台電在國內推動 CCS 試行計畫之現況、成果與實際困難

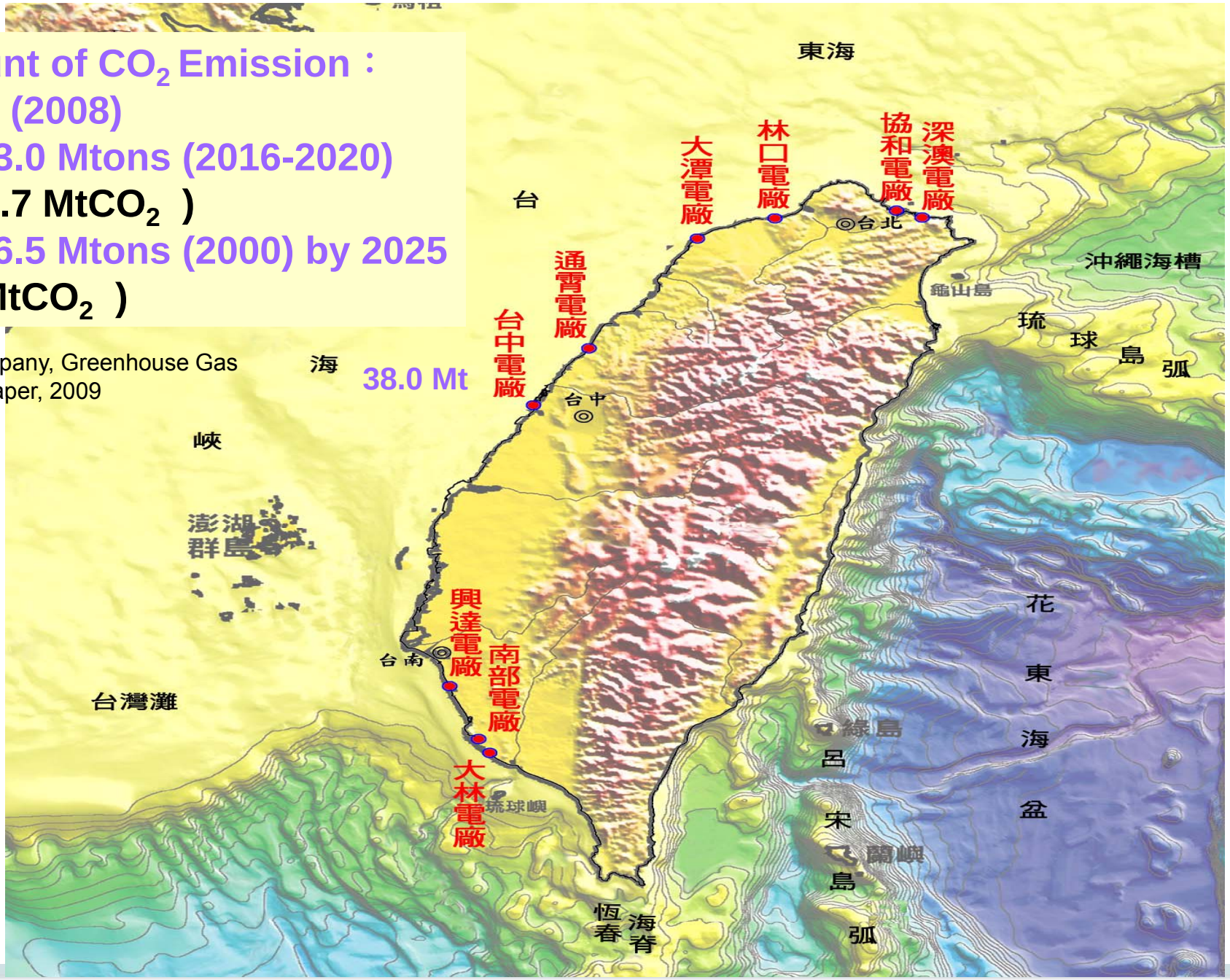
一、台電公司溫室氣體減量策略
二、二氧化碳捕捉計畫執行現況和成果
三、二氧化碳封存計畫執行現況和成果
四、台電公司推行CCS面臨實際困難
五、結語

杜悅元 專業總工程師
台灣電力公司
2010年11月9日

台電公司溫室氣體減量策略

Total amount of CO_2 Emission：
83.0 Mtons (2008)
Target 1: 83.0 Mtons (2016-2020)
(△：6.2-24.7 $MtCO_2$)
Target 2: 76.5 Mtons (2000) by 2025
(△：46.8 $MtCO_2$)

Taiwan Power Company, Greenhouse Gas Reduction White Paper, 2009

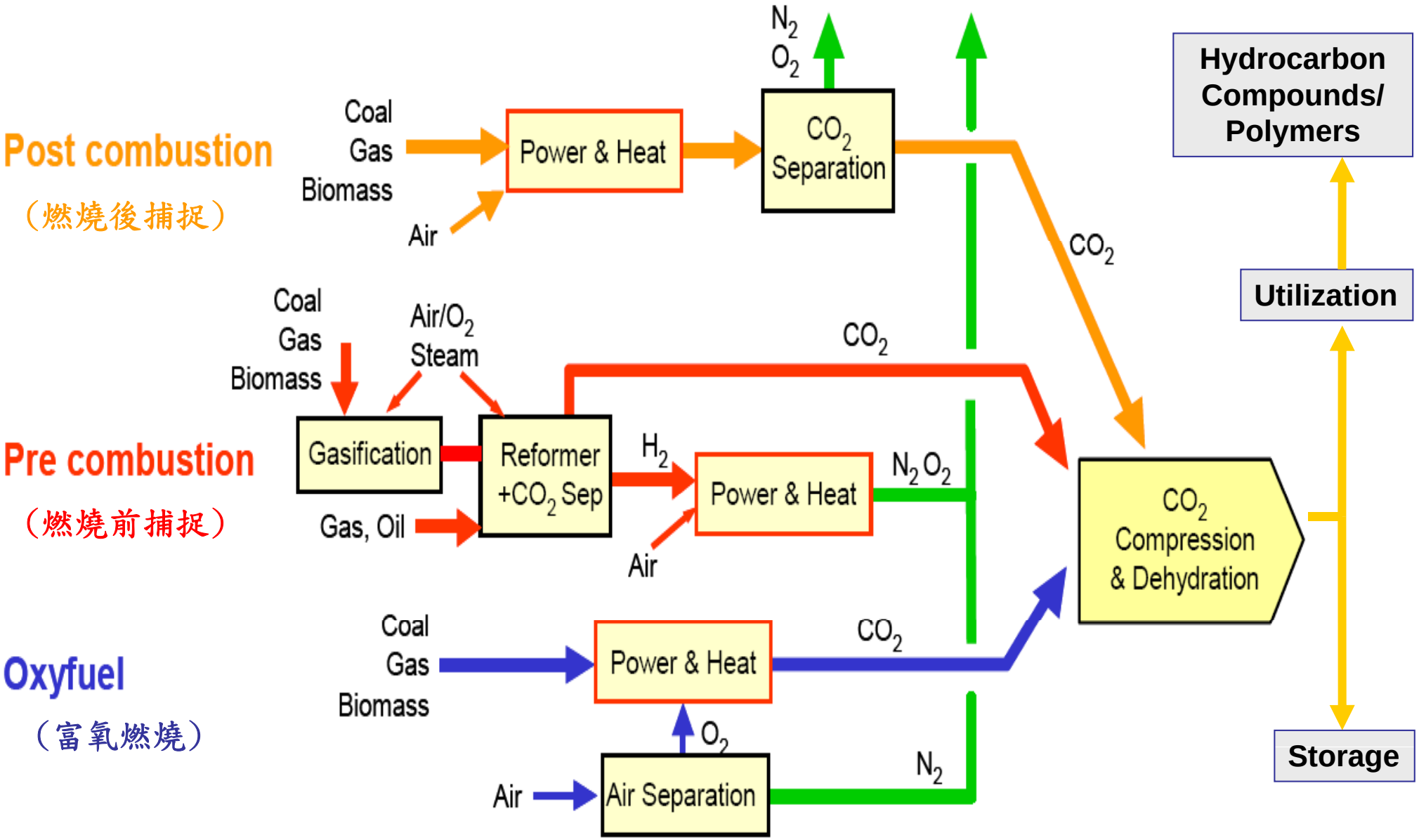


台灣電力公司

TPRI 綜合研究所

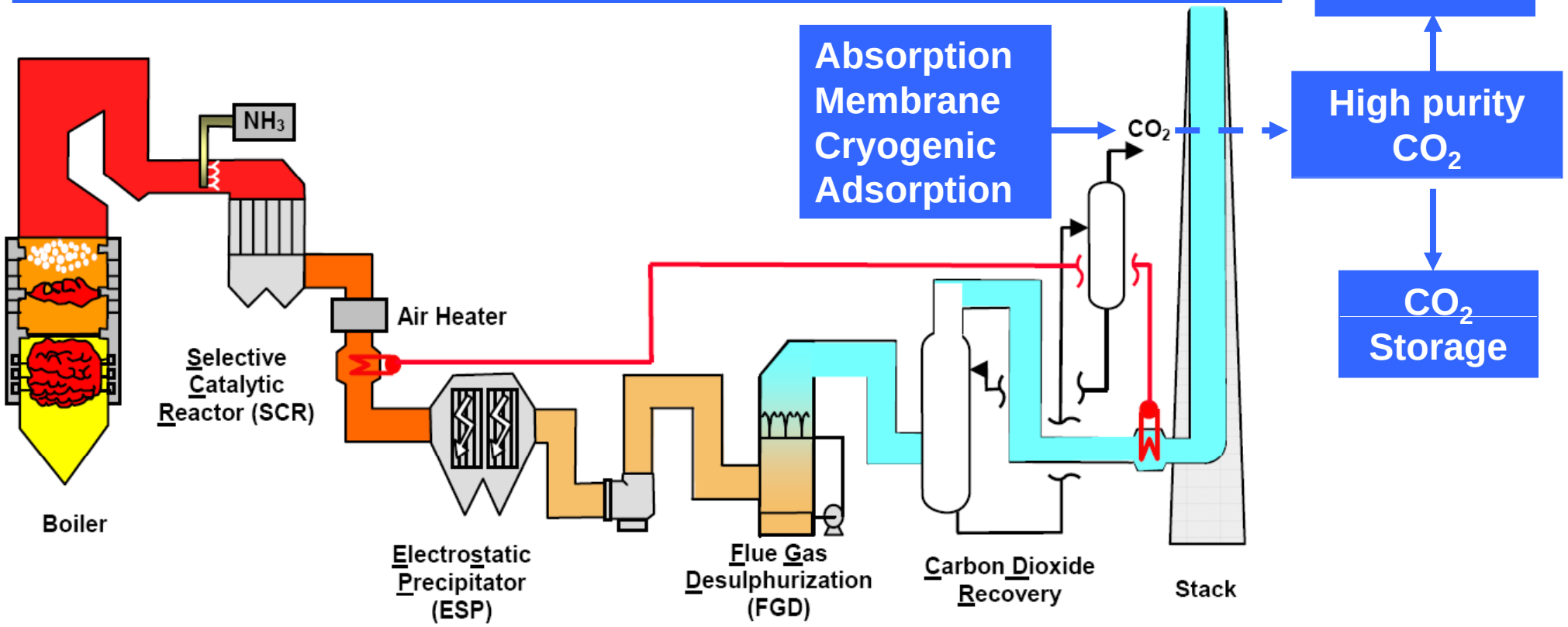
台電公司溫室氣體減量策略

二氧化碳捕捉計畫執行現況和成果


Post combustion
（燃燒後捕捉）
Coal
Gas
Biomass
Air
Power & Heat
N_2
O_2
CO_2 Separation
CO_2
Hydrocarbon Compounds/ Polymers
Utilization
Pre combustion
（燃燒前捕捉）
Coal
Gas
Biomass
Air/O_2
Steam
Gasification
Gas, Oil
Reformer +CO_2 Sep
H_2
Air
Power & Heat
N_2 O_2
CO_2
CO_2 Compression & Dehydration
Oxyfuel
（富氧燃燒）
Coal
Gas
Biomass
Power & Heat
CO_2
O_2
Air
Air Separation
N_2
Storage
CO_2 capture systems

