberta Basin-Sulphur Point Formation	Saline
6	SECARB	Interior Salt Basin-Tuscaloosa Formation	Oil/Saline
7		Interior Salt Basin-Paluxy Formation	Saline
8	SWP	Wasatch Plateau-Navajo Sandstone	Saline
9	WESTCARB	Regional Characterization	TBD

Midwest Geological Sequestration Consortium

Decatur Site Large-Scale Project

Target Formation

- *Mt. Simon Sandstone*

CO_2 Source

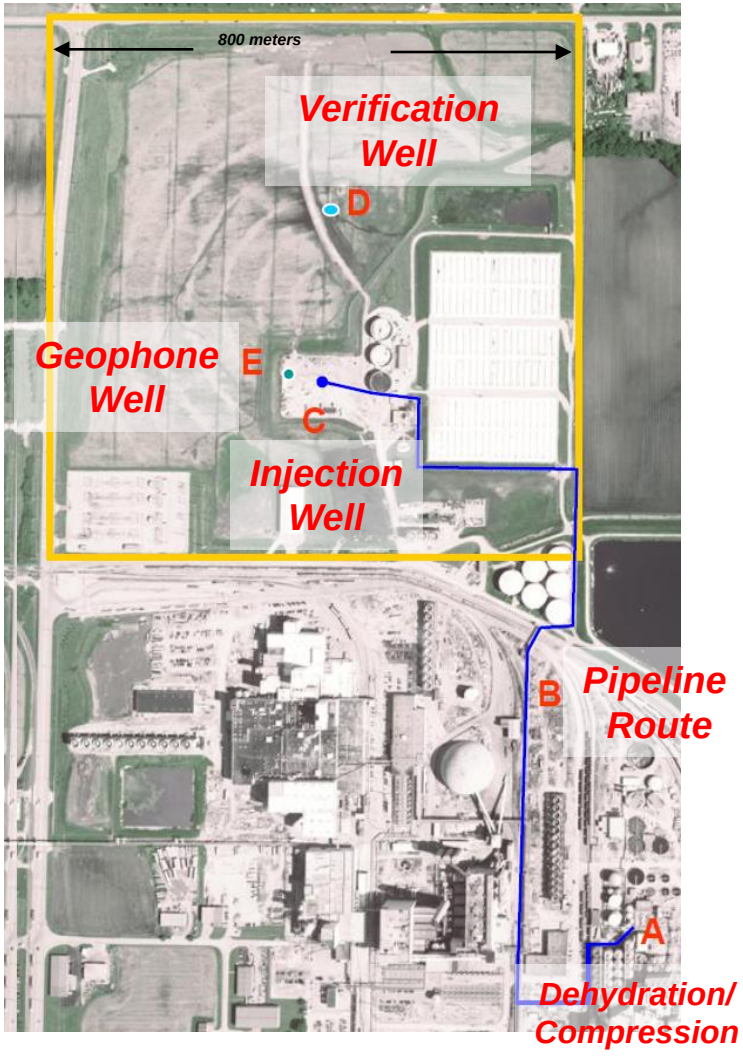
- *ADM's Ethanol Production Facility*

CO_2 Injection Amount

- *1 million metric tons over 3 years (Nov 2011)*

Current Status

- *Completed 4 square mile 3D seismic survey*
- *Completed drilling injection well, groundwater monitoring wells, geophone well, and verification well.*
- *CO_2 Pipeline installed and connected to injection wellhead.*
- *Installed all subsurface monitoring equipment.*
- *Completed commission of compression/dehydration facility*
- *Completed baseline fluid samples from verification well.*
- *Completed satellite interferometry (InSAR) baseline imaging data collection.*
- *UIC Permit finalized in March, 2011. Approval from IEPA to begin injection granted November 4, 2011.*
- *As of mid-January 2012 cumulative CO_2 injection volume is 50,000 metric tons*



Major CCUS Demonstration Projects

Project Locations & Cost Share

CCPI

ICCS Area 1

FutureGen 2.0

FutureGen 2.0
Large-Scale Testing of Oxy-Combustion w/ CO_2 Capture & Sequestration in Saline Formation
~$1.3B Total; ~$1.0B DOE
SALINE – 1.3M TPY 2016 start

Archer Daniels Midland
CO_2 Capture from Ethanol Plant
CO_2 Stored in Saline Reservoir
$208M Total; $141M DOE
SALINE – ~1 M TPY 2013 start

Summit TX Clean Energy
Commercial Demo of Advanced IGCC w/ Full Carbon Capture
~$1.7B Total; $450M DOE
EOR – 3M TPY 2014 start

HECA
Commercial Demo of Advanced IGCC w/ Full Carbon Capture
~$4B Totall; $408M DOE
EOR – 3M TPY 2018 start

Southern Company
Kemper County IGCC Project
IGCC-Transport Gasifier w/Carbon Capture
~$2.67B Total; $270M DOE
EOR – 3 M TPY 2014 start

NRG
W.A. Parish Generating Station
Post Combustion CO_2 Capture
$339M Total; $167M DOE
EOR – 1.4M TPY 2014 start

Air Products and Chemicals, Inc.
CO_2 Capture from Steam Methane Reformers
EOR in Eastern TX Oilfields
$431M – Total, $284M – DOE
EOR – 1M TPY 2013 start

Leucadia Energy
CO_2 Capture from Methanol Plant
EOR in Eastern TX Oilfields
$436M - Total, $261M – DOE
EOR – 4.5 M TPY 2015 start

