參加「第六屆碳封存領袖論壇部長級會議」

行政院及所屬各機關出國報告
（出國類別：出席國際會議）

第6屆碳封存領袖論壇部長級會議出國報告

服務機關：經濟部能源局
姓名職稱：陳世南　視察兼臨編科長
出國地區：沙烏地阿拉伯王國
出國期間：**104**年**10**月**31**日至**11**月**07**日
報告日期：**105** 年 **01** 月 **15** 日

經濟部能源局

行政院及所屬各機關出國報告提要

出國報告名稱：第6屆碳封存領袖論壇部長級會議出國報告

頁數 71 含附件：■是□否

出國計畫主辦機關/聯絡人/電話

經濟部能源局/陳世南/(02)27757789

出國人員姓名/服務機關/單位/職稱/電話

陳世南/經濟部能源局/能源技術組/視察兼臨編科長/02-27757789

出國類別：□1考察□2進修□3研究□4實習■5其他

出國期間：104年10月31日~11月07日

報告期間：105年01月15日

出國地區：沙烏地阿拉伯王國(Saudi Arabia)

關鍵詞：二氧化碳捕獲與封存、碳封存領袖論壇

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一、內容摘要

(一)出國目的

1、本次出國主要目之係參加 2015 年 11 月 1 日至 5 日於沙烏地阿拉伯阿拉伯利雅德(Riyadh, Saudi Arabia)王國中心(Kingdom Centre-如圖 1)舉行之第六屆碳封存領袖論壇部長級會議(6th CSLF Ministerial Meeting)，預期就二氧化碳捕獲封存(Carbon Capture and Storage, CCS)技術與各國代表、專家及學者進行討論及意見交流，並藉以掌握國際間 CCS 技術發展之現況與趨勢，拓展國際關係並促進國際合作機會。

2、本屆會議主視覺設計海報，亦以王國中心為背景(如圖 2)，會議主題則涵蓋碳捕獲及封存之技術發展以及相關之推動策略等。除了 CSLF 之 23 個國家會員及歐盟代表外，另有國際大型企業與研究機構之專家學者以及利害關係人(stakeholder)共同出席研討會，並對前述議題展開廣泛之交流與討論。此會議之前 4 天，各國代表、專家及學者針對碳捕獲封存及再利用之大型示範計畫以及技術發展與推廣應用面分別進行專案審查小組會議、技術團隊會議、利害關係人團隊會議、政策團隊會議，以及部長級會議，最後並舉行記者會發布公報。第 5 天之活動主要在介紹地主國沙烏地阿拉伯阿拉伯之碳排放管理以及沙烏地阿拉伯國家石油公司之 CO2-EOR 計畫。

3、我國目前正積極進行 CCS 技術發展及相關政策法規之制定，藉由此項會議之參與，得與國際學者專家討論及分享我國近年來之 CCS 技術發展及研究成果，並進一步瞭解國際間 CCS 技術發展之現況與政策推動之趨勢，以拓展臺灣與國際間之關係並促進國際合作之機會。

(二)參加人員

1、經濟部能源局陳視察兼臨編科長世南

2、行政院原子能委員會核能研究所陳副研究員一順

3、財團法人工業技術研究院綠能與環境研究所歐陽博士湘

(三)行程紀要

1、 會議地點

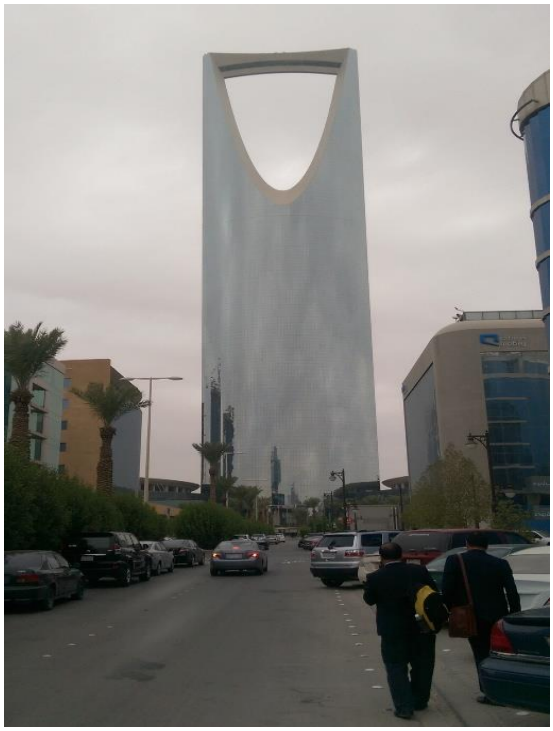


圖 1 會議地點--四季大飯店(王國中心 Kingdom Centre)

圖 2 會議主視覺設計海報

2、行程安排

項次	日期	地點		事由
		出發	抵達	
1	104 年 10 月 31 日	桃園國際機場	阿拉伯聯合大公國杜拜國際機場	啟程/轉機
2	104 年 11 月 1 日	阿拉伯聯合大公國杜拜國際機場	沙烏地阿拉伯阿拉伯利雅德機場	抵達目之地
3	104 年 11 月 1 日 至 104 年 11 月 5 日	沙烏地阿拉伯阿拉伯利雅德		研討會報到及出席會議，並進行討論及意見交流
4	104 年 11 月 6 日	沙烏地阿拉伯阿拉伯利雅德機場	阿拉伯聯合大公國杜拜國際機場	轉機/回程
5	104 年 11 月 7 日	阿拉伯聯合大公國杜拜國際機場	桃園國際機場	回到臺灣

3、會議議程

	Sunday 01 November 2015	Monday 02 November 2015	Tuesday 03 November 2015	Wednesday 04 November 2015	Thursday 05 November 2015
Morning		CSLF Technical Group Meeting	CSLF Policy Group Meeting CSLF Stakeholders Meeting *(continues)*	Ministerial Conference and Roundtable	Visit to Saudi Aramco's Dhahran Facility *(intended for Ministers and Heads of Delegations only)*
Afternoon	Task Force Meetings	CSLF Technical Group Meeting *(continues)* CSLF Stakeholders Meeting	CSLF Policy Group Meeting *(continues)*	Ministerial Conference and Roundtable *(continues)*	Visit to Dhahran *(continues)*

二、會議內容

(一)背景介紹

1、碳封存領袖論壇（Carbon sequestration leadership forum, CSLF）為一國際間推動碳捕獲和封存技術之主要組織，屬於國際氣候變遷領域中之部長級倡議，該論壇於 2003 年 6 月 25 日在美國華盛頓特區成立，旨在透過適宜之技術、政治、經濟、管制規範等環境之建立，加速二氧化碳捕捉與長期安全封存技術之研發活動、示範計畫與商業化運轉之發展，並強調技術之成本效益以及國際間之應用。

2、CSLF 設立之中心思想及具體目之，即透過相關研發示範計畫之推動、周邊議題之探討與合作機制之定期檢視等，加速國際間對碳捕獲封存這項前瞻之減碳技術之應用，以達到能源與環境之永續發展。原有 23 個會員國(含歐盟)，2015 年新增**羅馬尼亞**及**塞爾維亞** 2 國。

3、本屆會議共有美國、沙烏地阿拉伯阿拉伯、荷蘭、阿拉伯聯合大公國及挪威等 5 位部長出席，其他會員國代表及觀察員約 150 位與會。會議分為「計畫互動與評估小組會議(Projects Interaction and Review Team Meeting, PIRT Meeting)」、「技術團隊會議(Technical Group Meeting)」、「政策團隊會議(Policy Group Meeting) 」、「利益關係人會議(Stakeholders Meeting) 」，以及「部長級會議及圓桌會議(Ministerial Conference and Roundtable) 」等 5 項分組會議。

4、本次參加各分組會議之重點包括：瞭解其所推行財務投資增進之計畫，包括提供發展中國家 CCS 計畫項目融資，並透過專業資料庫提供各項 CCS 商業計畫之財務誘因資訊；透過 CSLF 技術藍圖與技術差異分析，確認國際 CCUS 發展方向；瞭解全球 CCS 技術發展之現況與研發課題；拓展國際交流與合作機會。

(二)本屆各項分組會議分述如下：

1、PIRT 會議(Projects Interaction and Review Team Meeting)

(1)此小組會議是此次大會第一個舉行之分項會議(如**圖 3**)，截至 2015 年 10 月份之統計，碳封存領袖論壇共認可有 44 個與 CCS 研發應用直接相關之計畫，分佈在五大洲，其中已有 15 個計畫執行完畢

，行進中之仍有 29 個計畫；最近結束之包括 CGS Europe、CO2CRC Otway Project Stage 1，以及 CCP3 等 3 個計畫。

(2)此次小組會議向大會推薦 5 個新計畫：

A. CO2 Capture Project, Phase 4 (USA)

B. CO2CRCX Otway Project - Stage 2 (Australia)

C. Oxy-Combustion of Heavy Liquid Fuels Project (Saudi Arabia)

D. Carbon Capture and Utilization Project/CO2 Network Project (Saudi Arabia)

E. Dry Solid Sorbent CO2 Capture Project of 10MWe Scale (Korea)

圖 3 CSLF 之 PIRT 會議

2、技術團隊會議(Technical Group Meeting)

(1)本次技術團隊會議首先聽取 PIRT 小組會議推薦 5 項計畫之簡報，經討論投票後同意附屬推薦，並提報大會認可。此外，2015 年 6 月 CSLF 技術團隊於加拿大瑞吉那(Regina)召開之年中會議，另組成一個工作小組(Task Force)探討並排序二氧化碳捕獲封存所需之潛在行動方案；該工作小組業於沙烏地阿拉伯利雅德舉行之年會中報告工作成果(如圖 4)，建議優先考量以下 4 項潛在行動方案，摘述於下：

A. ***Geo-steering and pressure management techniques and applications***：

加速研究地工技術導引之二氧化碳封存層之壓力管理與應用，由碳封存層中將鹽水引出以調節二氧化碳注入之速率及封存層壓力之管控，有實務上之應用需求，應該加速發展。

B. ***Bioenergy with carbon capture and storage (CCS)***：

燃燒生質物來發電或將其轉化成燃料，並與 CCS 技術結合，具有負碳排放(negative carbon emission)效益。

C. ***Offshore EOR***：

目前全球僅有巴西 Lula 一例，但北海國家最近研究顯示，利用捕獲之二氧化碳進行離岸之強化產油，是值得深入研究之可能雙贏議題。

D. ***Improved pore space utilization***：

根據美國能源部研究，單純將二氧化碳注入鹽水質之地層中儲存，估計實際使用到之地層孔隙空間僅佔 1-4%。因此，如果能夠改善或是增加地層孔隙空間之利用，便是極具產業效益之技術開發。CSLF 技術團隊希望國際各研發機構能夠蒐集並分享這方面之資訊。

圖 4 CSLF 之技術團隊會議

(2)此工作小組之其他建議，條列如下：

A、Advanced manufacturing techniques for CCSA technologies

B、Dilute stream/Direct air capture of CO2

C、Global residual oil zone(ROZ) analysis and potential for combined CO2 storage and EOR

D、Study/Report on environmental analysis projects throughout the world

E、Update on non-EOR utilization options

F、Ship transport

G、Definitions, TRL, scales and other (尤其對第二代及第三代之技術發展，有(3)必要釐清盲點及統一定義與用法)

H、Industrial CCS

I、Global scaling of CCS

J、Compact CCS

K、Capturing CO2 from mobile application

(4)此會議中亦對 2013 CSLF Technology Roadmap(TRM)進行檢視。在 2013 年公布之 TRM 報告裏，已將 2020 年訂為第一代 CCS 技術完成示範展示之時間點，2030 年則為第二代 CCS 技術完成示範展示之時間點。兩年後來看，CSLF 技術團隊發現法規之不完備及計畫財務缺乏誘因機制，致使推動 CCS 大型示範計畫之進度緩慢延滯，勢將妨礙 2013 TRM 既定目標之達成。技術團隊因此向政策團隊提出建言，呼籲未來幾年是關鍵時刻，相關政策法規以及財務融資機制應儘快建立完備，以減少推動 CCS 產業化之障礙。

(5)技術團隊會議最後進行團隊主席與副主席改選，挪威將繼續擔任下一任期之技術團隊主席，3 位副主席席次將由澳洲、加拿大及南非派員擔任。最後，這一任期之技術團隊宣佈將於網路上釋出「二氧化碳海床下儲存」(Sub-Seabed CO2 Storage)之專題報告。

(6)另外值得特別一提之專題報告是「離岸海床下二氧化碳地質封存之技術障礙與研發機會」(Technical Barriers and R&D Opportunities for Off-shore, Sub-seabed Geologic Storage of Carbon Dioxide)。此專題研究於技術團隊之年中會議中即曾報告過，在年會期間再度報告，表示 CSLF 技術團隊對這一個議題之重視。目前挪威 Sleipner 與 Snohvit 之二氧化