Post Combustion CO_2 Capture

Fuels	Main Constituents in Flue Gas of Fossil Fuel Power Plant (Mol%)			
	CO_2	H_2O	O_2	N_2
Coal	15.4	6.2	1.8	76.6
Oil	12.9	10.3	1.8	74.9
Gas	8.7	17.4	1.7	72.1



Capturing CO2 from Coal-fired Power Plants: Challenges for a Comprehensive Strategy

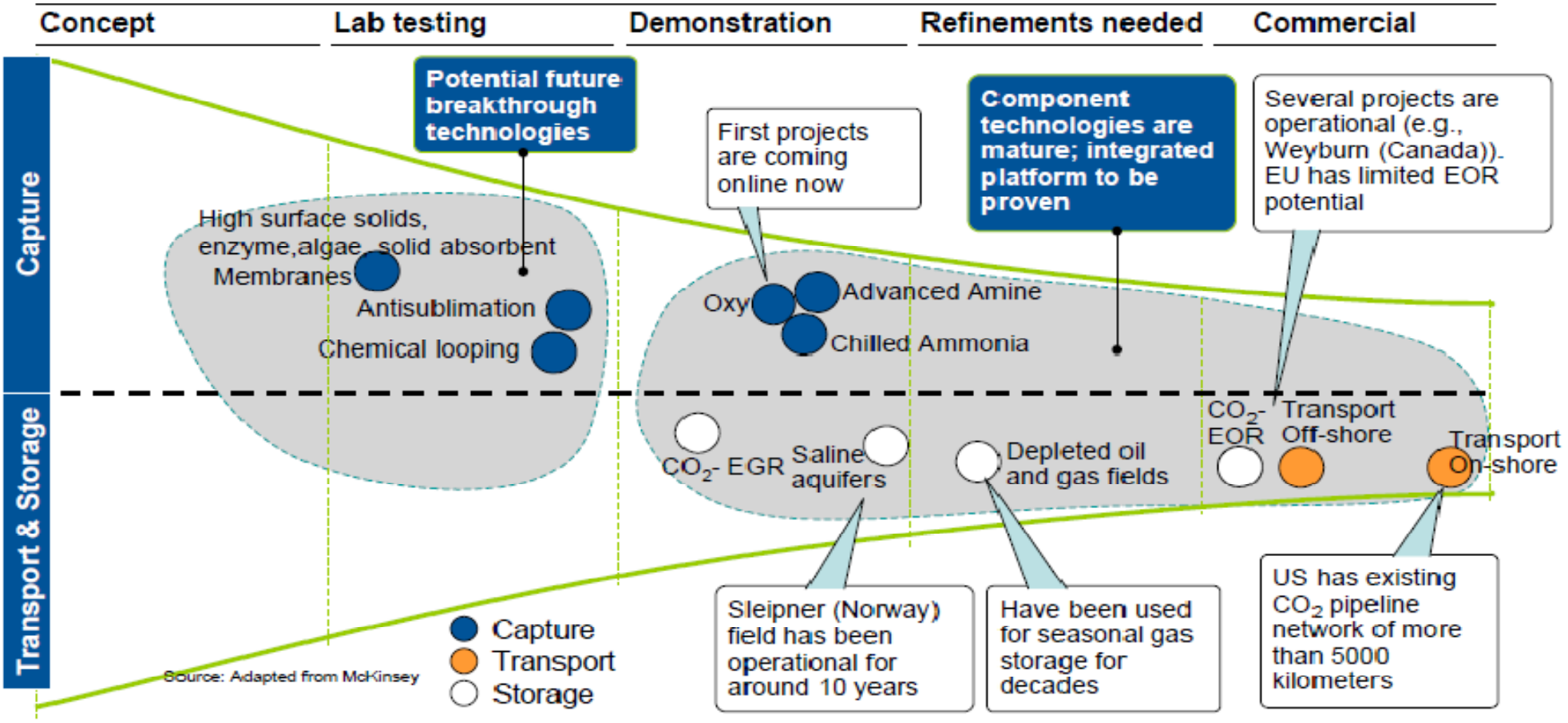
(CRS Report for Congress, Order Code RL34621, August 15, 2008.)

CCS Element	$/Metric Ton of CO_2
Capture	$40-$80
Storage	$3-$8
Monitoring and Verification	$0.2-$1.0

註：上表所示估計費用，不包括二氧化碳的運輸費用。

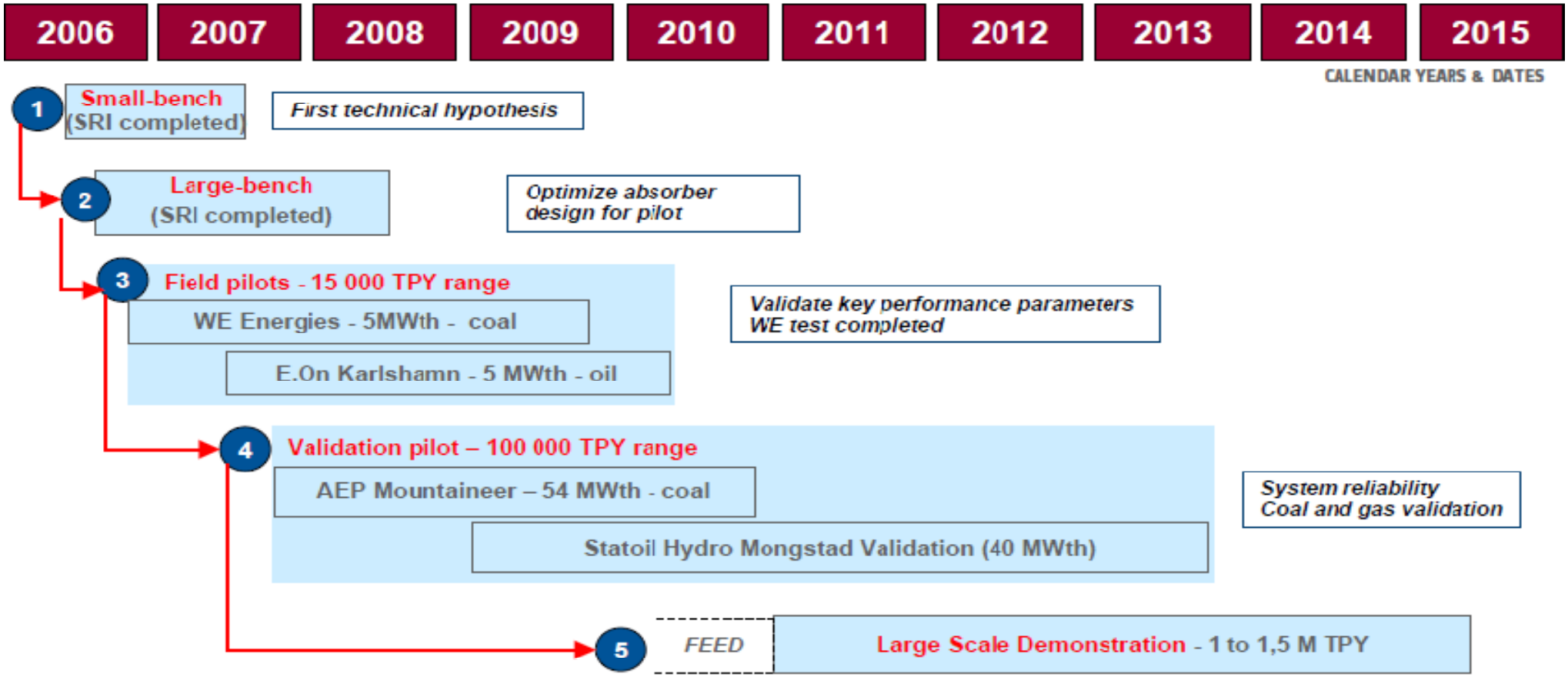
Status of Carbon Capture Technology Development

ALSTOM



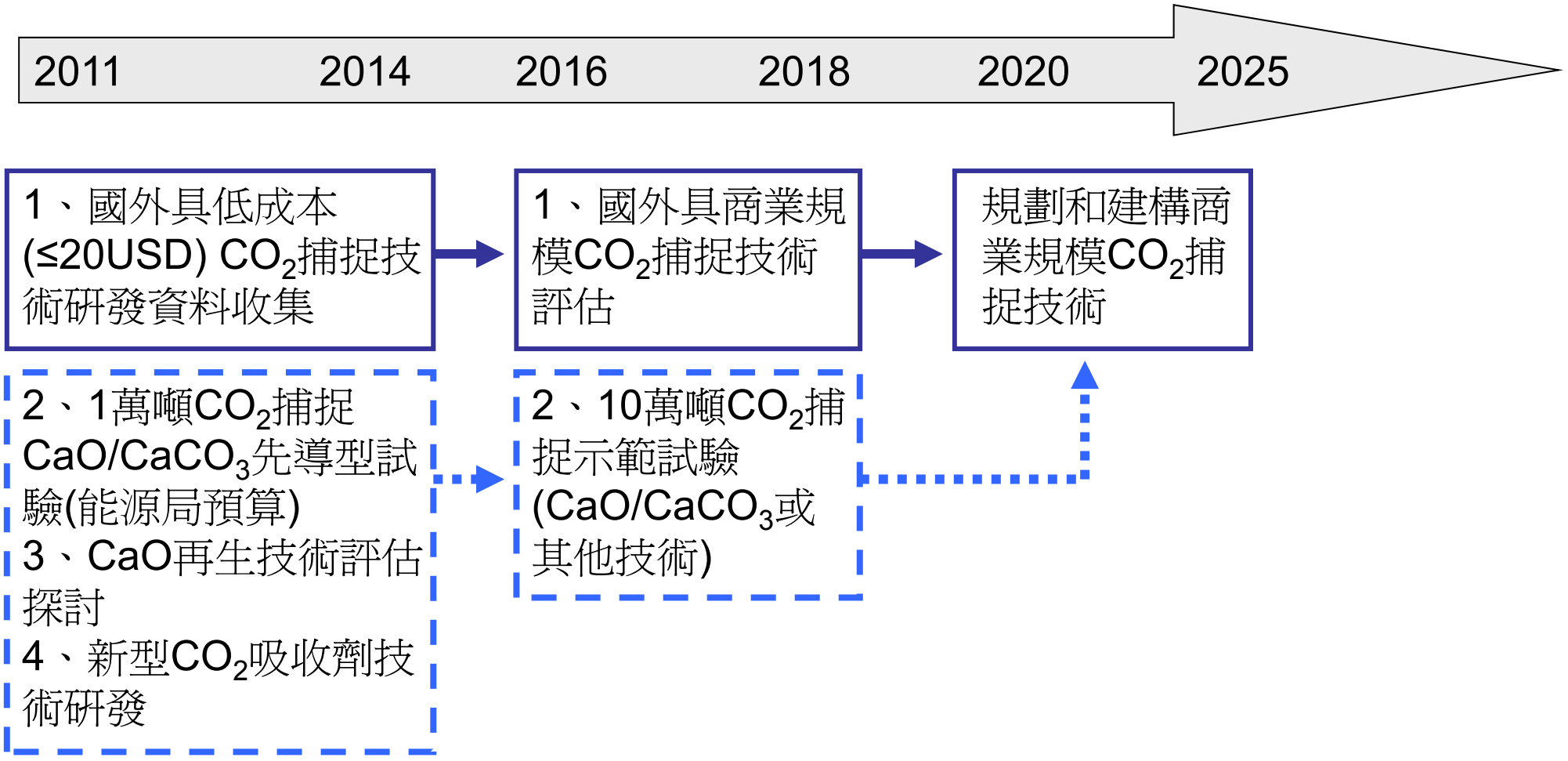
CAP Development Program
Summary Development Plan

