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CCSU Development in Taiwan

Green Energy and Environment Laboratories
Industrial Technology Research Institute, Taiwan

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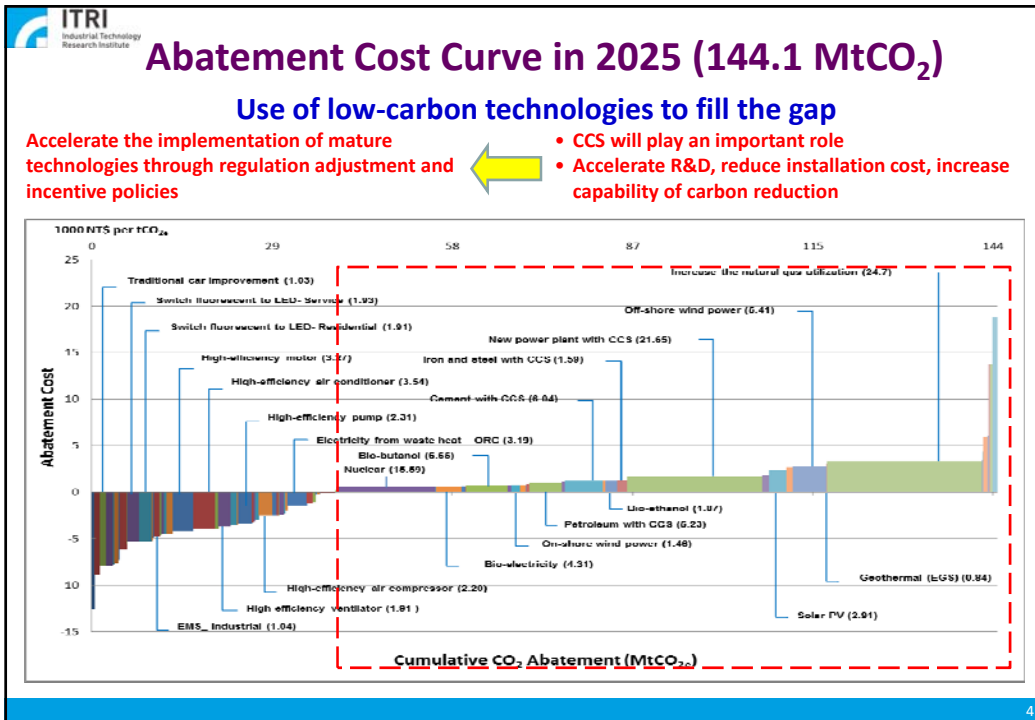