碳注儲，即為離岸海床下之二氧化碳地質封存，其他規劃中或有興趣之國家，還有荷蘭、英國、美國、日本、韓國、澳洲等國家(如圖 5)。

圖 5 國際上考慮進行二氧化碳離岸海床下地質封存之國家

(7)進行離岸海床下二氧化碳地質封存之優點(如)，擇要摘錄於後：

A、濱海與離岸海床下地層之潛在封存量大。

B、通常土地所有權以及土地管理權責相對單純。

C、離岸地區人口少也較不會影響到淡水水源。

D、可充分利用既有之沿岸設施與設備。

E、適合國家來建置二氧化碳封存場，增加政府收入。

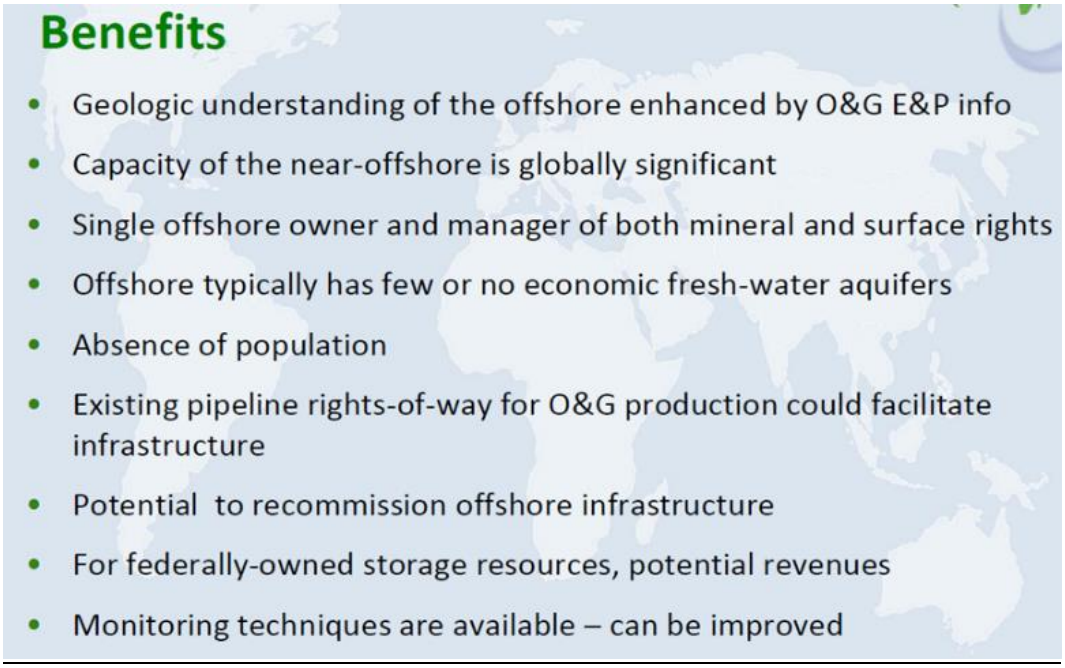


圖 6 離岸海床下二氧化碳地質封存之優點

(8)專案小組認為之挑戰及障礙，則包括：

A、交通運輸以及運轉維護較困難，

B、環境保護易引起爭議，對海洋生態之衝擊不明，

C、二氧化碳之來源(離排放源太遠)

D、風險高，財務融資較難，

E、法規監督管制較難等。

(9)綜觀前述之優缺點比較，同時考量臺灣之情形，包括土地取得之困難、民眾抗爭、環評爭辯不休等，而二氧化碳大排放源及可供做封存之深部鹽水層又均位於西部沿海一帶，建議國內應該深入考量二氧化碳之離岸式、海床下之地質封存。

3、利害關係人會議(Stakeholders Meeting)

(1)此次利害關係人會議分兩個半天舉行(如圖 7)，估計應該是考量不要跟技術團會議以及政策團隊會議在時間上完全重疊，讓與會者及業界代表得抽空出席並參與討論。除了來自臺灣之我們，其他與會者代表之單位包括：

A、United States Energy Association

B、North American CCS Association

C、The Americas, Global CCS Institute

D、Europe, Middle East and Africa, Global CCS Institute

E、Alstom

F、Jupiter Oxygen

G、FERTIL

H、Shell

I、CO2 Capture Project

J、The University of Texas at Austin

K、UC Berkeley Energy and Climate Institute

L、Saudi Aramco

圖 7 CSLF 之利害關係人會議

(2)經過兩個半天之討論，會議主席整理出來之建議，重點描述於下：

A、國際政治領袖必須認知，預計到 2050 年全球將增加 20 億人口，人類之能源供應仍然會相當程度地依賴化石能源之使用。

B、政策擬定者必須認知到，欲降低大氣中二氧化碳之濃度以避免氣候變遷之危機，二氧化碳捕獲再利用與封存(CCUS)是必要之技術手段，否則減碳成本會更高。

C、CCS/CCUS 是低碳能源策略之重要一環，短期內需要政府大力支持相關示範計畫，然後在政策上應給與相同之鼓勵與對待，並提供長期之市場需求訊息。

D、政策擬定者應給與所有低碳或無碳能源供應相同之政策考量。執政者擁有許多行政手段以維繫政策之平等性，例如訂定碳價值(Carbon valuation)、建立清潔生產機制(Clean Development Mechanism)、實施優惠費率(Feed-in-tariffs)、加速設施折舊、投資抵稅、發行綠色債券、設置綠色氣候基金、公-私合夥機制等。

E、政策擬定者應考量建立誘導機制，以鼓勵技術研發之創新，尤其是針對一些具有前瞻性之碳捕獲與再利用之技術發展。

F、中央政府層級及地方政府層級均應考慮政策性之機制，以減少二氧化碳封存之長期與短期之法律責任負擔。例如，有些政府層級便選

擇接受長期之法律責任負擔。這個考量對於採行離岸封存尤其重要；至於 CCS-EOR 型之陸域封存操作方式多係依據油氣產業之土地租約期程來進行，此與所謂封存後之長期法律責任負擔是不一致之。

G、政策擬定者應持續協助大型示範計畫構想能進入「最終投資決定」(Final Investment Decisions)，也應該考量額外之運作機制，來協助降低資本支出。

H、未來在開發中國家進行多元之示範計畫是絕對必要之，CSLF 應該考慮與其他團隊合作來促成此事，並需要就減碳成效與計畫財務如何分攤進行政策性之討論。CSLF 應持續努力，以建立技術面與法規面之能量。

I、CCS/CCUS 之社會宣導以及民眾溝通仍有待加強。

J、CSLF 亦應特別關注 Off-shore CCS 以及 Off-shore EOR with CO2 之發展，以增進對地層如何儲存二氧化碳之瞭解，並評估技術移轉之契機。

K、CSLF 亦應檢視 CCS 應用在燃燒褐煤(Lignite)之減碳潛力或可行性，尤其像羅馬尼亞、塞爾維亞、印度、中國、澳洲都燃燒大量之褐煤。

L、CSLF 可組成專案或工作小組，以探討生質燃料以及與化石能源共燒之減碳機會與面臨之挑戰。

4、政策團隊會議(Policy Group Meeting)

(1)11/04(星期三)一整天都是政策團隊會議，一開始由團隊主席 Mr. Christopher Smith 致開幕詞，接著由地主沙烏地阿拉伯阿拉伯石油與礦產資源部永續顧問 Mr. Khalid Abuleif 致歡迎詞，再來便是會員國代表介紹(如圖 8)。接下來是檢視及確認 CSLF 年中會議之會議記錄以及建議之工作項目、討論新之會員申請案(羅馬尼亞與塞爾維亞)，以及聽取技術團隊之年度報告。後半段之政策團隊會議主要便是聽取各項專案

小組簡報，以及邀請來自 IEA、GCCSI、與 CSLF Stakeholders 之專題報演講。

圖 8 CSLF 之政策團隊會議

(2)有關「加速發展第二代及第三代碳捕獲技術」之專案小組報告中，特別提及當初成立之原由，主要是考量 CCS 之成本，尤其是捕獲之成本，是推動產業應用之最顯著障礙；發展第二代及第三代之碳捕獲技術，以降低 CCS 之成本便成為一個緊要之課題。所謂第二代技術係指仍 TRL(Technology Readiness Level)介於 4(5)-6，目前能專 CCS 計畫進行之鈣迴路碳捕獲技術研發即屬於第二代技術；第三代技術則指 TRL 介於 1-3(4)，例如化學迴路碳捕獲以及酵素減碳技術等。而發展第二代及第三代碳捕獲技術之困難，仍然是在政策及財務支援上之不足；加拿大之小組成員就 35 個利害關係人/團體進行訪談，綜整後之建議如圖 9 所示。

(3)就 CCS 技術發展之角度，2015 年 6 月在加拿大瑞吉那召開之年中技術團隊會議中，便有人呼籲重啟 CSLF 學術研究社群任務小組(Academic Community Task Force)，以整合學術界之研發能量，共同加速碳捕獲技術之發展，並有效降低 CCS 成本。此建議亦值得國內參考，但建議要慎選研究議題，並適度規範工作項目及欲達成之具體目標，以加速研發進程，並避免執行偏差及失焦之情事發生。

Barriers	High priority mechanisms identified in interviews
Lack of a market	• Carbon pricing
High costs	• Government funding programs • Tax incentives for research and development • Operational support programs • Test centers / facilities • Cooperation and knowledge-sharing networks
Technical and operational challenges	• Government funding programs • Operational support programs • Test centers / facilities • Cooperation and knowledge-sharing networks
Insufficient test sites in key geographies/sectors	• Test facilities, ie. Industrial pilots/demos
Storage availability and lack of clear regulations	• Cooperation and knowledge-sharing networks

圖 9 發展 CCS 技術在政策及財務支援上之不足與建議因應之道

(4)現階段推動 CCS 大型示範計畫之困難有二：一是缺乏明確政策與法規；另一個為技術團隊與政策團隊相當關注之議題便是 CCS 計畫之財務準備(Financing for CCS Projects)不足。這個 CCS Finance Task Force 之主席由法國之 Mr. Bernard Frois 擔任。他之報告指出，全球在 CCS 投入之經費遠落後於原來之估算，亟須要在政策面釋出對 CCS 技術之長期需求與支持之訊息；在減碳與能源政策上也應給 CCS 與其他低碳技術(如再生能源)同樣之競爭條件及待遇；短期內應持續支持及建立 CCS 示範廠，以昭公信(如圖 10 與圖 11)。本專案小組具體之建議有 3 點：

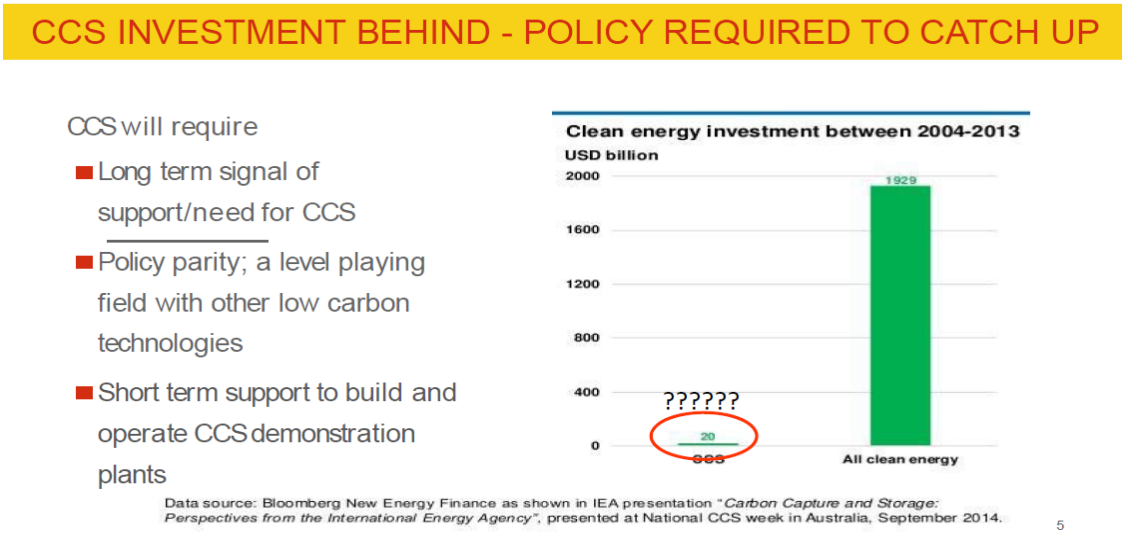


圖 10 推動 CCS 大型示範計畫之缺失及補強措施

A、推動區域性及國際性之合作，帶動大型示範計畫之實施與經驗累積。

B、在碳價制度建立之前，提供政策性之誘因及經費來支持大型示範計畫。

C、進行社會溝通，在鼓吹善用再生能源之餘，說明 CCS 仍然是必要採行之減碳手段，才能達成 2030 年之國家碳排放減量之目標。

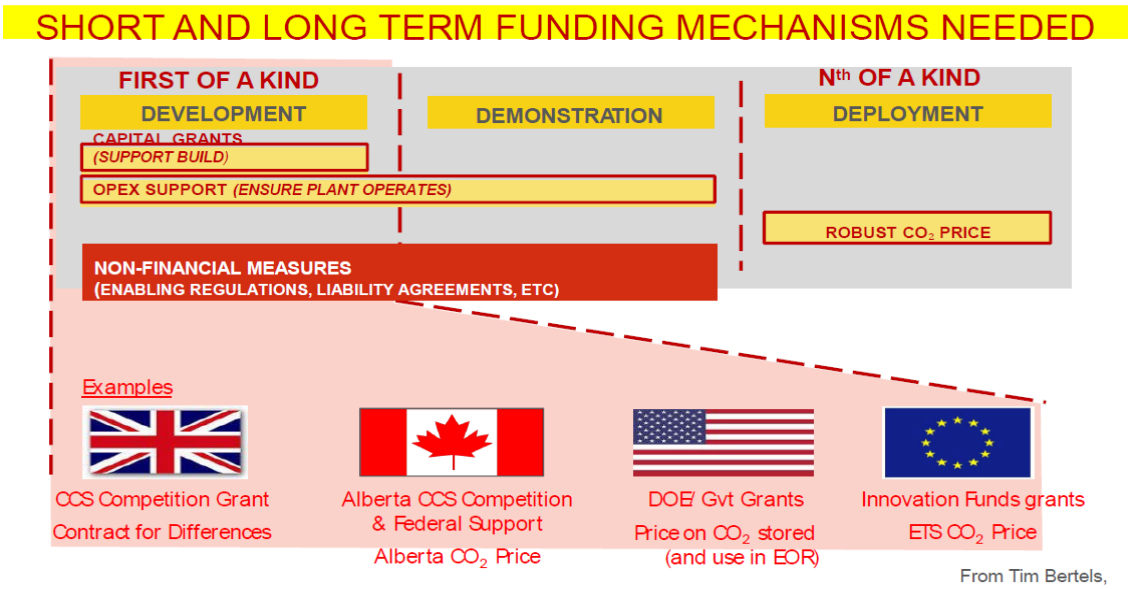


圖 11 發展 CCS 技術/示範/產業需要短期及長期之經費支援機制

(5)國際能源署(International Energy Agency, IEA)亦應邀出席發表演說，其永續能源政策與技術處處長 Mr. Kamel Ben Naceur 表示，即使就燃料轉換很樂觀之情境來看，到 2050 年化石能源仍然會扮演 44%之重要角色，因此要滿足地表升溫不超過 2℃，CCS 將是一個必要之減碳手段。根據 IEA 之研究，對於發電減碳與工業減碳兩大範疇，CCS 將扮演同樣重要之角色；未來全球有超過 2/3 之二氧化碳捕獲來自 non-OECD 國家(如圖 12)。

(6)IEA 之統計資料顯示，包括運轉中、建造中，以及進入投資決策審查階段之二氧化碳捕獲設施及示範計畫，其捕獲總量相當於每年 6,500 萬噸 CO2；而要滿足 2℃之情境，估計 2025 年開始每年需要封存 50,000 萬噸(5 億噸)之 CO2，如何減少兩者之差距，仍有待大家努力。