ALSTOM

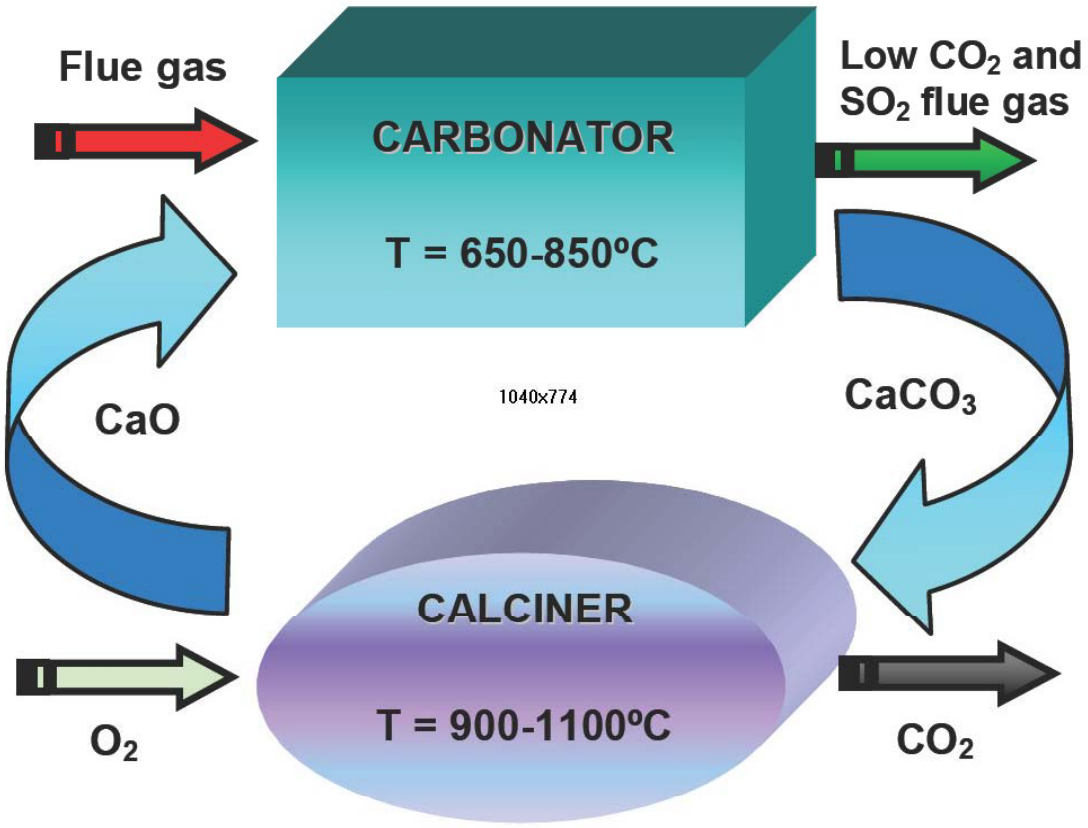


Commercial Deployment in 2015

台電公司CO_2 Capture Roadmap規劃



$CaCO_3$/CaO looping捕捉CO_2原理



$$CaO_{(s)} + CO_2 \underset{calcinatio\ n}{\overset{carbonatio\ n}{\Leftrightarrow}} CaCO_{3(s)} \qquad \Delta H < 0$$

高溫CO_2 Capture 技術

- **碳酸化(carbonation)反應**
  - 放熱反應，合理反應速率環境在650℃以上
- **煅燒(calcination)反應**
  - 吸熱反應，必要條件850℃以上持溫30分鐘，且避免超過950 ℃造成燒結(sintering)劣化，降低吸附活性與容量。

CO_2捕獲試驗示範廠行動規劃

- 源起
  - 經濟部能源局將於FY99起之四年計畫，推動於2012年(FY101)分別建立CO_2捕獲與封存示範試驗廠。
- CO_2來源
  - 大型燃煤發電廠或燃煤汽電廠接引部份煙氣
  - 流量約5,000~10,000nm^3/hr (~2~3MW)，捕獲量約1.0~2.0公噸/hr (CO_2 12%, 90%效率計算)
- 捕獲方法
  - 以工研院發展之$CaCO_3$/CaO Looping為優先選項
  - 結合學界能量之混合醇胺吸收法，或其他具潛力之捕獲技術為次要選項
- 示範試驗場址
  - 台電公司大型燃煤發電廠為第一優先
    - 台中電廠(環差分析作業申請)
  - 民營燃煤電廠
    - 和平電力、麥寮汽電
  - 燃煤汽電共生廠
- 預計經費
  - 能源局預計投入6,000萬元作為建廠經費，不足部份由參與業者分擔。

化學吸收法

Alkanolamine process

$2RNH_2 + CO_2 + H_2O \rightleftarrows (RNH_3)_2CO_3$

$(RNH_3)_2CO_3 + CO_2 + H_2O \rightleftarrows 2RNH_2HCO_3$

$2RNH_2 + CO_2 \rightleftarrows RNHCOONH_3R$

Alkaline salt solution process

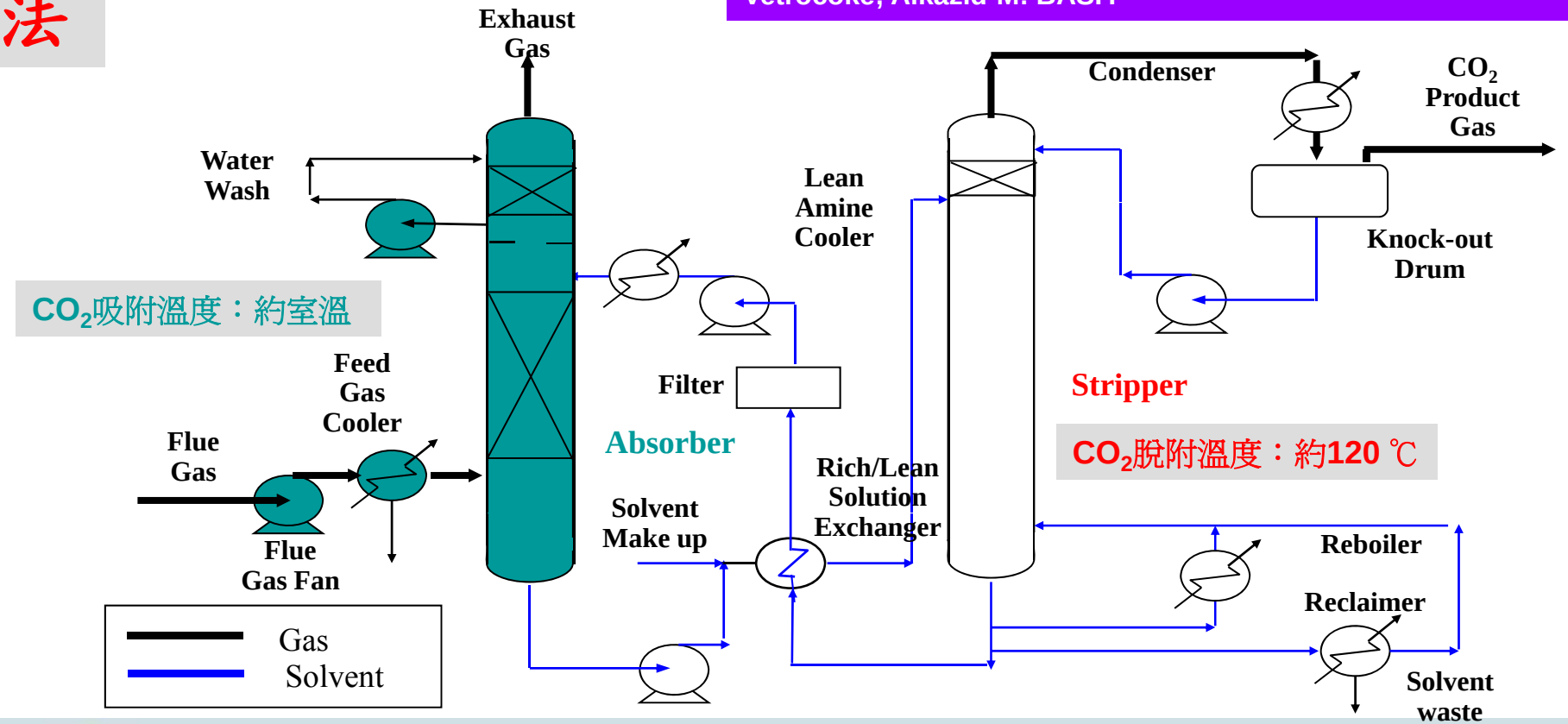
$K_2CO_3 + CO_2 + H_2O \rightleftarrows 2KHCO_3$

Alkanolamine

- 1° Amine (MEA; $HO\text{-}CH_2CH_2\text{-}NH_2$): Gas/spec FT-1, Amine Guard :Dow Chemical; Econamine-FG : Flour Daniel
- 2° Amine (DEA; Diethanolamine): SNPA-DEA: SNEA; ADIP-DIPA: Shell
- 3° Amine (TEA; Triethanolamine): KP-1: Kansai electric power; Amine Guard FS: Dow Chemical; Flexsorb-SE: Exxon; Activated MDEA: BASF; ADIP-MDEA: Shell; SANE-MDEA: SNEA

Alkaline salt solution

- K_2CO_3 solution: Benfield: UOP; Catacarb: Eickmeyer; GV: Giammarco-Vetrocoke; Alkazid-M: BASF.