Changing Energy Dynamics

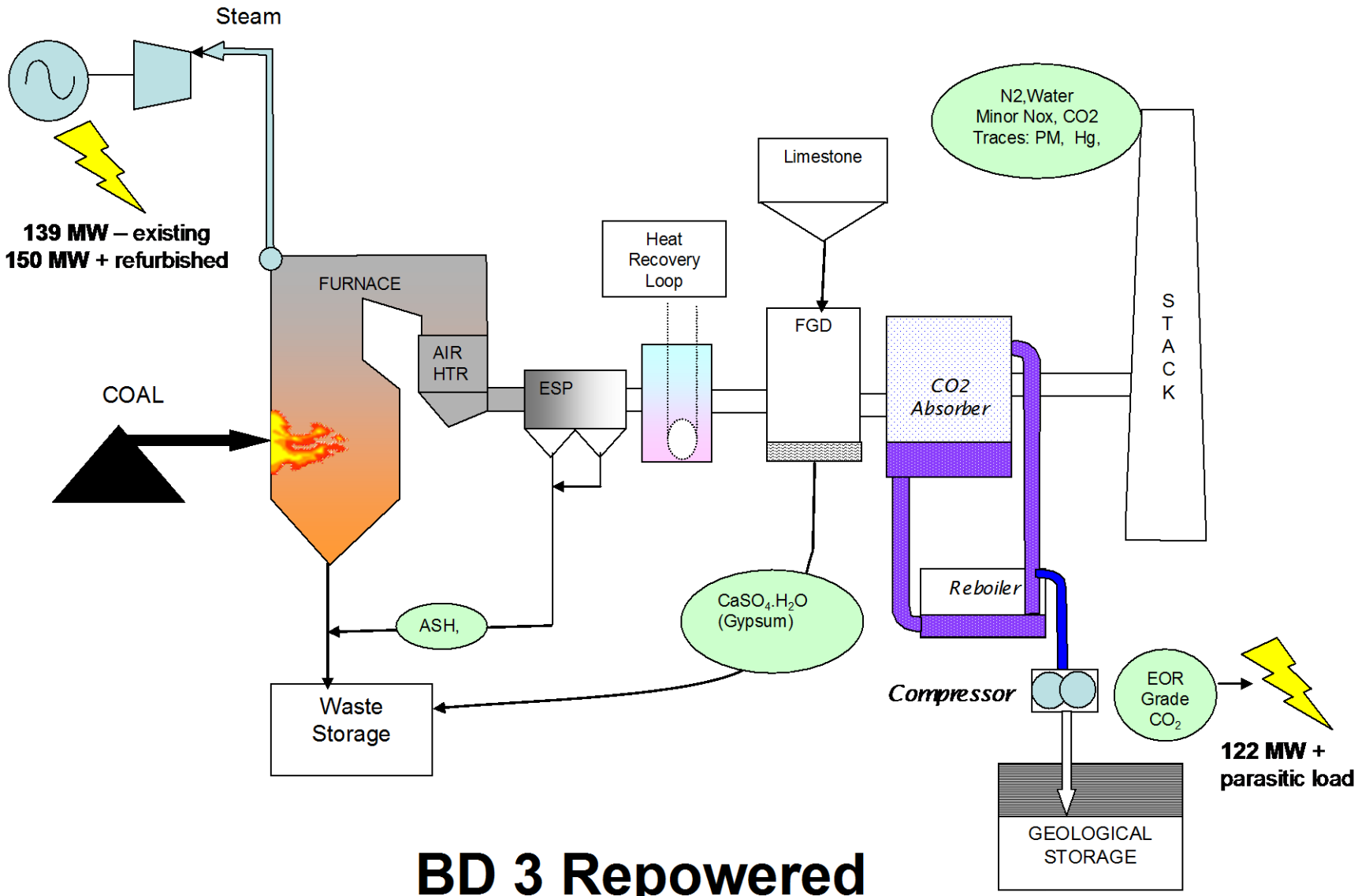
- Shale gas is changing energy dynamics in USA
- USA could become self sufficient/exporter of natural gas
- Low gas prices in USA shifting interest to NGCC away from coal fired generation
  - US EPA regulations
  - Permitting problems with coal plant in many states
  - Anti “Coal” Lobby

CCS/CCT in Canada

- Most activities on CCS relate to tar sands/oil and gas extraction in Alberta
- Major coal development is the Boundary Dam post combustion capture retrofit in Saskatchewan
  - Fully financed private and State capital
  - Could be first Post combustion Demo.

Boundary Dam Near Estevan Saskatchewan

Boundary Dam Integrated Unit 3 Design



BD 3 Repowered

European Developments on CCT/CCS

- European developments influenced by a number of issues that have hampered CCS deployment
  - Financial Stability Pact/Eurozone Crisis
  - Austerity measures/Country debt
  - Coalition Governments
  - Price of CERs in European Trading Scheme
  - Public concerns – CO_2 storage/fossil fuel use
  - Nuclear safety issues
    - No CCS rebound
  - Poor delivery on Energy Efficiency/Renewable targets
    - No CCS rebound
  - Environmental Issues – Nitrosamines/Mongstad Norway

Current CCS Status in Europe

- UK - Two FEED studies complete
  - Longannet and Kingsnorth – neither project going forward
  - Second project call underway – aligned with NER300 outcome
- Netherlands – ROAD project FEED completed
  - First project approved by European Commission
    - Project awaiting Dutch Government announcement – due in June 2012?

Current CCS Status in Europe (2)

- Spain – Compostilla OXYCFB300
  - Tested at 30MWth scale
- Poland – Belchatow
  - Geological screening underway
- Norway
  - Statoil/Snohvit underway
  - Mongstad NGCC with CCS
    - Projected stalled due to environmental issues
      - Nitorsamines/Nitramines
    - Current implementation status unknown

NER300

- World's largest CCS funding mechanism.
- 300 million emission unit allowances (EUAs)
- Today's value app. €4.5bn – allocated by two calls for proposals for large-scale demonstration projects of CCS and innovative renewable projects (6 - 8 CCS)
- 1st call (200 million EUA): Applications by May 9th 2011

  to European Investment Bank and European Commission
- 2nd call (100 million EUA): 2012 (selection: late 2013)
- Current status:
  - 22 CCS Projects
    - 4 250 MW Power Gen – Post Combustion
    - 8 250 MW Power Gen - IGCC
    - 4 250 MW Power Generation – Oxyfuel
    - 4 industrial projects