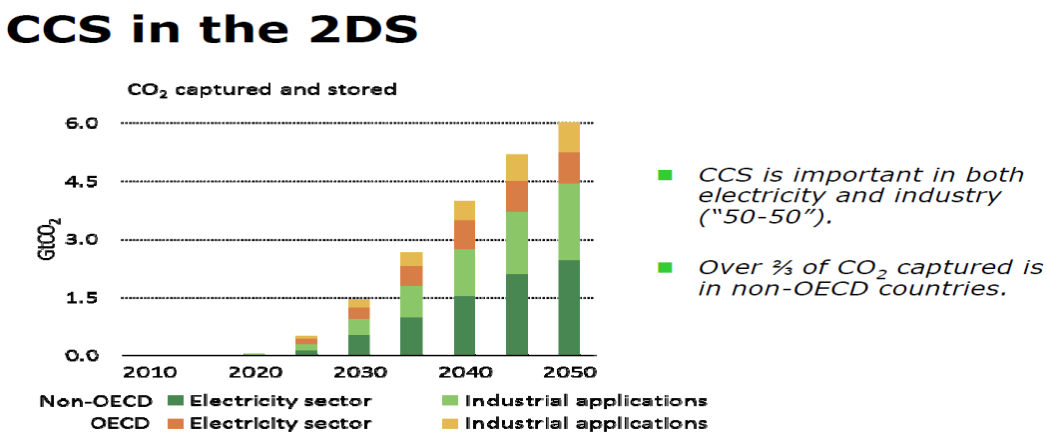


圖 12 CCS 對於發電減碳與工業減碳是必要之手段

(7)國際能源署呼籲，不論是大氣二氧化碳濃度不超過 450ppm 之情境，還是地表升溫不超過 2℃之情境，都意味著到 2050 年全球每年須捕獲封存 50 億～60 億噸之二氧化碳；政府領導人或政策研擬者需要重新思考政策之架構，以推動再生能源之同樣方式來推動 CCS 技術應用之市場。Mr. Naceur 之簡報也提出 IEA 對建構 CCS 產業之長期願景，包括技術發展架構、鼓勵措施架構，以及行政法規之核決架構(如圖 13)；另外，亦提出以下 7 點建議(如圖 14)：

A、導入財務支援機制，鼓勵民間資金投入 CCS 示範計畫以及先期實施計畫。

B、推行政策以鼓勵二氧化碳封存之場址探勘、特性調查，以及場址開發計畫。

C、建立相關法律、規定、及制約條件，並創造多元之財務契機，以要求新建、可作為基載之燃燒化石燃料之電廠，具有擴增及施作 CCS 之能力(即為 CCS-Ready)。

D、證明碳捕獲先導系統在未曾進行示範測試之工業類別之應用。

E、積極加強與社會大眾及利害關係人之溝通，增進他們對 CCS 技術之瞭解，以及推動 CCS 之重要性。

F、持續推動 CCS 之技術研發，提升發電效率，並降低施作碳捕獲之發電成本。

G、鼓勵以大型二氧化碳排放源之地理位置為中心，建立有效之二氧化碳輸送設施。

(7)最後，政策團隊會議無異議地通過**羅馬尼亞**及**塞爾維亞**兩國之入會申請案。

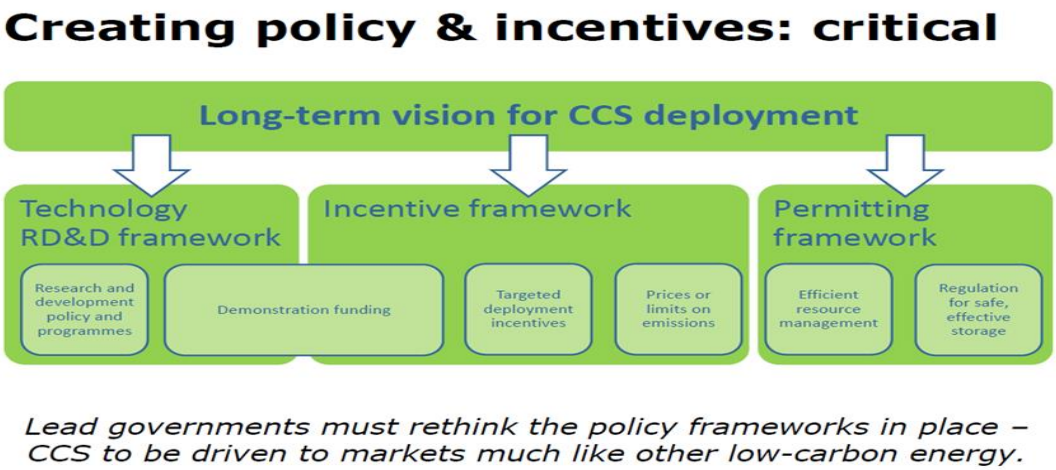


圖 13 IEA 對建構 CCS 產業之長期願景

IEA seven key actions to advance CCS

Lead stakeholder	*Actions*
Government	Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing of projects.
Government	Implement policies that encourage storage exploration, characterisation, and development for CCS projects.
Government	Develop national laws and regulations as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCS-ready.
Industry	Prove capture systems at pilot scale in industrial pilot applications where CO_2 capture has not yet been demonstrated.
Government	Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment.
Industry/R&D	Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles.
Government	Encourage efficient development of CO_2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO_2.

圖 14 IEA 建議對推動 CCS 之 7 項行動方案

5、部長級會議(Ministerial Meeting)

(1)出席本屆會議之部長，計有美國能源部部長 Mr. Ernest Moniz，沙烏地阿拉伯阿拉伯石油與礦產部部長 Mr. Ali bin Ibrahim Al-Naimi，阿拉伯聯合大公國能源部部長 Mr. Suhail Mohamed Faraj Al Mazrouei，挪威石油與能源部部長 Mr. Tord Lien，以及荷蘭經濟部部長 Mr. Henk Kamp 共 5 位(如圖 15)；另外亦邀請國際能源署、聯合國歐洲經濟署之代表，以及沙烏地阿拉伯阿拉伯阿布都拉國王科技大學副校長蒞臨演講。

圖 15 第 6 屆 CSLF 部長會議

(2)本屆會議主題為 Moving Beyond the First Wave of CCSA Demonstrations，後續兩場圓桌會議(如圖 16)討論事項如下：

A、要採取什麼樣之步驟來持續推動 CCS 之大型示範計畫(Steps to Complete and Move Beyond the First Wave of CCS Demos- How Fast is Reasonable。

B、加速 CCS 產業應用之國家策略與國際策略(National and International Policies to Accelerate the Deployment of CCS)。相關之內容與之前 PIRT 會議、技術團隊會議、利害關係人會議，以及政策團隊會議中之簡報與討論非常近似，在此不再贅述。

(3)部長級會議結束後，稍事休息，隨即召開記者會並發布會議公報(Communique)，公報全文詳見**附件一**。

圖 16 第 6 屆 CSLF 部長會議之圓桌會議

三、心得

(一)國際 CCS 發展趨勢

1、2009 年 12 月哥本哈根會議(COP15)提出哥本哈根協議(Copenhagen Accord)，初步達成應控制全球地表溫度上升不能高過 2℃，並要求於 2010 年 1 月 31 日前，世界各國應提出其於 2020 年之量化減量目標。2011 年於南非德班會議中確認 CCS 相關技術議題已獲得國際認可(COP17/CMP.7)， 正式通過將 CCS 之模式與程序納入清潔生產機制(Clean Development Mechanism,CDM)，以加速推動國際間合作減碳。

2、根據 Global CCS Institute(2014)之統計資料，國際間大規模二氧化碳捕獲與封存整合計畫計有 60 個。有鑑於 CCS 技術商業化之急迫性，先進國家多投入資源，期以支持技術產業化所需之商轉等級示範應用，分述如下：

A、歐盟 NER300 支持之 12 個 CCS 應用計畫。

B、美國能源部推動之 7 個區域夥伴聯盟(Regional Partnerships)之 CCS 示範試驗，投入 4.5 億美元進行 CCS 示範試驗，目前已邁入第 3 階段，並有數個大規模之地質封存注儲試驗正在進行。

C、澳洲亦投入約 20 億美元於 CCS 旗艦計畫，預計興建 2 至 4 個整合型 CCS 示範廠，澳洲政府特別成立 CO2CRC 組織，結合產學研之力量一齊推動 CCS 之技術發展與應用。

D、日本則已完成小規模地質封存前導計畫(Nagaoka Project)，並與產業共同成立「Japan CCS Company」來進行大規模之 CCS 整合計畫，其中 Tomakomai 計畫即挹注超過 2 億美元之經費，預計將鄰近鋼鐵廠所捕獲下來之二氧化碳注儲到海床下地層，另在監測及數值模擬技術亦投入約 1.5 億美元。

E、南韓則於 2010 年 7 月起，宣布未來 10 年內將投入 19.2 億美元於 CCS 之技術發展。

F、中國大陸「863 計畫」在 2008 ~ 2010 年針對 CCS 技術投入約 0.5 億美元扶植 CCS 產業，亦積極與美、歐、日、澳等國家合作發展

CCS 技術。中國最大之煤礦生產商神華集團在內蒙鄂爾多斯建立煤液化工廠，每年灌注約 1 百萬噸之二氧化碳至深部鹽水層。

(二)碳封存之關鍵技術

1、碳封存之相關技術，雖已在石油氣開採工業應用許久，但其僅為增加油氣生產為主，注入之二氧化碳並非以永久封存為目的。為長期封存二氧化碳，則必須考慮注儲安全、預防洩漏，以及可能衍生之風險議題。碳封存之關鍵技術包含：「場址封存量評估」、「蓋層完整性評估」、「CO_2 團塊移棲模擬」、「量測/監測/確認 (Measurement/ Monitoring/ Verification，MMV) 」、「風險評估」等。

2、場址封存量評估：

國際間已有如美國能源部(US DOE)、澳洲(CO2CRC)及日本 RITE 等提出評估方法，各封存量評估方式雖然依尺度不同而有不同之算法，但基本原則不外乎考慮封存層體積、地層孔隙率、超臨界二氧化碳流體密度性質、地層可儲存效率等因子，然後予以相乘，即可得場址之封存量。封存量評估與地層參數、二氧化碳特性、封存效率等參數有密切關係，若欲提高場址封存量評估之準確性，對於目標封存場址之地質特性必須有充分之瞭解並且詳細蒐集場址之各項封存參數，包括相關之室內與現地試驗數據，方可獲得較可信之封存量評估結果。

3、蓋岩層完整性評估：

主要係評估在灌注壓力下是否會造成蓋岩層之破壞，進而導致儲存之二氧化碳穿過蓋岩層向上移棲，或因蓋岩層存在垂直且連通之裂隙，而形成洩漏風險。另外，對岩體進行二氧化碳灌注會導致其上蓋層之孔隙壓力增加，進而降低有效應力之數值，使得應力莫爾圓向破壞包絡線逐漸移動，最終造成蓋層之破壞。

4、CO_2 團塊移棲模擬：

碳封存計畫不論在時間或空間尺度上，皆難以透過室內或現地試驗得到驗證，因此欲評估 CO_2 團塊之移棲行為，通常會採數值模擬手段進行多情境分析，以評估碳封存之效益及安全性。TOUGH2 為國際

上常採用之分析程式，TOUGH 係 Transport of Unsaturated Groundwater and Heat (非飽和地下水流及熱流傳輸) 之縮寫，可用於模擬一維、二維和三維多孔或裂隙之多相流(Multi-phase)、多成分(Multi-component)及非等溫(Non-isothermal)之水流及熱傳數值模擬程式。模式參數主要為滲透性相關參數，為考慮超臨界二氧化碳取代原地層孔隙內之鹽水，故需要有相關二相流試驗參數。

5、量測/監測/確認：

二氧化碳封存計畫實施灌注量測、安全監測以及驗證工作(Measurement, Monitoring and Verification, MMV)之主要目的，係藉由該等作業項目得到之成果，來評定地質封存計畫之執行成效。「量測(Measurement)」及「監測(Monitoring)」，係確保實施計畫之安全性與完整性。「驗證(Verification)」則藉由比較預測目標與實際施行之結果，來檢視計畫施行之成效。

6、風險評估：

包括地面設施操作安全風險、灌注誘發地震風險、地層洩漏風險、汙染地下水層風險與洩漏造成環境風險等等。一般而言，社會大眾最關心之就是地層洩漏風險以及灌注誘發地震風險，包括灌注井與鄰近既有廢棄井間可能出現之洩漏、灌注壓力增加造成蓋岩層破裂或鄰近斷層錯動之風險。先進國家已有地方民眾對二氧化碳地質封存之安全性存有疑慮之報導，國內亦有類似之民間反應出現，二氧化碳地質封存之概念與風險評估，以及相關之教育宣導與民眾溝通，將是後續工作之重點。

(三)我國減碳現況

1、依據國際能源總署 IEA(2012)之能源使用二氧化碳排放量統計資料顯示，我國 2010 年二氧化碳排放總量為 270.2 百萬公噸，占全球排放總量之 0.89%，為全球排名第 20 位，至於每人平均排放量則為 11.66 公噸，全球排名第 19 位。另根據國際碳監測行動組織(Carbon Monitoring for Action, CARMA)2009 年統計資料顯示，就單一電廠而言，我國台

中電廠碳排放量為世界第一，麥寮電廠則為世界第八。以上數據均顯示我國為全球高排碳量之國家。

2、「京都議定書」以 2008 至 2012 年為減量時程，要求聯合國氣候變化綱要公約國家將溫室氣體排放總量減至比 1990 年時少 5.2%(平均值)。我國行政院為推動節能減碳，於 2008 年 6 月核定「永續能源政策綱領」，同年 9 月通過「永續能源政策綱領－節能減碳行動方案」；續於 2009 年通過「國家節能減碳總計畫」及其 10 大標竿方案、35 項標竿型計畫，據以推動我國節能減碳方案。根據「國家節能減碳總計畫」訂定之減碳目標：「全國二氧化碳排放減量，於 2020 年回到 2005 年排放量，於 2025 年回到 2000 年排放量」。研究指出，2020 年我國二氧化碳基線排放量將達 390~433 百萬噸， 若要回到 2005 年之排放水準(即 244 百萬噸)，仍有巨額減碳缺口(差距為 146~189 百萬噸)。

