INER-F0974 INER-F0974

出國報告（出國類別：其他）

赴荷蘭能源研究中心(ECN)等能源機構參訪出國報告

服務機關：核能研究所
姓名職稱：黃文松　研究員
　　　　　黃金城　研究員
　　　　　林金福　副所長
派赴國家：荷蘭
出國期間：104 年 10 月 3 日~104 年 10 月 10 日
報告日期：104 年 11 月 6 日

摘要

本報告說明此行赴荷蘭公差之過程與心得，行程包括赴荷蘭最大的能源研究機構:荷蘭能源研究中心(ECN, Energy Research Center of the Netherlands)進行技術參訪及交流，並在我國駐荷蘭代表處經濟組及荷蘭駐台貿投辦事處之協助下，核研所與 ECN 簽署科技合作備忘錄(MOU, Memorandum of Understanding)，此將有助於未來雙邊之合作。ECN 為荷蘭歷史悠久的能源研究機構，其發展由早期之核能研究轉型至再生能源與新能源之研究，ECN 與核研所有相當類似的歷史沿革及背景，其發展過程及研發成就可供核研所後續發展之參考。此行也拜訪我國駐荷蘭代表處，說明核研所於核能、再生能源及新能源的研究現況，並前往荷蘭最大的科技研發機構 TNO、核能研發機構 NRG、生質能測試廠 BPF 等單位參訪。

此行除完成核研所與 ECN 簽署 MOU 之任務外，也體驗到 TNO 與 ECN 除致力於創新技術的研發外，也極力結合市場需求，進行研發技術的推廣應用。對於荷蘭境內設立許多陸域風機，而風能發電公司均邀請地主、農戶、乃至風場附近居民加入股東，於設立之初已就相關議題進行充分溝通、討論，如此能全然免除諸多居民抗爭，此機制可為國內建置風機(甚至其他新及再生能源)設施時參考。此外，ECN 發展生質物間接氣化技術已相當成熟，國內在能源國家型計畫發展氣化技術之時，可將 ECN 列為合作的對象。最後，荷蘭 NRG 生產醫用同位素，其國際供應比率相當高，我國普遍使用 Tc-99m 作為核醫診斷之用，為確保未來 Mo-99/Tc-99m 發生器不會缺貨，NRG 可為供應端之另一選項。

目　　次

圖 目 錄

表　目　錄

一、目　的

核研所配合行政院組織改造，將移撥經濟及能源部，並更名為能源研究所。核研所約自 2004 年起，除原本肩負國家核能科技研究與發展，落實於原子能和平及民生之應用外，也著手規劃及投入再生能源之應用研究及發展，如太陽能、風能與生質能等科技研發陸續推展。核研所未來將根基於既有綜合能源之研發技術，落實成為國家重要能源研究機構。

本次國外公差由核研所林金福副所長率化學組黃文松組長與機械及系統工程專案計畫黃金城主持人一同前往荷蘭，公差主要目的為前往荷蘭最大的能源研究機構荷蘭能源研究中心(ECN, Energy Research Center of the Netherlands)進行技術參訪及交流，並代表核研所與 ECN 簽署未來雙方國際科技合作的備忘錄(MOU, Memorandum of Understanding)，作為未來核研所進一步推展國際能源科技研究之重要合作夥伴。此行亦順道拜訪我國駐荷蘭經濟暨貿易代表處，說明核研所於綜合能源研究領域，包括核能及再生能源如風能、太陽能、生質能以及智慧電網相關的研究現況，並藉此了解荷蘭之能源科技佈局及與我國之合作現況。此外並前往荷蘭最大的科技研發機構 TNO、核能研發機構 NRG、生質能測試廠 BPF 等單位參訪，進行雙邊交流及推展核研所之研發成果。

二、過　程

(一).行程概要

此行公差由 10 月 3 日-10 月 10 日，共計 8 天，主要拜訪我國駐荷蘭代表處經濟組，另參訪 TNO、ECN、NRG、BPF 等四個能源機構，並於 10 月 7 日與 ECN 召開雙邊會議暨簽署合作備忘錄，公差行程如表 1，參訪期間訪談人員如附錄 1。

表1.荷蘭出國公差行程

日期	地點	行程
10/03 (六)	桃園-荷蘭海牙	啟程
10/04 (日)	海牙(Den Hagg)	抵達及準備參訪資料
10/05 (一)	海牙	參訪我國駐荷蘭代表處經濟組
10/06 (二)	台特夫(Delft)	參訪 TNO
10/07 (三)	佩滕(Petten)	參訪 ECN 及 NRG，並與 ECN 召開雙邊會議暨簽署合作備忘錄
10/08 (四)	台特夫	參訪 BPF
10/09-10/10 (五-六)	荷蘭-桃園	回程

- TNO: Netherlands Organisation for Applied Scientific Research
- ECN: Energy Research Centre of the Netherlands
- NRG: Nuclear Research and Consultancy Group
- BPF: Bioprocess Pilot Facility

(二).參訪內容概要

1. 台灣駐荷蘭經濟暨貿易代表處

10 月 5 日早上依據行程規劃，由下榻於海牙之旅館搭乘計程車，於 10 點抵達台灣駐荷蘭經濟暨貿易代表處。主要由經濟參事沈建一組長接待及王利桐一等秘書陪同(圖 1)，核研所除說明本次於荷蘭參訪目的及預計拜會各研究機構包括 ECN、NRG、TNO 及 BPF 之外，也說明將於 10 月 7 日早上於 ECN 簽署核研所與 ECN 在能源科技合作備忘錄(MOU)，特別感謝沈組長將親自出席 MOU 的簽署典禮，並作見證。本代表團主要由林金福副所長說明核研所之組織及業務現況，也特別著重目前於綜合能源研究領域，包括核能與再生能源如風能、太陽能、生質能及智慧電網相關的研究現況。並由黃文松組長及黃金城主持人分別針對生質能、燃料電池開發、風能研發等，以及國內的再生能源研發現況進行補充及互相交換資訊及經驗。沈組長等原本對核研所相當陌生，但經過

此次之交流說明核研所於再生能源之研究及技術開發後，覺得印象深刻。此外，為讓吾等對於荷蘭之能源科技研發有一概括的認識，沈組長亦說明 ECN 的歷史沿革及背景，尤其在風能技術領域的研究發展在荷蘭是最早的，約在 1970 年代就開始。而配合荷蘭在歷史上最著名的風車水利工程，荷蘭對於風力應用有其傳統，接受度也特別高。另外，沈組長也說明國內工研院與荷蘭科技單位如 ECN 及 TNO 近幾年交流互訪頻繁並進行實質之國際合作計畫，除 ECN 為荷蘭最大的能源研究中心外，TNO 則為規模龐大的綜合科技研究的非營利組織，接受政府預算及業者公司預算執行創新技術研究及應用技術開發等，協助荷蘭政府、學界、研究單位及其產業推展先進技術開發之業務，其角色與國內工研院類似。經由與沈組長及王秘書等訪談後，更加了解荷蘭之能源科技佈局及研發以及與我國之國際合作現況。

荷蘭有近 1/3 的土地在海平面以下，自古荷蘭與海爭地，水利設施著名，除了歷史上著名的風車之外，沈組長也向我們介紹北部著名的荷蘭北海保護工程，此以填海造陸，防洪結構屏障 30 公里以上，相當壯觀列名世界 7 大工程奇蹟之一。顯示荷蘭與海爭地的決心，而所形成的內海也有許多的設施規劃以及土地規劃等等，或許是因為如此，也造就荷蘭相當熟悉及熱衷進行團體公共建設的分享。另外，關於風能利用開發，沈組長特別提到擬定風電開發計畫時，荷蘭會先邀請各相關單位及居民參與，有些情況甚至是居民團體主動邀集成立風電開發計畫，並請專家學者及業者共同開發，共同分享此共有的天然資源，因此對於風電的開發自然抗爭及矛盾就少，所以居民參與，事前共同規劃是相當重要的，值得國內推動風力發電，乃至其他新及再生能源建設之參考。

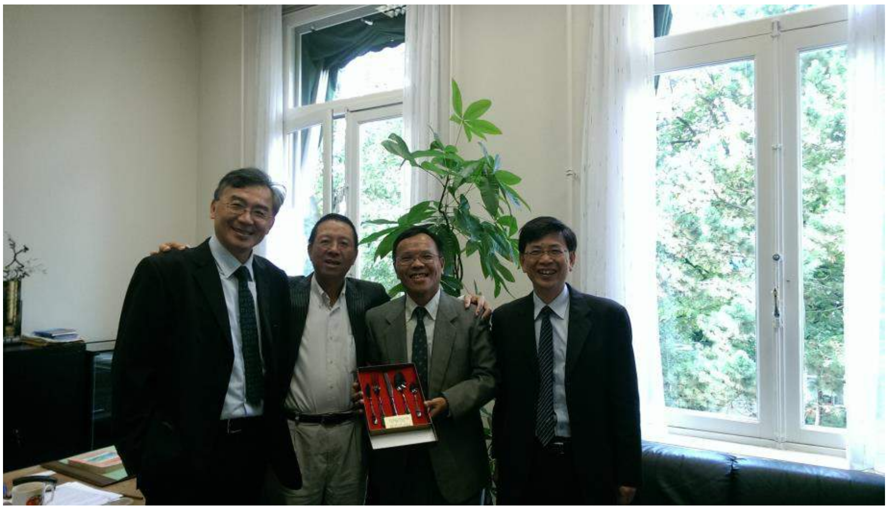


圖1 核研所林金福副所長一行與駐荷蘭代表處經濟組沈建一組長合影

2. 荷蘭應用科學研究組織 TNO(Netherlands Organisation for Applied Scientific Research)

10 月 6 日早上由下榻於海牙之旅館前往火車站，搭火車前往位於台夫特(Delft)之

TNO 院區(圖 2)。本代表團一行 3 人於 10 點準時抵達位於 Delft 科技大學(Technology University at Delft, TUD)校區之 TNO，於辦公大樓換證後，經聯繫由 TNO 永續能源中心主任 Mr. Rene Hooiveld 接待並前往其會議室進行研討，當日參與會議之 TNO 人員尚有 Mr. Rob van der Stel 其主要負責新事業及機會能源。TNO 於荷蘭主要有兩個主要院區一個是位在海牙之總部，另一個主要負責能源相關研發則位於 Delft 科技大學校區，即此行的拜訪地點。首先，由核研所林金福副所長介紹此行之目的在進行本所與荷蘭能源相關科技研發機構的技術交流，也說明核研將與 ECN 在 10 月 7 日簽署雙方科技合作之備忘錄，藉以更實質推動後續雙方在能源科技的合作。林副所長首先介紹核研所於各項能源相關領域的研究現況及過去研究成果，分享給與會的 TNO 科技人員，讓 TNO 能了解核研所於能源技術所累積之能量。林副所長首先介紹核研所為政府之國家實驗室，主要負責核能科技的研究發展及應用，而過去 10 年來，為配合國家於永續能源技術研發之需求，於核能科學技術研發之基礎上，逐漸加大在永續能源的技術開發，包括風能、太陽能、生質能、微電網技術、燃料電池、儲能技術等，也都已獲致不錯的研發成果，並對於相關產業界有提供技術或先期參與合作之合作計畫。林副所長也請與會的化學組黃文松組長介紹核研所於生質能等相關的技術研發，以及請機械及系統工程專案黃金城主持人介紹風能技術領域的研發成果等，TNO 人員也關注國內目前的風力發電利用情形以及技術研發現況與主要瓶頸等。林副所長的簡報也讓 TNO 人員留下對核研所於能源科技研究及發展留下深刻印象，奠定未來核研所與 TNO 技術交流之基礎。

圖2 荷蘭最大科技研究機構(TNO)

其次，由 Mr. Hooiveld 簡報 TNO 的組織及能源相關之科技研究與發展，TNO 成立於 1923 年，擁有約 4000 名員工，是目前荷蘭最大的科技研發機構，其研發任務與角色，主要整合學術界，、研究機構與產業界以共同研發，建立先進技術，提升產業競爭

力並共享成果為主要目的，並持續享有國際非常優良的聲譽，與我國工研院近年來亦有執行國際合作計畫，因此與我國工業技術研發合作相當密切。TNO 為荷蘭歷史最悠久的綜合型研究組織，除指導委員會及管理委員會外，下設國防服務委員會及事業服務委員會及 5 大技術群，分別為:(1).工業(Industry)；(2).健康生活(Healthy Living)；(3).國防、安全及保防(Defense, Safety and Security)；(4).都市化(Urbanisation)；(5).Energy(能源)等，而在每一技術群都設兩大科學主軸，分別為技術科學(Technical Science)以及地球生命與社會科學(Earth ,Life and Social Science)。TNO 每年營收約 5.27 億歐元，以創新研發產生影響力為宗旨，其自許能源領域研究的任務乃以創新技術提供安全可靠、永續發展以及兼具經濟效益的能源供給系統。在 5 大技術群中，能源發展項目著重於永續性能源(Sustainable Energy)、地熱(Geo Energy)、離岸風力發展(Maritime & Offshore)及荷蘭國土調查(Geological Survey of the Netherlands)等 4 項。TNO 於能源研究領域之發展優勢在地熱能源方面、油氣探勘、儲能系統、二氧化碳封存利用等，同時與荷蘭能源研究所(ECN)之間有密切合作及設施共享。歐盟能源政策之目標為 2020 年時再生能源使用占比須達 20%，荷蘭現階段僅達 4.5%，因此當前最大挑戰乃轉型至永續性與可靠性兼具之能源供應系統(如圖 3):

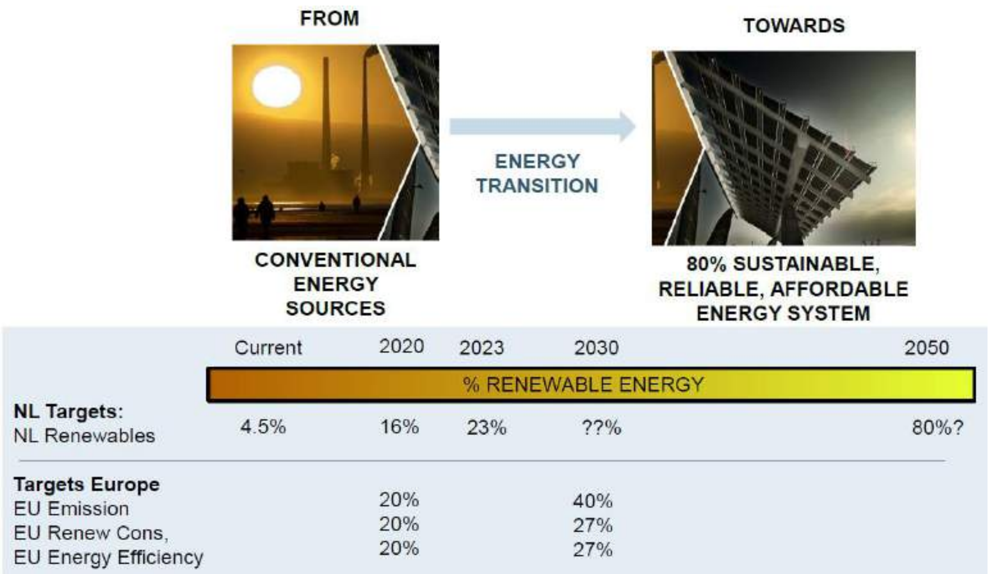


圖3 TNO 發展永續性與可靠性兼具之能源供應系統

TNO 在永續能源方面的願景是整合各種再生能源(如天然氣、風能、太陽能、地熱等)成為一能夠提供使用端之穩定永續能源供給系統，包含油氣、熱、電力的供應等，並利用電網及供需管理等整合，如圖 4。 TNO 新一期 2015-2018 能源領域策略 4 年計畫重點包括:(1).油、氣探勘、運輸、生產之方法與技術， 二氧化碳分離、封存及再利用技術