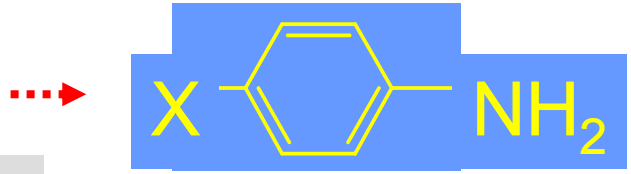
Advanced CO_2 Capture Technologies

Phase 1 (2009-2010) Novel CO_2 absorbent development

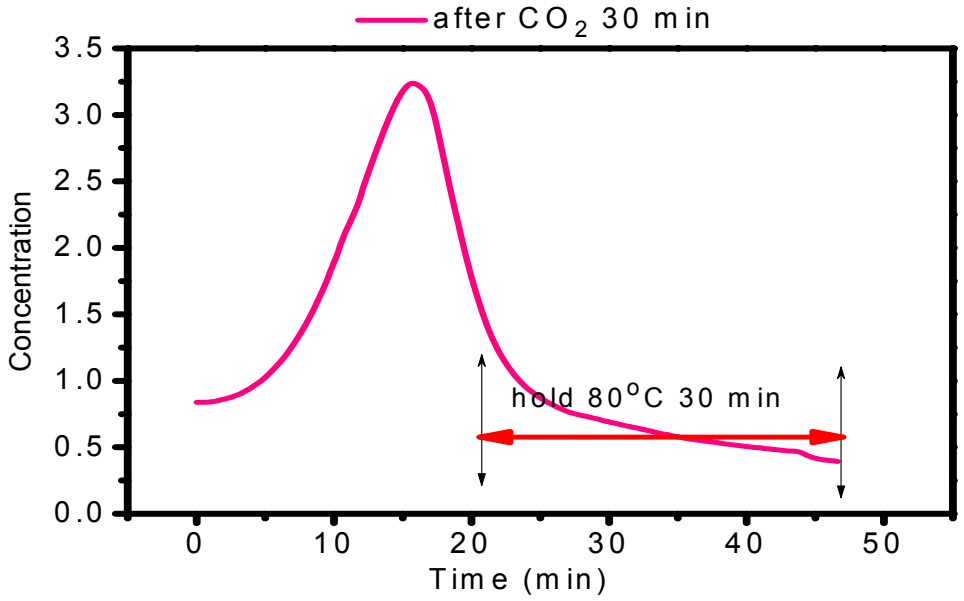
低溫CO_2 Capture 技術

$H_2NCH_2CH_2OH$
2-aminoethanol

CO_2吸附溫度：約室溫
CO_2脫附溫度：約120℃



Aryl amine



降低現行化學吸收法捕獲CO_2成本的主要參數：

1、吸收劑成本花費。
2、二氧化碳脫附能源消耗。
3、系統操作電力消耗。

本計畫初期完成成果：

1、建立固態胺基吸收劑製備技術。
2、具備固定床操作優勢。
3、二氧化碳脫附溫度約為70-80℃，具備與電廠煙氣餘熱整合的可行性。

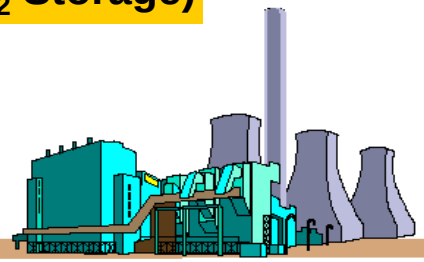
二氧化碳封存計畫執行現況和成果

CO_2封存的方式

生物封存(Biological CO_2 Storage)

Natural Processes

碳酸化封存
(Mineral Carbonation)



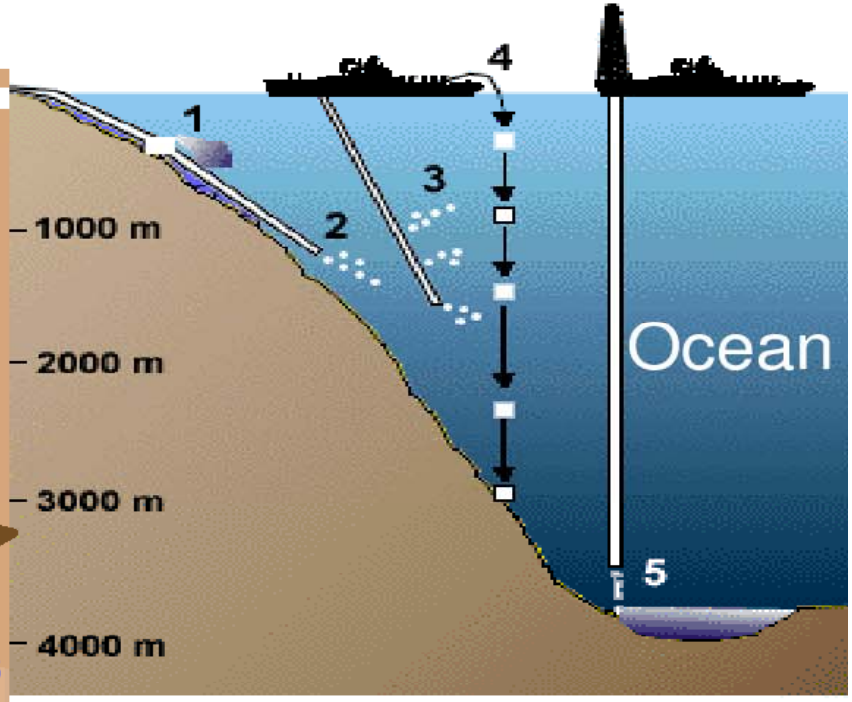
Unminable Coal Beds

Depleted Oil or Gas Reserves

Enhanced Oil Recovery

Deep Saline Formations

地下層封存 (Geological CO_2 Storage)



海洋封存 (Oceanic CO_2 Storage)

不同型態地質封存場的封存潛能

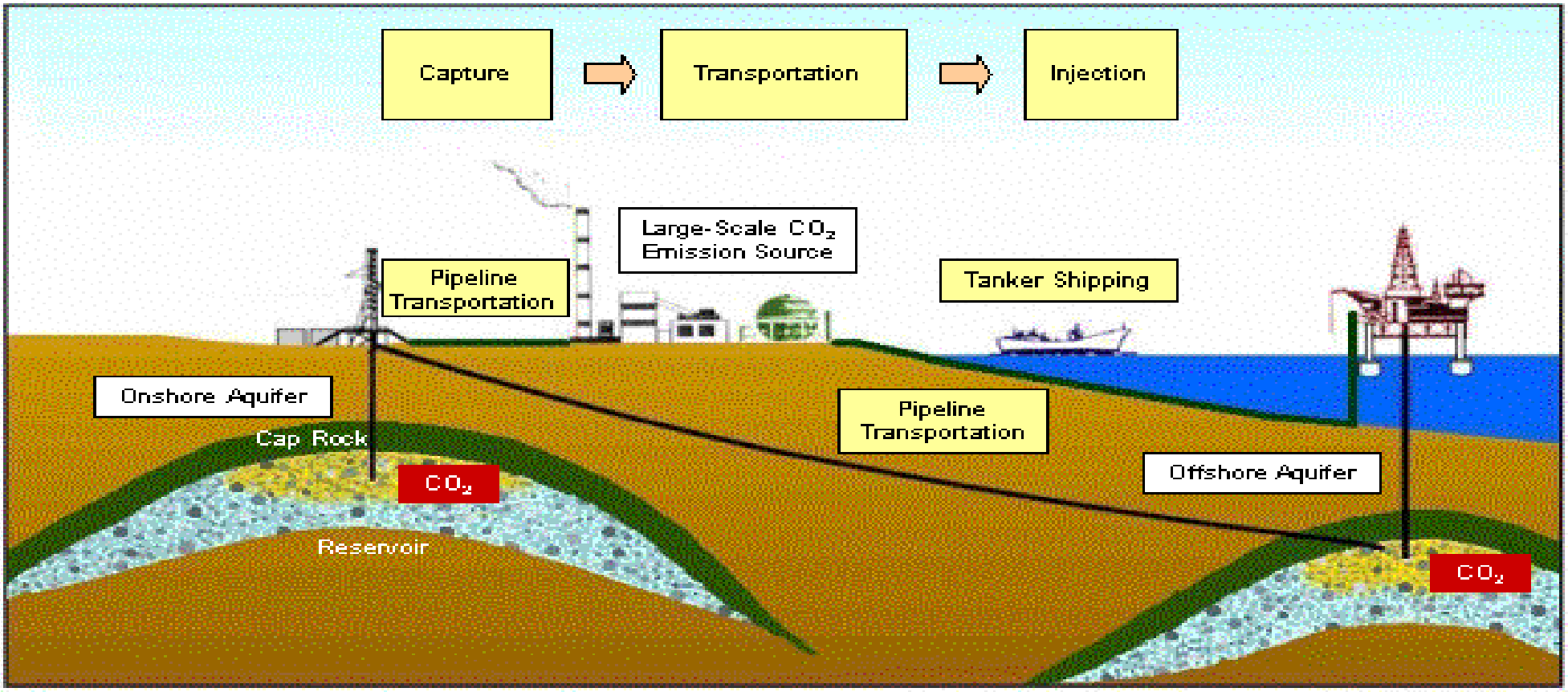
封存場型態 (Reservoir type)	封存潛能估計(保守) ($GtCO_2$)	封存潛能估計(樂觀) ($GtCO_2$)
石油和天然氣田 (Oil and gas fields)	675[a]	900[a]
未開採煤層 (Unminable coal seams)	3-15	200
深層鹽水地質結構 (Deep saline formations)	1,000	～10^4

[a]當新發現的石油和天然氣田可併入計算，則該數值可增加25%的程度。

[資料來源] IPCC Special Report Carbon Dioxide Capture and Storage (2005): Summary for Policymakers and Technical Summary

執行中每年百萬噸規模級的二氧化碳儲存計畫

1、Sleipner計畫 (挪威；1996)：北海海底地下鹽水層封存二氧化碳，1 Mt CO_2/y。
2、Snohvit計畫 (挪威； 2006)：巴倫支海海底地下層封存二氧化碳，0.7 Mt CO_2/y。
3、Weyburn計畫 (加拿大； 2000)：進行EOR，1.5 M CO_2/y。
4、In Salah計畫 (阿爾及利亞； 2004)：耗乏天然氣田封存二氧化碳，1.2 Mt CO_2/y。