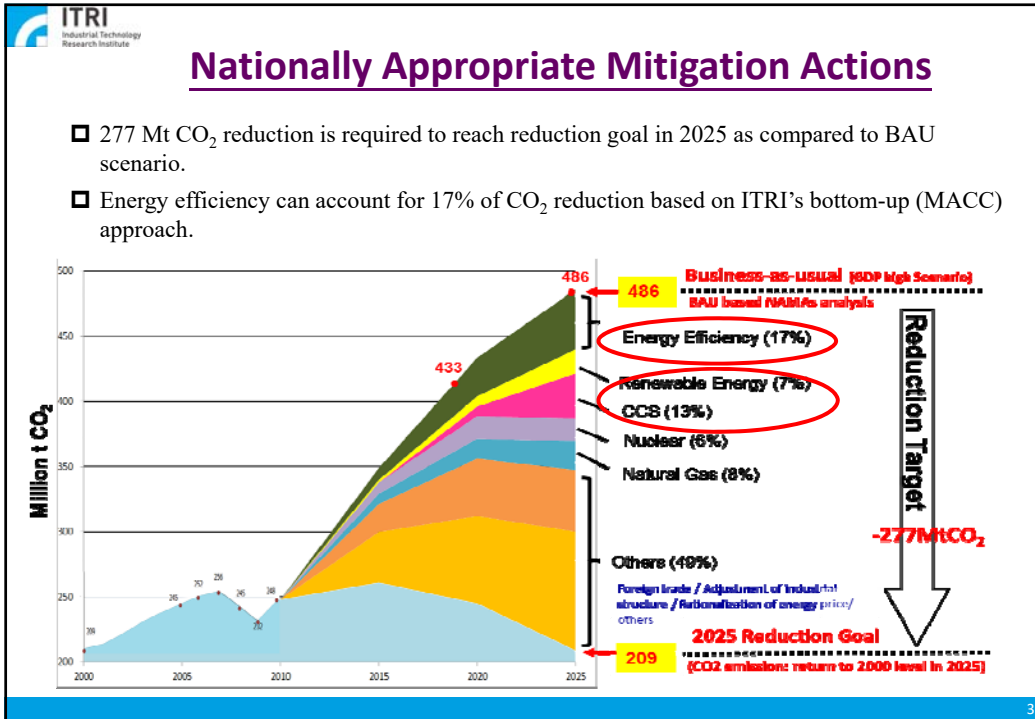
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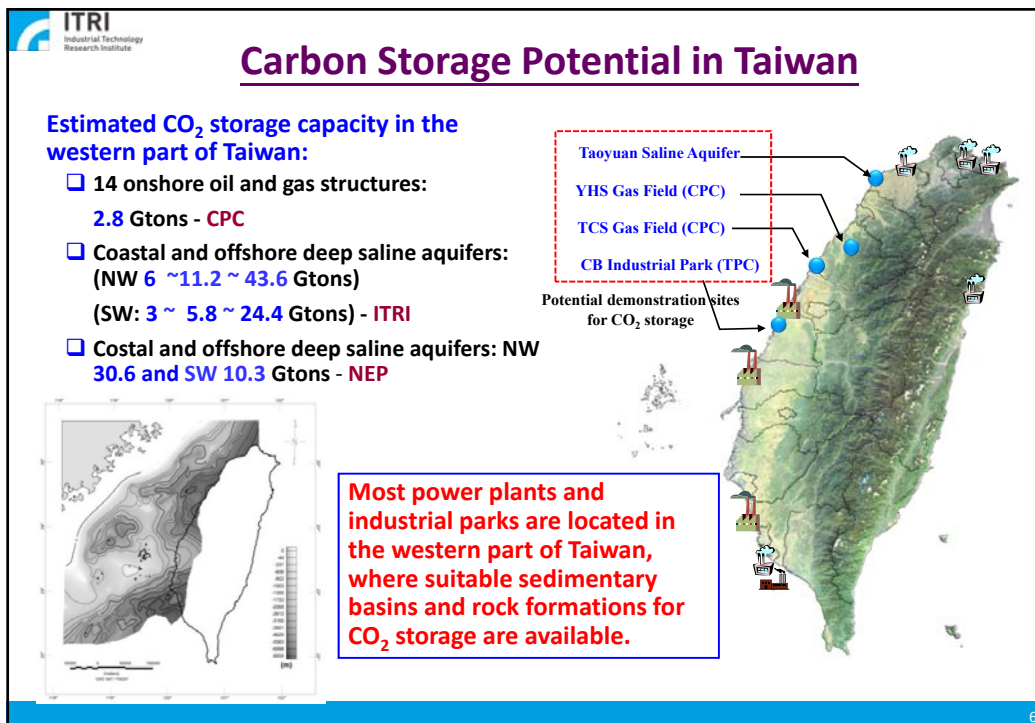
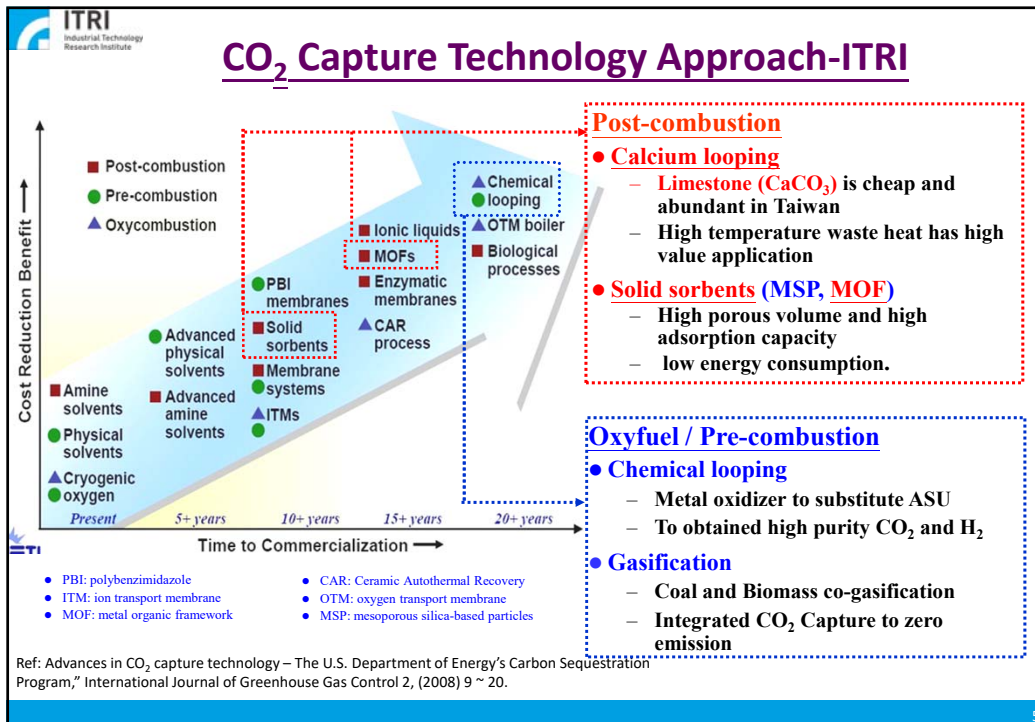
Taiwan's CO₂ Emissions Indicators