方法開發；(2).致力開發建置複合性之地區性永續能源系統之技術方法；(3).以荷蘭國家為本，並致力於輸出創新之能源解決方案知識技能提供外界；(4).開發新技術整合荷蘭國土資料包含境內底層土等資訊，建置公開的資料庫供其國內各界參用。

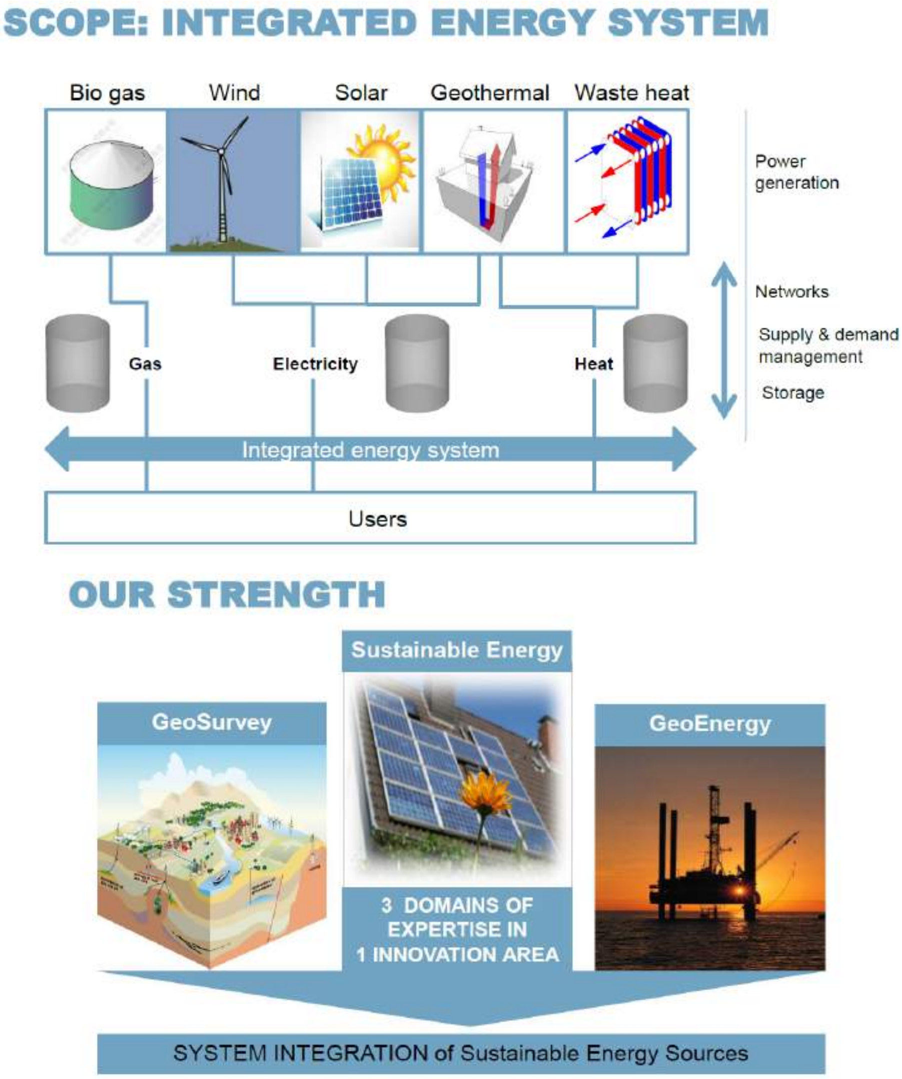


圖4 TNO 著力於各種再生能源之整合

3. 荷蘭能源研究中心 ECN(Energy research Centre of the Netherlands)

本次於荷蘭公差行程，最主要的任務之一為前往 ECN 參訪及代表核研所與 ECN 簽訂雙方科技合作 MOU。10 月 7 日依行程規劃將前往 ECN 及位於相同院區的 NRG 參訪，而當日會議行程及參訪安排，時間緊湊，於出國前已透過核研所綜合計畫組羅偉華先生之聯繫，確定當日行程安排如附錄 2。

依據行程規劃，當日將先前往 ECN 之風機測試園區(Wind Turbine Test Site)聽取 ECN 之風力研發技術簡報及完成 MOU 簽署。之後再前往 ECN 總部進行其他再生能源包括太陽能、生質能等相關之簡報與技術研討，並同時也邀請 NRG 之人員進行簡報與

討論相關研究計畫。因此，10 月 7 日一早約 8 點由 ECN 人員接送前往位於 Wieringerwerf 之風機測試園區，此園區已相當接近北海，地勢相當平坦，是荷蘭唯一之大型風機測試園區。本代表團一行抵達風機測試園區之會議室，我國駐荷蘭經濟既貿易代表處經濟參事沈建一組長已先行抵達。因此，於會議室碰面後，ECN 總營運長 Mr. Robert A. Kleiburg 也隨後抵達，並開始當日議程。

核研所與 ECN 簽署雙方共同合作備忘錄(MOU)是當日會議最重要及令人興奮的一刻，核研所由林金福副所長代表與 ECN 總營運長 Mr. Robert A. Kleiburg 共同簽署此 MOU，在場與會人員包括 ECN 風場營運業務代表 Mr. Piet Warnaar、我國駐荷蘭經濟暨貿易代表處經濟參事沈建一組長、核研所化學組黃文松組長及機械系統工程專案黃金城專案主持人等。本所與 ECN 順利於 10 月 7 日 9:30 完成雙方科技合作備忘錄的簽約儀式，並於當日將相關照片及新聞寄回核研所以製作相關媒體訊息發佈，如圖 5 。

荷蘭的再生能源研究於歐盟居舉足輕重之角色，ECN 更是其唯一之能源研究中心，因此此次核研所與 ECN 簽署共同於能源科技的國際合作 MOU，相信對於未來國內推展再生能源的研究將有相當大的助益。ECN 為荷蘭歷史相當悠久的能源研究機構，成立於 1955 年。ECN 早期以從事核能研究為主，並以 RCN (Reactor Centrum Nederland) 稱之，1976 年始改名為現在的名稱 ECN，並逐漸將研究領域集中於綜合能源技術研究，並將核能領域移撥位於相同研究園區內的核能科技研究機構 NRG。由於核研所未來配合行政院組織改造，將移撥經濟及能源部之能源研究所，核研所與 ECN 因此有相當類似的歷史沿革及背景，ECN 的發展及成就確實可以提供核研所重要的參考。

ECN 近年來與我國在能源科技研究上已有展開部分的國際合作，而且態度非常積極並與台灣保持密切聯繫。近年來，ECN 與我國工研院也已簽訂 MOU，並在離岸風機技術於運轉及維護領域展開實質的研究計畫合作。ECN 於今年(104 年)亦積極與核研所展開接觸，並於今年 7 及 9 月間兩度訪問核研所，除充分了解核研所研發背景及現況，也讓核研所再生能源相關領域認識 ECN 的能源研究成果。因此，經雙方密切聯繫及準備與多次的溝通協調，確定於 104 年 10 月 7 日於 ECN 由核研所代表林金福副所長與 ECN 代表總營運長 Robert A. Kleiburg 先生共同簽署未來雙方國際合作之 MOU，預期雙方將展開能源科技之國際合作。ECN 主要投入包括風能、太陽能、生質能、燃料電池、能源效率、核能安全及政策研究等領域研發，發展性質與核研所的研發領域相近，都是扮演基礎研究與應用研發之間的中繼者角色。未來與 ECN 合作，將以資訊交流、研討會、科研人員互訪、合作計畫等活動方式，進行適當的主題研究，強化雙方在科技研發技術上的知識、經驗與能力交流關係。

圖5 荷蘭貿易暨投資辦事處網頁於 10 月 8 日刊登核研所與 ECN 簽訂合作備忘錄

完成 MOU 之簽訂後，由 ECN 風場營運業務代表 Mr. Piet Warnaar 進行 ECN 之組織、業務及風能研發技術的簡報。簡報說明 ECN 為荷蘭最大之能源研究中心，也是歐洲最大的能源研究機構之一，主要致力於開發永續能源系統之知識與科技。其次，由於 Mr. Piet Warnaar 為風機測試園之業務代表，因此也針對 ECN 在風能領域之研發進行簡報。說明 ECN 風能領域是 ECN 最早成立的再生能源研究領域約在 1977 年左右，也是配合 ECN 由原來之反應器研究中心 RCN 轉型以針對 1970 年代之能源危機，以因應再生能源研究之需求而成立。由 RCN 轉而改制為 ECN 而將核能研究領域移撥 NRG 而專注於再生能源研究，此為其主要任務之一。不過，ECN 組織的調整倒是與核研所目前即將面臨的行政院組織改造，未來移撥經濟及能源部成立能源研究所，有類似之處，也值得借鏡。荷蘭自古以來即以風車利用風力進行水利設施，以解決地勢低窪的嚴重問題，或許是 ECN 首先成立風能研究領域的原因吧。ECN 風能研究領域已累積超過 40 年的經驗，已具有雄厚及先進的風能技術，也積極參與各項的歐盟聯合技術開發計畫如 FP7(Framework 7th) 及 H2020(Horizon of 2020)等。

由於 ECN 總營運長 Mr. Robert A. Kleiburg 於 9 月初曾經抵台並訪問核研所，當時已向他進行各項簡報及領他參觀再生能源設施，因此本代表團就不再進行有關簡報介紹，但對國內再生能源的環境及資訊倒有更多的討論，尤其詢問國內離岸風電之發展近況，及核研所目前有關計畫及參與情形，此皆由機械及系統工程專案黃金城主持人補充說明國內的離岸風電計畫內容及執行近況。依據 101 年 7 月能源局頒布的風力發電離岸

系統示範獎勵辦法，有民間 2 家離岸風電場開發商分別為上緯科技公司(Swancor)及永傳能源公司(TGC)與台電共同參與此離岸風電示範風場的開發，各風場規模約 108 MW。而上緯公司的示範場址位於苗栗外海，永傳能源公司及台電則位於彰化外海。由於海事工程及示範風機設計規格與場址條件(Site Condition)的延遲，原定 104 年底完成之上緯公司及永傳能源公司之首兩座示範風機已確定延期至 105 年底，而台電之示範風機則將在 109 年底完成。黃主持人也說明離岸風電開發將是台灣未來重要的再生能源選項之一，政府也正積極協助推動，而國內確實缺乏相關工程技術能力。此外，離岸風機承受更複雜之極端氣候及地理條件如颱風及地震也是目前台灣正積極研究的課題之一。

目前核研所也參與科技部的能源國家型科技計畫之離岸風力及海洋能源主軸專案之離岸風力產學合作計畫，主要就是負責開發離岸風機支撐結構整合系統的動態載重設計分析與驗證技術，並考量國內的特殊颱風與地震條件進行設計載重的分析，甚至也會針對 IEC 等國際標準進行檢視。經過核研所風力研發負責人黃金城專案主持人的說明，ECN 人員也更清楚國內及本所於離岸風電之發展及技術研發的現況。此外，黃主持人也於會中，提出計畫於 11 月初派遣核研所科技人員前來 ECN 風能領域部門短期實習，學習風機機械組件及載重測試技術的需求，ECN 總營運長 Mr. Robert A. Kleiburg 也欣然同意，指派由 Mr. Piet Warnaar 擔任聯繫窗口，並期盼未來本所與 ECN 可以繼續加強再生能源方面的科技合作。

結束於 ECN 風機測試園區會議後，Mr. Kleiburg 及 Mr. Warnaar 也特別帶代表團前往現場參觀運轉測試風機，依據說明目前在測試場有 Nordex 風機 5 台持續運轉，6 台不同廠牌大型風機包括 GE、Siemens、Vestas 及 Darwind 等，不過由於商業機密關係，測試場禁止拍照。另外，測試場也設置 5 支氣象塔量測及蒐集有關風速、風向等數據。Mr. Warnaar 也提及早期 ECN 的風機測試園區同時也是風機測試驗證授證(Certification of wind turbine testing)的機構，以協助廠家進行各風機生產的型式驗證(Type certification)，不過維護成本過高，近年來已不做上述業務，而是開放給各風機製造公司或研究機構進行樣機(Prototype)及荷蘭國內或國際研究計畫測試使用。測試場位於周圍廣大，一望無際的農田中，地形平坦，紊流係數應相當小，是相當優良的測試場。

代表團一行結束 ECN 風機測試園區參訪後，隨即搭乘 ECN 提供之車輛前往位於 Petten 的 ECN 總部，約於 11:30 抵達。由於目前 Petten 院區內仍有 ECN 及 NRG，也有一運轉中的 HFR(High Flux Reactor)等核設施，因此門禁管制較為森嚴，待換證手續完成隨即驅車前往已插上中華民國國旗之場館會議室，並立即開始接下來的太陽能研究領域的技術簡報。ECN 於太陽能研究領域由 Mr. Michiel Koorn 負責簡報，ECN 投入太陽能領域的研究人員約 80 人，研發高效能太陽能技術主要包括降低材料成本，提高效率，

製程改良加速以及降低安裝及系統成本等。具備材料特性及量測技術，矽晶薄膜電池模組化設計及生產技術，透過系統整合量產等，ECN Solar 並具備多項實驗室如現場測試及太陽能應用中心(Field test and solar energy application center, SEAC)，工業級太陽能電池生產線及相關實驗設備等。

太陽能議題討論結束後，接著由核研所由林副所長簡報再生能源與新能源之研究發展，簡報資料如附錄 3，在結束上午的會議前，雙方人員在 ECN 合影(圖 6)。

圖6 核研所林副所長等一行及駐荷蘭代表處沈組長與 ECN 研究人員合影

10 月 7 下午議程主要討論生質能議題，由 ECN Mr. Klass Berkhof MA 簡報，黃文松組長也向 ECN 說明核研所生質精煉技術發展現況。整體而言，ECN 生質能部門係開發以生質物為永續性料源，生產電、熱、運輸燃料及化學基質材料等技術製程，這同時也是荷蘭邁向發展生物經濟(biobased economy)的重要領域。技術開發集中於發展能夠兼具能源效率與工程放大可行性之生質物熱化學技術製程(thermochemical processes)，研究領域則涵蓋產品整體製程技術鏈包括生質物特性研究、料源前處理程序(Fractionation and pretreatment)、轉化製程技術:如焙燒、氣化、燃燒、裂解(torrefaction, gasification, combustion, pyrolysis)等主要熱化學技術、產品分離及再製程(reprocessing)等。產品除了生質能源外，同樣製程亦應用於生產化學材料(chemical feedstocks and materials)等。深入區分，ECN Biomass 的研究與技術發展主要分為兩種類別，分別是生質能源(Bioenergy)與生物精煉(Biorefinery)。