CCS Project Applications

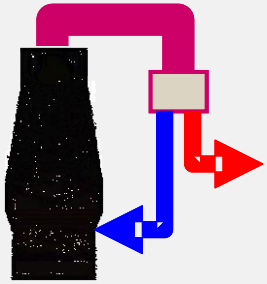
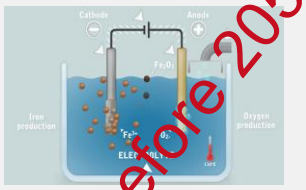
Project Name	Capture type	Country	Scale	Status
Easton Grange	IGCC	UK	850 MW new build	
Lynemouth	IGCC	UK	Retrofit of existing 420MW plant	
Killinghome	IGCC	UK	430 MW new build	
Hatfield No. 1	IGCC	UK	New 900 MW IGCC	
Hatfield No. 2	Post Combustion	UK	450MW NGCC new build	Cancelled
Longannet	Post Combustion	UK	600MW retrofit	Cancelled
Drax Power	Oxyfuel	UK	New 420MW plant	
Peterhead	Post Combustion	UK	New 385MW NGCC	
Hunterston	Post Combustion	UK	New 1700MW Coal plant	
Eemshaven	Post Combustion	NL	New 1600 MW coal plant	
Buggenham	IGCC	NL	Retrofit on 233MW plant	
Corus CO2	Oxyfuel	NL	HISARNA ULCOS technology	
Air Liquide Refinery	Rotterdam	NL	New hydrogen plant	
Florange	Oxy blast	FR	ULCOS technology	
Janschwalde	Oxyfuel	DE	New 250 MW coal boiler	Cancelled
Porto Tolle	Post Combustion	I	Retrofit 660 MW boiler	Cancelled
Belchatow	Post Combustion	PL	Retrofit 250MW boiler	
Compostilla	Oxyfuel	ES	300MW CFB	
Turceni	Post Combustion	RO	330MW new lignite plant	

Going Forward

- Originally planned for 6-8 projects
  - Based on CO_2 price of €30/t
  - Current price static around €8/t
- Waiting on pronouncements from EIB/EC
- As we wait more projects fall by the wayside for financial or political reasons
- CCT/CCS Stalling in Europe
- Most active countries are UK and Netherlands

Europe is worldwide the strongest driver with the ULCOS processes

ULCOS brand process families

Coal & sustainable biomass		Natural gas	Electricity
Revamping BF	Brownfield	Revamping DR	Greenfield
TGR-BF 	HIsarna 	ULCORED 	ULCOWIN ULCOLYSIS  Not before 2050
Pilot tests (1.5 t/h) Demo phase launch in 2015	Pilot plant (8 t/h) start-up 2010	Pilot plant (1 t/h) to be erected in 2011?	Laboratory pilot

Depend critically on CCS

Australia

- ***Active R&D Programme***
  - Otway/CO2CRC large scale injection
  - Gorgon will come on line in 2014
    - Largest offshore injection project
  - A lot of projects not gone forward in Australia
    - Both political, financial and technical reasons

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.

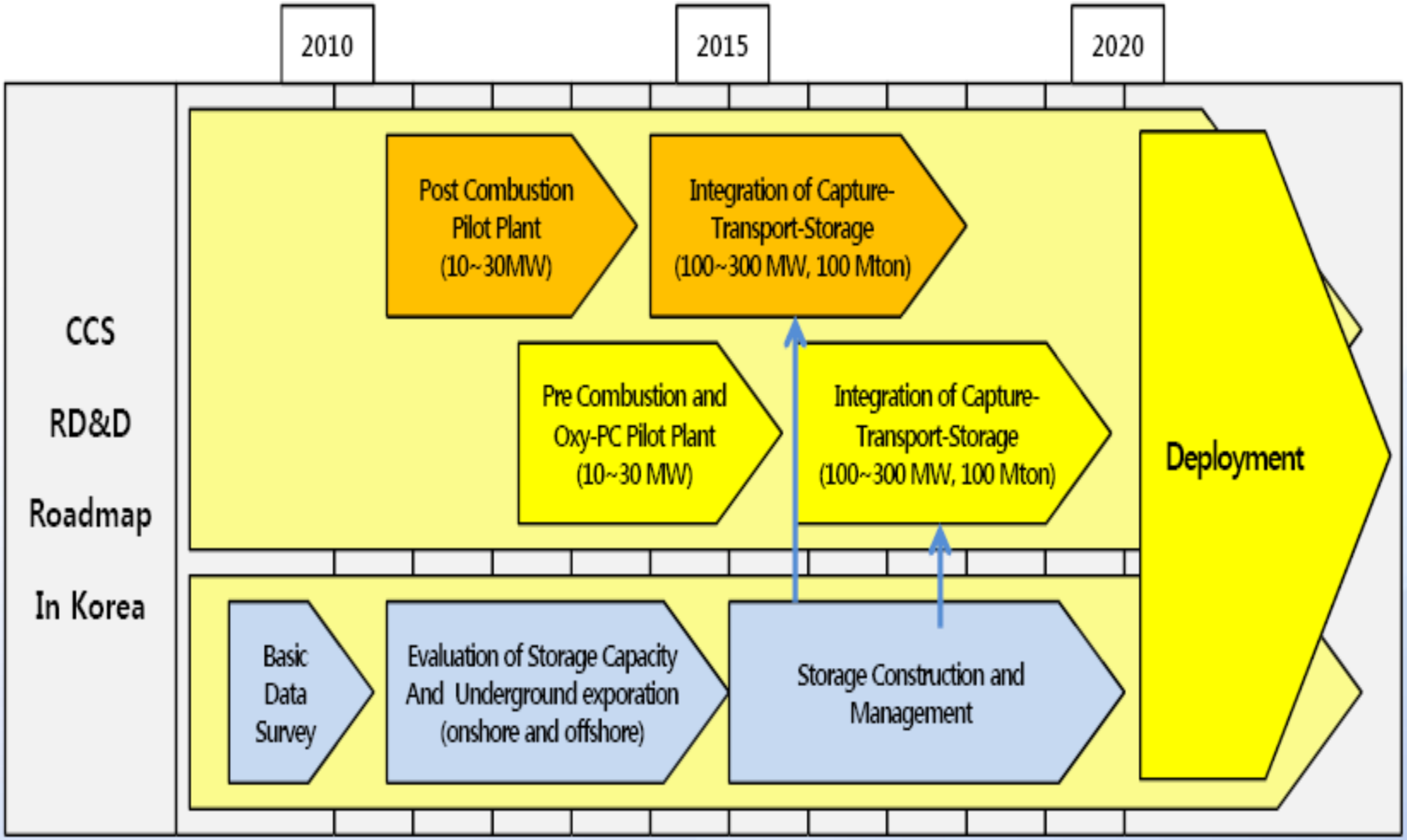
- 1st oxyfuel and world's largest pilot plant that will actually produce electricity.
- 2 ASU (330 tpd each)
- 1 CPU - Capturing ~22,000 t/y CO_2
- Installation of 2 new Wall Fired Burners
  - A unique position to provide information related to the burner – burner interaction

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 1MtCO_2/yr
  - Cost target at $30/tCO2 ($20 for capture, $10 for storage)
- ***Benefits/Expectation***
  - CO_2 reduction up to 32 MtCO_2 by 2030, contributing 10% of the total domestic CO_2 reduction amount.
  - CCS business opens 100 Trillion KRW (cumulative) market by 2030.