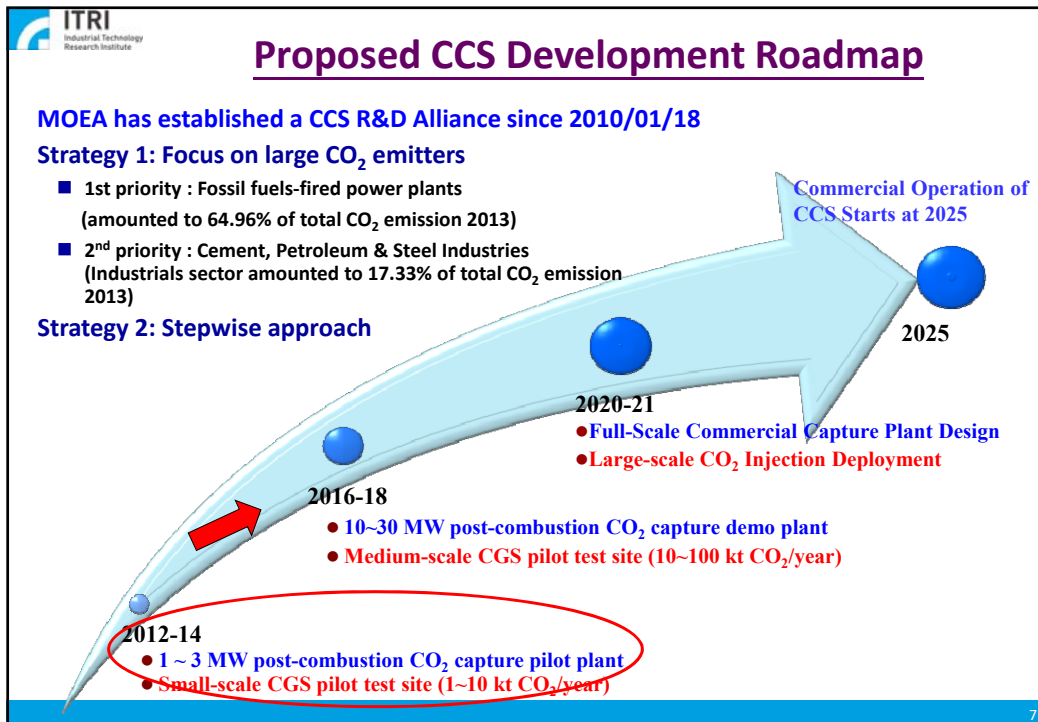
- Taiwan emitted 250.3 million tons of CO₂ in 2013.
 - Emission by sector: **Energy(162.6Mt, 64.96%), Industrials(43.4Mt, 17.33%), Transportation(34.5Mt, 13.77%), Residential(4.7Mt, 1.87%), Services(4.2Mt, 1.67%), Agriculture (1Mt, 0.4%)**
- Represented 0.81% of global CO₂ emissions, ranking 24 of emissions and ranking 20 of emissions per capital by countries in 2012.
- Annual growth rate of CO₂ emissions from 3.66% in 1990~2013 decrease to 1.38% in 2000~2013.