在生質能源方面主要著重於以熱化學方法轉化生質物生產能源，也就是生質料源經前處理成有機物質後燃燒產生能源，製程開發集中於氣化(gasification)與乾燥、焙燒(torrefaction)的技術開發，並且已獲致顯著的研究成果。氣化技術的特點有:(1).為一獨特的 MILENA 生質物氣化專利製程；(2).Complete conversion and 80% cold gas efficiency, achieving calorific values in the range 12-15 MJ//Nm^3；(3).可將生質物轉化成為相當於天然氣的能源，可供應如渦輪、蒸氣鍋爐、引擎等設備之發電燃料或燃料電池使用；(4).可同時生產如綠氣丙烷(green gas)、運輸用途燃料(如壓縮天然氣 CNG 或液化天然氣 LNG 等)以及化學基質材料等副產品；(5).此氣化技術已開始進入工程放大製程技術驗證中。焙燒的技術特點有:(1).生產生質造粒燃料(biomass pellet)可供應燃煤為主之電廠或熱電共生廠燃料使用；(2).所生產之生質造粒具有高能源密度、容易運輸及貯藏等特點；(3).目前正進行工業規模級之製程放大與驗證測試。

而在生質精煉技術方面主要專注於:(1).以轉型至生物經濟(biobased economy)為目標，因此主要與產業合作，開發新技術來轉化不同生質料源生產能源、化學品及其他等；(2).對纖維生質物料源的研究，主要開發利用 organosolv 技術進行纖維解聚醣化，特別是纖維素、半纖維素的水解糖化能力以及木質素高質化開發成化學品及材料等；(3).ECN 亦投入第三代料源暨水生生質物料源(如海藻等)利用，開發產製能源及化學基質材料產品，主要著重於分離萃取水生生質物中的糖類，再轉化生成能源、化學品或其他產品等。

由於 ECN 的生質物氣化技術相當成熟，我國後續如發展此類技術，ECN 之技術可做為借鏡。ECN 具有 12 年循環式流體化床氣化技術開發經驗，已發展出間接氣化技術，擁有一座經由修改並操作在 800kW 的氣化先導設施 MILENA(圖 7)。此氣化爐包含氣化(gasification) 和燃燒 (combustion) 兩個獨立的部分，氣化段可分為三個元件：氣化爐提升管(riser)，沉降室(settling chamber) 和下沉管 (downcomer)；燃燒段則僅燃燒器一個元件，MILENA 氣化程序產出的合成氣經氣體淨化系統(圖 8)後可以轉化成替代天然氣(SNG)、 綠色瓦斯 (green gas)、和 Fischer-Tropsch 柴油。SNG 可進入氣體供應鏈或可作為運輸燃料 Bio-SNG 使用。MILENA 氣化技術已由 25 kW 實驗室規模放大至 800 kW 先導廠規模(2008 年進行運轉)。

此行離開 ECN 之前，ECN Mr.Klass Berkhof MA 帶領我們參觀生質能源設施，其中 800kW 氣化先導廠設施，ECN 宣稱其各項轉換效率皆優於奧地利維也納大學發展之 FICFB 氣化系統。核研所目前與奧地利合作，今年底之前將由維也納大學完成百 kW 間接氣化系統之概念設計，對於是否引進 ECN 之氣化系統，核研所將尋求雙方合作的可能性。

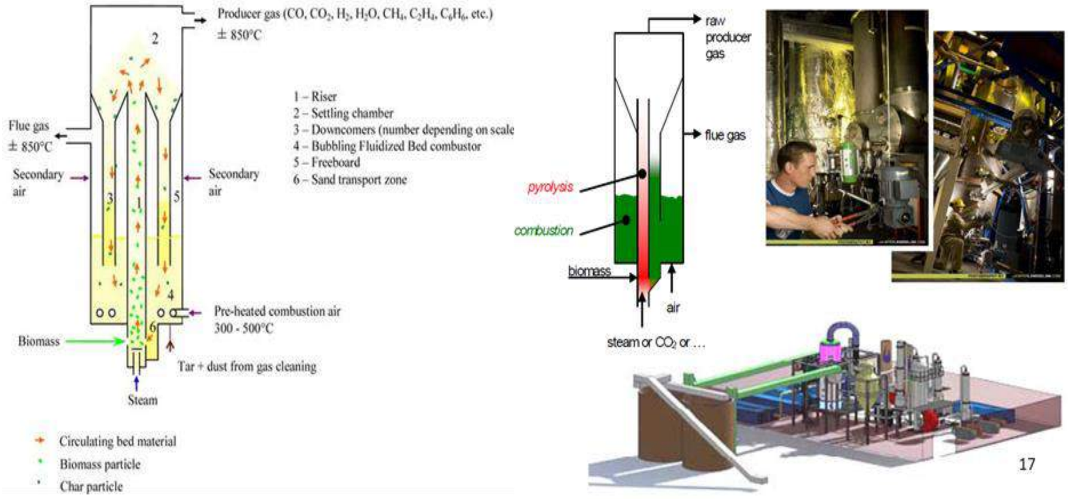


圖7 ECN MILENA 間接氣化技術

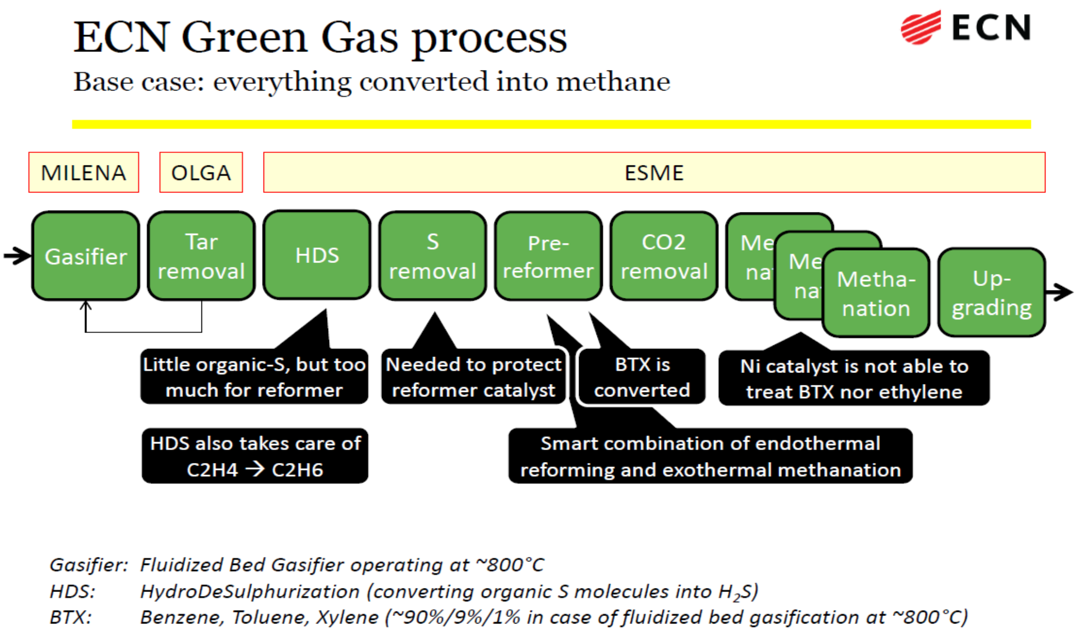


圖8 ECN 生質物氣化之氣體淨化系統

10 月 7 日在 ECN 的參訪於參觀生質能設施後結束，經過此次的接觸，雙方已有進一步了解，有助於推動後續的實質交流。最後雙方也提供簡報資料供彼此參考，核研所代表團簡報資料如附錄 3、4、5。

4. 核能研究機構 NRG(Nuclear Research and Consultancy Group)

NRG 與 ECN 同屬 Petten 研究園區，10 月 7 日下午議程由 NRG Mr. Martijn Jimmink 向核研所參訪人員簡報。NRG 現有員工 500 人，主要任務為進行高品質的核

能技術研發及安全、可靠之放射源生產與服務。NRG 利用高通量反應爐(High Flux Reactor，HFR)大量生產 Mo-99/Tc-99m 醫療用同位素，全球市佔約 33%，應用在診斷肺、腦、甲狀腺癌症，及腎功能、感染性、骨質疾病等。此外 NRG 在全球之生產及提供同位素市場中亦領先群倫，每天全世界約有 24,000 名病患使用之診斷用同位素來自 NRG，每天在荷蘭則有 1300 名病患使用診斷用同位素 Mo-99，有關 NRG 生產之治療用與診斷用放射性同位素，如表 2 及表 3 之說明。NRG 之 HFR 已使用超過 50 年，為提供客戶穩定之同位素服務，已於 2013 年開始進行規劃 PALLAS (55MW)新反應器之建置，分兩階段進行，第一階段(2013-2017):進行設計、授權、投標等工作，第二階段(2017-2024)將使新反應器的運轉實現。核研所目前使用迴旋加速器生產醫用放射性同位素，對於國內使用之 Tc-99m 射源(進口 Mo-99)主要從加拿大等國家進口，由於國內擔憂加拿大之反應器即將退役，可能造成 Mo-99 之短缺。NRG 亦有類似問題，但新反應器完成後，將不至於造成 Mo-99 缺貨，因此國內亦可考量 Mo-99 從荷蘭 NRG 進口。另外，Mr. Martijn Jimmink 已主動與黃組長連繫，希望與核研所藥產中心負責人討論雙方共同感興趣的合作項目。

表2. NRG 生產之治療用放射性同位素

Isotope	Medical application
Cobalt-60	High dose rate brachytherapy.
Copper-64	Used to study genetic diseases affecting copper metabolism, such as Wilson's and Menke's diseases.
Erbium-169	Arthritic conditions.
Gold-198	Head and neck cancer, tongue and mouth cancer (low dose rate brachytherapy).
Holmium-166	Liver cancer. Used in clinical trials in Europe for new blood cancer treatment.
Iodine-131	Thyroid, lung, brain and liver cancer, non-Hodgkin.
Iridium-192	Various cancer therapies, e.g. cervical cancer, lung cancer (high dose rate brachytherapy) and head and neck cancer.
Lutetium-177	Cancer therapy of solid tumors, ovarian and neuroendocrine cancer.
Phosphorus-32	Treatment of excess red blood cells.
Rhenium-186	Metastatic bone pain relief and arthritic conditions.
Samarium-153	Metastatic bone pain relief (palliative care) and in development for treatment of bone cancers.
Strontium-89	Metastatic bone pain relief.
Yttrium-90	Liver cancer, arthritic conditions and metastatic bone pain relief.

表3. NRG 生產之診斷用放射性同位素

Isotope	Medical application
Chromium-51	Used to label red blood cells and quantify gastro-intestinal protein loss.
Iodine-131	Adrenal imaging.
Molybdenum-99	Mo-99 is the parent for Tc-99m generator used for a broad range of imaging in serious medical conditions: all areas of oncology, cardiology, kidney function, brain function, brain disorders, lung function, infection detection, thyroid function, bone disorders.
Xenon-133	Imaging for lung function.

5. 生質精煉示範場 BPF (Bioprocess Pilot Facility)

BPF(Bioprocess Pilot Facility)位於荷蘭 DSM 生技園區內(圖 9)，是一生物精煉示範場設施，在 2012 年建置完成，對外公開提供一個研究生物精煉製程技術之工程放大測試平台，類似核研所建置之纖維酒精暨生物精煉噸級廠設備。BPF 的經費來自各界，包括荷蘭政府，產業界如 DSM 公司，以及部分歐盟的經費支持等。2014 年起 BPF 之部分設施擴建，並已於 2015 年春天建置完成重新開幕。

10 月 8 日參訪 BPF，由該示範場設施運轉經理 Ans Ligtenbarg 負責接待，Ans Ligtenbarg 向核研所參訪人員簡報該公司之營運現況。BPF 現有員工 30 人，5 位技術人員，17 人為設施操作人員，其他 8 人為設施經營及客服人員，主要執行客戶需求之生質物精煉測試工作。雙方於會議室交換意見，核研所林副所長亦向 Ans Ligtenbarg 女士介紹核研所在再生能源及新能源的發展現況，黃文松組長則說明生質能在核研所的研究與推廣現況(如附錄 5)，最後 Ans Ligtenbarg 女士也帶領我們參觀生質 BPF 示範場之前處理、酵素水解、與發酵等設施，在進入示範場前，我們被要求做好一切防護措施(圖 10)，此要求與進入核研所噸級測試廠相同。

BPF 示範場之設計採用生物轉化製程，包含生質物料源前處理、酵素水解、微生物發酵、發酵產物回收純化等製程程序，將生質物轉化製成生質燃料或生質化學品。BPF 本身具備有數十年以上的發酵及下游端產品回收純化的技術，除提供設施進行技術放大驗證外，亦提供產業相關技術諮詢、教育訓練等。

BPF 設備配置有 4 模組(如圖 9)，包括: 模組 1:Pretreatment and hydrolysis (前處理與酵素水解)；模組 2:Fermentation (發酵)；模組 3:Downstream processing (下游產品處理，或稱分離純化)；模組 4:Food Grade (食品級)。其中模組 1/模組 2/模組 3 與核研所噸級測試廠類似，而模組 4 則特別針對食品級產品規劃，與其他區域有所區隔(含發酵與下游產品處理設備，可在 ATEX 防爆環境下)，另外強調製程具彈性，依產品需求透過以上 4 個模組進行整合。

圖9 BPF 示範場設備配置含 4 模組

圖 9 中 BPF 前 3 個模組與核研所噸級測試廠之模組類似，而核心部分仍在模組 1(前處理與水解)及模組 2(發酵)部分，表 4 及表 5 為說明兩單位在模組 1 及模組 2 之比較。從任務而言，BPF 之示範廠僅執行生質物與生物資源之測試，測試需求決定於客戶端，其所需之技術支援主要來自 TU Delft。核研所纖維酒精團隊，除需運轉噸級測試廠外，亦需負責技術發展、技術服務、技術授權等工作，二者為截然不同任務的團隊。

表4.核研所與 BPF 在模組 1:Pretreatment and hydrolysis (前處理與水解)之比較

	料源	產品	規模	渣料乾重處理量	前處理方法	前處理反應器	酵素水解反應槽
BPF	麥稈或稻稈(straw)、蔗渣、玉米稈及其他農林廢棄物	• 化學品 • 燃料 • 食品 (未具體指出項目)	Bench (ATEX防爆環境)	4kg/batch	Autohydrolysis, acidic and alkaline treatments, liquid hot water, SO_2, steam explosion, ammonia, organosolv, ionic liquids, oxidizing agents *並無說明主要發展技術	2階段臥式反應器	10L
			Pilot	40kg/h	Autohydrolysis, acidic and alkaline treatments, liquid hot water, SO2, steam explosion		<10 m^3
INER	稻稈、蔗渣、木片、狼尾草、竹子等農林廢棄物	• 酒精 • 乳酸 • 脂肪酸	Bench	>1kg/batch	Acid-catalyzed steam explosion (Diluted-acid & steam explosion)	室溫混酸/立式反應器	5L、100L
			Pilot	100kg/h			5~9 m^3