陸上地下層儲存二氧化碳

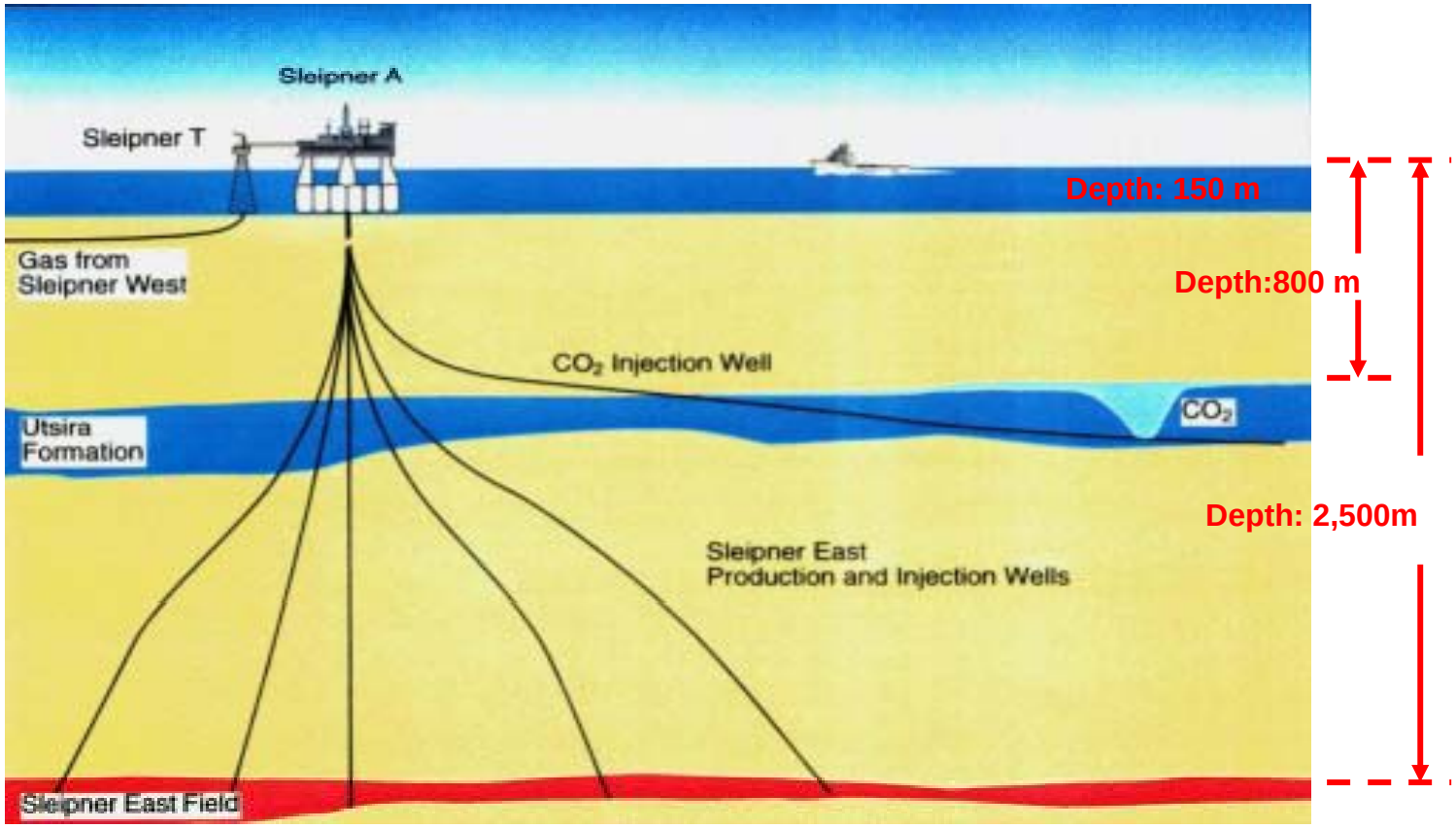
待克服問題

1. 說服大眾接受此處理方式。
2. 台灣本島不易尋獲大規模CO_2儲存潛能場址 。

離岸海底地下層封存二氧化碳技術

1. 目前已有每年1佰萬噸二氧化碳注入海底地下層， 進行儲存的實例。
2. 國際公約已修法通過海底地下層封存二氧化碳技術，為具合法性的二氧化碳減量對策。
3. 依據APEC 的資料顯示， 台灣海域海底地下層具備二氧化碳封存的潛力。

Organization: Statoil; Norway
Operation period: 1996~
CO_2 Injection Period: 20 years (Planning)
CO_2 Injection Rate: 1 Mtonne CO_2/year
CO_2 Source: Natural Gas



New International Rules to Allow Storage of CO_2 under the Seabed

London Protocol; 1972 ratified by 81 countries

↓

1996 Protocol ratified by 30 countries
(replaces the London Convention 1972)

↓

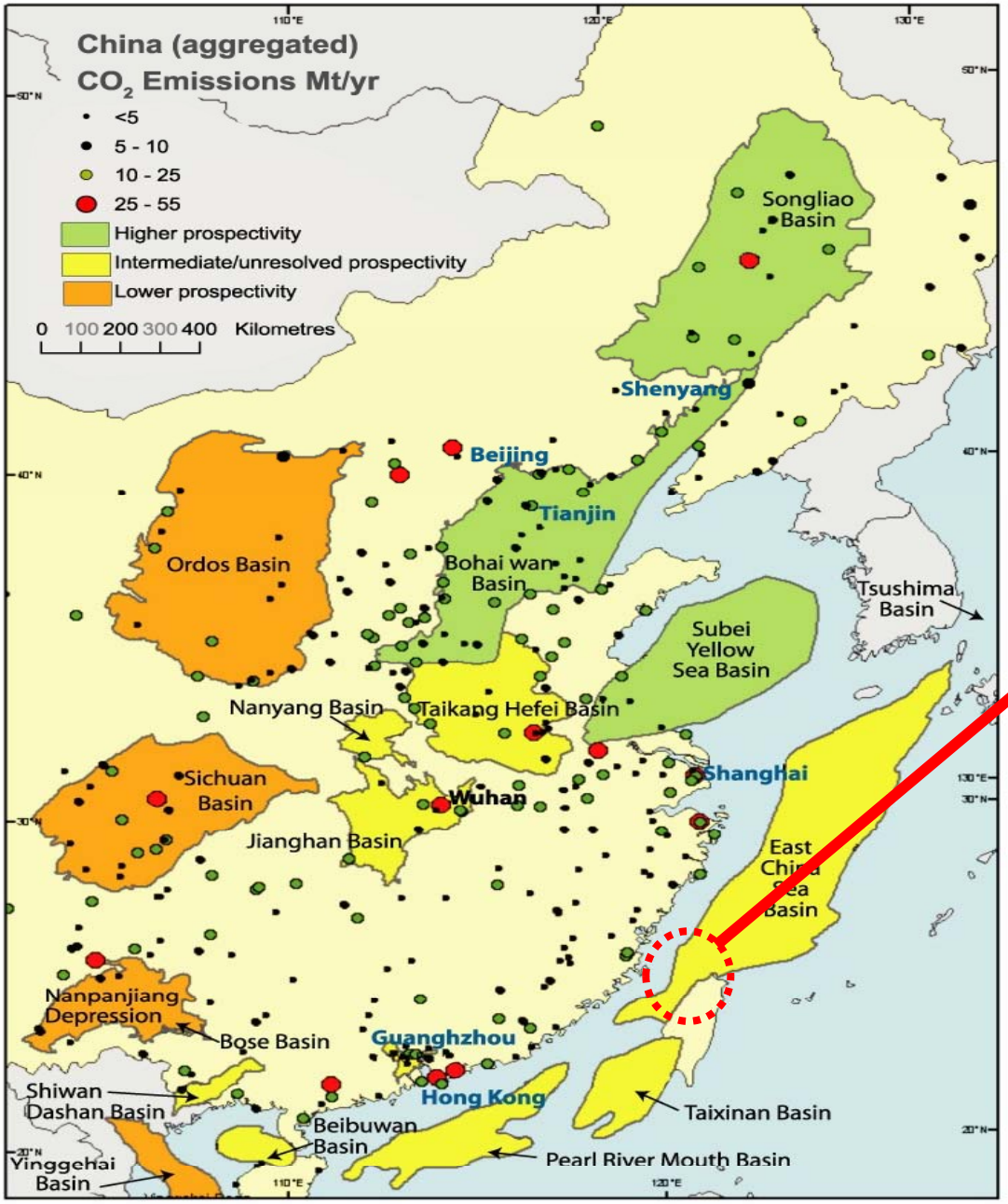
Storage of CO_2 under the seabed
(Amendments were adopted on 2 November 2006 at the First Meeting of the Contracting Parties to the London Protocol)

↓

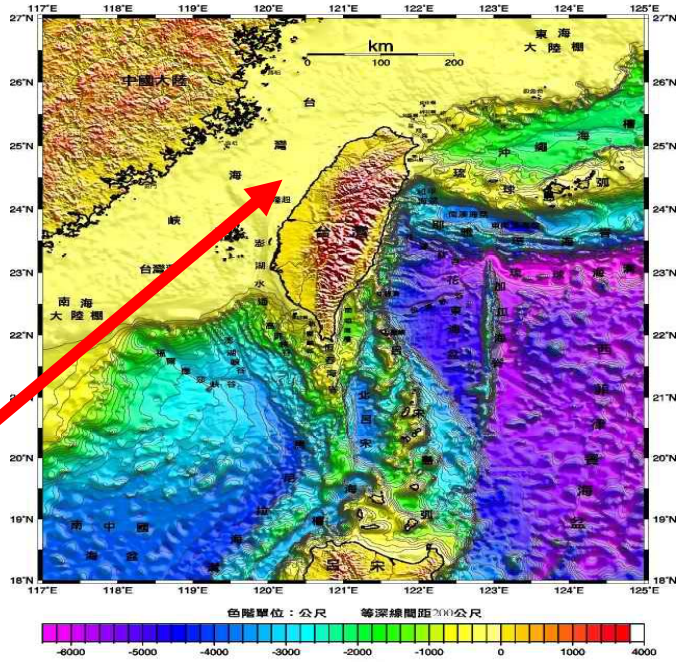
Storage of CO_2 under the seabed was allowed from 10 February 2007
(Under amendments to an international agreement governing the dumping of wastes at sea)

↓

Guidelines on how to store CO_2 in sub-seabed geological formations
(Adoption by the Parties to the London Protocol when they meet for the second session in November 2007)



Sedimentary basins in Asian APEC economies that would potentially be primary targets for CO_2 geological storage based on their proximity to major CO_2 sources.



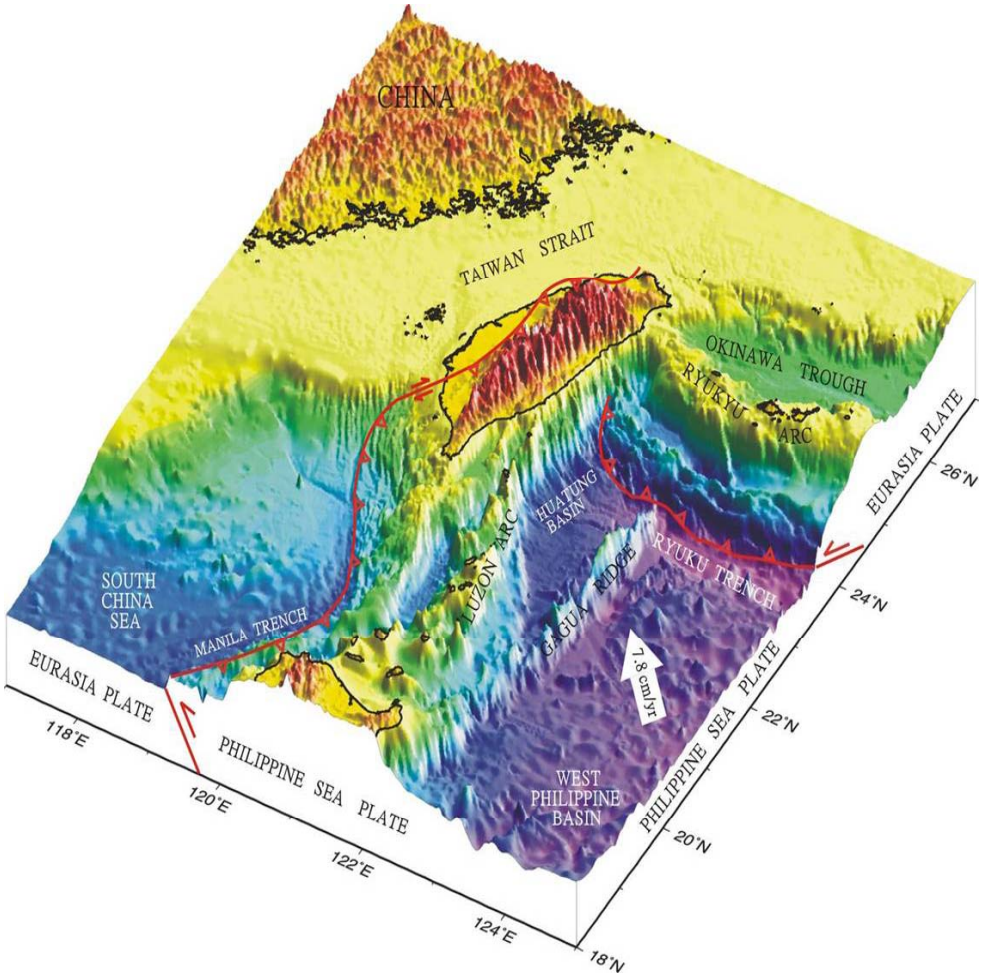
依據能源局初估：台灣西北部海域地下層封存潛能約200億噸CO_2；濱海地區約23億噸CO_2。

(能源局Fy96計畫成果)