The top graph shows two data series: 'CO₂ emissions Per Capita' (solid red line) and 'CO₂ Emissions' (dashed blue line). Both series show a steady increase from 1990 to 2006, peaking around 2006, and then showing a slight decline and stabilization through 2012. The bottom graph shows 'CO₂ Emission Intensity' (solid blue line with markers), which follows a similar trend, peaking around 2006 and then declining significantly through 2012.

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ITRI – R&D Activities(1/4)

■ **Calcium Looping CO₂ Capture Technology**

- Currently the world's largest pilot plant for carbon dioxide capture using calcium looping in 2013
 - ✓ Cooperation with the Taiwan Cement Company, has installed the test facility at Ho-Ping cement plant in Hualien
 - ✓ Scale: ~ 1.9 MWt (flue gas: 3.1 t/hr, capture rate: 1ton CO₂/hr)
 - ✓ Completed continuous testing, the CO₂ capture efficiency was more than 90%
- Integration of Hydration Reaction into Calcium-Looping Process
 - ✓ Built up 20kWt Bench scale test facility
 - ✓ Steam hydration (Slaking process) is used to improve the reaction activity of the sorbent
 - ✓ Cascade cyclones to increase efficiency and reduce heat lost
- Won 2014 R&D100 Awards and ITRI's Excellent Research Gold Medal

Algae Farm

CO₂ Liquefaction Plant

1.9MWt Pilot Plant

R&D 100
2014 Winner

20kWt Bench Scale

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ITRI – R&D Activities(2/4)

■ Business Model for Commercialization

- The primary stage of application is targeted from cement industry and move forward to Mainland China, Southeast Asia and North America.
- Total plant module to reduce carbon for coal-fired power plant and industry furnace.
 - To initiate a new venture in 2015
 - To built up a 30~50MWt demo plant in 2017
 - To establish the commercial technology in 2020
- Integrate EOR with 50MW co-generation plant to develop a commercial zero-emission plant

CO₂

- EOR, EGR
- Geologic storage
- CO₂ reutilization
- Light CaCO₃ byproduct

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ITRI – R&D Activities(3/4)

■ Chemical Looping Process for CO₂ Capture and H₂ Generation

- Setup a 30 kWt Chemical Looping System
 - ✓ Consists of reducer, oxidizer and combustor
 - ✓ Counter-current moving bed for oxygen carrier
 - ✓ ~99% CO₂ was generated from the reducer, while methane was completely consumed by oxygen carrier.
 - ✓ ~94% H₂ was generated from the oxidizer


30 kWt Chemical Looping System

■ Amine-Functionalized Mesoporous Silica Particles (MSP) Adsorption

- Development of various modification technology, the adsorption capacity more than 120mg CO₂/g
- Establish a Pilot-scale spray drying manufacture system, Production rate of MSP is 1 kg /h
- Setup a Bench-scale fixed-bed adsorption system
 - ✓ Gas Flow rate : 100 L/min, Loading: 200 g~1 kg of MSP

Bench-scale adsorption system

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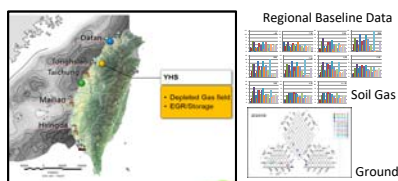