National CCS Roadmap of S. Korea



Project Outline

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

Phase Ⅰ (2007~2010)

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

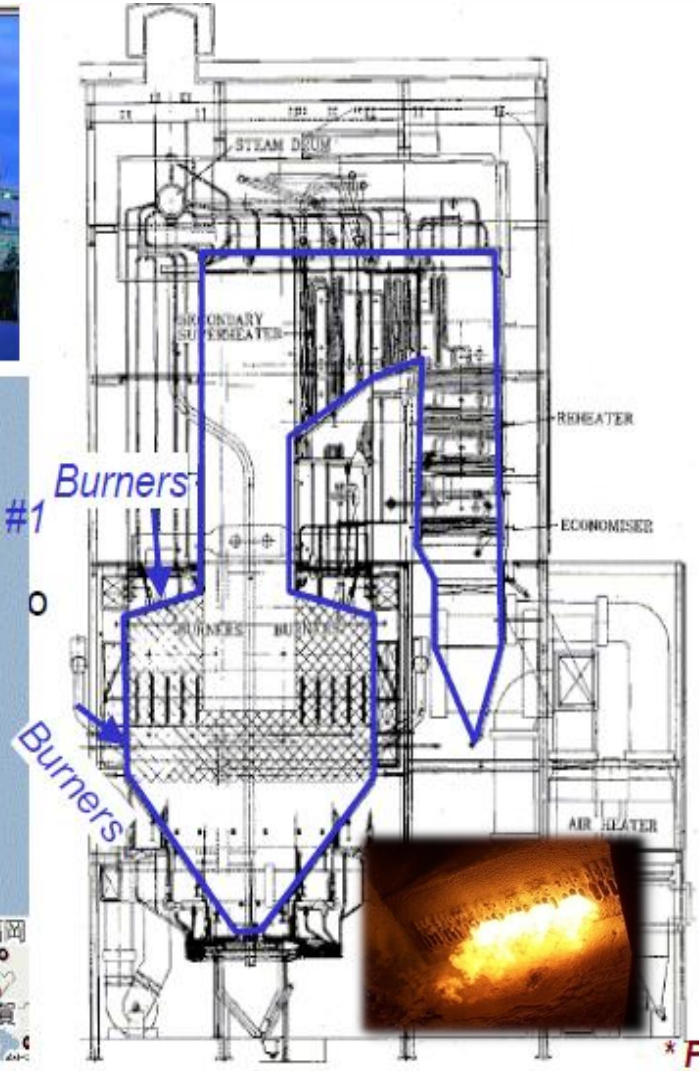
Phase Ⅱ (2010~2012)

Detailed Design & Construction of Demo. Plant

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

Phase Ⅲ (2012~2015)

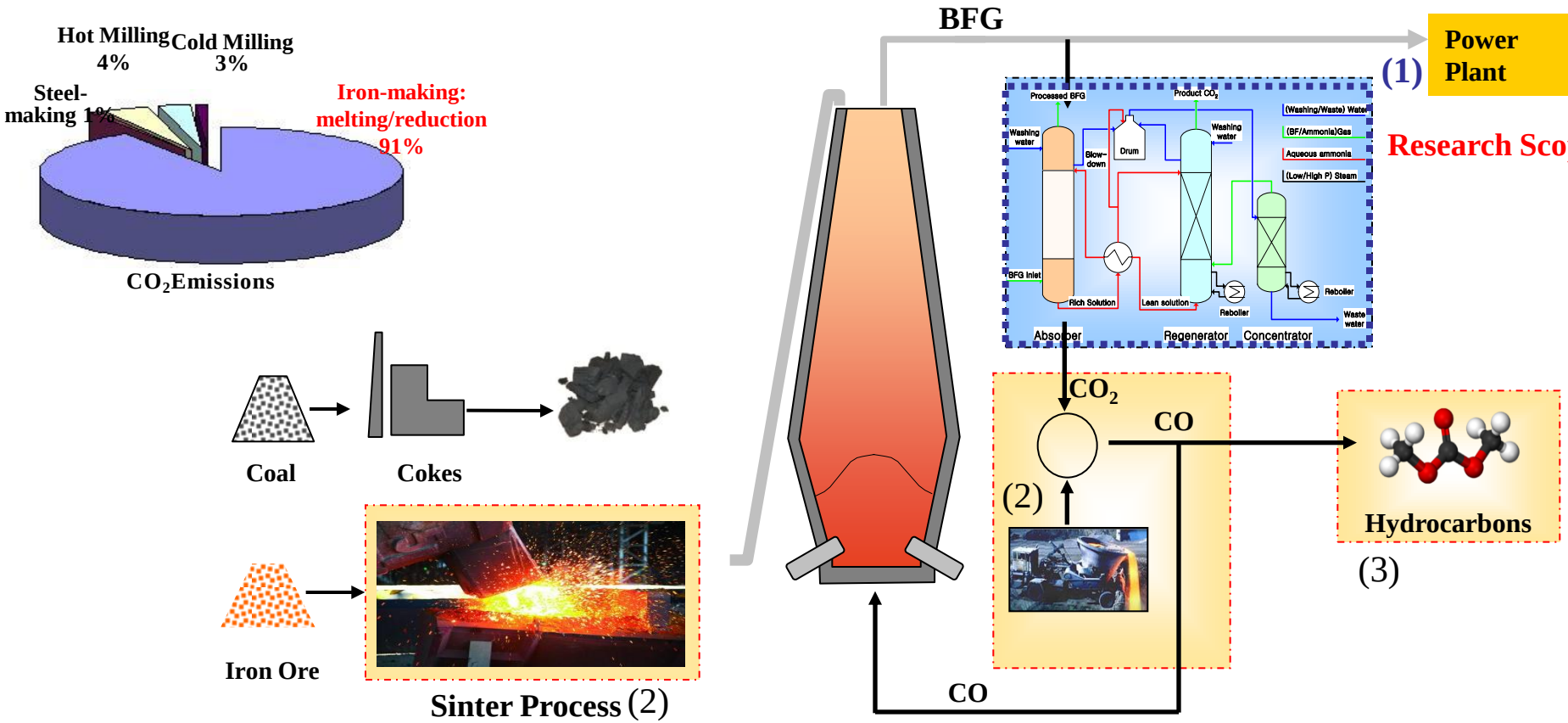
Tentative Demo. Site (Youngdong TPP)