3、經由 2013 年第 5 屆及 2015 年第 6 屆 CSLF 部長級會議中技術團隊與政策團隊會議之討論，加上 IEA 對國際減碳需求及技術發展之趨勢分析觀之，CCS 技術已確定需要作為重要之減碳手段，方有可能達到地球表面升溫不超過 2℃之情境目標。我國立法院於 2015 年 6 月 15 日三讀通過「溫室氣體減量與管理法」，環保署亦於同年 8 月份提出 INDC 碳減排目標：相對於 2005 年之碳排放量，2030 年減少 20%，2050 年減少 50%。既然政府已於國際上宣示我國之減碳決心與目標，接下來便亟須各界凝聚共識，建言政府並落實 CCS 減碳技術與產業發展之決心。

(四)沙烏地阿拉伯之 CCS 活動(Overview of CCS Activities in Saudi Arabia)

1、沙烏地阿拉伯雖是產油大國，長久以來亦非常重視環境議題及保護之問題，近年來致力於降低產油、煉油、能源生產及能源耗用上之二氧化碳排放，主要之工作分為 4 個部分：(1)Gas Flare Reduction，(2)Energy Conservation，(3)Renewables，(4)Carbon Management。沙烏地阿拉伯是產油大國，煉油產業是其工業之重要一環，煉油廠燃燒廢氣非常普遍，夜空衛星照片顯示處處紅光點點，形成嚴重之空氣污染；沙烏地

阿拉伯自 1980 年代開始整治廢氣燃燒問題，80 年代末期成功減少了 95%之煉油廢氣排放，2000 年推動另一波減排計畫，將減排比例提到 98%，2012 年再啟動 Near Zero Flaring 計畫，目前已達到 99.5%之目標。在推動能源節約上，主要鎖定工業節能、住商節能，以及陸上運輸節能。在能源安全方面，沙烏地阿拉伯致力於提升能源效率並大力推動太陽光電，同時亦籌建 1 座核能電廠。

2、沙烏地阿拉伯亦展示 Carbon Management 計畫，其中包括兩個研究中心，一個是沙烏地阿拉伯國家石油公司(Saudi Aramco)之 KAIST CO_2 Management Center，另一個是 KACST-Technology Innovation Venter on Carbon Capture and Sequestration，兩個中心之研發重點與主題如**圖 17** 所示。

圖 17 沙烏地阿拉伯阿拉伯兩個與 CCS 相關之研究中心

3、沙烏地阿拉伯之 Uthmaniyah CO2-EOR Demonstration Project(如圖 18)於 2013 年成為 CSLF 認可之計畫。此計畫係沙烏地阿拉伯之第一個 CO2-EOR 計畫，每年從 Hawiyah 天然氣田捕獲 800,000 噸之二氧化碳，用管線輸送到相隔 85 公里之 Uthmaniyah 油田(如圖 19)，進行高壓灌注以增加原油產量，目前是中東地區最大之 CO2-EOR 計畫。沙烏地阿拉伯之 Saudi Basic Industries Corporation(SABIC)是中東最大之 non-oil 公司，也名列世界十大石化公司之一。SABIC Carbon Capture

and Utilization 計畫係將其石化工廠產生之二氧化碳匯集起來，用管線輸送到 SABIC 之三個附屬公司，作為甲醇(Methanol)及尿素(Urea)之增產用途(如圖 20)。

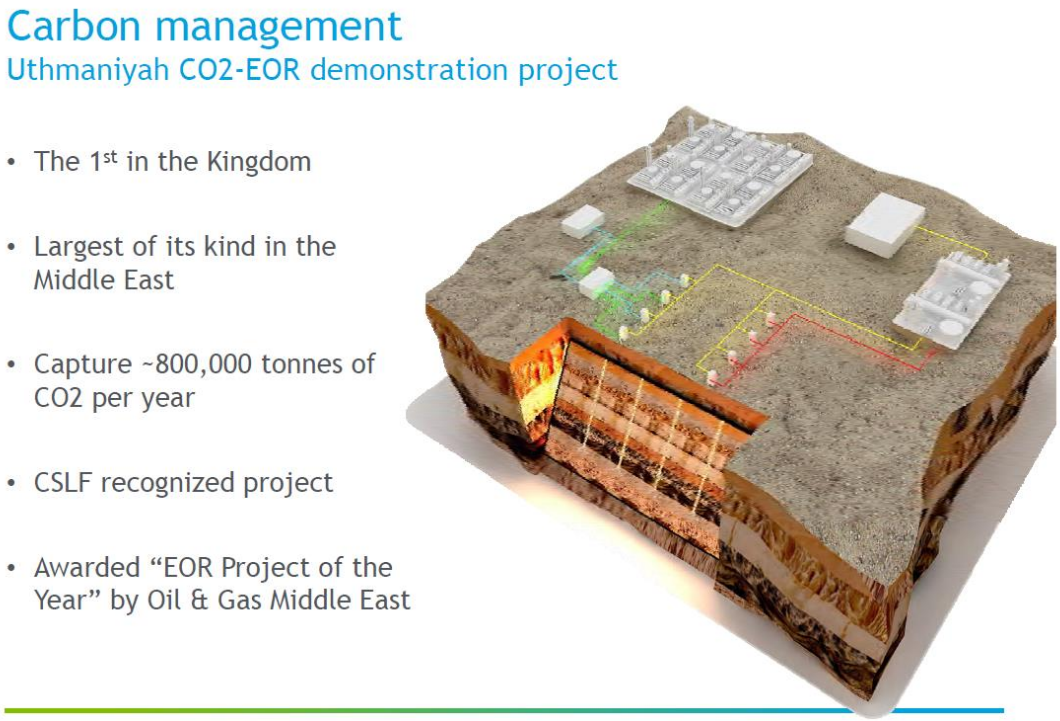


圖 18 沙烏地阿拉伯阿拉伯之 Uthmaniyah CO2-EOR 示範計畫

4、沙烏地阿拉伯國家石油公司投資成立了 Novomer 公司，專門從事將 CO_2/CO 轉換成具高附加價值之聚合物及化學介質，擁有獨到之觸媒轉化核心技術。其主力產品為 CONVERGE Polyols Products，包括塗料(Coatings)、黏著劑(Adhesives)、填充劑(Sealants)、合成橡膠(Elastomers)、聚胺基甲酯(Polyurethane)等；CO2 表面活化劑(CO2 Surfactant)，以及熱塑膠材，如陶瓷材料之膠合劑，以及供做電子材料(如**圖 21**)。

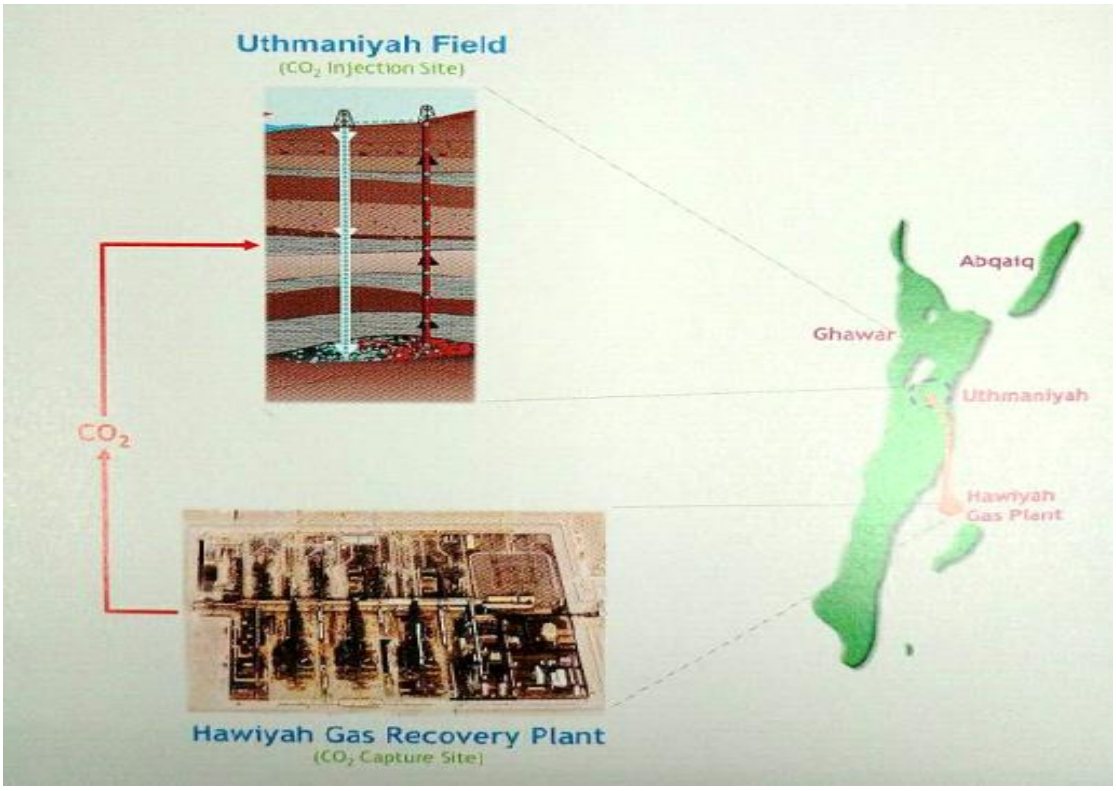


圖 19 沙烏地阿拉伯 Hawiyah 天然氣廠捕獲之 CO2 輸送到 85 公里外之 Uthmaniyah 進行驅油增產

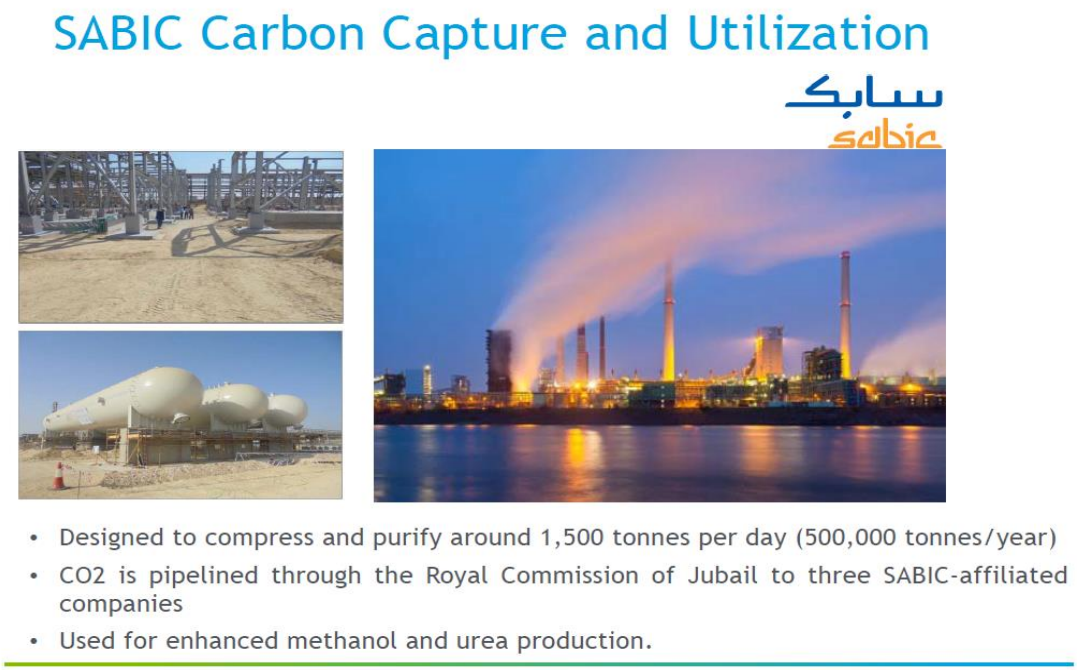


圖 20 沙烏地阿拉伯阿拉伯之 SABIC 碳捕獲及再利用計畫

圖 21 沙烏地阿拉伯 Novomer 公司將 CO2 製成高價值之聚合物及化學介質

5、沙烏地阿拉伯阿拉伯針對二氧化碳活動源之減碳與捕碳研究，亦令人印象深刻。一個是 CO_2 Reduction Technology for Heavy Duty Trucks，另一個是 On-Board CO_2 Capture & Utilization。國際能源署 2014 年之報導，估算 2012 年之全球碳排放有 24 億噸來自於重型卡車運輸，而運輸過程中之引擎運轉有 1/3 之時間處於怠速狀態，因而有節能與減碳之空間。前者之研究在建立一額外之能源供應單元，譬如加裝燃料電池提供卡車怠速時之電力需求，來減少化石能源之燃燒以及二氧化碳之排放；後者之研究則擬從中型卡車與一般客車之廢氣中將二氧化碳捕獲下來，供做再利用、強化驅油、及封存之用途。沙烏地阿拉伯國家石油公司之研究中心，於 2011 年在中型卡車上裝設固體材質之二氧化碳吸附裝置並進行測試，可達到 10%之捕獲率；此項研究於 2013 年轉向研究小客車廢氣之碳捕獲，使用液態吸收劑，目標為整體二氧化碳淨排放減少 25%(如圖 22)，會場亦布置一部展示車(如圖 23)。