離岸海底地下層封存二氧化碳技術

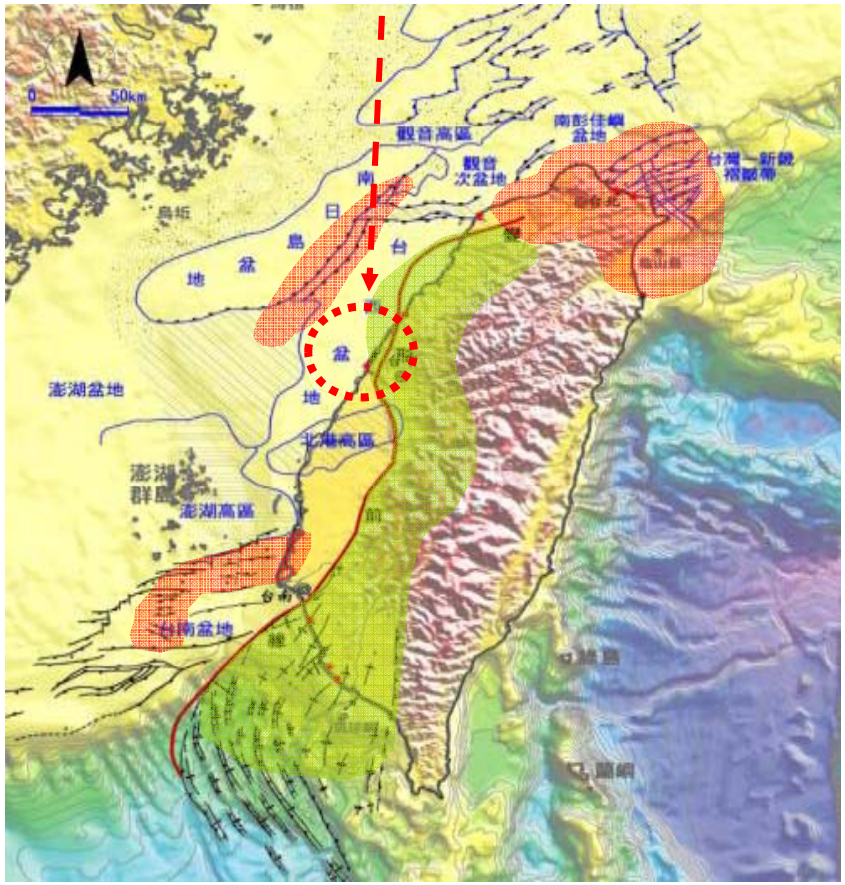
第一期執行目標(2008-2010)

1、進行二氧化碳封存場址的地質調查及場址選擇
2、建立二氧化碳封存潛能的評估能力
3、建立離岸海底地下層封存二氧化碳相關技術和因應對策資料庫



Researching Achievements of Off-shore Geological CO_2 Storage Projects in 2009

Potential site for CO_2 storage with about 4 billion tons capacity

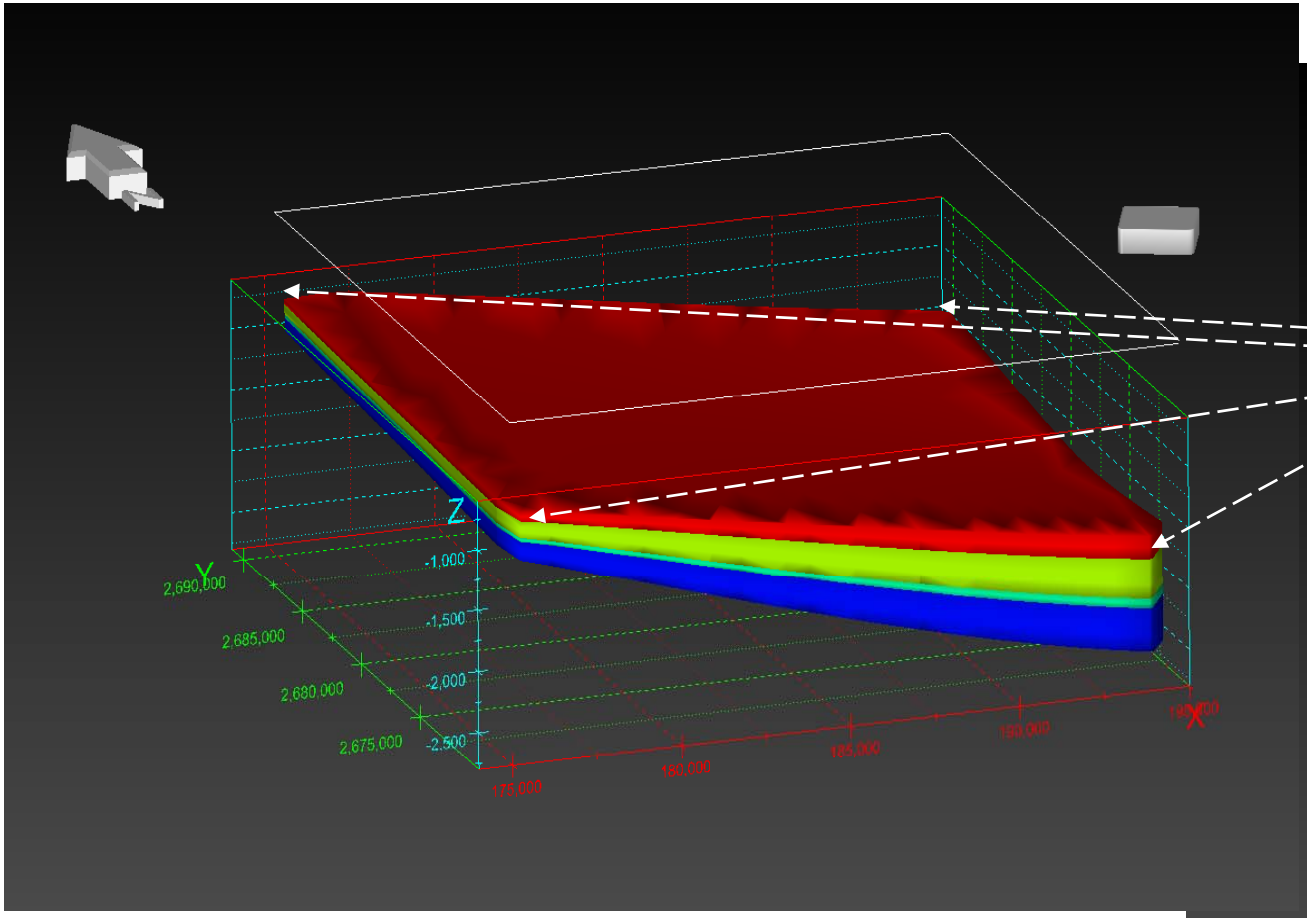


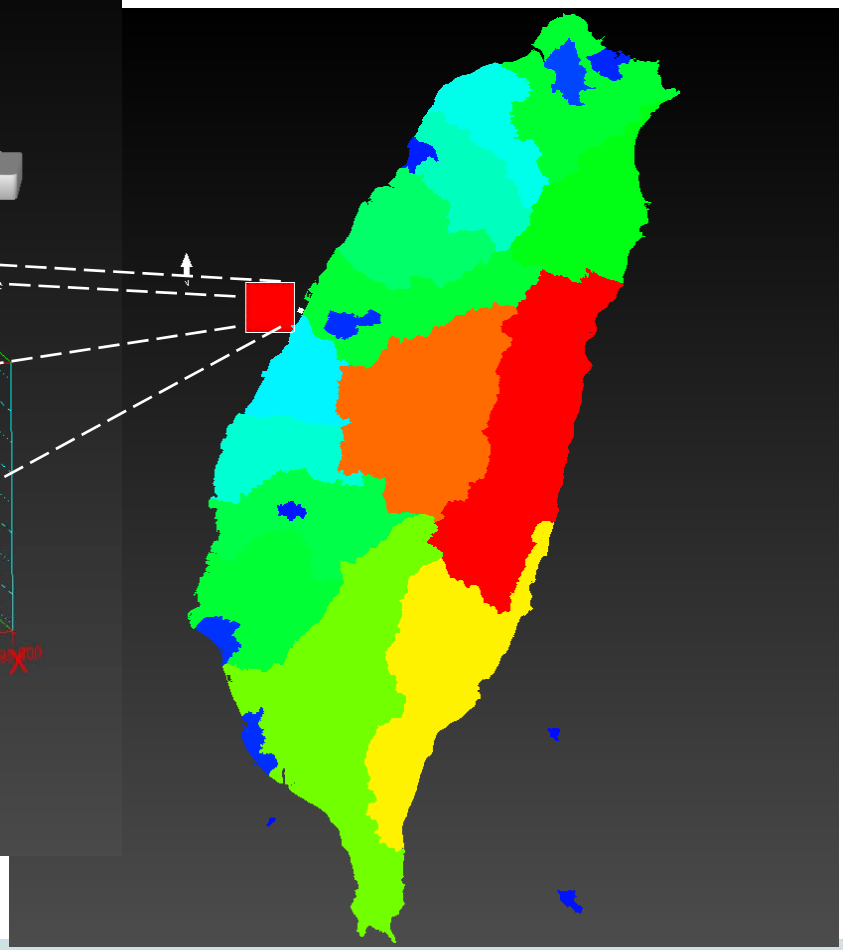
Specific parameters input and Monte Carlo Simulation results at Taihsi basin

parameters	Min.	Most likely	Max.
Vt ($\times 10^3 m^3$)	3,333	4,166	4,999
r	0.693	0.789	0.792
ϕ	0.059	0.119	0.235
ρ (kg m^{-3})	100.0	365.0	500.0
ε (%)	33.3	50.0	66.7
s (%)	30.0	60.0	90.0
Observed Max. capacity	15.49 Billion. tons		
Observed Min. capacity	0.564 Billion. tons		
Observed Avg. capacity	4.518 Billion. tons		
10^{th} percentile	2.168 Billion. tons		
90^{th} percentile	7.359 Billion. tons		

$$Q = (Vt \times r \times f) \times \rho \times (e \times s)$$

Behaviors of CO_2 injected in Tai-Hsi Basin simulated by TOUGH2 and TOUGHREACT Codes



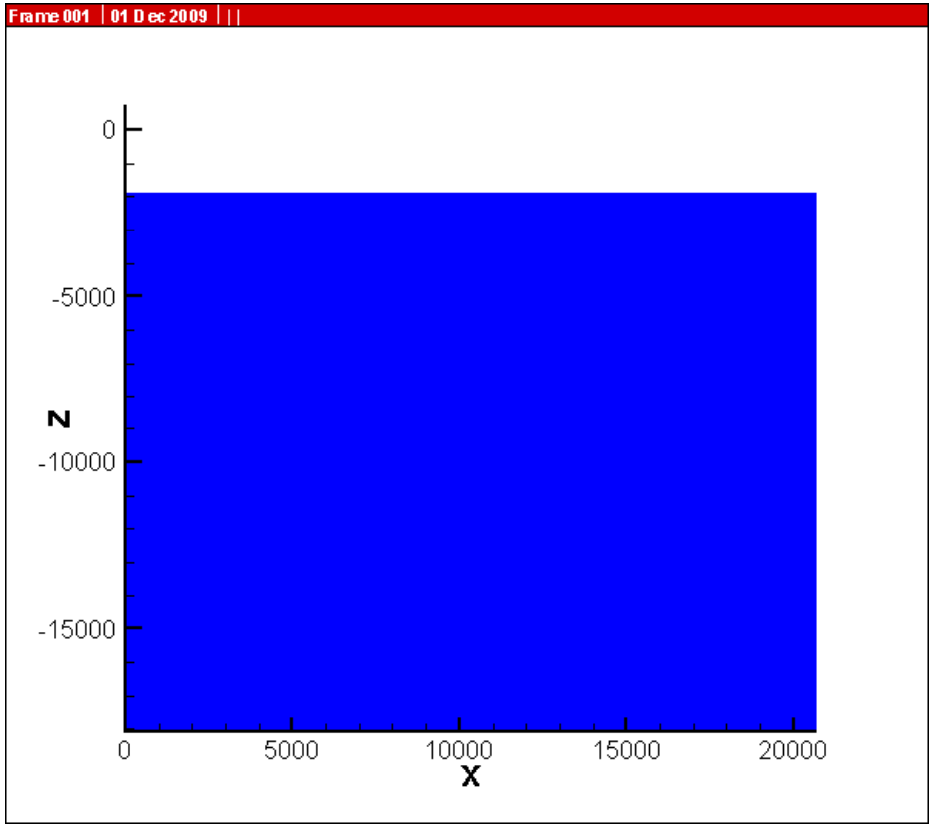


(20Km×20Km×500m)