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 × 16 Bent type × 12
Mill type	Tube type × 6 (Standby × 1)
Fuel	Anthracite(FR*=14)
Efficiency	36%

* Fuel Ratio= Fixed Carbon/Volatile

Ideas/Projects for CO_2 Reduction

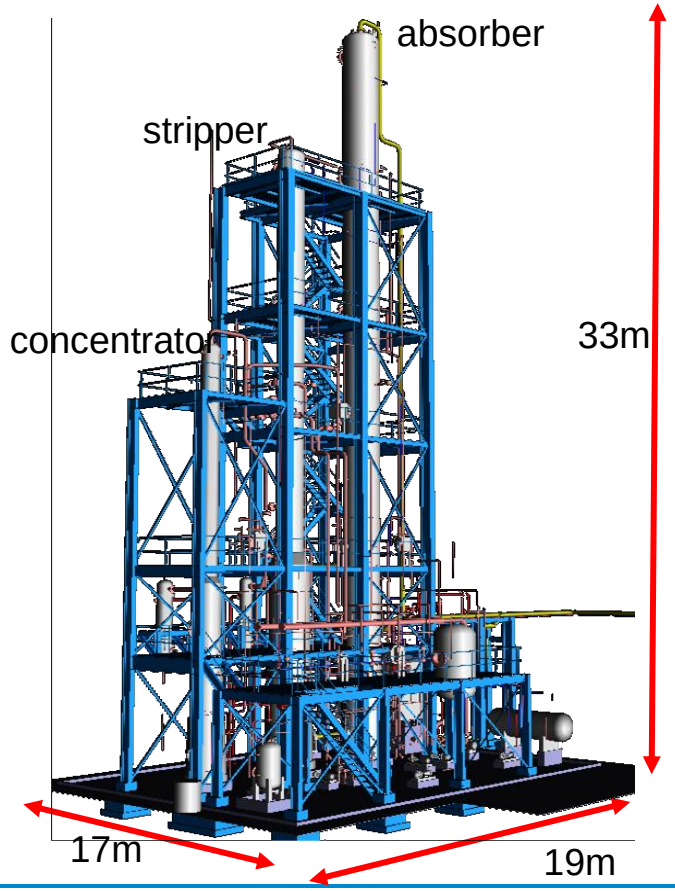


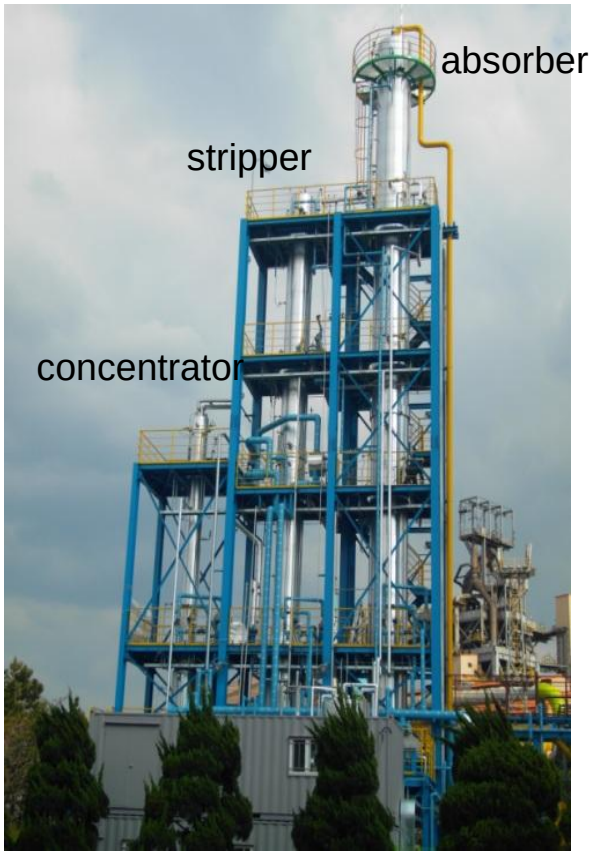
- Research Activities of CO_2 Project in RIST
  - (1) CO_2 Capture from BFG stream using aqueous ammonia
  - (2) Waste heat recovery from molten slag and hot sinter
  - (3) CO_2 utilization

2nd Stage pilot plant

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

- Development of CO_2 capture process for commercialization using aqueous ammonia in iron & steelmaking In
  - Utilizing the waste heats at low and mid-temperature waste heat as regeneration energy
  - Ultimate goal: CO_2 removal > 90%, CO_2 purity > 95%, energy requirement < 2.0 GJ/ton-CO_2





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

- Capacities
  : 1000 Nm^3-BFG/hr
  as 0.5 MW
  (CO_2 conc: 20~25%)