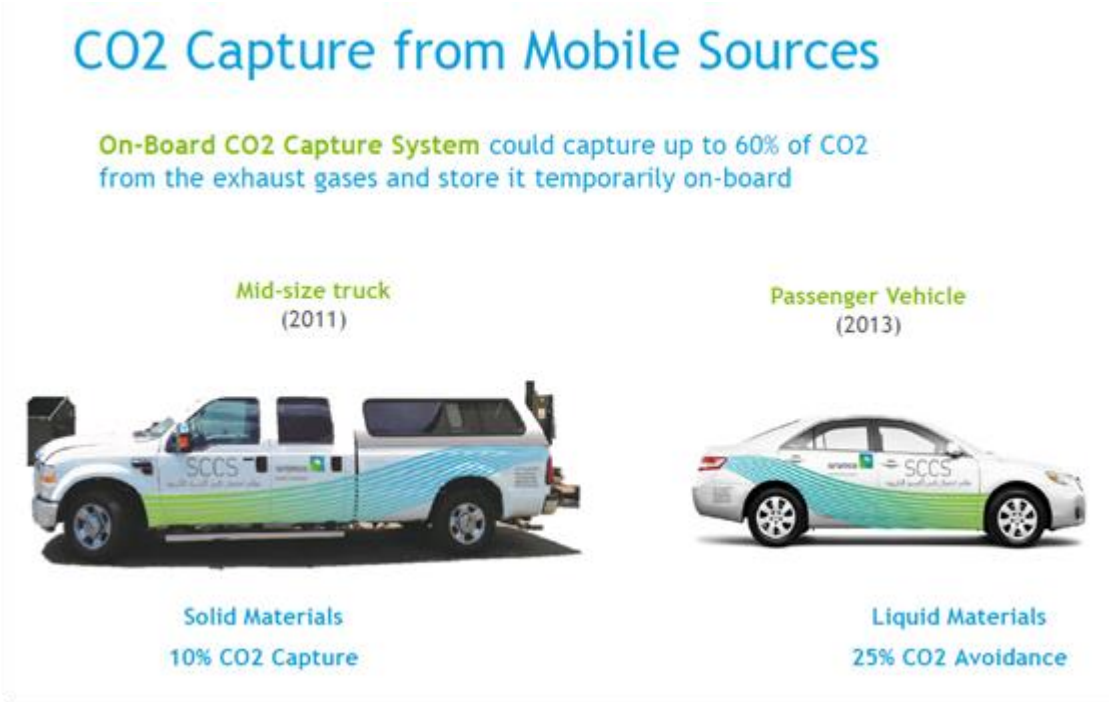


圖 22 沙烏地阿拉伯 Aramco 之 On-Board CO2 Capture & Utilization 計畫

圖 23 會場展示之廢氣碳捕獲之小客車

四、結論及建議

(一)此次會議邀請國際能源署永續能源政策與技術處處長 Mr. Kamel Ben Naceur 出席並發表演說，其內容顯示即使就燃料轉換很樂觀之情境來看，到 2050 年化石能源仍然會扮演 44%之能源供應角色，因此要滿足地表升溫不超過 2℃，CCS 將是一個必要之減碳手段。根據 IEA 之研究，對於發電減碳與工業減碳兩大範疇，CCS 將扮演同樣重要之角色，而未來全球有超過 2/3 之二氧化碳捕獲將來自 non-OECD 國家。IEA 之統計資料顯示，要滿足 2℃之情境，估計 2025 年開始每年需要封存 50,000 萬噸(5 億噸)之 CO_2。

(二)現階段在推動 CCS 大型示範計畫之困難有二，一是缺乏明確之政策與法規，另一個便是大型 CCS 計畫之財務準備不足。目前國際上在 CCS 投入之經費遠落後於原來之估算，亟須要在政策面釋出對 CCS 技術之長期需求與支持之訊息，同時在政府之減碳與能源政策上也應給 CCS 與其他低碳技術(如再生能源)相同之競爭條件及待遇，短期內政府仍應擔任領頭羊並持續支持及推動 CCS 示範計畫。更積極之建議有三：(1)推動區域性及國際性之合作，帶動大型示範計畫之實施與經驗累積；(2)在碳價制度建立之前，提供政策性之誘因及經費來支持大型示範計畫；(3)進行社會溝通，在鼓吹善用再生能源之餘，說明 CCS 仍然是必要採行之減碳手段，才能達成 2030 年之國家碳排放減量之目標。

(三)經過此次會議之廣泛討論，CCUS 已再次被國際公認為有效且必須採用之減碳技術，現階段雖可藉由 CCU 或 CC-EOR 之方式來推動大型示範計畫，但最終仍需回到將捕獲之二氧化碳進行地質封存之手段。臺灣西部具有良好之二氧化碳地質封存潛能，若能妥善利用，對於我國經濟發展逐漸轉至低碳能源環境具有極大之助益。目前我國 CCS 推動遠落後於國際，若以現階段之進展來看，恐難於 2020/2030 年達成政府設定之減碳目標，未來仍有賴政府相關單位以及產學研機構之共同努力，尤其要加強溝通宣導，爭取社會民眾之認同與配合。

(四)CCS 技術發展之先導試驗計畫或是於場址調查研究階段並未涉及真正之開發行為，現行環評相關法規應可適度鬆綁，否則將嚴重影響我國 CCS 技術發展之進程。建議國內可透過既有法規之解釋或修訂，以能讓 CCS 先導試驗及示範計畫往前邁進，同時藉由計畫執行過程來獲取並累積後續推動商轉所需之知識與經驗。

(五)綜上所述，我國欲全面推動 CCS 技術發展與產業化，除面臨安全、風險等技術層面問題外，諸如民眾接受度、政策法令是否完備，以及資金是否充裕等非技術性問題亦必須面對與克服。

五、附件及參考資料

【附件一】第 6 屆 CSLF 部長級會議公報

【附件二】Carbon Capture and Storage: A necessary clean energy option.
by Mr. Kamel Ben Naceur, International Energy Agency

【附件三】Financing for CCSA Projects.
by Mr. Bernard Frois

【附件四】Technical Barriers and R&DS Opportunities for Offshore, Sub-Seabed Geologic Storage of Carbon Dioxide
presented at Regina, Canada, June 16, 2015 by Mr. Mark Ackiewicz

【附件五】2015 CSLF Stakeholders' Messages to Ministers.
by Mr. Barry Worthington

附件一
第 6 屆 CSLF 部長級會議公報

Carbon Sequestration leadership forum
www.cslforum.org

6th Meeting of the
Carbon Sequestration Leadership Forum (CSLF) Ministers

Moving Beyond the First Wave of CCS Demonstrations

Communiqué
4 November 2015 at 1700

We, the Ministers and Heads of Delegation of the CSLF Members, are greatly encouraged by the progress made in the research, development, demonstration and global deployment of Carbon Capture and Storage (CCS) since we last convened in 2013. R&D portfolios have grown, international collaboration has expanded, and the world's first large-scale CCS project in the power sector commenced operation. There are now 22 large projects in operation or under construction, with several others in final design awaiting financial decision.

The advances in CCS are noteworthy, but more needs to be done to bring CCS to the marketplace where it can achieve significant reductions in CO_2 emissions and help combat climate change. As noted by the International Energy Agency (IEA), in a scenario in which global CO_2 emissions are constrained to levels consistent with a less than 2℃ rise in global temperatures at the lowest cost, CCS could contribute about one-sixth of needed CO_2 emission reductions in 2050, and 13 percent of the cumulative emissions reductions between 2015 and 2050 compared to a business-as-usual approach. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Synthesis Report (AR5) concluded that without CCS the costs of climate change mitigation would increase by 138 percent, and without CCS, 2℃ may not be possible.

Considerable progress in the deployment of CCS has been made in the last two years, and we have the opportunity to accelerate CCS deployment now and in the near future with strong global commitments and supportive government policies. Such government policies would be built on existing national circumstances, priorities, and obligations. We met today to discuss and address the key remaining challenges facing CCS and especially to identify collective activities necessary to support and accelerate further deployment. Our common goal is to ensure that the conditions are right for all CCS projects currently under construction or in advanced stages of planning to be completed. We must increase the number of new large CCS demonstrations by 2020, and support the development of the next generation technology for full-scale demonstration in the 2020s.

The CSLF is the world's only Minister-level multinational CCS forum and this year celebrates its 12th year of operation. While it is clear that significant progress has been made on CCS, challenges remain that we must – and can – overcome.

Key Actions Needed for CCS Deployment:

1. **We assert and advocate for clean energy policies that support CCS alongside other clean energy technologies, such as renewable energy and efficiency measures.** We are pleased that the role of CCS is recognized under the United Nations Framework Convention on Climate Change (UNFCCC) processes and mechanisms. Global momentum is building toward an agreement on ambitious climate change mitigation goals, and CCS can and should be an important part of the solution. Governments should work together to ensure the UNFCCC processes and mechanisms support all clean energy technology development including CCS.

2. **We will continue to foster international collaboration aimed at advancing development and deployment of large-scale projects that demonstrate CCS technologies and build government, investor, and public confidence in CCS.** This will include encouraging the development of open networks to share lessons learned and help stakeholders, especially in non-OECD countries, to deal with difficult and time-consuming challenges such as financing. These will build on existing CSLF initiatives including the International Test Centre Network, the Large-Scale Saline Storage Project Network, the Capacity Building Program, and the CCS in the Academic Community Task Force. We will also publicly communicate benefits of CCS.

3. **We commit to coordinated global efforts to deploy CCS projects and build technical and regulatory capacity around the world.** Many emerging 2nd and 3rd generation technologies with potential to significantly reduce the cost of CCS are in the process of being developed, tested, and scaled up, with timeframes for commercialization and deployment generally beyond 2020. We will actively seek and support such opportunities through bilateral and multilateral collaboration with other key bodies and organizations including the IEA, the IEAGHG, and the Global CCS Institute. We believe that the increasing number of such collaborations reflects the growing global recognition of the criticality of CCS and view such collaborations as complementary to the CSLF.
4. **We will create opportunities and remove barriers for private sector investment in order to advance CCS and spark innovation.** Around the world, CCS is being implemented in selected "sweet spots" where regulatory, commercial, and technical factors converge with timely government support to realize a business case that attracts private investments. We will learn from these opportunities and take policy actions to create and sustain conditions that support investment and broaden CCS deployment.

5. **We will give CCS fair consideration in clean energy policies and resource commitments, while also supporting development of comprehensive CCS policy frameworks**. CCS can provide different opportunities and solutions for different countries, and the appropriate design of a CCS policy framework, including development of financing policy and incentives, will vary among countries and across industries. Comprehensive policy frameworks should be created to help improve technology performance, reduce cost and create favorable conditions for CCS deployment by providing greater parity for CCS as a clean technology option. This may build upon existing frameworks and structures, such as those under the UNFCCC, including its technology mechanism, the Green Climate Fund, and the Clean Development Mechanism.

6. **We support industrial CCS applications as a pathway to implement substantial, scalable CCS pilot plants.** CCS is the only option for decarbonizing high emission

process industries such as refineries, and the chemical, cement and steel sectors. By 2050, half of the captured CO_2 could come from industrial sources outside the power sector. Furthermore, industrial processes will offer opportunities for early projects, as many processes produce relatively pure streams of CO_2, and thus will have significantly lower capture costs.

7. **We encourage early stage exploration and development of common user storage and transport infrastructure which can significantly de-risk many potential CCS projects.** Governments can facilitate early-stage projects by supporting the development of transport hubs and clusters and by anticipating the characterization of potential storage sites.

8. **We will continue to explore the potential of CO_2 utilization technology to accelerate the deployment and technology maturation of carbon capture and mitigation**. The CSLF will encourage creative, economically beneficial, environmentally friendly uses of CO_2 by disseminating relevant information supplied by its members, and recognizing new projects that deploy Carbon Capture, Utilization and Storage (CCUS) approaches with significant market and CO_2 abatement potential.

Importance of Stakeholder Involvement

We will seek input from stakeholders on how to further the goals of the CSLF and implement the actions identified above. Supportive and engaged stakeholders in industry, society, and the academic community are critically important to the development and commercial deployment of CCS. While the CSLF is a means of international collaboration by governments, collaboration at the international level between governments and industry is also vitally important. We applaud the efforts of stakeholders to advance CCS and to be involved in CSLF activities. We strongly encourage their continued involvement in the CSLF.

Building on the Success of the CSLF

We recognize the success of the CSLF in providing governments with an international forum to collaborate and create shared commitments to CCS research, development, demonstration, and deployment. This includes CSLF initiatives to:

- Lead global collaborations on pilot scale capture testing and large scale injections in deep saline geological formations;
- Share information internationally on important CCS projects, policy initiatives, and legal and regulatory developments in member countries;
- Build the capacity for CCS in the developing country CSLF Members;
- Explore methods for financing CCS projects, including in developing countries; and
- Develop global roadmaps for research, development, demonstration, and deployment of CCS technologies.

We are pleased to announce our recognition of 5 additional CCS projects, making a total of 49 active and completed CSLF-recognized projects sharing their results globally. We also commend the CSLF's capacity building initiative for successfully supporting 14 projects in 5 developing nations.

We are very pleased to welcome Romania and Serbia as new members of the CSLF and look forward to their active participation.

Moving Forward: Next steps for CSLF and its Members

We advocate the need for CCS to compete on a comparable basis with other clean energy options as they prepare their Nations for implementation of the outcome of the UNFCCC Conference of the Parties next month in Paris.

This includes advocating for large-scale integrated projects as well as for the infrastructure needed for capture, transport and storage of CO_2. Co-benefits of CCS projects that are integrated with production of hydrocarbons or water resources or heat should also be leveraged.

We also convey support to the International Maritime Organization (IMO) for its leadership on *The 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972(*See http://www.imo.org/en/OurWork/Environment/LCLP/Pages/default.aspx*).* The steps taken to enable safe sub-seabed CO_2 storage and address transport issues under this agreement seek to create future CCS opportunities for countries with unsuitable or insufficient geological storage. The ratification of the export amendment to the London Protocol, or a similar agreement, is required to enable cross-border transfer of CO_2 for permanent sequestration.

To support the key actions above, we task the CSLF to work to accelerate CCS deployment through specific actions, including:

- Establishing a global CCS project network to facilitate the sharing of lessons learned from early CCS projects now being deployed;
- Exploring opportunities to collaborate on research, development, and demonstration projects advancing CCS combined with fresh water co-production;
- Promoting appropriate recognition of and crediting for bioenergy plus CCS (BECCS) and enhanced oil recovery plus CCS (CO_2-EOR) in regional, national and multinational CO_2 accounting mechanisms;
- Expanding outreach to the academic community to engage the next generation of CCS scientists, engineers, and policy makers.

The CSLF will continue to lead strategic multi-national initiatives, leverage investments, and share knowledge. Specific CSLF initiatives include ongoing capacity building efforts, reinvigorated CCS in the Academic Community Task Force efforts, multi-lateral R&D collaborations, the International Test Centre Network, and the Large-Scale Saline Storage Project Network.

These joint efforts will help streamline global collaboration on CCS and help position CCS as a competitive and deployable low-carbon technology, attracting investments, and enhancing the growth in CCS. This will help to resolve barriers for successful implementation of CCS projects worldwide in a time frame consistent with global climate change mitigation aspirations.

附件二

Carbon Capture and Storage: A necessary clean energy option

by Mr. Kamel Ben Naceur, International Energy Agency

Carbon Capture and Storage: A necessary clean energy option

Kamel Ben Naceur
Director, Sustainable Energy Policy and Technology

Carbon Sequestration Leadership Forum Ministerial meeting
4 November 2015 – Riyadh, Saudi Arabia

Carbon capture and storage is necessary,

is moving forward,

but needs more steam!