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ITRI – R&D Activities(4/4)

Carbon Storage Research

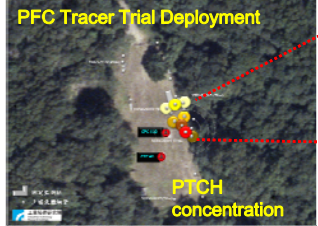
- **CPC YHS potential storage/EGR site in northeastern Taiwan**
 - ✓ **Baseline data collection**
 - ✓ **Technology validation platform**
- **International collaboration with U.S.DOE National Energy Technology Laboratory**
 - ✓ **Monitoring:**
Surface monitoring (PFC tracers, fiber optics for leakage detection)
 - ✓ **Risk Assessment:**
Quantitative risk assessment framework
 - ✓ **Site Characterization:**
Review of potential storage sites data, borehole core experiment (planned)




Regional Baseline Data
Soil Gas
Groundwater



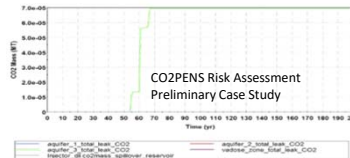
Real-time Monitoring Station



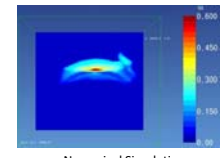
PFC Tracer Trial Deployment
PTCH concentration



Technology validation platform
Shallow aquifer CO₂ / PFC tracer test with PTCH and PMCP




CO2PENS Risk Assessment Preliminary Case Study



Numerical Simulation

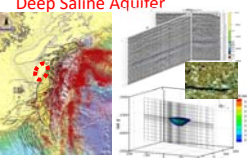
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TaiPower– R&D Activities

Tai-hsi Basin
Deep Saline Aquifer



Site Characterization Well
3000m Deep



- 2012/Jul/25 Drilling Start
- 2012/Aug/03 Reach 1500 m (Cutting)
- 2012/Aug/11-12 First Round Open-hole Logging (SLB)
- 2012/September PQ Core Drilling 1500-3000m Start-up
- 2013/Nov/14 down to 3005m
- Will Become one of the **monitoring wells**


- Site screening
- Site characterization

- **Drilling**
- Core sampling
- Core analysis
- Geological analysis

- Monitoring well
- Geological analysis

- Injection well
- Geological analysis

- Injection test
- Monitoring



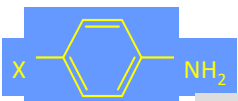
On-site Baseline Monitoring

2009	2010	2011 ~2013	2014	2015	2016	2017	2018
<ul style="list-style-type: none"> • Advanced CO₂ capture technology 		<ul style="list-style-type: none"> • Technology assessment(PC; NGCC, Oxy...) • Cost analysis • Heat lost and thermal integration • Investment risk analysis 	<ul style="list-style-type: none"> • Test platform • CoE impact 	<ul style="list-style-type: none"> • Flexible operation • Solvent emission monitoring 	<ul style="list-style-type: none"> • Monitoring instrument 	<ul style="list-style-type: none"> • Solvent emission control • Load tracking 	

H₂NCH₂CH₂OH
2-aminoethanol

CO₂ adsorption : room temp.
CO₂ desorption : ~120 °C


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Aryl amine

- Low temperature CO₂ capture technology
- Waste heat integration

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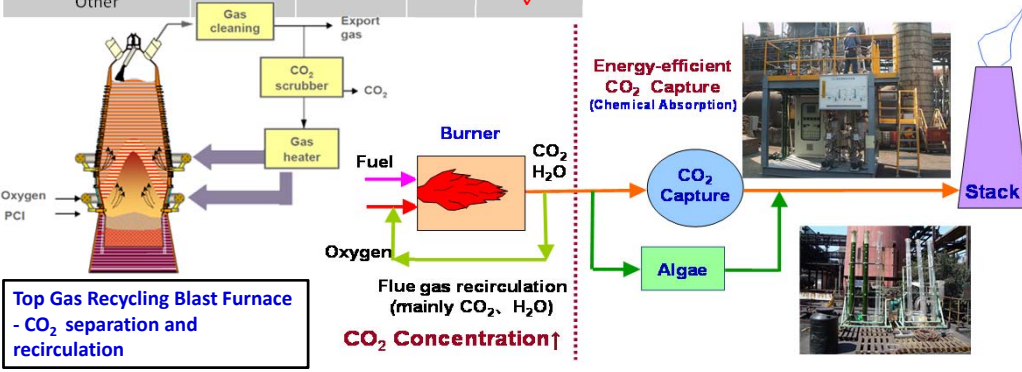
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China Steel Corp. – R&D Activities