CCS Development in China

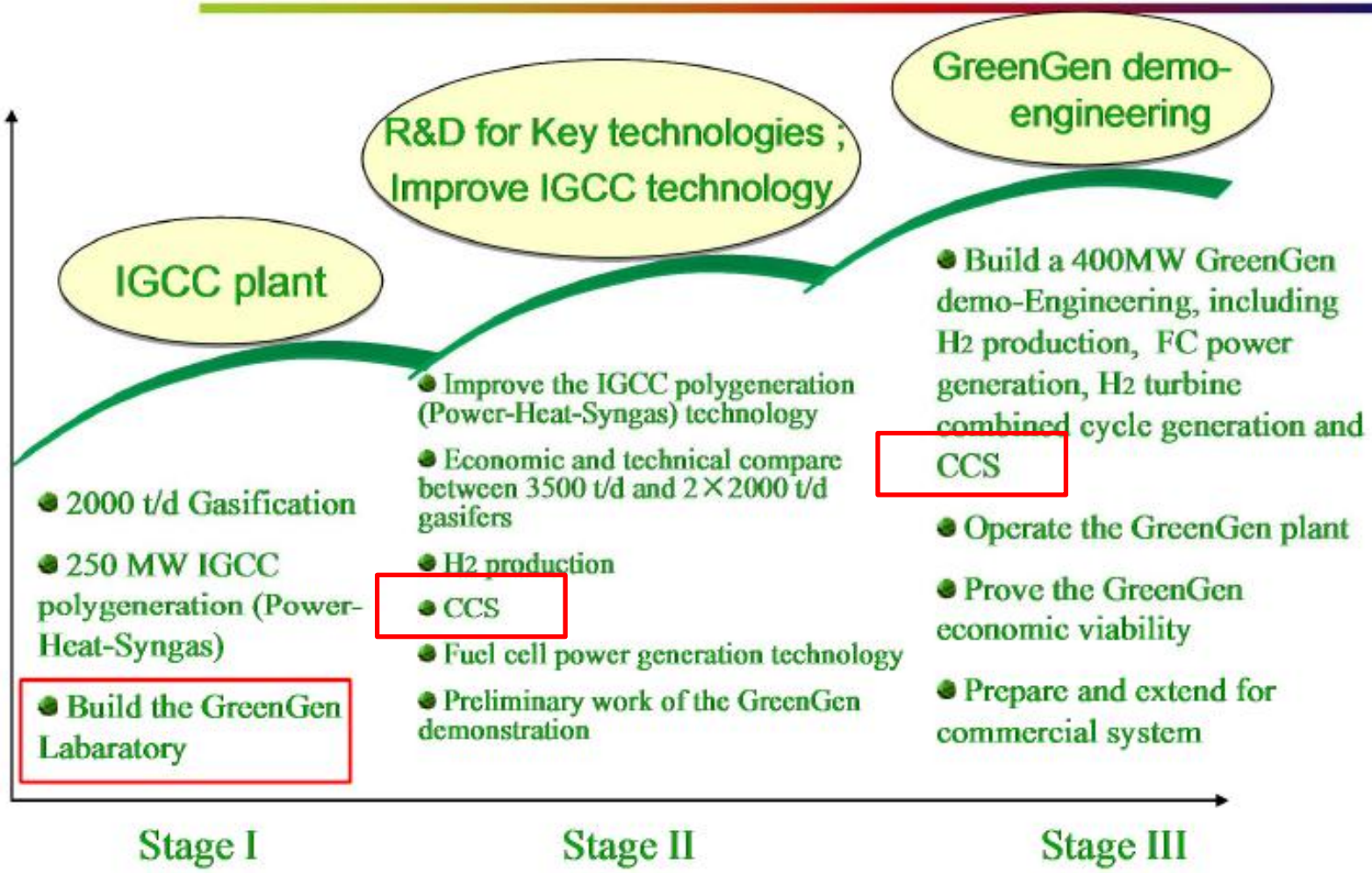
- Does not feature in the economic goals of 12th FYP but is included as a high technological priority within the R&D programme
- MOST supports both fundamental research (Programme 973) and technology development (Programme 863) while the National Science Foundation focuses on fundamental and generic research.
- Significant activities initiated by SOE – where CO_2 Utilisation (i.e. for supply of Food Grade CO_2 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 CO_2.
- ***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 CO_2 Capture
  - To verify key technologies, system integration, availability and reliability of key components consisting of the "GreenGen" technology

Three Stages of the GreenGen Programe

中国华能
CHINA HUANENG



GREENGEN IGCC Laboratory

(Under Commission and Fully Operational by 2012)

- Power: 265MW
- Net eff. 41%
- SO_2 : <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,NWEPDI

Data and Information from China Huaneng Group (2011)

GREENGEN Project:
CO_2 Capture Component

- ***SynGas slip stream (6000 Nm^3/h or ~15 MW_t) to demonstrate***
  - the delivery of high purity H_2 from coal based IGCC for Fuel Cell application; and
  - CO_2 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 CO_2

~120,000 t/y CO_2

- Cooperation between CSIRO and China Huaneng Group – CHNG
- CO_2 captured from flue gas slip stream of 800MWe Gaobeidian Coal Fired CHP (Beijing)
- Operation started July 2008

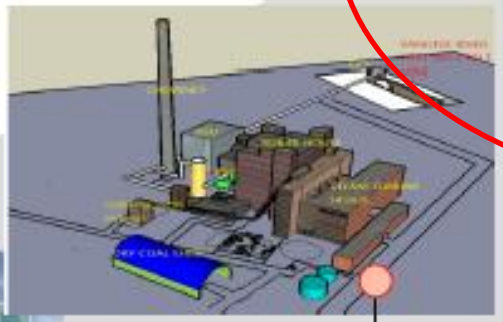
- Project led by Huaneng and TPRI
- CO_2 captured from the flue gas slip stream of 660MWe USC Shidongkou (No. 2) Power Plant (Shanghai)
- Operation started in December 2010
- Total Investment: US$ 14.6 Million
- **Total CO_2 capture cost of < 200RMB/t (US$ 30-35/t) incl. processing to food grade.**