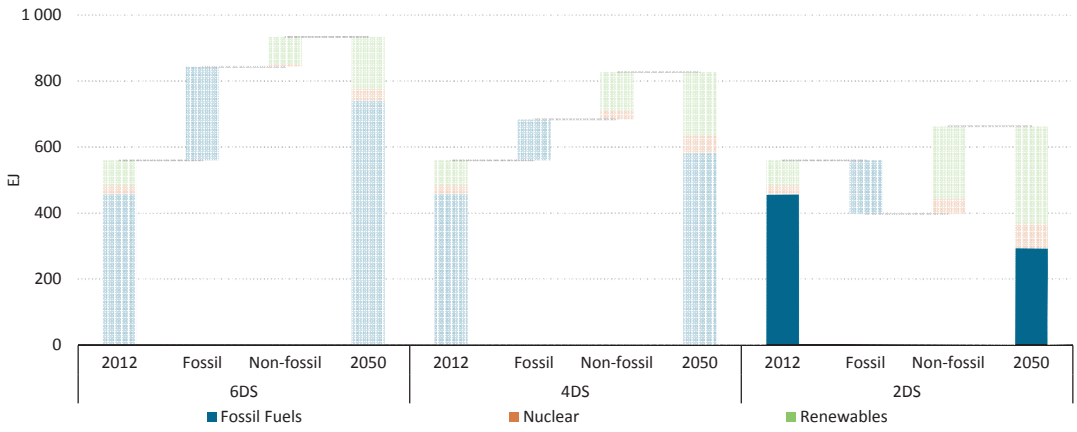
Carbon capture and storage is necessary,

is moving forward,

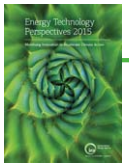
but needs more steam!

International Energy Agency
Secure Sustainable Together

Ambitious energy transformation - fossil fuels retain a strong role



*Role of fossil fuels diminishes, but still has a **44% share in 2050** in IEA 2DS*



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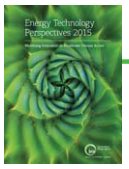
CCS is essential for meeting a 2°C target

- Energy system models (including several used by IPCC) indicate that CCS is essential, and needed to keep mitigation costs to acceptable levels.
- CCS is the only way to sufficiently reduce emissions intensity from certain industrial sectors and enable "negative emissions".
- CO_2 emissions from natural gas up by 30% in the last ten years, while coal has been the fastest-growing source of primary energy for the past five years. **We cannot rely on strategies that assume fossil fuels are rapidly eliminated.**



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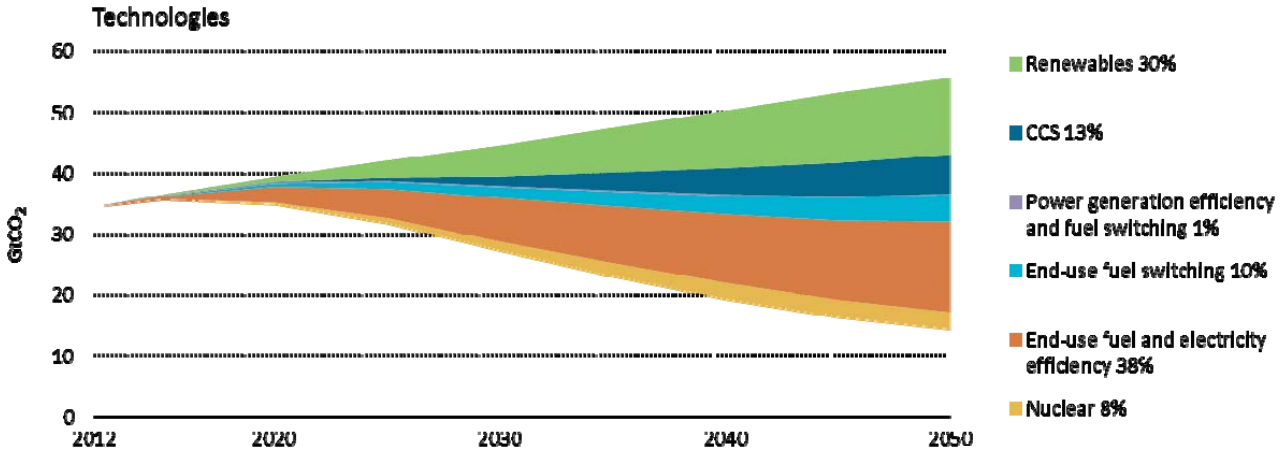
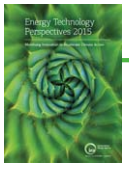
From 6DS to 2DS requires a portfolio of technologies and policies



Percentage numbers represent cumulative contributions to emissions reduction relative to 6DS



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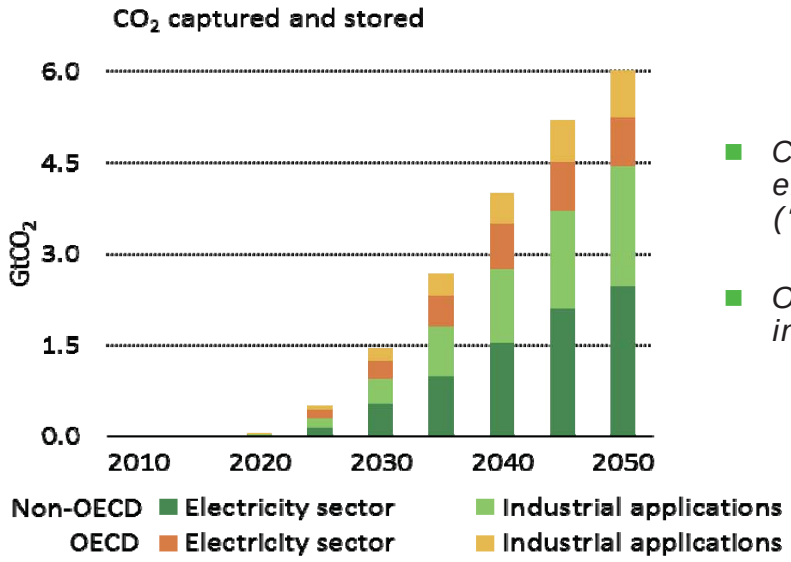
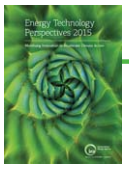
CCS in the 2DS



- *CCS is important in both electricity and industry ("50-50").*
- *Over ⅔ of CO_2 captured is in non-OECD countries.*



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Carbon capture and storage is necessary,

is moving forward,

but needs more steam!

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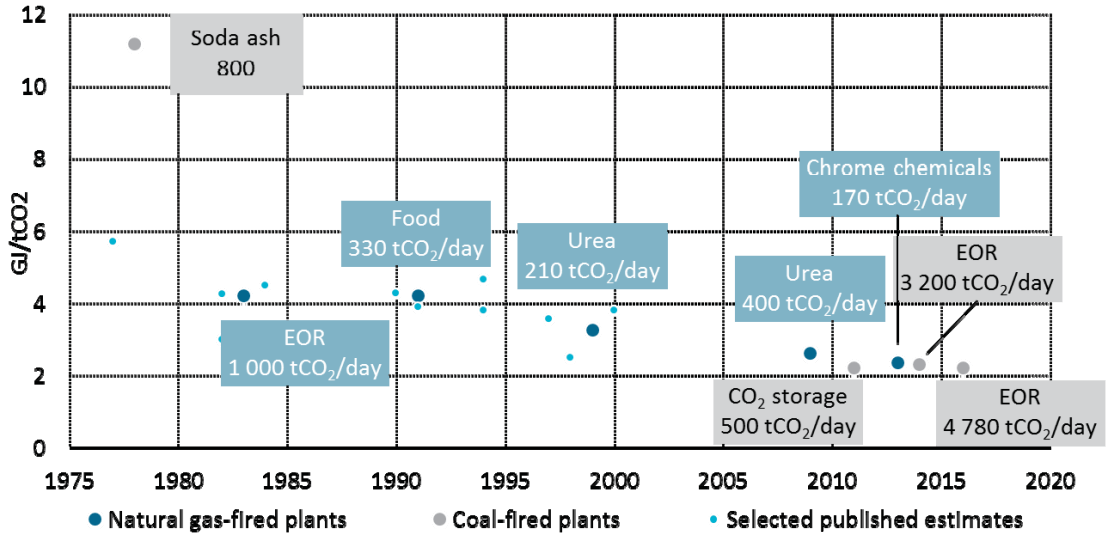
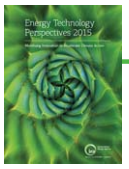
Technology has come a long way



Rochelle, G. (2014) Presentation at GHGT-12 conference; Yeh, S. and E. Rubin (2012) *Energy Economics*, Vol. 34/3

The energy requirement to separate a tonne of CO_2 has been reduced by 50% over the past 25 years.



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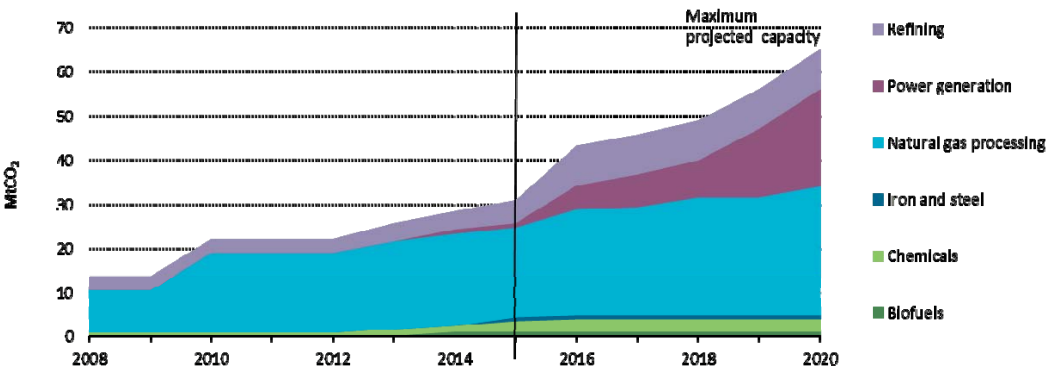
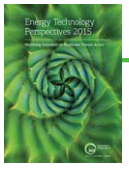
Projects keep advancing – but slowly

60

MILLION TONNES OF CO_2 STORED WITH MONITORING TO DATE



The maximum capture capacity from all projects in the pipeline is 65 $MtCO_2$ a year – The 2DS calls for 500 $MtCO_2$ a year to be stored by 2025.



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Early opportunities: where is CCS succeeding, and why?


Sleipner
(Source: Statoil)


Great Plains Synfuels
(Source: Dakota Gasification)


Boundary Dam
(Source: SaskPower)


Kemper
(Source: IEA)


Decatur
(Source: US DOE)


Port Arthur
(Source: Air Products)


Peterhead
(Source: Shell)


Gorgon (Source: Chevron)


Scotford Upgrader
(Source: Shell)

What has worked - Criteria for positive FID for existing projects

Common success factors:

1. Certainty of fossil fuel value: Clear opportunity for continued use or export of local fossil fuel resources.	**2. Understood local geology**: Suitable geology for CO_2 storage and available expertise.
3. Market opportunity beyond technology demonstration: Low expectation of near-term competition (e.g. regulated tariffs etc.)	**4. Low-risk political and social environment**: Including a predictable regulatory framework for CO_2 storage.

Plus one or more of the following criteria:

- Dependable **revenue stream** for CO_2 sales, for example for EOR
- Strong **government financial support** for the development of CCS
- Explicit national **emissions reduction policy** that includes reductions via CCS
- Manageable impact on profit **margins** (e.g. low-cost producer, or can pass on costs)
- **Strategic benefits** (e.g. a boost to reputation or an advantage from being first)

Carbon capture and storage is necessary,

is moving forward,

but needs more steam!

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IEA seven key actions to advance CCS

Lead stakeholder	*Actions*
Government	Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing of projects.
Government	Implement policies that encourage storage exploration, characterisation, and development for CCS projects.
Government	Develop national laws and regulations as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCS-ready.
Industry	Prove capture systems at pilot scale in industrial pilot applications where CO_2 capture has not yet been demonstrated.
Government	Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment.
Industry/R&D	Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles.
Government	Encourage efficient development of CO_2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO_2.

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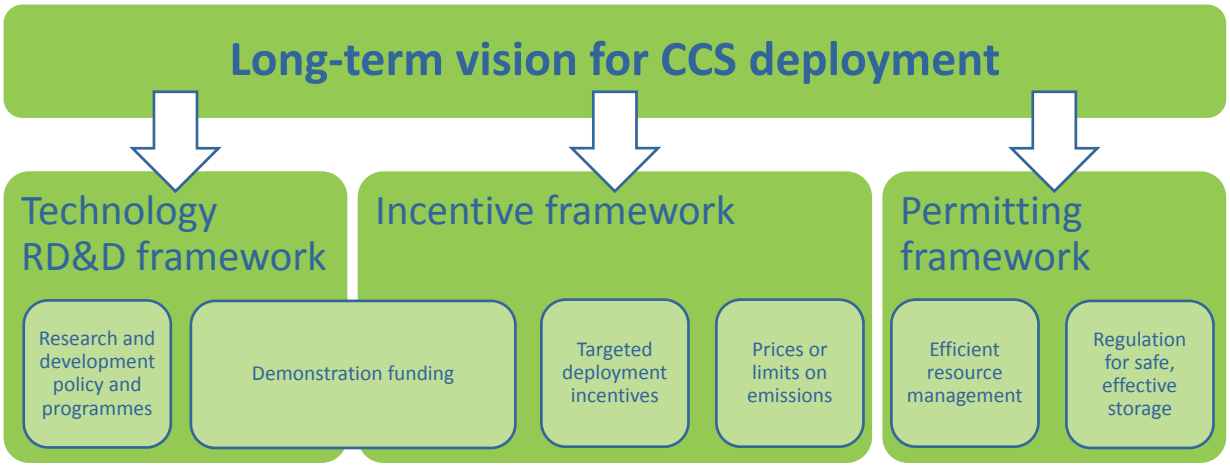
Creating policy & incentives: critical



Lead governments must rethink the policy frameworks in place – CCS to be driven to markets much like other low-carbon energy.