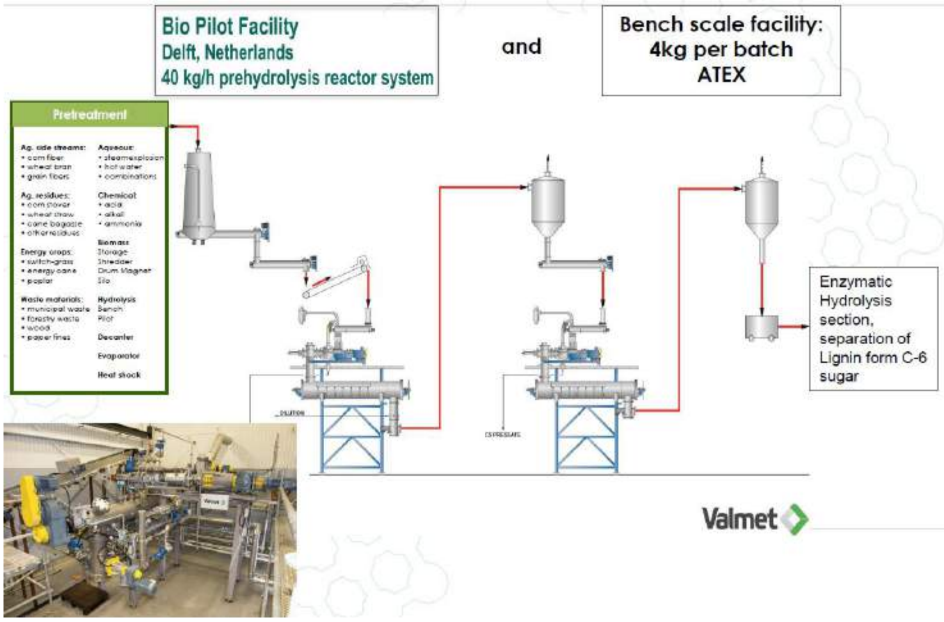


表5. 核研所與 BPF 在模組 2:Fermentation (發酵)之比較

	菌株	發酵槽
BPF	•微生物:BACTERIA, YEASTS OR FUNGI •酵素	•10L、100L、300L、4m³ 攪拌槽(Rushton turbine) •8m³ 氣泡塔(bubble column) •配置有碟式離心機 *部分設備可於ATEX防爆環境下使用可燃氣體
INER	•微生物:BACTERIA, YEASTS OR FUNGI •酵素	• 5L、100L、7m³ 、9m³攪拌槽 (Rushton 或斜翼式turbine，可通氣) • 配置有碟式離心機

圖10 BPF 生質精煉示範場座落於 DSM 生技園區

圖11 進入 BPF 生質精煉示範場之人員安全準備區

三、心　得

荷蘭地理位置特殊，位於歐洲西北部，瀕臨北海並與德國及比利時比鄰。其人口約 1600 萬比台灣少，地勢低窪約有 30%領土低於海平面。荷蘭為我國於歐盟之第二大貿易夥伴，與我國經貿來往頻繁，且荷蘭為全世界第 3 大的農產品輸出國，與我國在花卉來往密切。荷蘭於再生能源領域切入也很早，於第一次能源危機 1973 年即有鑑於石油短缺問題，開始投入再生能源之研究領域，至今也超過 40 年，而荷蘭能源研究中心 ECN 也就是於此一時間背景成立於 1976 年，負責荷蘭主要的再生能源研究發展，主要包括風能、太陽能及生質能等。但是，如從組織上，ECN 的前身為荷蘭反應器研究中心 RCN 則是建立於 1955 年，而於組織調整後於 1976 年 RCN 改制為 ECN 而核能部門則雖僅維持研究用反應器的研究，但於約 2000 年也納入 NRG。所以，ECN 應為 NRG 的部分擁有者，但並不實際經營。

本次赴荷蘭公差之主要目的為由核研所林金福副所長率化學組黃文松組長及機械及系統工程專案黃金城主持人一行前往 ECN，代表核研所與 ECN 簽定雙方科技合作之備忘錄，也期望藉由 MOU 之簽定得以加速拓展本所與 ECN 未來於能源科技研究發展的國際合作。此行除前往 ECN 參訪之外，亦順道拜訪我國駐荷蘭經濟暨貿易代表處，及參訪荷蘭最大的科技研發機構 TNO、NRG 與 BPF 等研發機構，以推展核研所之研發成果並與荷蘭重要之國際級研發機構進行必要的國際交流。針對此行參訪活動，列舉心得如下:

(一) 荷蘭長期與海爭地的決心，對於設施規劃及土地利用很有心得，也或許是因為如此，造就荷蘭相當熟悉及熱衷進行公共建設的團體分享。這也在風能利用開發上，我國駐荷蘭經濟技貿易代表處經濟參事沈組長特別提到擬定風電開發計畫時荷蘭會先邀請各相關單位及居民參與，有些情況甚至是居民團體主動邀集成立風電開發計畫，並請專家學者及業者共同開發，共同分享此共有的天然資源，因此對於風電的開發自然抗爭及矛盾就少，因此對於風力發電開發，居民參與及事前共同規劃是相當重要的，值得國內推動風力發電建設參考。

(二) TNO 之組織定位與國內工研院類似，其對於新創科技的研發，從孕育技術開發就思考整合其所說明的黃金三角分別是政府、學術界及產業界，以達到更快速聚焦的研究發展，而更特殊之處為 TNO 對於 其 5 大技術群包括(1)工業(Industry)、(2)健康生活(Healthy Living)、(3)國防、安全及保防(Defense, Safety and Security)、(4)都市化(Urbanisation)，與(5)Energy(能源)等，在每一技術群都設兩大科學主軸分別為技術科學(Technical Science)以及地球生命與社會科學(Earth ,Life and Social Science)。依據闡述相關科技最後要能應用於人類社會，一定要引進社會科學的元素，從不同的角度評定此項科技研發的應用面，也會影響技術開發方向，這也是為何其會於技術群內引進所謂地球生命與社會科學的原因。

(三) TNO 為荷蘭規模最大的研究機構，也是唯一協助荷蘭政府進行國防相關研究發展的單位。TNO 為歐盟相當活躍的國際研究組織，於世界各地有為數眾多的辦事處，而 TNO 對於參與歐盟國際合作計畫非常積極，並結合大學及研究機構，以大學進行基礎知識開發，研究機構則開發技術，再與使用端進行應用技術合作，最後再與市場端進行技術之應用，TNO 對於此應用科技的研發路徑整合及落實於市場應用，已有純熟的發展模式，困難度高，實屬不易，但確實是目前國內推動及落實科技研發及整合資源，需借鏡與學習之優點。

(四) ECN 為荷蘭最主要的能源研究中心，具悠久歷史，由成立於 1955 年的反應器研究中心 RCN 在 1976 年轉型成立。ECN 之沿革由專責核能相關研究技開發逐漸轉型為綜合能源領域研究，與核研所未來配合行政院組織改造，面臨移撥經濟及能源部並更名為能源研究所，有諸多相似及值得參考之處，而核研所也將在既有的核能與再生能源研究堅實基礎上，朝向我國能源智庫之角色邁進。 ECN 於再生能源科技研究及發展，目前主要涵蓋風能、太陽能及生質能源相關領域，各項研究領域已投入相當久的研發能量，也有優良的績效成果。除此之外，ECN 也持續參與歐盟跨國之研究團隊及國際計畫，例如 FP7、H2020 及 Solliance 等，或許因歐盟的地源關係，造就 ECN 研提各項研發計畫，資源雄厚，也可藉由不同國家及團隊的合作，有效的提升能源科技的研究實力。

(五) 核研所與 ECN 藉由本次參訪，並由本所林金福副所長率化學組黃文松組長，及機械及系統工程專案黃金城主持人，共同參加 2015 年 10 月 7 日於荷蘭 ECN 舉行之本所與 ECN 簽定雙方科技合作備忘錄簽署儀式，雙方分別由本所林副所長及 ECN 總營運長 Mr. Robert A. Kleiburg 代表簽署，未來將可望在雙方有興趣的能源科技議題上進一步開展國際合作。而藉由本次 ECN 參訪，本所也順利表達將於 11 月初派遣本所機械及系統工程專案計畫負責風機相關機械測試專長之科技人員前往 ECN 進行實習，當場獲得其總營運長同意及指派聯繫窗口，將率先展開 ECN 與本所在風能科技研發領域之合作。此外，由於 ECN 在歐盟國家的能源科技研究，相當積極也具有巨大的影響力。因此，長期而言，持續與 ECN 於能源科技的交流合作，將有助於本所未來增進能源科技研發實力並提升能源科技研發之國際能見度。

(六) ECN 在生質氣化方面的技術相當成熟，其所發展之間接氣化系統與奧地利維也納大學之氣化技術 FICFB 相當類似，二者皆有產業應用之實績，ECN 甚至宣稱其各項轉換效率皆優於維也納大學發展之 FICFB 氣化系統。核研所目前亦正在發展氣化系統，同時並與維也納大學合作，預計今年底前由維也納大學完成百 kW 間接氣化系統之概念設計，作為核研所未來建置百 kW 的間接氣化設施依據，據以協助國內企業發展 MW 級的氣化設施。此行參訪 ECN 生質氣化單位，無論設施或人員皆有相當的水準，核研所或國內單位如想發展氣化技術，ECN 可做為學習的對象。

(七) 此次拜訪 ECN，除了測試風場負責人對於簡報內容能充分掌握，並能深入討論回覆問題之外，其餘的都是在本業工作數年之後，進一步研習有關 business 及 sales 方面的知能，進而開始負責 business management 方面之業務，此做法對於從事研發工作的單位而言，應有助於所開發之技術的推廣。

(八) 荷蘭面積比我國多出 6000 平方公里，生質物如我國數量有限，然而生質能的發展卻非常多元化，目前以熱化學(thermochemical)技術平台及生化(biochemical)技術平台為發展主軸，技術的應用不限國內，亦輸出至國外。我國目前生質能的發展，在生化技術平台的發展比荷蘭較有規模，熱化學技術平台的發展則較落後荷蘭，而此落差主要在於國內在氣化技術之應用，未見產業端有具體的需求。因此國內氣化技術發展之走向，應是國內產、學、研等專家重視的議題。

(九) NRG 之 HFR 已使用超過 50 年，為提供客戶穩定之同位素服務，已於 2013 年開始分兩階段進行規劃與建置新反應器 PALLAS (55MW)，預計於 2024 年建置完成暨運轉。Tc-99m 射源用於放射診斷已非常普遍，其主要以 Mo-99/Tc-99m 發生器產生，然 Mo-99 以反應爐生產，國內 Mo-99 主要從加拿大等國家進口。NRG 利用高通量反應爐(High Flux Reactor HFR)大量生產 Mo-99/Tc-99m 醫療用同位素，全球市佔約 33%，因此國內在分散 Mo-99 缺貨的風險上，荷蘭 NRG 可為供貨的另一選項。另外，藉由此次參訪對雙方的了解，核研所與 NRG 在同位素生產方面，亦可建立互惠的合作議題。

(十) 考量技術能實際應用於產業，研發題目之選定非常重要；ECN 之作法為與業界共同議定，依其可應用的成熟度分為立即可用、1 至 3 年、與 3 至 7 年等 3 類計畫。其中技術立即可用者，如業者產品之精進與改質，產品則包括生產設備、量測設施、或成品等，計畫期程多為半年(6 個月)內之較短期程。中、長期計畫之推動並輔以定期進度考核制度，主要依據進度達成度與目標之比較，甚至考量市場技術現況與導向，討論是否需調整研究方針，必要時可以啟動退場機制，結束推動之計畫。

(十一) 因應組織任務及工作方針的改變，研發人員在參與新計畫前須參與轉職訓練，由於參訪單位並無類似我國公務員保障之制度，因此選擇並接受改變之工作內容，努力適應新工作環境，是每一單位同仁的責任及義務，若無法配合則可能遭致解職的情況。

四、建　議　事　項

(一) 核研所與 ECN 已簽署科技合作備忘錄(MOU)，未來應加強雙邊之合作，著重於資訊交流、科研人員互訪、技術交流、共提研究計畫等合作方式，強化雙邊能源技術開發與應用之能力。

(二) 荷蘭境內設立許多陸域風機，而風能發電公司均邀請地主、農戶、乃至風場附近居民加入股東，於設立之初已就相關議題進行充分溝通、討論，如此能全然免除諸多居民抗爭問題，不僅有利於設計與建置工作順利推動，同時運轉期間鄰近住戶對於噪音亦能理性地接受，此機制可為國內建置風機(甚至其他新及再生能源)設施時參考。

(三) 核研所未來擬建置百 kW 的間接氣化設施，據以協助國內企業發展 MW 級的氣化設施。由於 ECN 生質氣化技術已趨成熟，其設施或人員皆有相當的水準，建議核研所或國內單位在發展生質物氣化技術時，可將 ECN 列為合作及學習的對象。

(四) Tc-99m 射源於國內應用於放射診斷已非常普遍，其主要以 Mo-99/Tc-99m 發生器產生；然 Mo-99 目前以反應爐生產，國內 Mo-99 主要從加拿大等國家進口。NRG 利用高通量反應爐(HFR)生產 Mo-99/Tc-99m 醫療用同位素，全球市佔約 33%，因此國內在考量分散 Mo-99 缺貨的風險上，荷蘭 NRG 可為供貨的另一選項。

五、附　錄

附錄 1:參訪名單

附錄 2:核研所代表團至荷蘭 ECN 及 NRG 之參訪議程

附錄 3:核研所研究發展現況

附錄 4:核研所風能技術發展現況

附錄 5:核研所生質精煉技術發展現況

附錄 1:参訪名單

單位	姓名	職務	電子郵件
台灣駐荷蘭代表處經濟組	沈建一	組長	jyshen@taiwanembassy.nl
台灣駐荷蘭代表處	Wang, Li-Tong	First secretary	wanglitong55@gmail.com
TNO	Rene Hooiveld	Director, Sustainable energy	rene.hooiveld@tno.nl
TNO	Rob van der Stel	New business and ventures energy	rob.vanderstel@tno.nl
ECN	Robert A. Kleiburg	COO, Executive board ECN	kleiburg@ecn.nl
ECN	Piet Warnaar	Business developer, wind energy	warnaar@ecn.nl
ECN	Wouter J. van Strien MSc	Business developer, solar energy	vanstrien@ecn.nl
ECN	Jelle Blekxtoon	Business developer, biomass energy efficiency	blekxtoon@ecn.nl
ECN	Klaas Berkhof MA	Senior manager, heat biorefinery technology	berkhof@ecn.nl
ECN	Ye Zhang	Technical consultant, business developer	zhang@ecn.nl
NRG	M(Martijn) Jimmink	Business manager, irradiations solutions	jimmink@nrg.eu
BPF	Ans Ligtenbarg	Manager operation	ans.ligtenbarg@bpf.eu