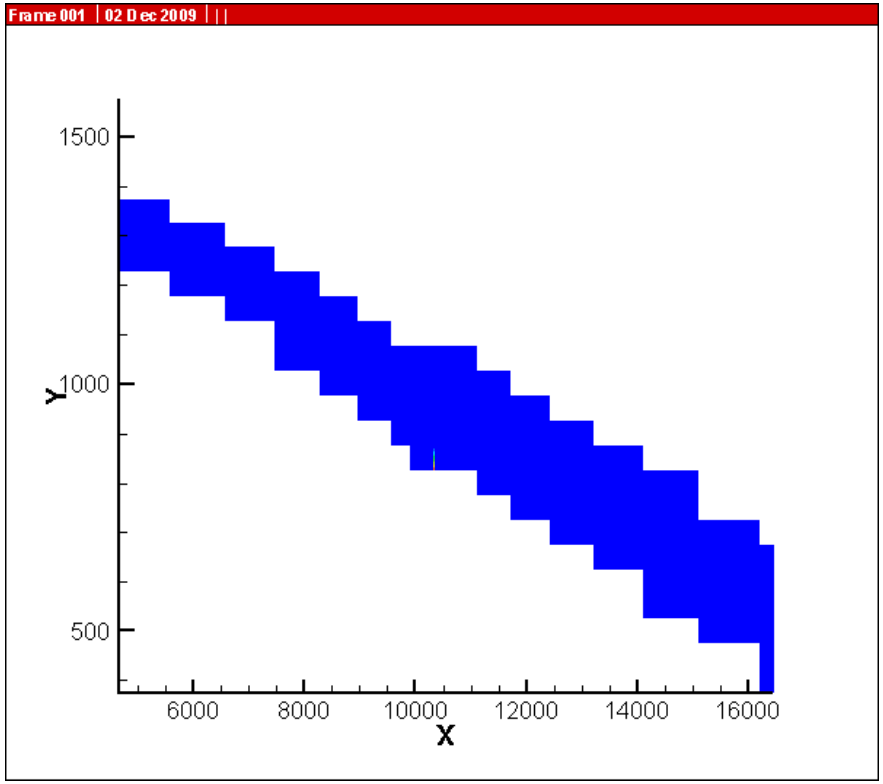
CO_2 Migration

CO_2注入速率:10kg/s
CO_2注入時間:100年
CO_2遷移觀察時間:1000年

★ Top View Animation



★ Side View Animation



Timetable proposed by TPC for Pilot Scale CCS Field Tests

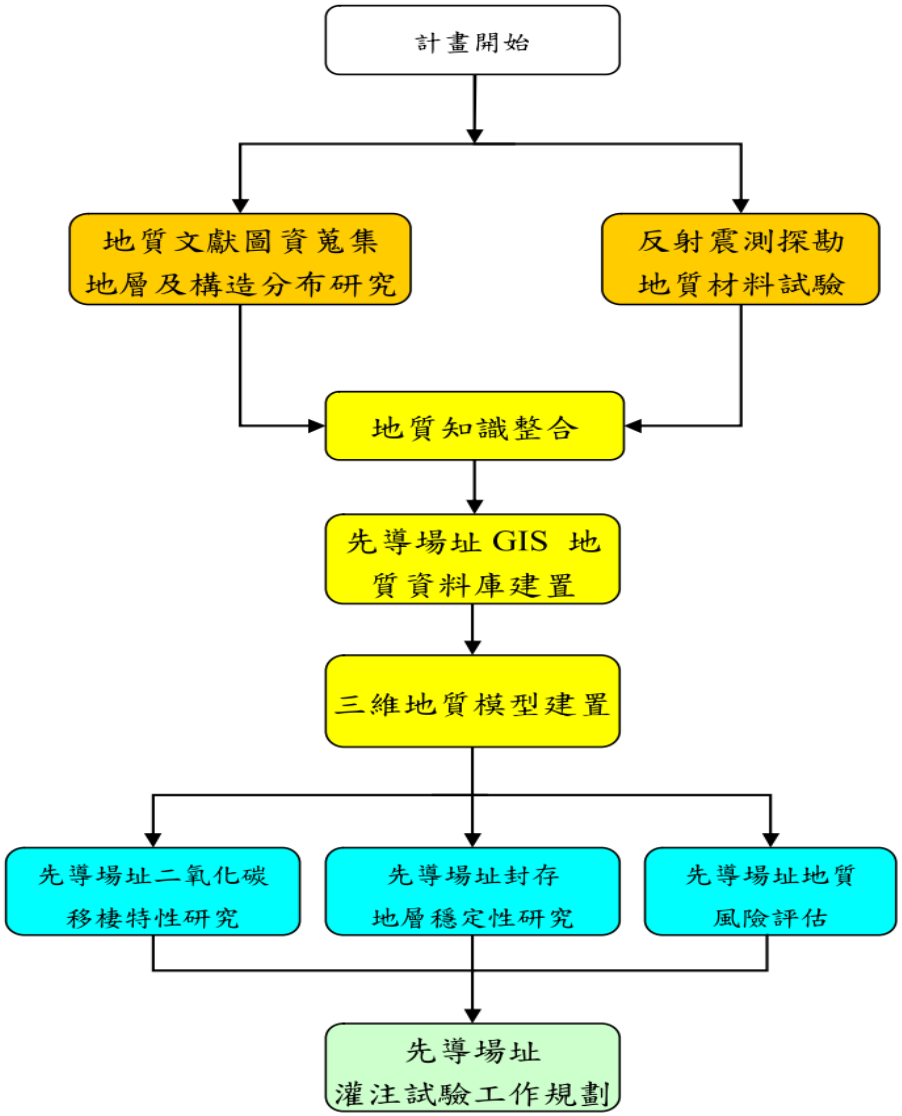
Geological CO_2 storage (TPC)

2009	2010	2011	2012	2013	2014
Potential CO_2 storage site selection.	Characterization and verification of potential site	CO_2 injection well drilling, Core sampling, geological modeling, etc.	Monitoring well drilling (1), verification of geological formation, etc,	Monitoring well drilling (2), verification of geological formation, etc.	Pilot scale CO_2 injection field test
Tai-Chung Coal-fired Power Plant	Design and construction of pilot plant	Installation of CaO/ $CaCO_3$ looping process	Test run of CaO/ $CaCO_3$ looping process	Operation of CaO/ $CaCO_3$ looping process	

$CaO/CaCO_3$ Looping Process (1.0~2.0 tCO_2/hr) (BOE/TPC)

Zhang-Bin Power Plant Reserved Area
(2.2 km x 0.75km)

地下層封存二氧化碳技術研究



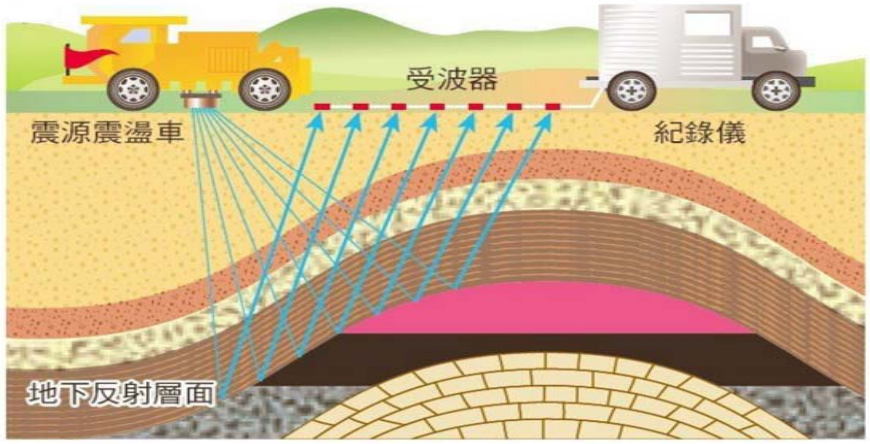
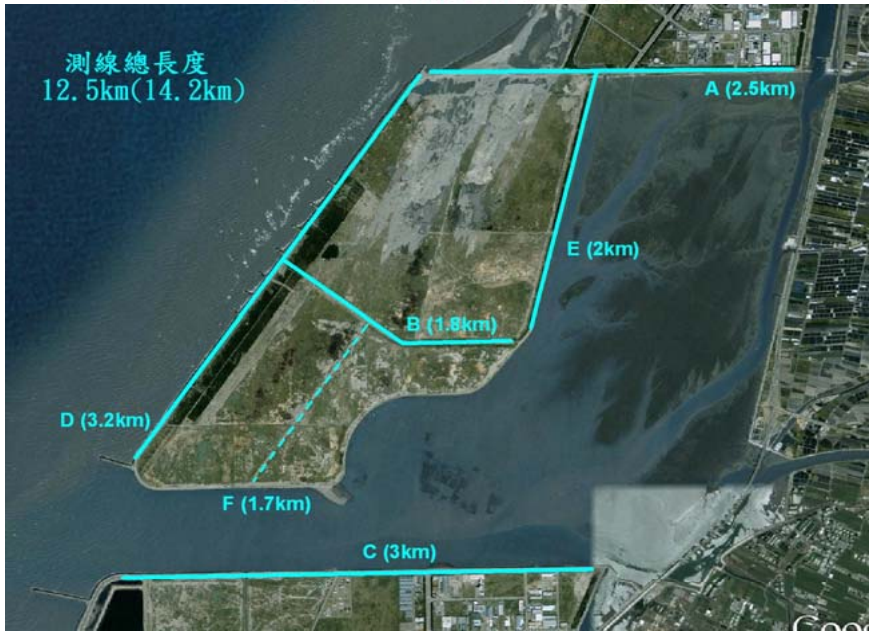
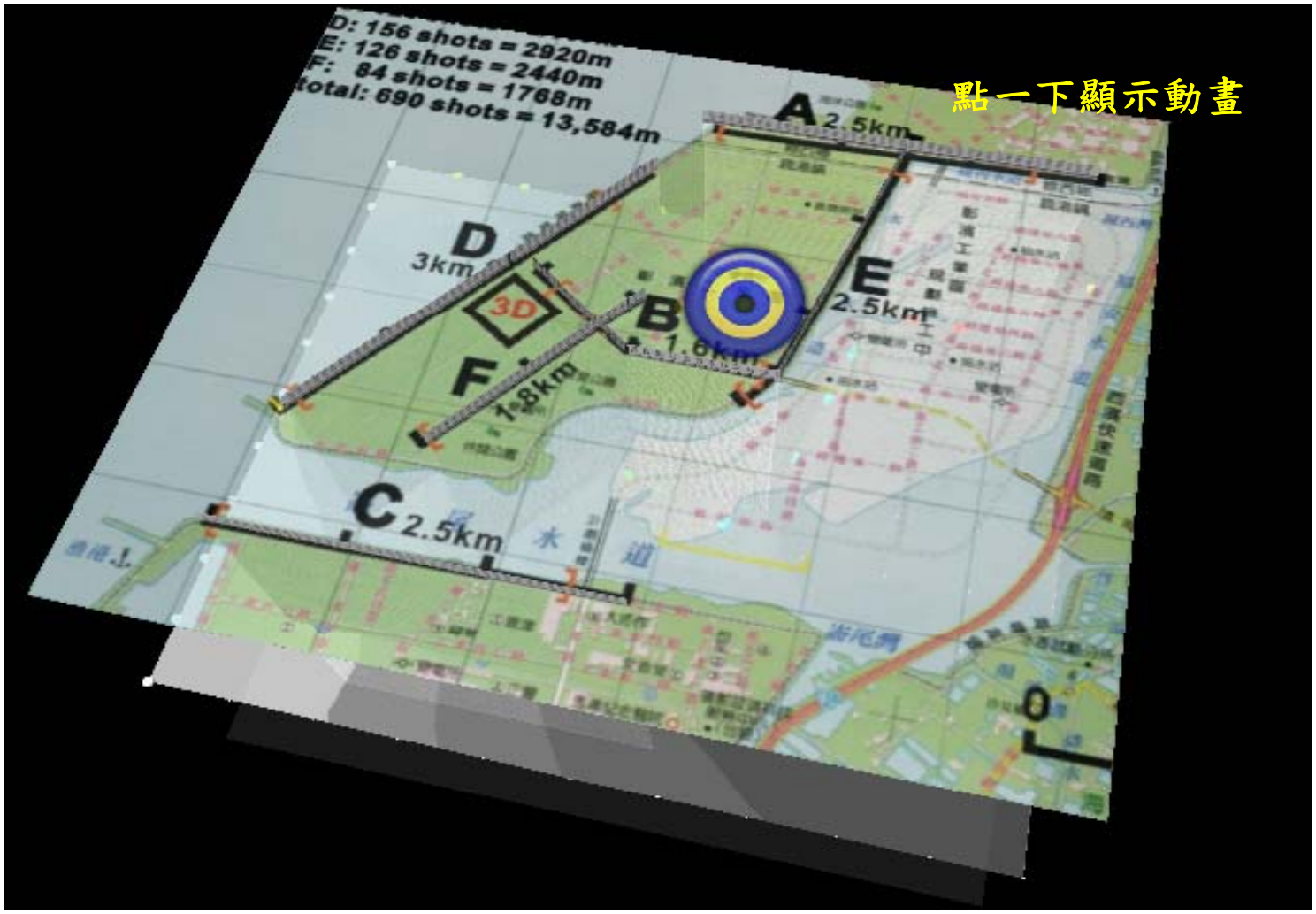