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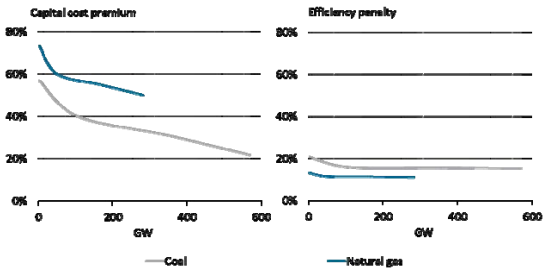
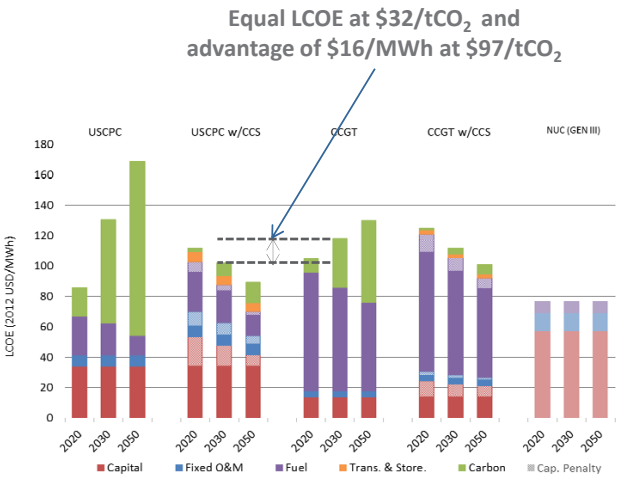
CCS can be competitive with cost reductions

As the installed capacity of CCS-equipped power plants grows, the efficiency penalty and capital cost premium fall



Case Japan: Post-2030 USCPC with CCS is lower cost than CCGT and even CCGT with CCS.



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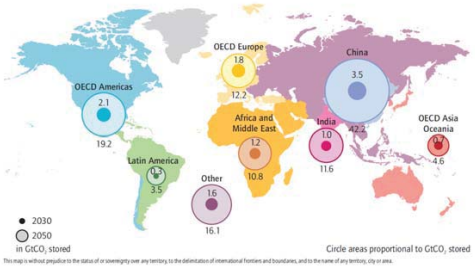
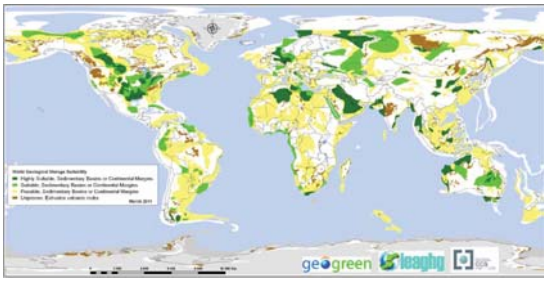
Develop CO_2 transport networks and storage as strategic assets

Significant storage requirements globally



Abundant suitable geologic <u>formations</u>



…but it can take up to 10 years to qualify a greenfield storage <u>site</u>!

- Identify potential storage on national/regional level
- Incentivise up-front storage site exploration for projects
- Invest in CO_2 transport networks
- Ensure safeguards: enact laws and regulations to ensure long-term containment
- Ensure that EOR activity is monitored

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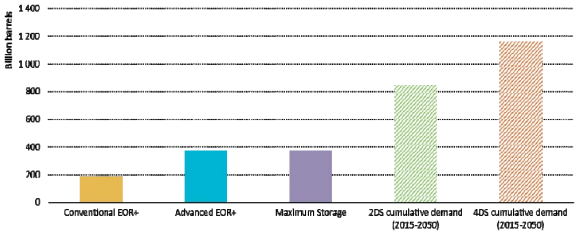
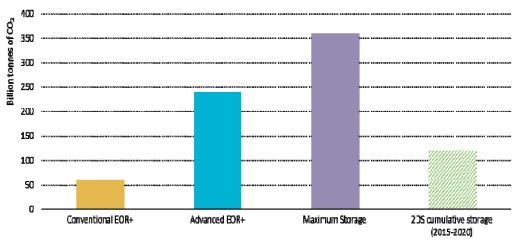
"EOR+": creating a win-win for business and climate

Significant additional oil production potential…



… and CO_2 storage potential



- *EOR+ requires additional activities compared with today's EOR.*
- *Additional activities in operation and monitoring increase cost, but can make economic sense if EOR+ operator is paid to store CO_2.*
- *On LCA basis, EOR+ operations can also be beneficial to the climate.*

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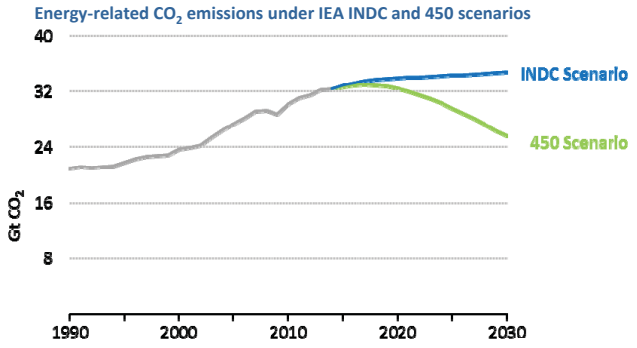
Energy & climate change – COP21

- A major milestone in efforts to combat climate change is fast approaching – COP21 in Paris in December 2015
- Momentum is building:
  - Historic US-China joint announcement; EU 2030 targets agreed etc.
  - 128 INDCs submitted, covering 150+ countries and 90% of energy-related green-house gases
  - Energy-sector CO_2 emissions slow down significantly if INDCs implemented



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CCS in UNFCCC – COP21

- Individual technologies are unlikely to feature in the text of the agreement reached in Paris – but the **UNFCCC processes can still make a big difference for CCS**
  - Individual **INDCs** may identify CCS as a part of their mitigation pathway
  - Funding for CCS can be available under the **Green Climate Fund** (is a dedicated window possible?)
  - Other mechanisms may help build capacity, e.g. the **TEM** can support CCS by creating enabling conditions

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Thank you.

kamel.bennaceur@iea.org

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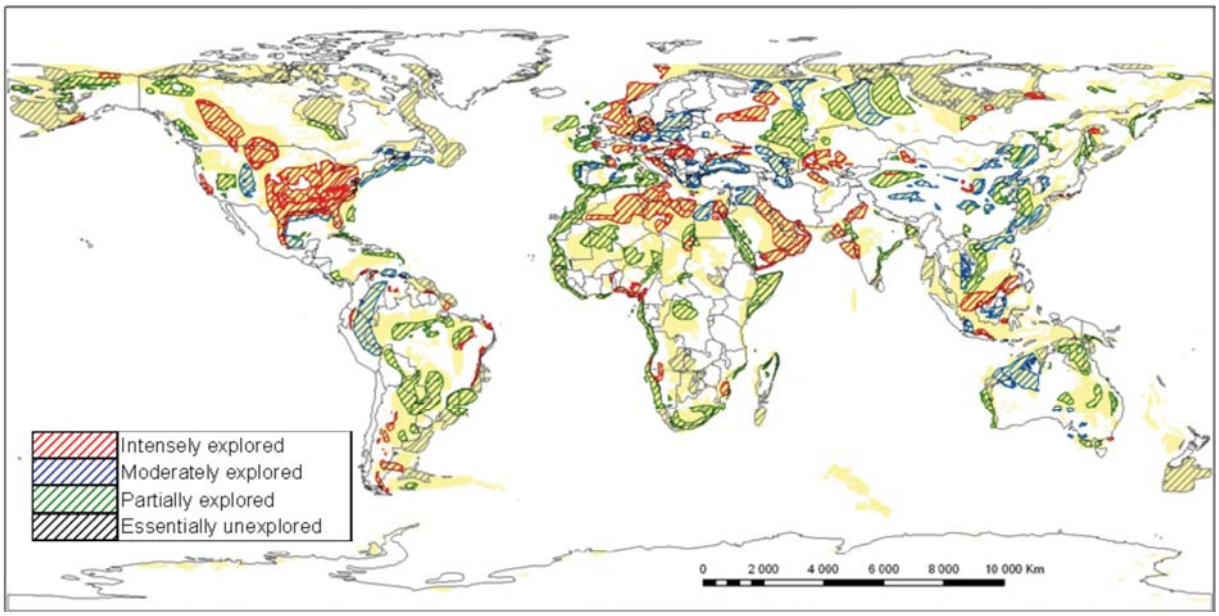
Exploratory status of world basins - 2011



IEAGHG, "Global Storage Resource Gap Analysis for Policy Makers", 2011/10, September, 2011

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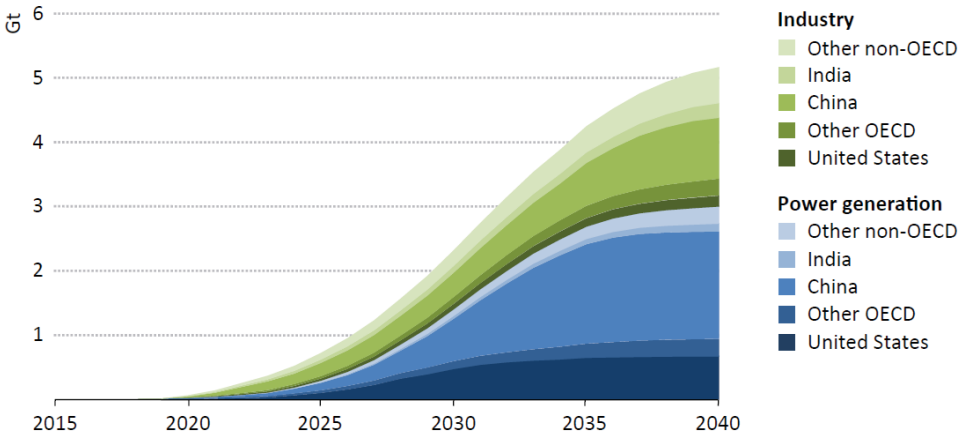
TS1

CCS in the 450 Scenario: An ambitious deployment pathway

Figure 4.4 ▷ CO_2 captured in the 450 Scenario by sector and region



5Gt captured by 2040

Over 6Gt by 2050 (ETP 2DS)

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Slide 23

TS1 This is a useful figure, however the following slides go into depth on the 2DS which could create confusion - especially given its a short presentation which doesn't allow for explaining the differences.

STANLEY Tristan, IEA/SPT/EED/CCS, 10/9/2015

How do we move forward?

1. In both 450 Scenario and the 2DS, 5 - 6 GtCO2/yr are captured and stored by 2050 in all sectors

2. CCS deployment has begun in “sweet spots”

3. “Learning-by-doing” is now also under way for CCS in power generation

How do we move forward?

4. The cost gap needs to be closed by determined, parallel action in technology development and market creation

5. Improving and using post-combustion technologies is of particular importance

6. Innovation and robust regulation will help CO_2 storage remain a minor cost component of CCS

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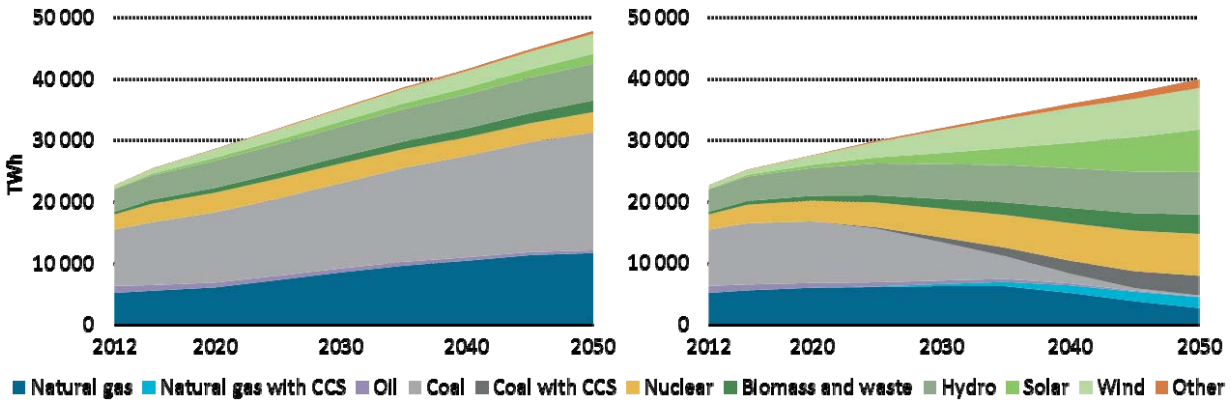
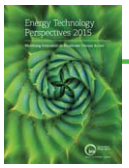
2DS - Fossil fuel electricity generation declines



By 2050 in the 2DS, fossil fuels in electricity generation declines to 20%, with ***CCS being applied to 63% of fossil fuel generation***



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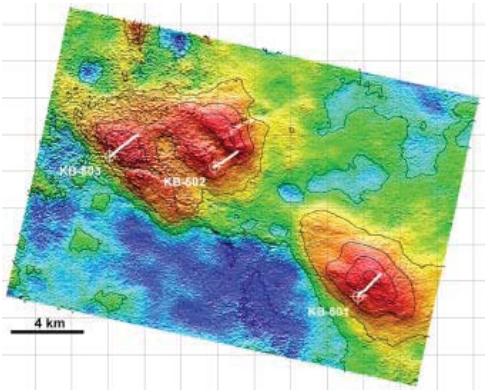
Monitoring is critical for confirming the storage of CO_2

- Developed new and refined MMV techniques
- Through experience – better understand which tools work where
- Better understand what can and needs to be monitored

Surface displacement at In Salah



Charles Jenkins, Andy Chadwick, Susan D. Hovorka, international Journal of Greenhouse Gas Control, Volume 40, 2015, 312–349, http://dx.doi.org/10.1016/j.ijggc.2015.05.009

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附件三
Financing for CCSA Projects
by Mr. Bernard Frois

Financing for CCS Projects

Bernard Frois

Chair of the Finance Task Force

Finance Roundtable

September 15, 2014,

Hunton & Williams LLP, 2200 Pennsylvania N.W. Washington D.C.