TNO: Netherlands Organisation for Applied Scientific Research

ECN: Energy research Centre of the Netherlands

NRG: Nuclear Research and Consultancy Group

BPF: Bioprocess Pilot Facility

附錄 2: :核研所代表團至荷蘭 ECN 及 NRG 之參訪議程

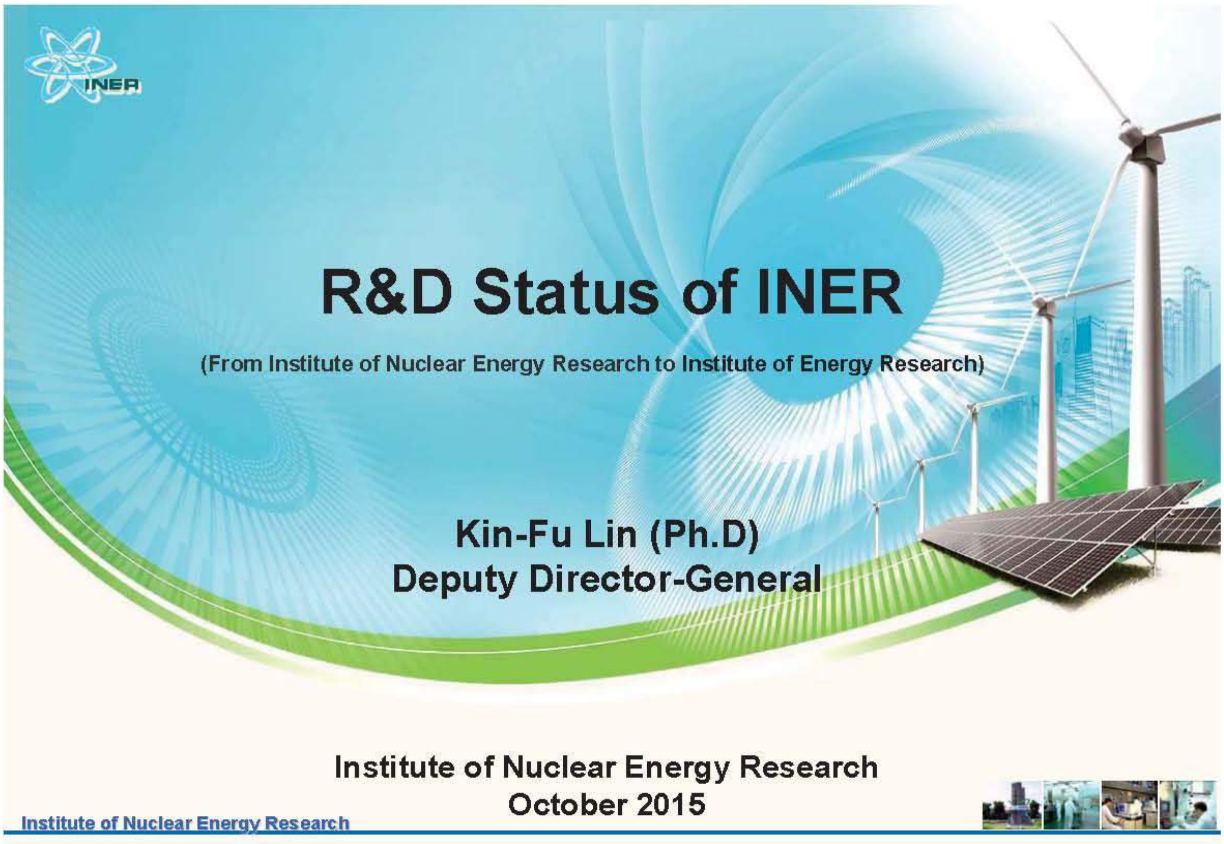
Visit of Institute of Nuclear Energy Research (INER) to Energy research Centre of the Netherlands (ECN) and Nuclear Research and consultancy Group (NRG)

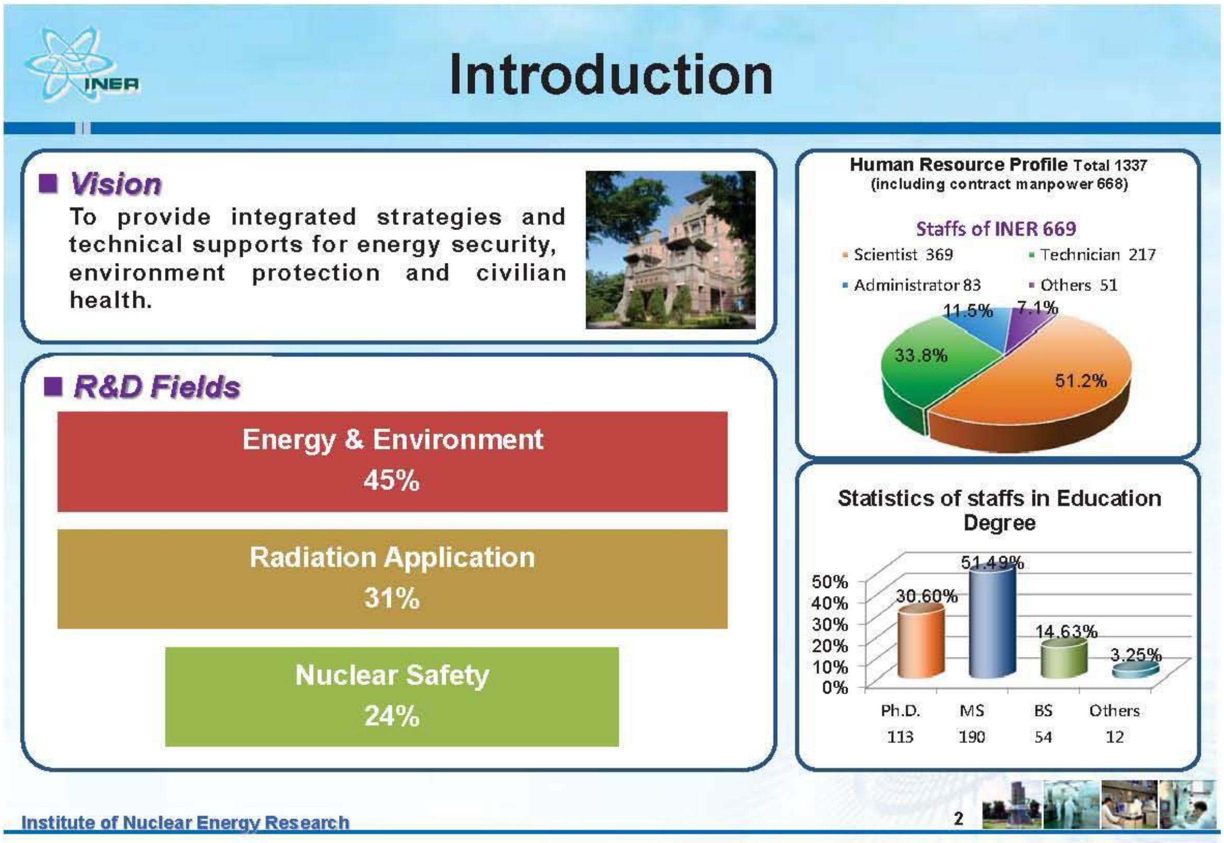
Wednesday 7th October 2015
Wind Turbine Test Site, Schervenweg 35a, 1771 RT Wieringerwerf
Westerduinweg 3, 1755 LE, Petten
the Netherlands

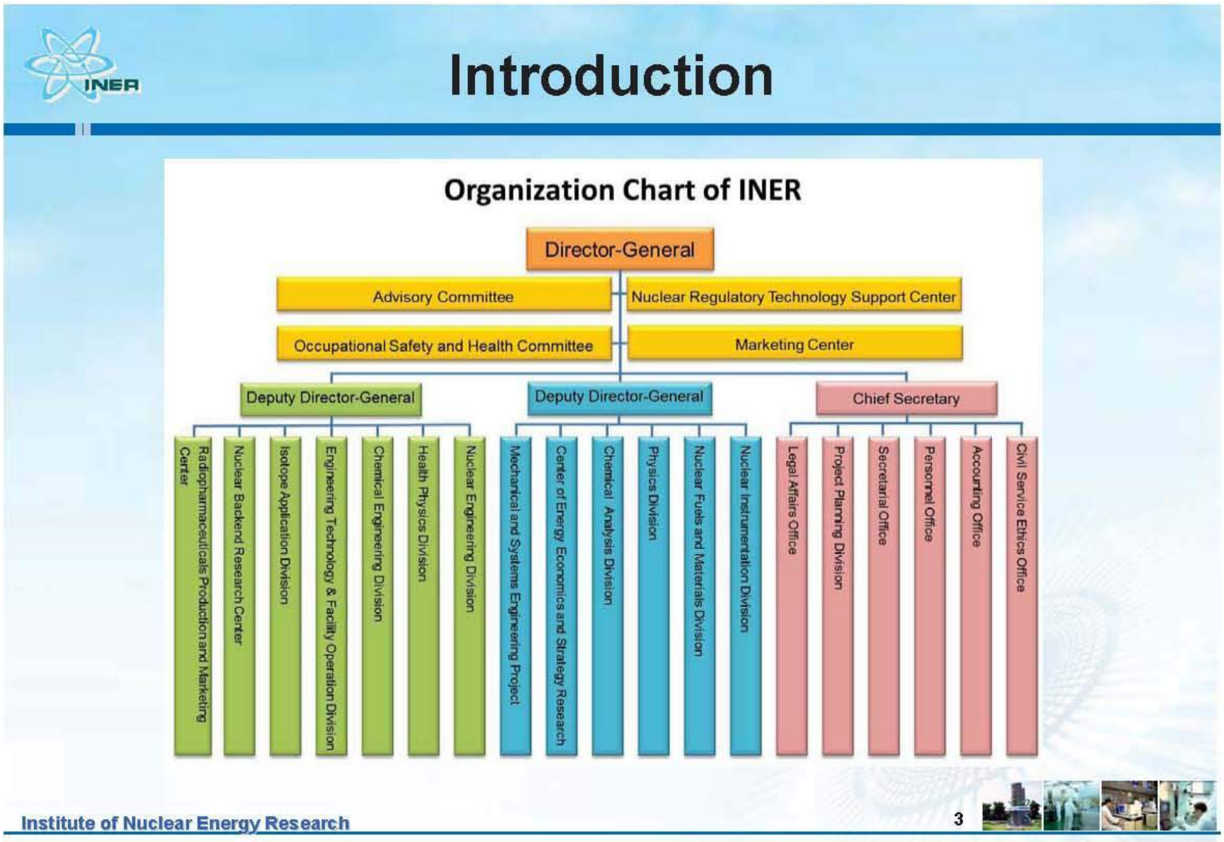
08.00	Pick-up at Amrâth Hotel Alkmaar for trip to Wieringerwerf	Piet Warnaar	Alkmaar
08.45	Arrival and welcome to visitors at ECN Wind Turbine Test Site	Robert Kleiburg	Wieringerwerf
09.00	Signing of MoU ECN/INER		
09.15	Presentation and site visit	Robert Kleiburg and Piet Warnaar	
10.30-11.15	Trip to ECN and NRG facilities Petten	Piet Warnaar	
11.30	- Introduction Solar Energy activities - Presentation on ECN SE R&D program and model of collaboration with industry	Wouter van Strien	Petten Toren Boven
	- Introduction on R&D Status of INER	Kin-Fu Lin	
	- Discussion on potential collaboration		
12.30	Lunch in meeting room		
13.30	Introduction Irradiation Solutions NRG (scope on medical isotopes)	Philippe Brouwers, Martijn Jimmink and René Meekel	
14.00	Visit to Control Room High Flux Reactor	Martijn Jimmink and René Meekel	HFR
15.00	Biomass & Energy Efficiency overall picture focus on thermochemical conversion and biorefinery, waste heat upgrading, hydrogen production	Jelle Blekxtoon	Meeting room G035-K110
15.45	Biomass lab tour	Jelle Blekxtoon	
16.15	End of visit, departure by taxi to Amrâth Hotel Alkmaar		

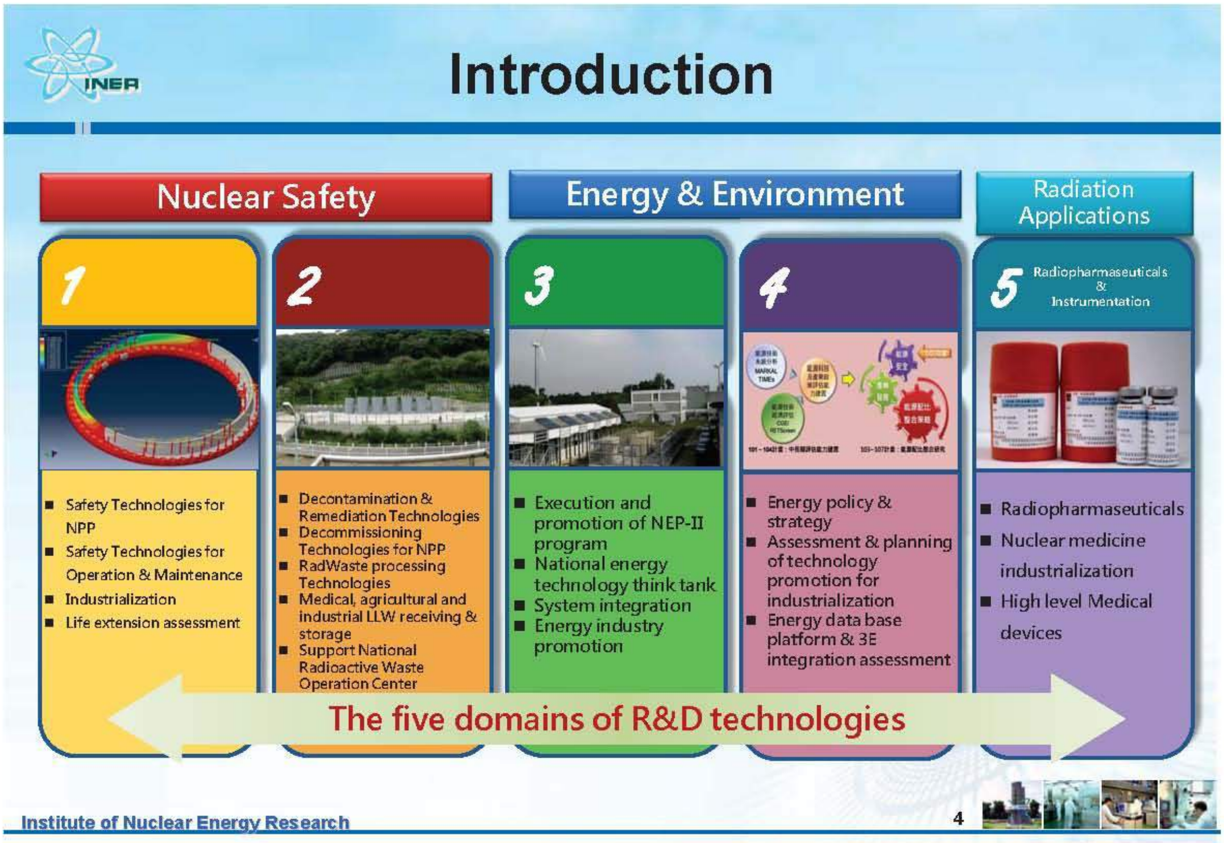
Participants:
INER:
Kin-Fu LIN, Deputy Director-General
Chin-Cheng HUANG, Director of Mechanical and System Engineering Program
Wen-Song HWANG, Director of Chemistry Division
ECN:
Robert Kleiburg, COO Executive Board
Piet Warnaar, Business Developer Wind Energy
Wouter van Strien, Business Developer Solar Energy
Jelle Blekxtoon, Business Developer Biomass & Energy Efficiency
NRG:
Philippe Brouwers, Unit Manager Irradiation Solutions
Martijn Jimmink, Account Manager Irradiation Solutions
René Meekel, Account Manager Irradiation Solutions