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

2020

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

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

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

2010

Fundamental Study

1995

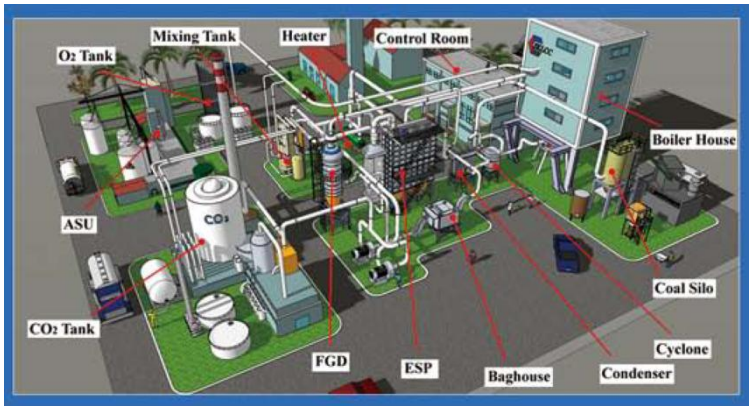
2005

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

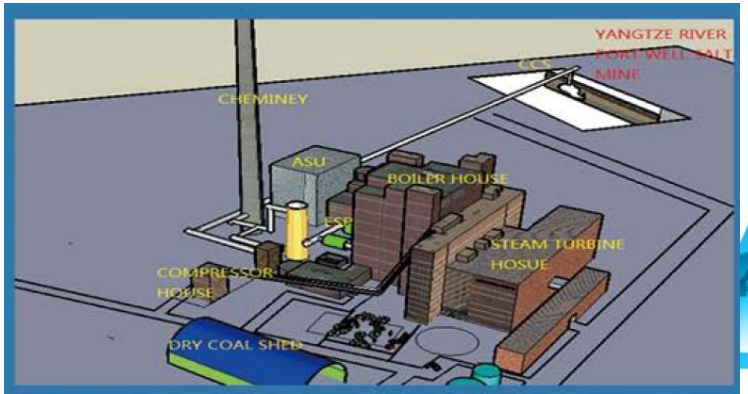
Consequence of shelving of Janschwalde Project means that Europe could lose grounds in the development of oxyfuel combustion

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 ca rbon 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



3 MWt Oxy-fuel Pilot Platform



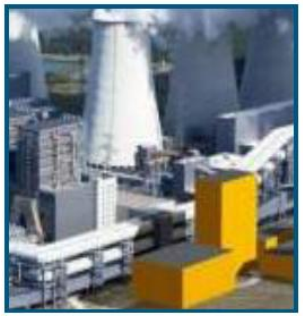
35 MWt Oxy-fuel Combustion Boiler Industrial Demonstration Project

Datang Oxyfuel Demo Project

- Daqing 350MWe Project
- Full size Oxyfuel Combustion CO_2 Capture
- Cogeneration of Heat and Power based on SC PC Boiler using lignite
- Location: Daqing, Heilongjiang province
- EOR and CO_2 storage: adjacent to PetroChina's Daqing oil field for EOR, near Songliao basin for geological sequestration

Anticipated Project Interface

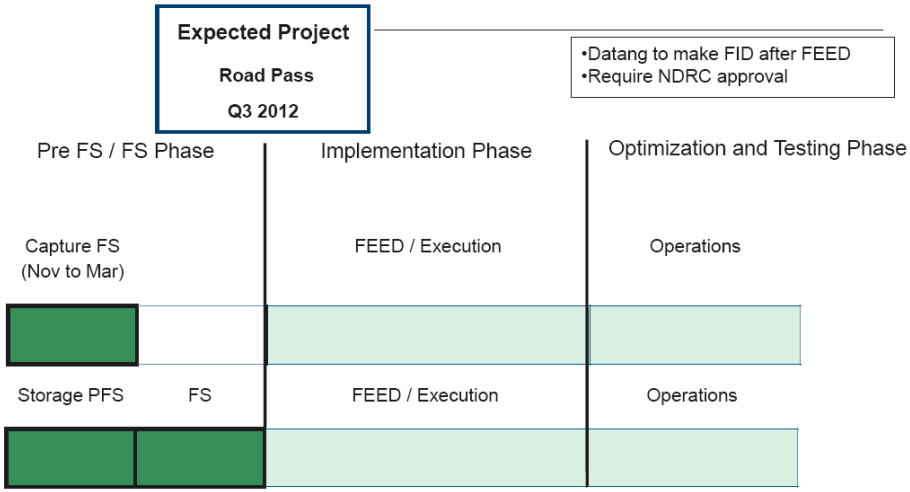
ALSTOM



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

Daqing Demo Project Timeline

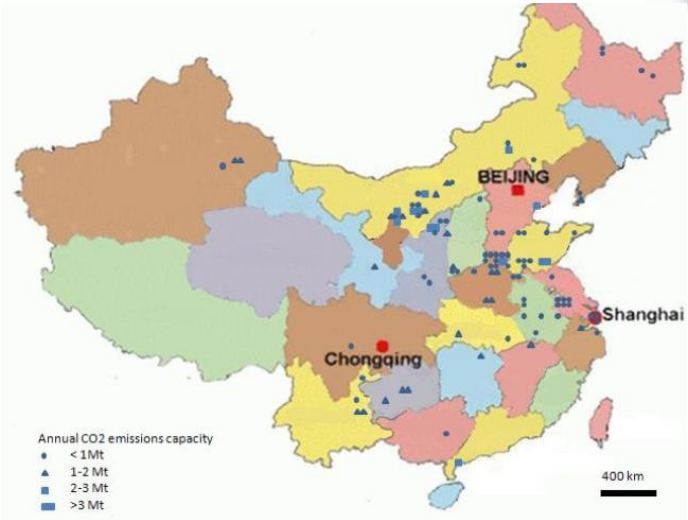
ALSTOM



Potential for Coal to Chemical with CO_2 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 CO_2.***
- ***Early opportunities of CO_2 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**