Fred Eames, Partner, Hunton & Williams LLP

Bernard Frois, Chair, CSLF Finance Task Force

47 participants, North America, Europe, Asia

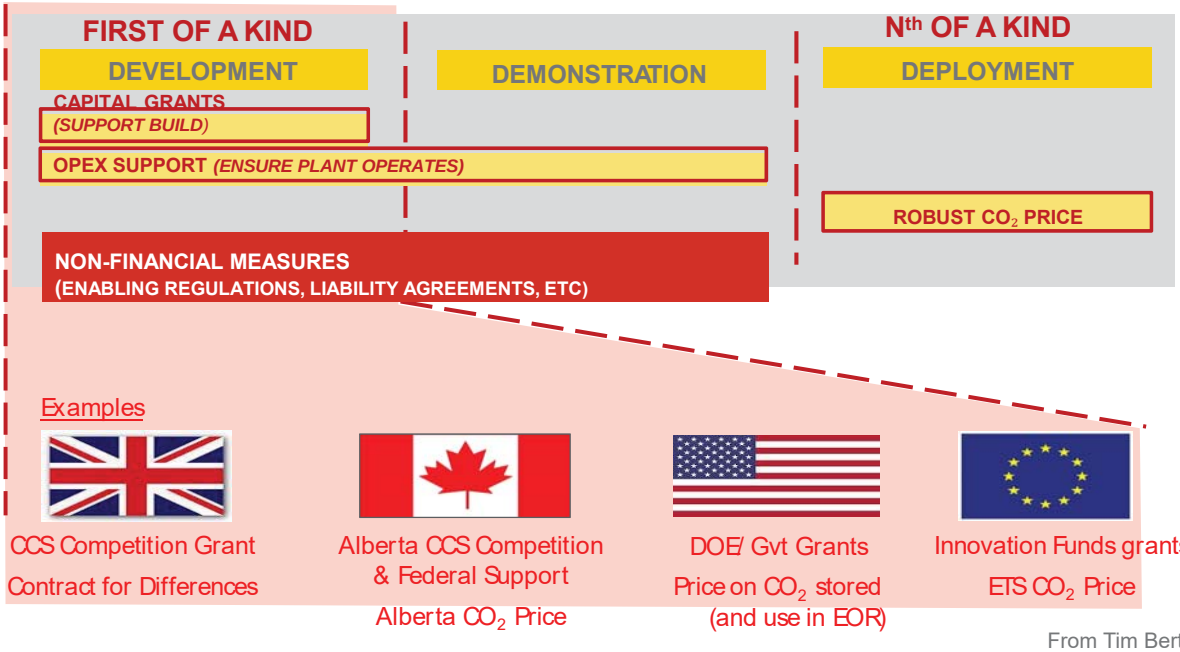
Increased interest for CCS

- The fact that now several operating plants exist employing a range of technologies has started to create the "precedent" base the financial world needs to get comfortable with the industry.
- Also contributing in Europe is the UK CCS Competition. The availability of both grant and the CfD mechanism has provided a potentially financeable framework (subject to risk allocation)
- In Eastern Europe, building major energy infrastructure is a challenge. Poland, Serbia and Romania, in particular, have great potential for CCUS.

A bird's eye view on CCS from the Finance World

- CCS is recognized as a clean energy mechanism
- IEA has identified CCS as one of the most important technologies to mitigate temperature increase
- A large number of projects around the world demonstrate that the technology works
- Growing recognition of CCUS projects economic impact (EOR, Water, Chemical products)
- Success stories encourage investments (SaskPower et al.)
- Broad suite of financing mechanisms exists

SHORT AND LONG TERM FUNDING MECHANISMS NEEDED

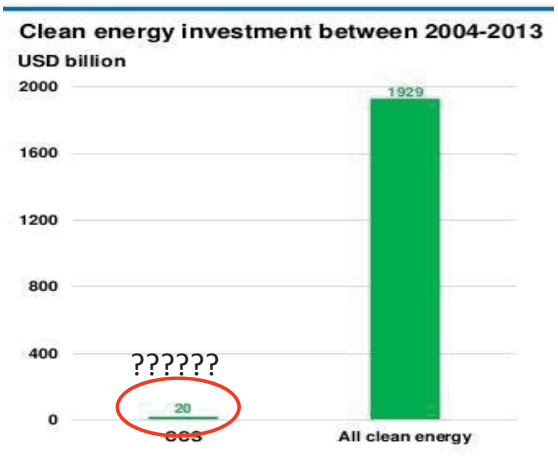


From Tim Bertels,

CCS INVESTMENT BEHIND - POLICY REQUIRED TO CATCH UP

CCS will require

- Long term signal of support/need for CCS
- Policy parity; a level playing field with other low carbon technologies
- Short term support to build and operate CCS demonstration plants



Data source: Bloomberg New Energy Finance as shown in IEA presentation "*Carbon Capture and Storage: Perspectives from the International Energy Agency*", presented at National CCS week in Australia, September 2014.

CSLF CAN DRIVE SUSTAINED DELIVERY OF CCS

- **Regional/global collaboration** to demonstrate CCS at scale and learn effectively, progressing from the first round of CCS demo projects to the next batch; hub/infrastructure planning

- **Policy incentives and funding mechanisms** to support CCS demonstration at scale, until the time that e.g. CO_2 pricing mechanisms supports commercial deployment. Enable commercial (3rd party/service provider) storage.

- **Engaging society and regulators** to explain that besides progressing Renewables CCS must be implemented to de- carbonise Fossil Fuels and deliver on country's GHG reduction needs 2030+

From Tim Bertels,

附件四

Technical Barriers and R&DS Opportunities for Offshore, Sub-Seabed Geologic Storage of Carbon Dioxide presented at Regina, Canada, June 16, 2015 by Mr. Mark Ackiewicz

Carbon Sequestration leadership forum
www.cslforum.org

Task Force on Technical Barriers and R&D Opportunities for Offshore, Sub-Seabed Geologic Storage of Carbon Dioxide

Mark Ackiewicz

Technical Group Meeting

Regina, Canada

June 16, 2015

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Purpose of Task Force

Identify technical barriers and R&D needs/opportunities for offshore, sub-seabed storage of carbon dioxide.

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Background

- **November 2013: Washington, DC Ministerial Meeting:**
  - University of Texas-Bureau of Economic Geology presented to Technical and Policy Groups on Advancing Global Offshore CCS.
  - Ministerial Communique included reference to offshore storage since diverse suite of options will be necessary for CCS deployment.

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Timeline of the Task Force

- ***February 2014: Task Force Proposal developed and included on CSLF Seoul Meeting Website.***
- ***March 25, 2014: Seoul, Korea Technical Group Meeting.***
- ***April 30, 2014: Membership Established/Finalized.***
- ***June 30, 2014: Outline of Report Drafted.***
- ***October 28, 2014: Progress/Status report at CSLF Technical Group Meeting.***
- ***June 2, 2015: First draft of report completed. Circulated to Task Force Members for comments and edits.***
- **July 17, 2015: Task Force Comments due.**
- **August 31, 2015: Report finalized.**

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Report Outline and Structure

High-Level Report Outline

1. Introduction
2. Status and barriers of existing and proposed offshore CO2 storage and EOR Projects
3. Offshore CO2 Storage and EOR Resource Assessments
4. CO2 Transport for Offshore Storage
5. Risk Analysis for Offshore CO2 Storage
6. Wellbore Management
7. Monitoring, Verification, and Assessment Tools for Offshore Storage
8. Summary of Regulatory Requirements for Offshore Storage
9. Summary and Recommendations

General Structure of Chapters

- Status/Overview
- Barriers/Technical Challenges
- R&D Opportunities
- Recommendations

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Offshore Large-Scale Integrated CCS Projects

Source: Global CCS Institute

Challenges and Barriers – Preliminary/High-Level

Challenges

- Protection of competing economic and environmental interests
- Accessibility
- Impact of CO_2 on marine ecosystems
- Operational challenges/Lack of infrastructure
- Financing

Saline Storage barriers

- Slow progress with large-scale onshore CO_2 capture projects
- Long-term storage of CO_2 storage in the offshore setting
- Long-term capacity for large-scale CO_2 storage in the offshore setting

EOR barriers

- A number of studies using different oil and CO_2 price assumptions
- Availability of CO_2 is a potential limiting factor
- Cost of converting existing installations
- Regulations: not a show-stopper, but varying levels of stringency in different countries

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Benefits

- Geologic understanding of the offshore enhanced by O&G E&P info
- Capacity of the near-offshore is globally significant
- Single offshore owner and manager of both mineral and surface rights
- Offshore typically has few or no economic fresh-water aquifers
- Absence of population
- Existing pipeline rights-of-way for O&G production could facilitate infrastructure
- Potential to recommission offshore infrastructure
- For federally-owned storage resources, potential revenues
- Monitoring techniques are available – can be improved

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Preliminary Recommendations

Topic	Status/Description	Recommendation
Knowledge-Sharing	Narrow set of past R&D activities, but growing interest – need to leverage opportunities early and often	Increase knowledge sharing to define potential areas for international collaboration on offshore storage.
Storage Capacity Assessments	currently inadequate.	Pre-qualify storage locations, basin evaluation; knowledge sharing and int'l collaboration.
Transport Infrastructure	Limited and potentially expensive, but less exposure to issues around routing.	Optimization of current practices and infrastructure; take advantage of pilots and demos.
Offshore CO2-EOR	Only one project - Lula in Brazil. Possible to catalyze storage opportunities and infrastructure.	Recent advances in subsea separation and processing could extend the current level of utilization of sea bottom equipment to also include the handling of CO2 streams. Explore opportunities to leverage existing infrastructure and field tests.
Understanding of CO2 Impacts on the Subsea Environment	Significant body of research exists, but complexity of impacts and the challenges to efficient monitoring, particularly natural variability to correctly identify and quantify non-natural change.	Leverage existing work. Understand buffering potential of sediments, and the impact of longer term exposures. Modeling: CO2 dispersion and influencing factors, marine systems.
Monitoring Technology Development	Technology exists but room for improvements. Cover large areas and lengthy periods.	Data processing and interpretation for CO2 storage. The quantification of CO2 within a reservoir still remains a challenge. Real-time data retrieval and navigation. Further development in integrated in situ sensors.

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Team Members

- Total team members: 28
- 6 countries, 4 continents
- Government agencies, universities, research laboratories, industry, non-governmental organizations

附件五

2015 CSLF Stakeholders' Messages to Ministers by Mr. Barry Worthington

2015 CSLF Stakeholders' Message to Ministers

Barry Worthington
CSLF Stakeholder Roundtable, Chair

November 4, 2015

Recommendations

1) Policymakers should recognize that fossil fuel use will continue to grow and may double by 2050 due to an increase in global population by 2 billion people; the need to bring energy access to the 1.3 billion people who today lack access and to the 1.3 billion people who lack adequate access to energy that is affordable, reliable, secure, and sustainable.

Recommendations

2) Policymakers should recognize that carbon capture, utilization and storage is critically important to hold a concentration of greenhouse gasses in the atmosphere to the levels scientist believe is critical to avoid climate change impacts. This will be unachievable without CCS. Both IEA and IPCC indicate that de-carbonization costs are substantially higher without CCS.

Recommendations

3) CCS/CCUS should be recognized as an important component of a broad portfolio of low carbon – no carbon energy strategies, which will include capture and storage on all fossil fuels and on biofuels, along with energy efficiency, renewable options and all nuclear technologies, as well as emission-intensive industries such as steel and cement. CCS requires short-term support for demonstration projects, policy parity and long-term market signals that support the need for CCS.

Recommendations

4) Provide policy parity for all lower carbon/no carbon energy supplies. Policy makers have a variety of fiscal tools to achieve policy parity and these should be applied as appropriate at National levels.

Recommendations

- Examples include:
  - Accelerated depreciation
  - Carbon valuation
  - Clean development mechanism
  - Contracts for differences
  - Feed-in-tariffs
  - Grants
  - Green bonds
  - Green climate fund
  - Investment tax credits
  - Portfolio standards
  - Preferential dispatch for electricity production
  - Private activity bonds
  - Production tax credits
  - Public-private partnership

Recommendations

5) Policy makers should consider incentives for technological innovation such as enhanced research, development, demonstration and deployment strategies, particularly for emerging capture and utilization technologies.

Recommendations

6) National and Sub-National Governments should consider policy mechanisms to reduce long and short-term legal liability for carbon dioxide storage. Some governments have chosen to accept liability for long-term storage.
   - This can be particularly important for offshore storage but also for on-land storage where operators of enhanced oil recovery facilities have defined leases and relinquish control of the property at some date.
   - Please realize that often corporations are required by oil and gas leases to vacate properties when leases expire so these companies being liable and responsible for verification and monitoring years in the future is inconsistent with legal structures and business models.

Recommendations

7) Progress has been made, but more is necessary to guide projects to "final investment decisions." Government support for development of improved costing methodologies and business models providing for multiple revenue streams are critical. Improved policy frameworks to reduce costs, improve technical performance and gain public support will be helpful.

Recommendations

8) Policy makers should consider additional mechanisms to drive down capital costs. This is best achieved by deploying multiple demonstration projects to improve learning across an array of technologies and fuel types - - essentially more energy for less CO_2, leading to decarbonized fossil fuels.

Recommendations

9) Multiple demonstration projects in developing countries are becoming an imperative. CSLF should consider cooperation with other groups to realize this goal. Policy discussions of how credits/financial value for achieving carbon dioxide reductions are necessary. CSLF should continue efforts to build technical and regulatory capacity.

Recommendations

10) Communications on CCS and CCUS needs to be enhanced. CSLF; GCCSI; IEA; and others all have a role. We need CSLF stakeholder's involvement in developing communications messages and resources and stakeholders pledge to be involved.

Recommendations

11) Stakeholders welcome the role that all CSLF members continue to play as CCS advocates, both domestically and internationally. And we the stakeholders pledge our continued support and involvement.

Recommendations

12) Stakeholders endorse the recommendations presented to you early today by Christian Friis Bach, Under Secretary of the United Nations and Executive Secretary of the UN Economic Commission for Europe to the UN Framework Convention on Climate Change regarding how the Paris Accord should treat Carbon Capture Utilization and Storage and for enhanced oil recovery. While we stakeholders may not agree with every word, there is certainly vast consensus.

Recommendations

13) CSLF should focus its attention on off-shore CO_2 utilization and storage, particularly the need which exists to improve understanding of the storage capacity of geological formations and to assess opportunities for knowledge transfer.

Recommendations

14) CSLF could review the usefulness of focusing attention on CSS potential of countries with sizeable lignite reserves such as Romania, Serbia, India, China, and Australia for the economic, environmental, and energy security benefits due to the expectation of their continued use of lignite.

Recommendations

15) CSLF could form a task force or working group with CCS to explore opportunities and challenges in bio energy and co-firing with fossil energy to demonstrate storage. Additionally, the stakeholder process can be expanded by including other carbon sequestration strategies.

2015 CSLF Stakeholders Message to Ministers

Barry Worthington
CSLF Stakeholder Roundtable, Chair

November 4, 2015