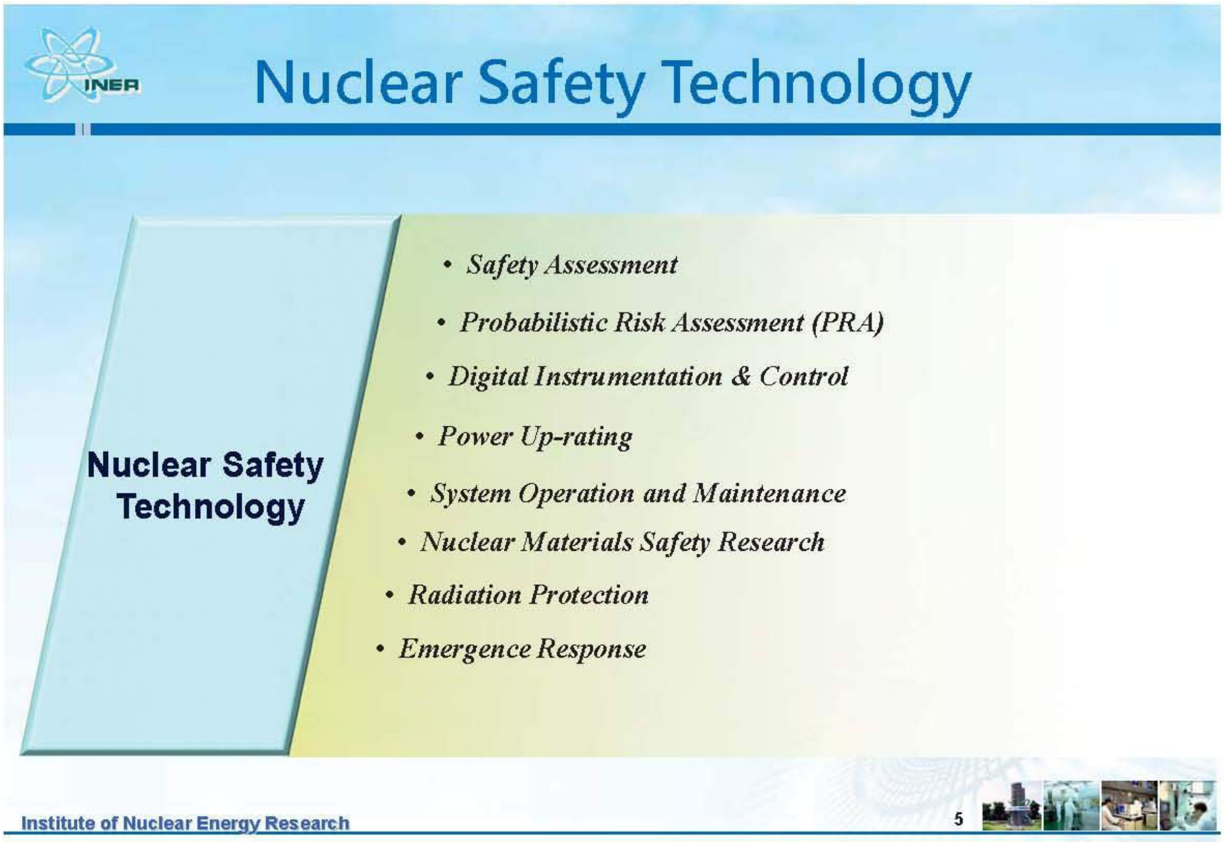
附錄 3:核研所研究發展現況

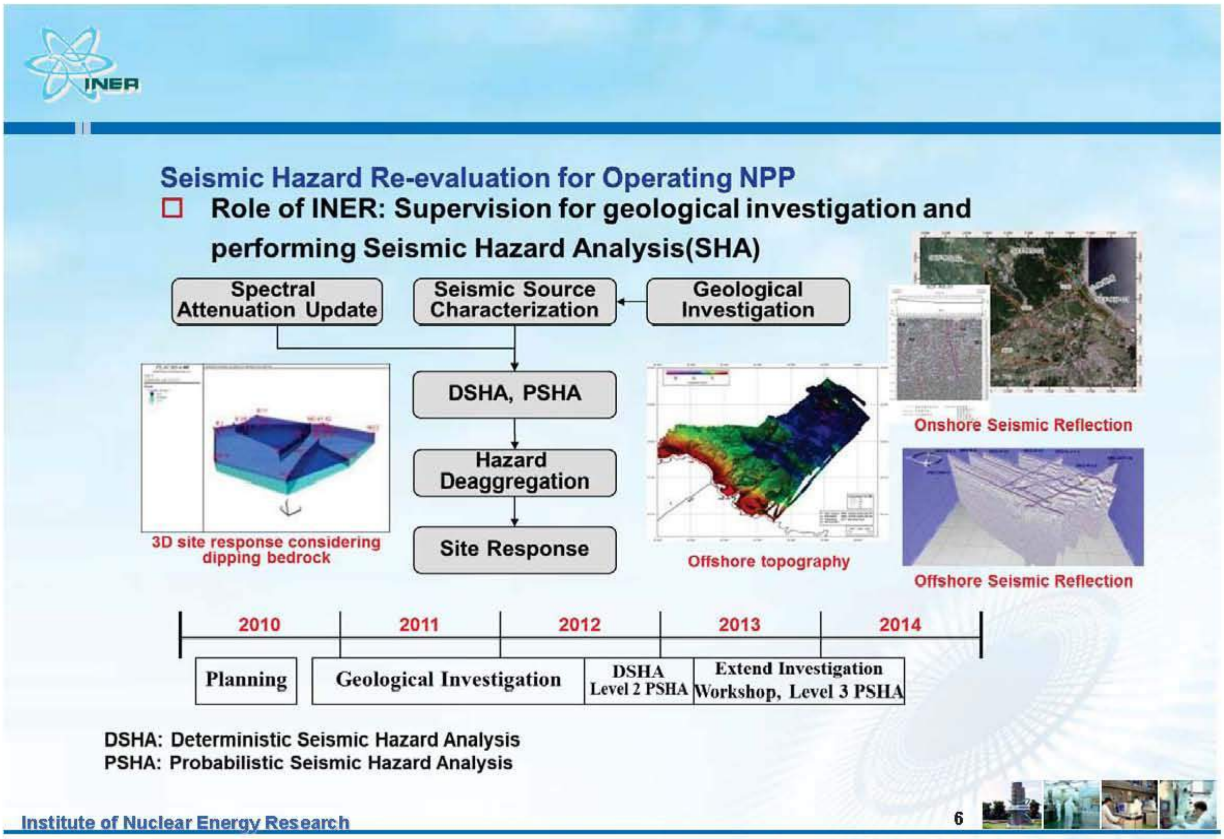


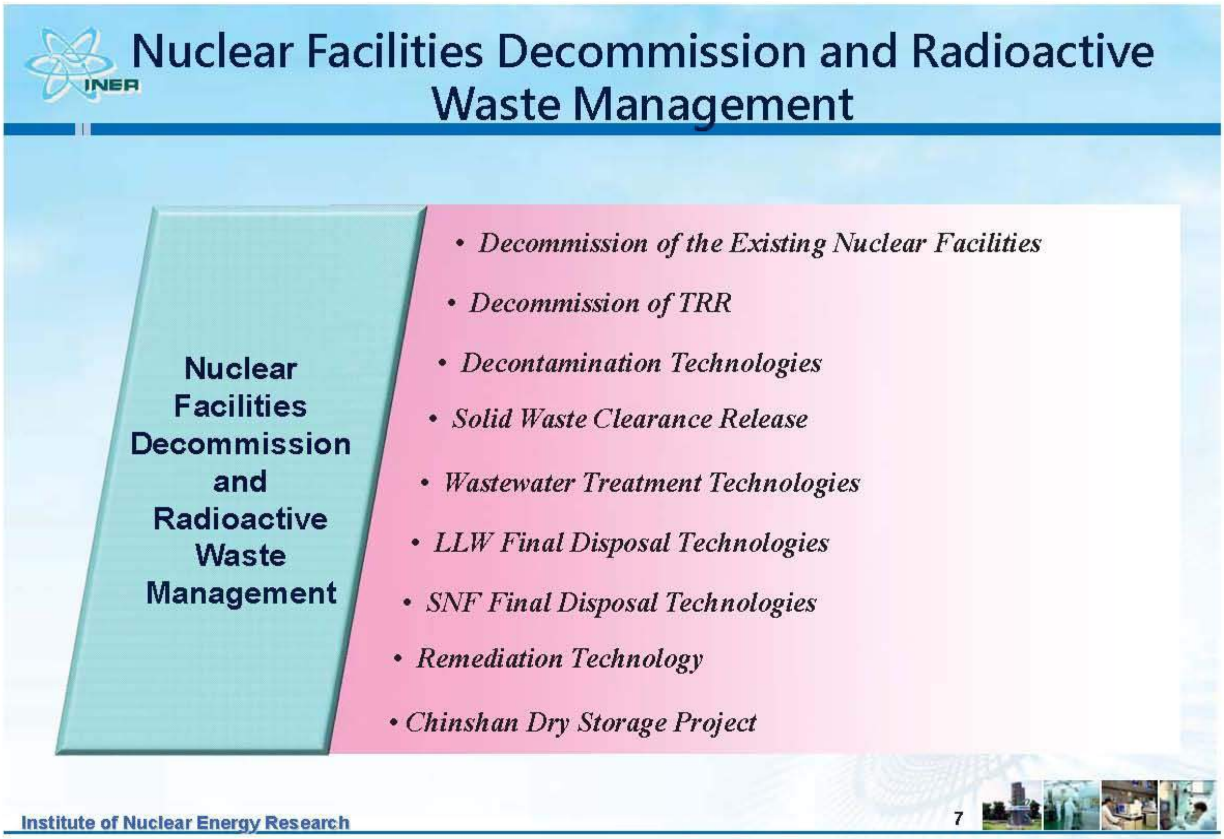

Introduction
■ Vision
To provide integrated strategies and technical supports for energy security, environment protection and civilian health.
■ R&D Fields
Energy & Environment 45%
Radiation Application 31%
Nuclear Safety 24%
Human Resource Profile Total 1337 (including contract manpower 668)
Staffs of INER 669
Scientist 369
Technician 217
Administrator 83
Others 51
11.5%
7.1%
33.8%
51.2%
Statistics of staffs in Education Degree
50%
40%
30%
20%
10%
0%
30.60%
51.49%
14.63%
3.25%
Ph.D. 113
MS 190
BS 54
Others 12
Institute of Nuclear Energy Research
2

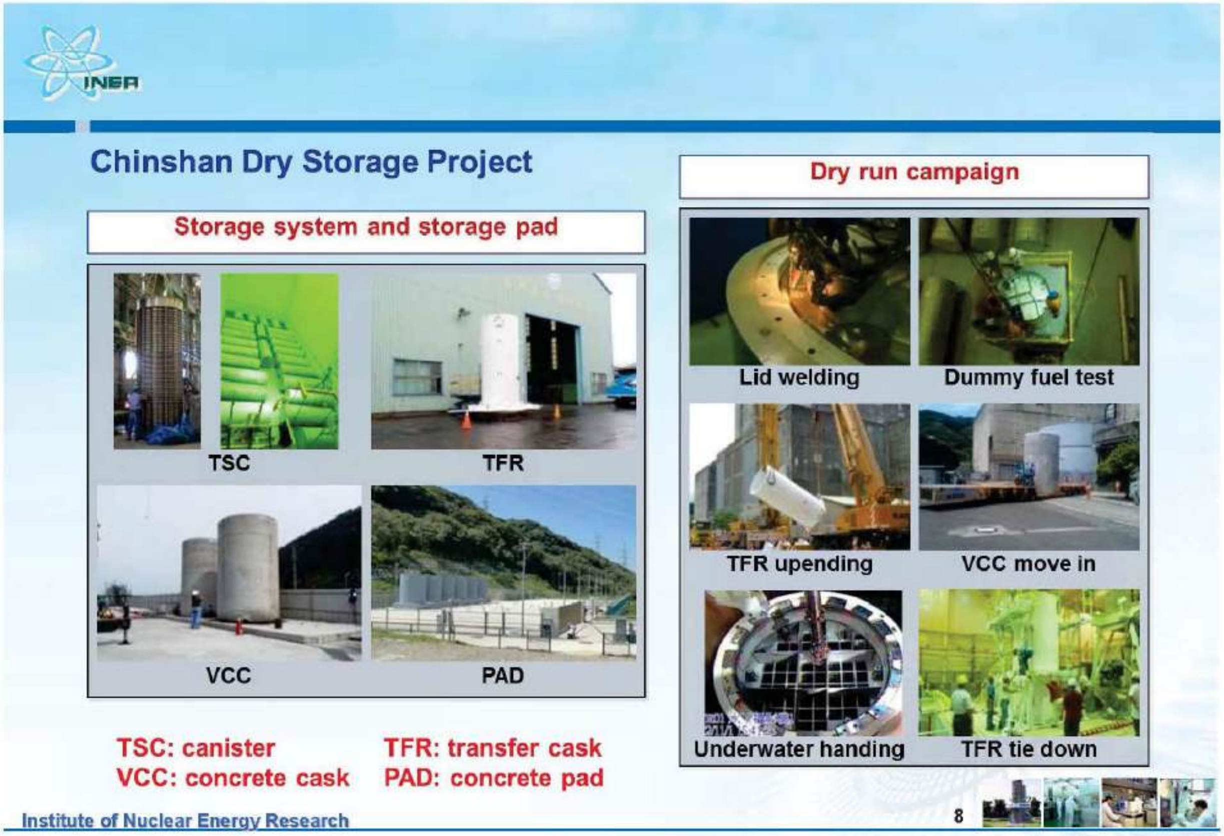

Introduction
Organization Chart of INER
Director-General
Advisory Committee
Nuclear Regulatory Technology Support Center
Occupational Safety and Health Committee
Marketing Center
Deputy Director-General
Deputy Director-General
Chief Secretary
Radiopharmaceuticals Production and Marketing Center
Nuclear Backend Research Center
Isotope Application Division
Engineering Technology & Facility Operation Division
Chemical Engineering Division
Health Physics Division
Nuclear Engineering Division
Mechanical and Systems Engineering Project
Center of Energy Economics and Strategy Research
Chemical Analysis Division
Physics Division
Nuclear Fuels and Materials Division
Nuclear Instrumentation Division
Legal Affairs Office
Project Planning Division
Secretarial Office
Personnel Office
Accounting Office
Civil Service Ethics Office
Institute of Nuclear Energy Research
3