	Lab work	Simulation	Pilot	Observe
Chemical Absorption	✓	✓	✓	✓
Physical Absorption		✓		✓
Molecular sieve	✓			✓
Mineral sequestration	✓			✓
Algae (bio-fixation)	✓		✓	✓
Calcium Looping				✓
Other				✓

Resource Integration:
Waste heat and water, Slag, etc.

Process Integration:
Aqueous NH₃ produced from coke oven by-product




Top Gas Recycling Blast Furnace - CO₂ separation and recirculation

Energy-efficient CO₂ Capture (Chemical Absorption)

Algae

Stack

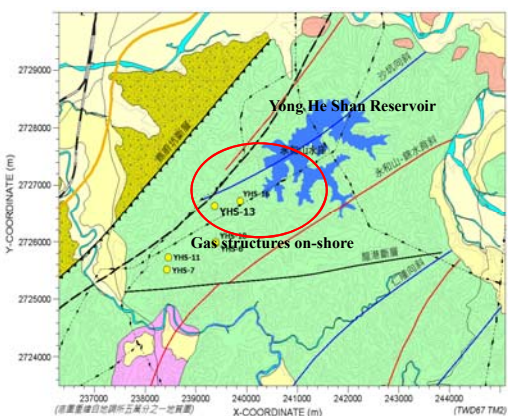
Flue gas recirculation (mainly CO₂, H₂O)
CO₂ Concentration ↑



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CO₂ Storage and EGR - CPC Pilot Test

- Phase I – Pilot Test (2012/10~2013/12)
 - CO₂ injected: 1000 tons
 - Objectives: trial injection, baseline monitoring, risk analysis and warning system
- Phase II – Full Operation (2014~2017)
 - CO₂ injected: 10,000~300,000 t/y
 - Objectives: evaluate monitoring techniques, accumulate CCS demonstration experience, explore the storage capacity in overlying aquifers
- Phase III – Scale up (2018~2020)
 - Injection scale : 500,000~1,000,000 t/y
 - Objectives: EOR/EGR application, promotion of CO₂ storage in upper saline aquifers
- Phase IV – Commercialization (2021~)
 - Injection scale: 1Mt/y and up
 - Objective: commercial operation of CO₂ storage and monitoring