圖 3.13 反射震測方法示意圖



反射震測結果3D展示

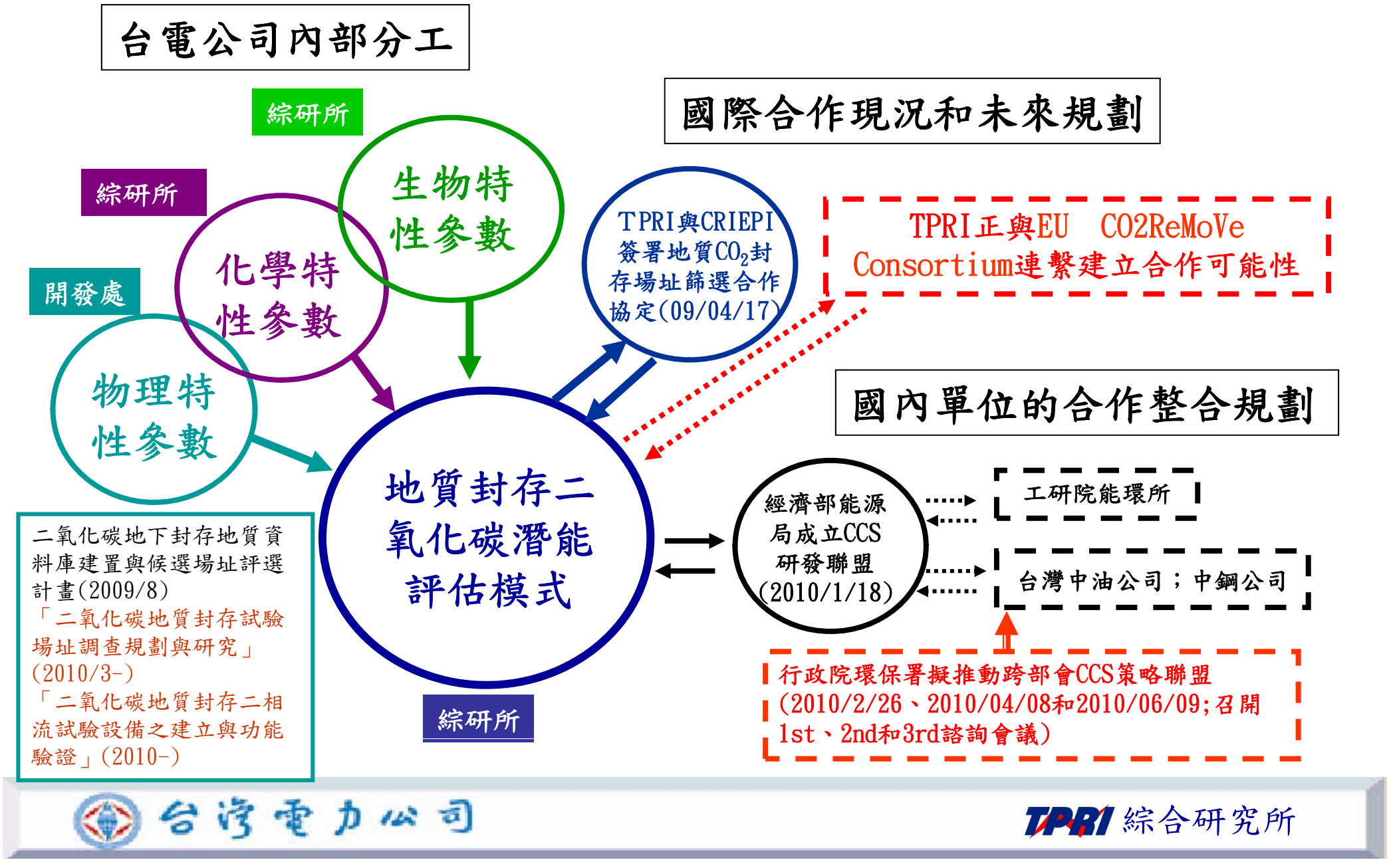


灰階等高線為錦水頁岩可能深度位置 白色區深約2200m 黑色區深約2400 m

台電公司推行CCS面臨實際困難

一、技術發展和實廠示範(Technology Development and Demonstration)
二、資金贊助計畫(Financing Projects)
三、法律和管理架構(Legal and Regulatory Frameworks)
四、公眾參與和教育(Public Engagement and Education)

地下層封存二氧化碳計畫分工和外界合作規劃

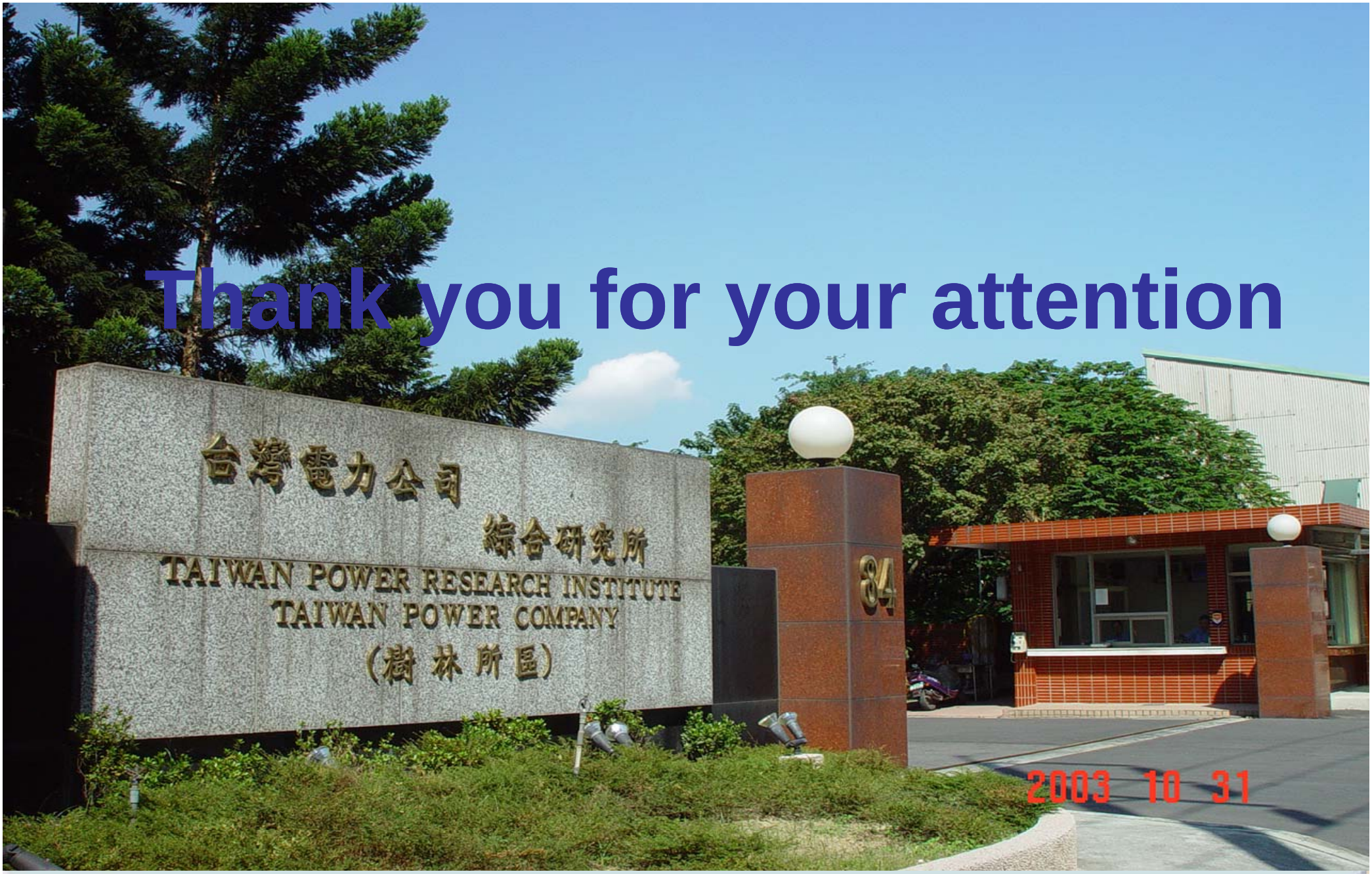


結語

1、經濟部能源局已於2010年1月18日成立CCS研發聯盟，冀望CCS研發聯盟能夠有效整合我國各研發團隊，如期完成CCS商轉目標。

2、商業化CCS相關工作的推行，所需金額龐大，台電公司無法單獨承擔，期待政府可統籌主導。

3、法律管理、公眾參與和教育等事務，需政府各部會專責單位共同參與協助推行。



Thank you for your attention