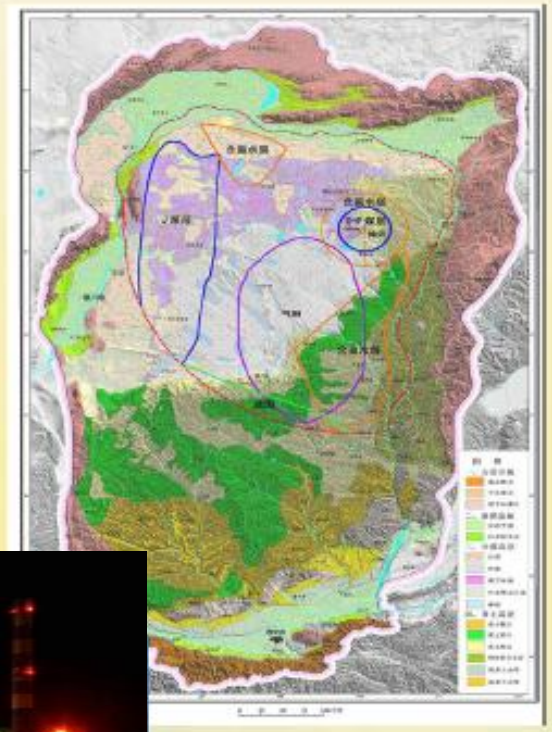
Direct CTL with CCS Demonstration

- ***Shenhua CTL (Ordos, Inner Mongolia) – operational since 2008***
  - ~1 MMTPY of Oil Products
    - LPG
    - Naptha
    - Diesel
    - Phenol
- ***Capture of ~100,000 t/y of CO_2 and stored in saline aquifer – operational since 2011***

Shenhua's CTL Demonstration (CO_2 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

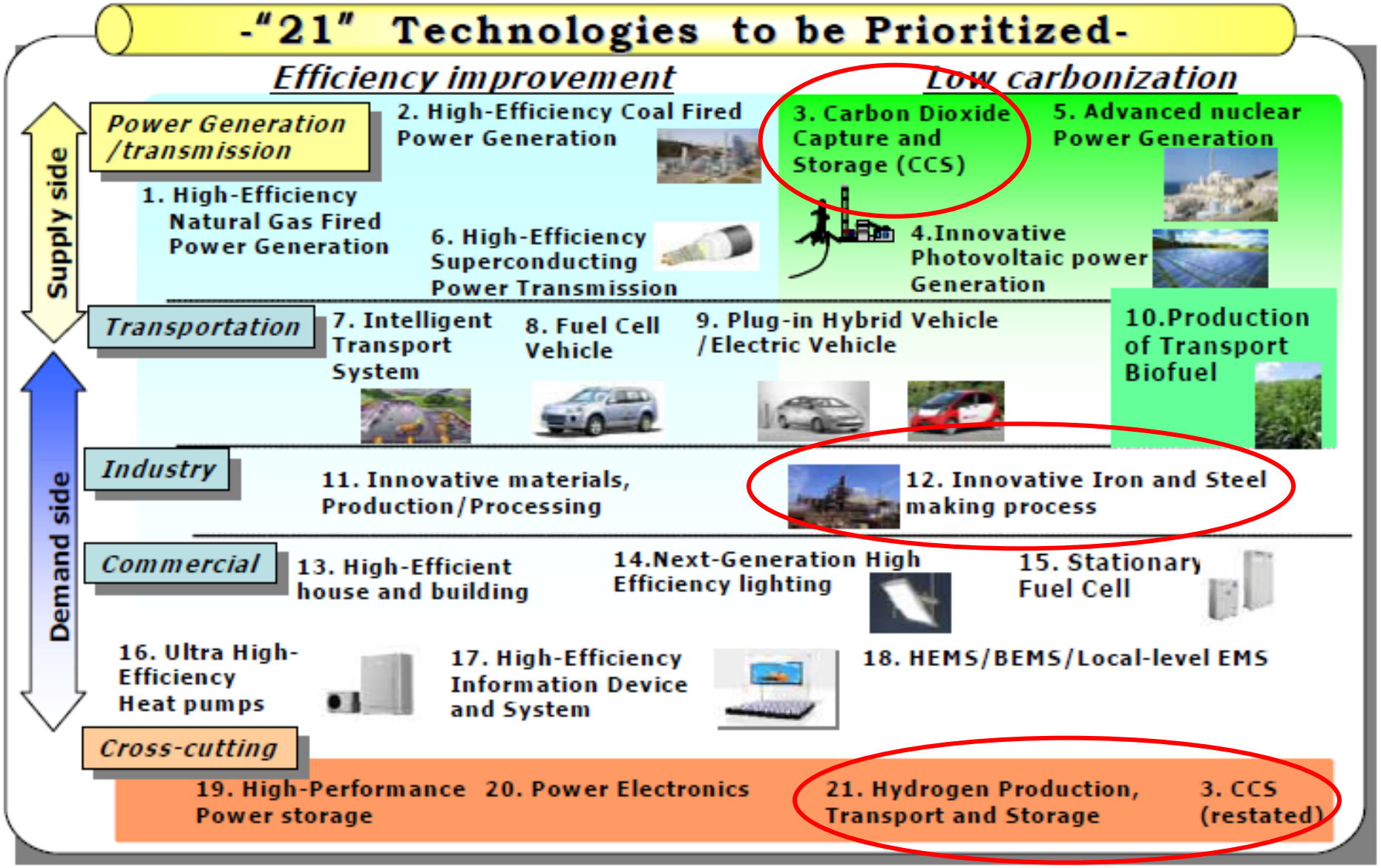


CO_2 Storage Demonstration started in 2011!

Japan

- CCS is an important part of Japan's strategic plan
- Target to commercialize CCS by 2020
- Japan has been a technology leader in IGCC for some time
- Japanese companies are world leaders in post combustion capture
- Japanese companies are actively involved in the Callide project in Australia
- Japan has been a leader in CCT/CCS the region for some time
- Japan is one of the world leaders on developing CCS for the iron and steel industry (COURSE 50 project)

Cool Earth Innovative Energy Technology Program



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

Concluding Remarks

- CCS Development is stalling in Europe and Australia, but moving ahead in North America and the Far East
- There is growing interest in IGCC and oxy fuel capture technologies around the world
- There is increased activity in the Far East, notably China in developing CCT and CCS technologies
- Whilst some Far Eastern countries are latecomer to CCT/CCS. The region is now moving into a position to lead the world in the demonstration of this technology.
- CCT/CCS application to industry is growing and we expect at least one demonstration project in the steel industry in Europe or the Far East by 2020.

GHGT-11

- 1220 Abstracts submitted
  - a new record
- Registration opened 23rd April 2012

GHGT-11

18th – 22nd November 2012

Kyoto, Japan.

www.ghgt.info

ありがとうございます

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すぐに見ることを期待します。

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