Yong He Shan Reservoir

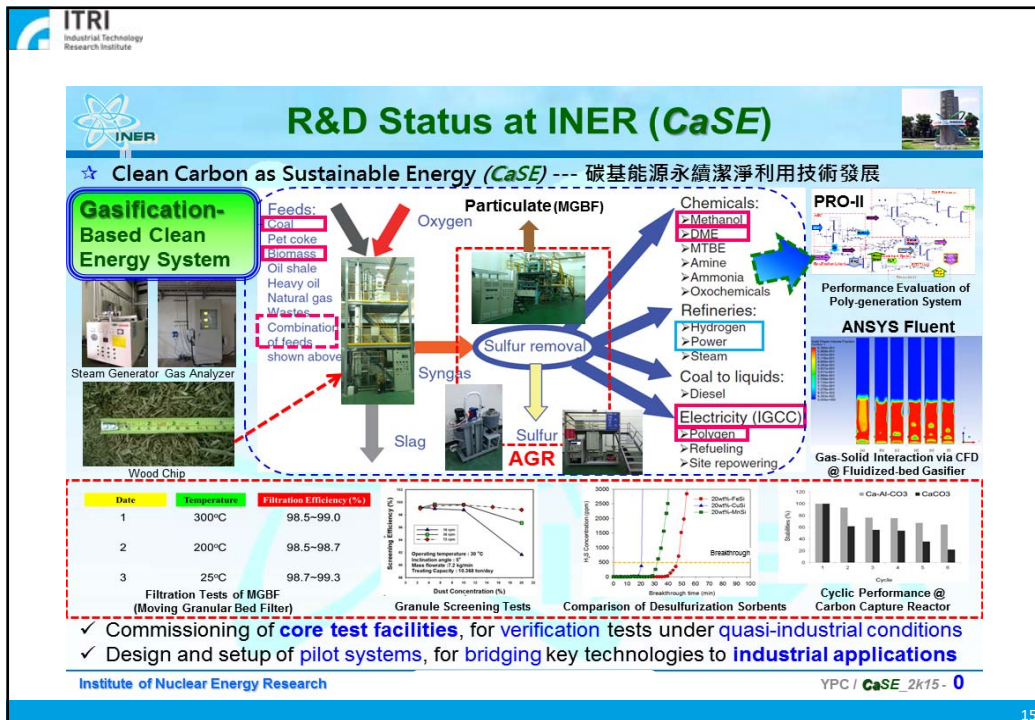
Gas structures on-shore

YHS-11, YHS-13, YHS-7

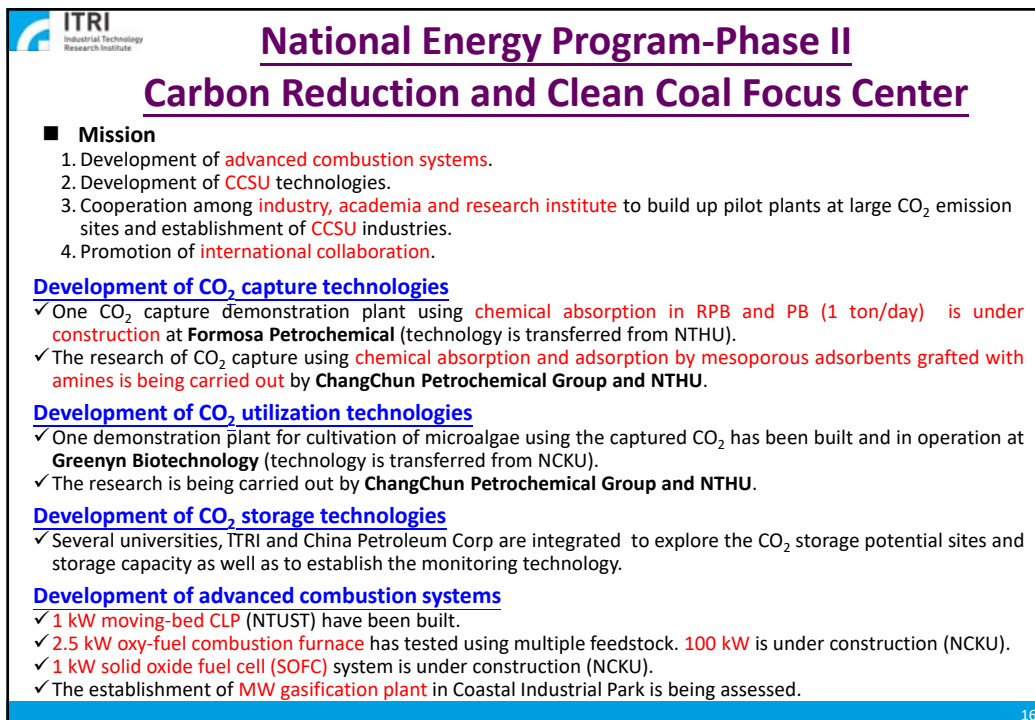
Y-COORDINATE (m)

X-COORDINATE (m)