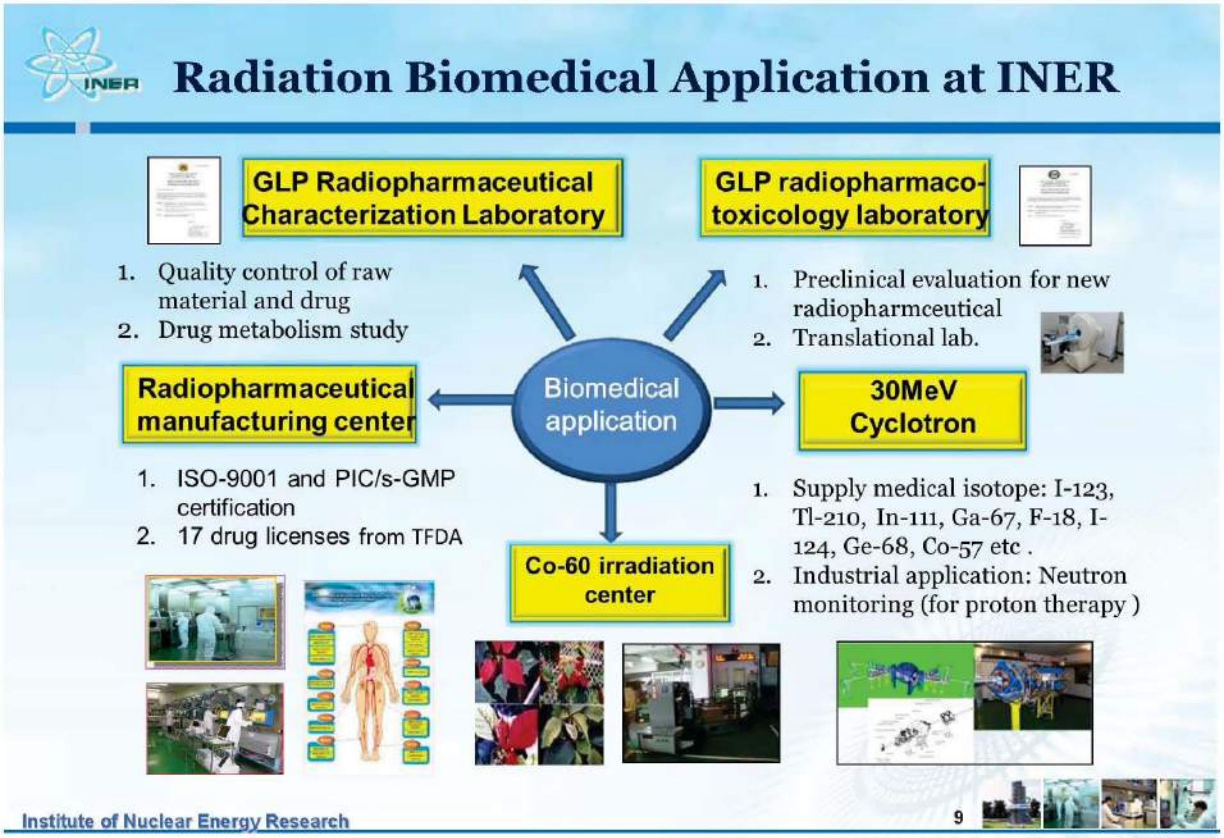

INER
Introduction
Nuclear Safety
Energy & Environment
Radiation Applications
1
2
3
4
5
Radiopharmaseuticals & Instrumentation
Safety Technologies for NPP
Safety Technologies for Operation & Maintenance
Industrialization
Life extension assessment
Decontamination & Remediation Technologies
Decommissioning Technologies for NPP
RadWaste processing Technologies
Medical, agricultural and industrial LLW receiving & storage
Support National Radioactive Waste Operation Center
Execution and promotion of NEP-II program
National energy technology think tank
System integration
Energy industry promotion
Energy policy & strategy
Assessment & planning of technology promotion for industrialization
Energy data base platform & 3E integration assessment
Radiopharmaceuticals
Nuclear medicine industrialization
High level Medical devices
The five domains of R&D technologies
Institute of Nuclear Energy Research
4


INER
Nuclear Safety Technology
Nuclear Safety Technology
• Safety Assessment
• Probabilistic Risk Assessment (PRA)
• Digital Instrumentation & Control
• Power Up-rating
• System Operation and Maintenance
• Nuclear Materials Safety Research
• Radiation Protection
• Emergence Response
Institute of Nuclear Energy Research
5


INER
Seismic Hazard Re-evaluation for Operating NPP
Role of INER: Supervision for geological investigation and performing Seismic Hazard Analysis(SHA)
Spectral Attenuation Update
Seismic Source Characterization
Geological Investigation
DSHA, PSHA
Hazard Deaggregation
Site Response
3D site response considering dipping bedrock
Offshore topography
Onshore Seismic Reflection
Offshore Seismic Reflection
2010
2011
2012
2013
2014
Planning
Geological Investigation
DSHA Level 2 PSHA
Extend Investigation Workshop, Level 3 PSHA
DSHA: Deterministic Seismic Hazard Analysis
PSHA: Probabilistic Seismic Hazard Analysis
Institute of Nuclear Energy Research
6


INER
Nuclear Facilities Decommission and Radioactive Waste Management
Nuclear Facilities Decommission and Radioactive Waste Management
• Decommission of the Existing Nuclear Facilities
• Decommission of TRR
• Decontamination Technologies
• Solid Waste Clearance Release
• Wastewater Treatment Technologies
• LLW Final Disposal Technologies
• SNF Final Disposal Technologies
• Remediation Technology
• Chinshan Dry Storage Project
Institute of Nuclear Energy Research
7

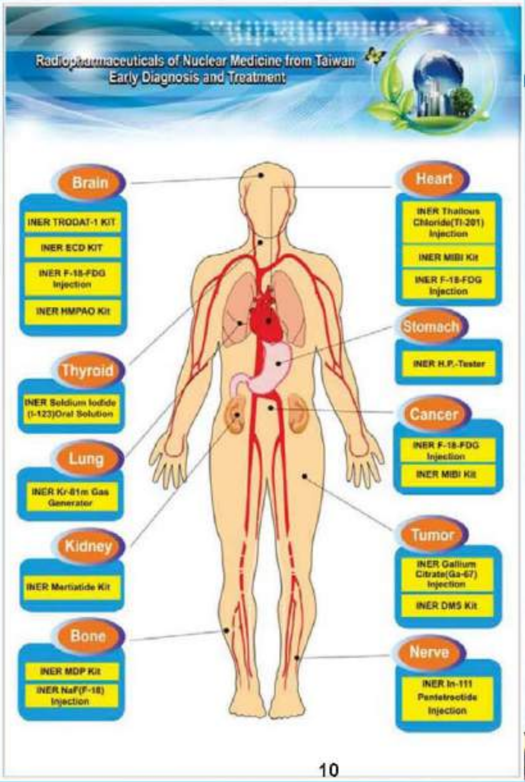

INER
Chinshan Dry Storage Project
Storage system and storage pad
TSC
TFR
VCC
PAD
TSC: canister
VCC: concrete cask
TFR: transfer cask
PAD: concrete pad
Dry run campaign
Lid welding
Dummy fuel test
TFR upending
VCC move in
Underwater handing
TFR tie down
Institute of Nuclear Energy Research
8


INER
Radiation Biomedical Application at INER
GLP Radiopharmaceutical Characterization Laboratory
1. Quality control of raw material and drug
2. Drug metabolism study
GLP radiopharmaco-toxicology laboratory
1. Preclinical evaluation for new radiopharmceutical
2. Translational lab.
Biomedical application
Radiopharmaceutical manufacturing center
1. ISO-9001 and PIC/s-GMP certification
2. 17 drug licenses from TFDA
30MeV Cyclotron
1. Supply medical isotope: I-123, Tl-210, In-111, Ga-67, F-18, I-124, Ge-68, Co-57 etc .
2. Industrial application: Neutron monitoring (for proton therapy)
Co-60 irradiation center
Institute of Nuclear Energy Research
9

INER

Radiopharmaceutical manufacturing center

(ISO-9001 and PIC/s-GMP certification)



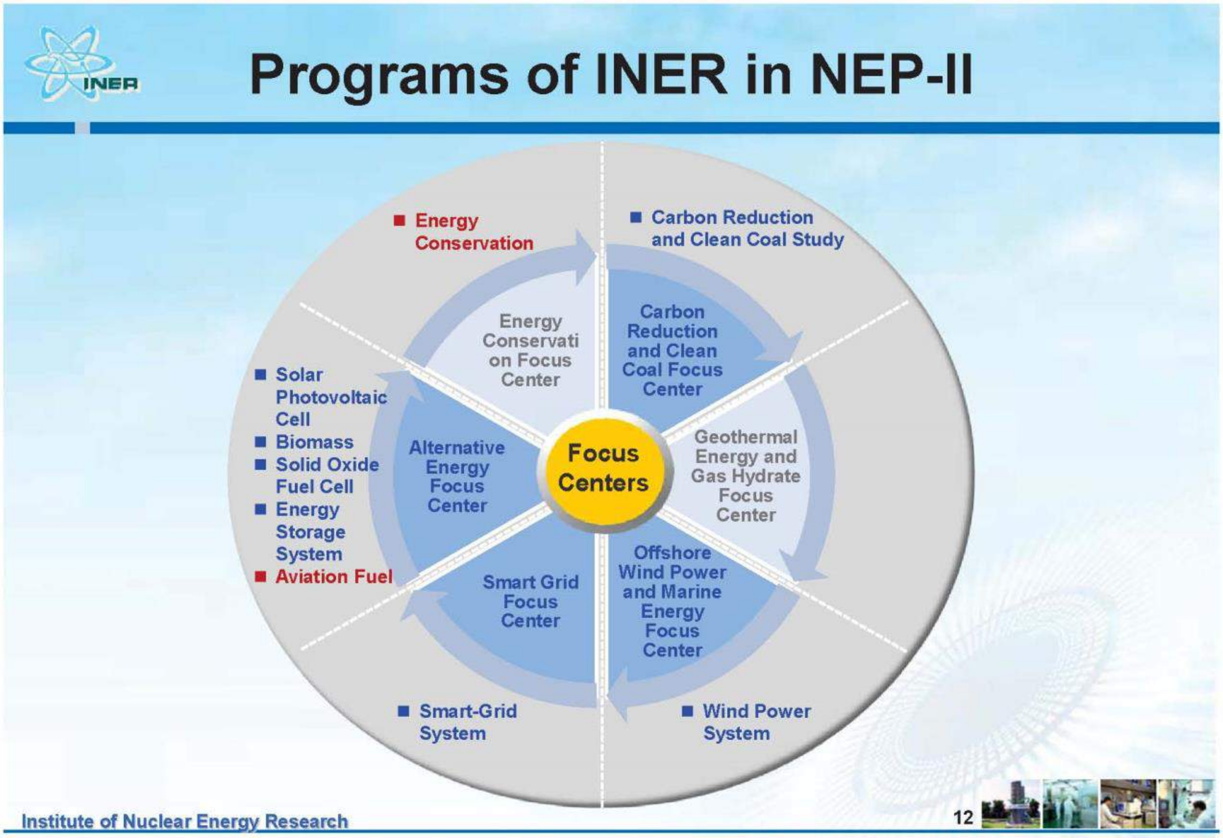
Institute of Nuclear Energy Research

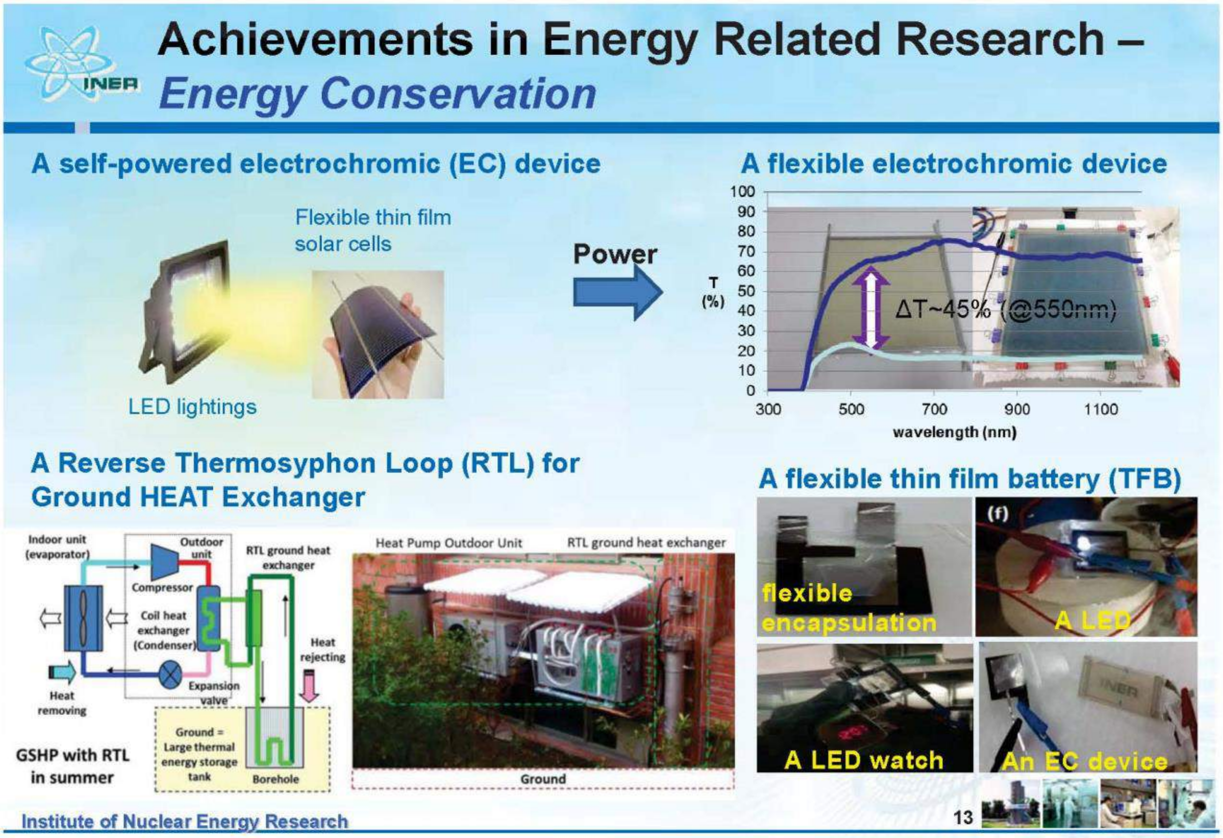
INER

17 Medicinal Licenses

		藥品許可證			藥品許可證
Heart		■ 核研氯化亞鉈(鉈-201)注射劑 (INER Thallous Chloride(Tl-201) Injection) ■ 核研美必鎝心臟造影劑 (INER MIBI Kit)	Lung		■ 核研氪-81m氣體發生器 (INER Kr-81m Gas Generator)
Tumor		■ 核研檸檬酸鎵(鎵-67)注射劑 (INER Gallium Citrate(Ga-67) Injection) ■ 核研去氧葡萄糖(氟-18)注射劑 (INER F-18-FDG Injection) ■ 核研銦-111胜肽銦腫瘤注射劑 (INER In-111 Pentetreotide Injection)	Kidney		■ 核研馬格鎝腎功能造影劑 (INER Mertiatide Kit)
Brain		■ 核研多巴胺轉運體造影劑 (INER TRODAT-1 KIT) ■ 核研宏寶鎝腦造影劑 (INER HMPAO Kit) ■ 核研雙胱乙酯腦造影劑 (INER ECD Kit)	Bone		■ 核研甲基雙磷酸骨骼造影劑 (INER MDP Kit) ■ 核研【氟-18】氟化鈉注射劑 (INER F-18 NaF)
Thyroid		■ 核研碘化鈉(碘-123)口服液 (INER Soldium Iodide(I-123) Oral Solution) ■ 核研琥珀鎝腫瘤造影劑 (INER DMS Kit)	Stomach		■ 核研碳-13驗菌劑INER H.P.-Tester