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CO₂ Capture





ChangChun Petrochemical Group, Coal Power Center

Post-combustion capture

- ✓ One CO₂ capture demonstration plant (**0.27 ton/day**) using **chemical absorption and adsorption in rotating packed bed (RPB) and packed bed (PB)** is in operation at China Steel Corporation. The technologies of chemical absorption and adsorption are transferred from National Tsing Hua University, (NTHU) and National Taiwan University, respectively.
- ✓ One CO₂ capture demonstration plant (**1.0 ton/day**) is under construction at Formosa Petrochemical (technology is transferred from NTHU).
- ✓ The research of CO₂ capture using chemical absorption and adsorption by mesoporous adsorbents grafted with amines is being carried out by ChangChun Petrochemical Group and NTHU. The grant comes from ChangChun and Ministry of Science and Technology.


CO₂ capture demonstration plant at China Steel Corporation






Chemical absorption
0.1 ton CO₂/day

RPB process



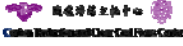
Adsorption
0.17 ton CO₂/day

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CO₂ Utilization



ChangChun Petrochemical Group, Coal Power Center


Direct use of CO₂ : Microalgae as the platform for CO₂ reutilization towards the production of renewable fuels and chemicals.

- ✓ One demonstration plant for cultivation of microalgae using the captured CO₂ has been built and in operation at Greenyn Biotechnology (technology is transferred from National Cheng Kung University).
- ✓ The research of directly use of CO₂ as solvent is being carried out by ChangChun Petrochemical Group and NTHU. The grant comes from ChungChun and Ministry of Science and Technology.


Conversion of CO₂ :

- ✓ The research of conversion of CO₂ to produce methanol as energy product and starting material of chemical is being carried out by ChangChun Petrochemical Group and NTHU. The grant comes from ChangChun and Ministry of Science and Technology.


Demonstration site at NCKU's An-Nan Campus Photobioreactor (PBR)




6 ton




300 ton




40 ton






Tubular PBR




Raceway pond

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Advanced Combustion System



碳資源中心
Carbon Resource Center


Oxy-fuel Combustion
A **100 kW oxy-fuel combustion furnace** has been built and tested using multiple feedstock at National Cheng Kung University, NCKU.

Chemical Looping Process
A **30 kW chemical looping process** have been built at Industrial Technology Research Institute (ITRI).


Gasification

- ✓ The establishment of MW gasification plant in Coastal Industrial Park is being assessed.
- ✓ A 100 kW gasification process have been built at Institute of Nuclear Energy Research (INER).


100 kW oxy-fuel combustion furnace at NCKU




100 kW gasification process at INER



30 kW chemical looping process at ITRI



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R&D Partnership and International Cooperation

R&D Topics	Partnership and Cooperation
Coal + O₂ Calcination (燃煤純氧燃燒煅燒技術)	University of New Orleans
Chemical Looping Process (化學迴路技術)	Ohio State University
Geo-sequestration Monitoring and Risk Assessment (封存監測與風險評估)	USDOE/NETL
Calcium Looping Process Validation and Scale-up (鈣迴路捕獲技術驗證與放大技術研發)	Taiwan Cement Corp.
30kWt Solid Fuels CLP Demonstration (30kWt固態燃料化學迴路測試系統技術)	CTCI Machinery Corp.
CLP for Hydrogen Production (化學迴路產氫技術開發)	CTCI and Taiwan Pneumtech Machine Corporation

*Also join GCCSI membership and be a CSLF Observer


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Closing Remarks

- **As almost 90% of the Taiwan's total energy supply come from fossil fuels and more than 71.1% of coal demand are used for power generation, CCS technologies are needed here for reducing the CO₂ emission while burning fossil fuels.**
- **In particular, CCS is envisioned to play a very important role for Taiwan's situation.**
 - **Speed-up of the RD&D is necessary.**
 - **Urgent needs for policy and regulatory framework to guide the CCS development and deployment.**
- **It is also important to cooperate with industries for RD&D of CCS technologies.**
- **International cooperation and information exchange are essential to expediting the global CCS technology development and deployment.**
- **Public outreach and acceptance to CO₂ geo-sequestration, however, is a critical issue that can not be ignored.**

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Thank You for Your Attention

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