Institute of Nuclear Energy Research 11


Programs of INER in NEP-II
Energy Conservation
Carbon Reduction and Clean Coal Study
Energy Conservation Focus Center
Carbon Reduction and Clean Coal Focus Center
Solar Photovoltaic Cell
Biomass
Solid Oxide Fuel Cell
Energy Storage System
Aviation Fuel
Alternative Energy Focus Center
Focus Centers
Geothermal Energy and Gas Hydrate Focus Center
Smart Grid Focus Center
Offshore Wind Power and Marine Energy Focus Center
Smart-Grid System
Wind Power System
Institute of Nuclear Energy Research
12

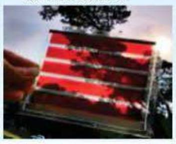

Achievements in Energy Related Research – Energy Conservation
A self-powered electrochromic (EC) device
Flexible thin film solar cells
LED lightings
Power
A flexible electrochromic device
T (%)
ΔT~45% (@550nm)
wavelength (nm)
A Reverse Thermosyphon Loop (RTL) for Ground HEAT Exchanger
Indoor unit (evaporator)
Outdoor unit
Compressor
RTL ground heat exchanger
Coil heat exchanger (Condenser)
Heat rejecting
Expansion valve
Heat removing
GSHP with RTL in summer
Ground = Large thermal energy storage tank
Borehole
Heat Pump Outdoor Unit
RTL ground heat exchanger
Ground
A flexible thin film battery (TFB)
flexible encapsulation
A LED
A LED watch
An EC device
Institute of Nuclear Energy Research
13

Achievements in Energy Related Research – *Solar Photovoltaic cell*

■ Solar Cell

Development of Mass Production and Commercial Module of Polymer Solar Cells (PSCs)

- □ Non-vacuum, Solution-processed, Flexible, Thin, light, Printable — The third generation solar cell
  - ■ Low-energy, low pollution, low carbon and low cost.
  - ■ Large-area coating techniques: ultrasonic spray, ink-jet printing and roll-to-roll slot-die coating.
  - ■ All-solution processed and transparent large-area PSCs or modules.



■ MW Grade HCPV System

Location		Lujhu, Kaohsiung, Taiwan
Area (hectare)		3.44 in total • 1.76 from National Property Administration • 1.68 from Taiyen Co.
		1.6 in acting
Equipment	Tracker (set)	7.5 kW (120), 5 kW (21)
	Module (ea)	8,040
	Inverter (ea)	201
Cost (USD/W)		8
Established/Operation		Dec. 2009/Feb. 2010
O & M Personnel		2

■ Concentration PV (CPV) Micro-module

Feature 1. High Efficiency
Module efficiency reaches 35.15%, is almost as twice as traditional PV's

Feature 2. Better Optical Performance
Concentration ratio is above 1100; optical acceptance angle is ±0.7°

Feature 3. Automatable Manufacture
Importing LED process technologies & packaging; effectively promote automation level and yield rate

Feature 4. Low Cost
Reduce customized components and highly cut the development cost; simplified the process of frame assembly; efficiently drop manpower

Feature 5. Carbon Dioxide Emission Reduced
Module height is only 1/3 of original; quantity of material used less; easier for transportation; effectively reduce carbon dioxide emission; save energy and protect environment

Feature 6. Raise Reliability
Capably lower working temp of solar cell because solar energy is spread; increase module durability and reliability

Achievements in Energy Related Research – *Biomass - Lignocellulose Biorefinery Technology*

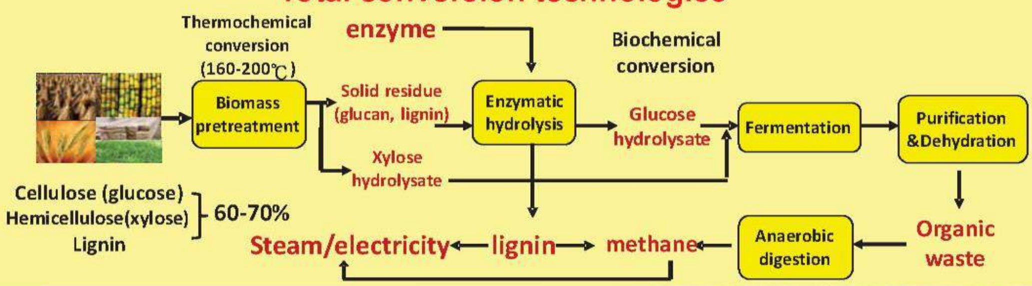
- ■ Core technology: Pretreatment System, Co-fermentation Yeasts and On-site Enzyme Production
- ■ Competitive Biorefinery process producing ethanol for ~$0.67/L (exclude feedstock cost)

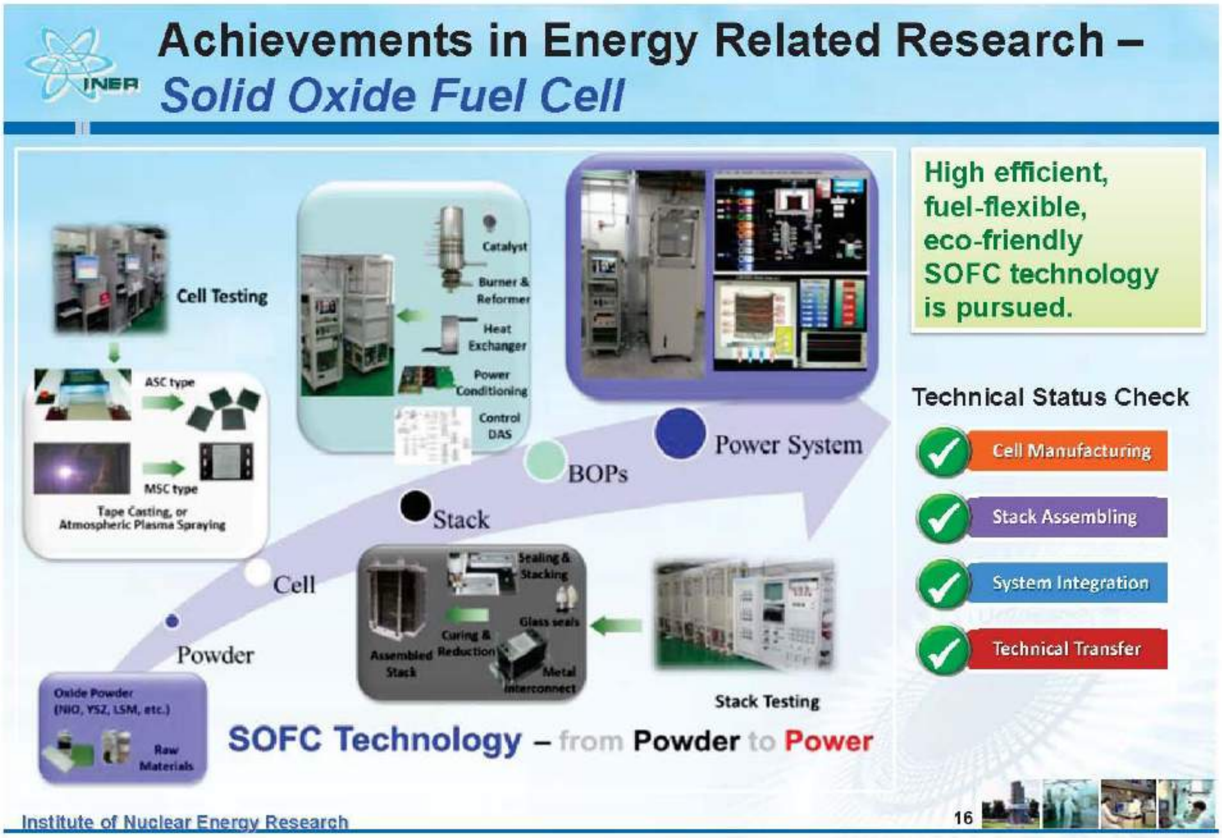
Facility:1 ton/d pilot plant

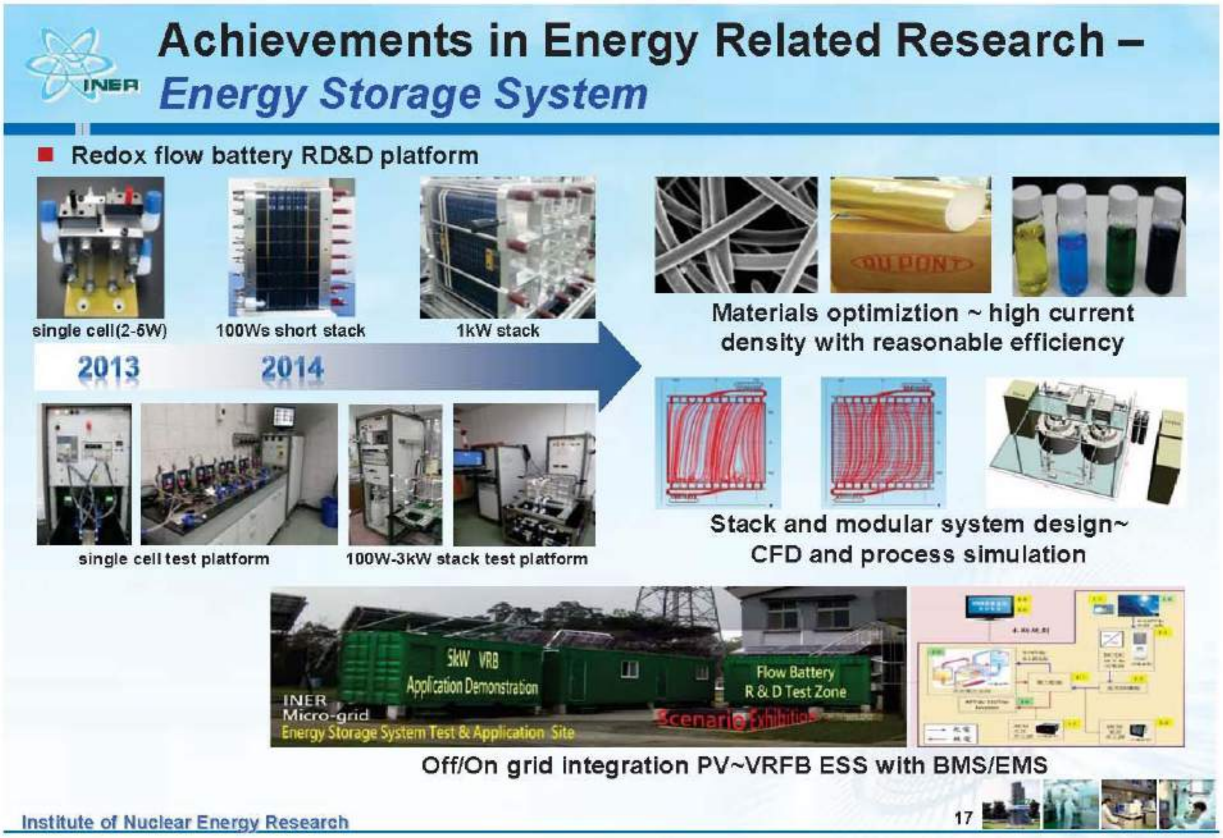
Diverse product

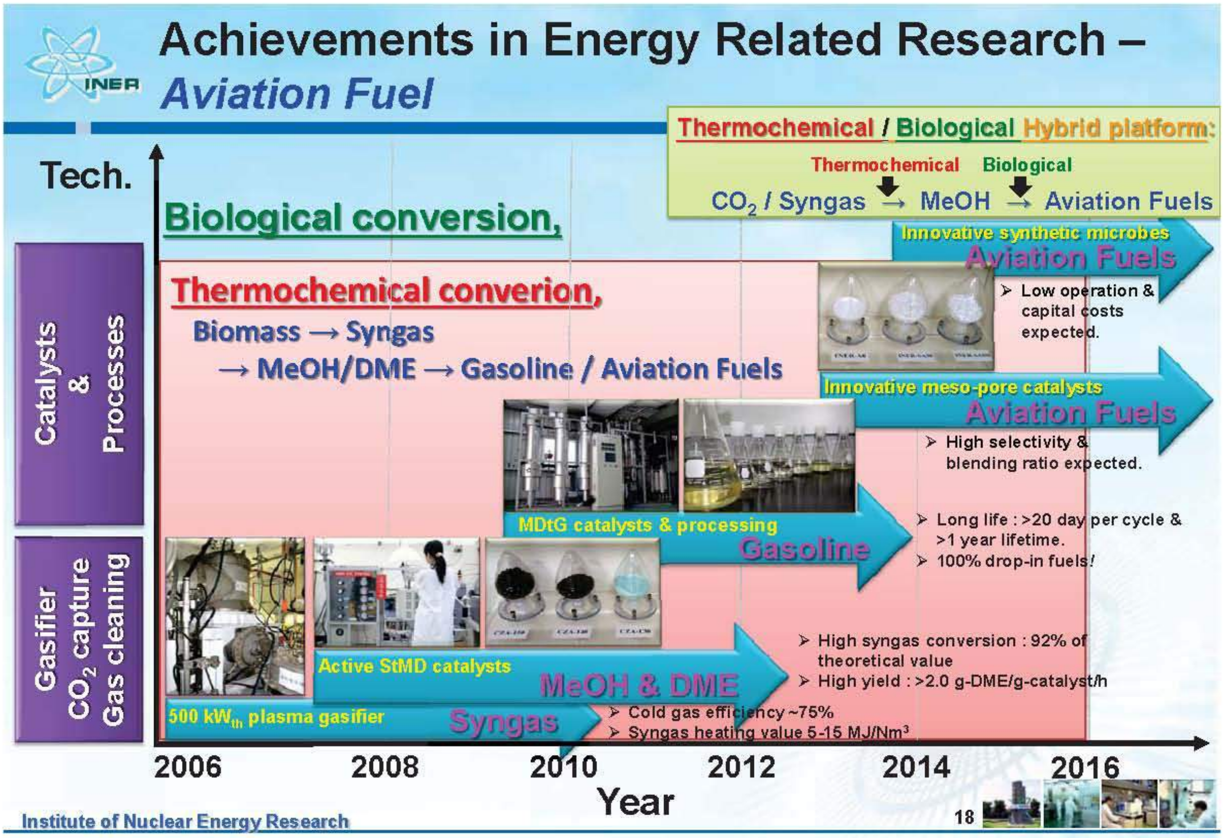
Long-chained hydrocarbons (jet fuel)
FDCA (PEF bottle)
Lactic acid (PLA plastics)
gasohol ↑ Cellulosic ethanol

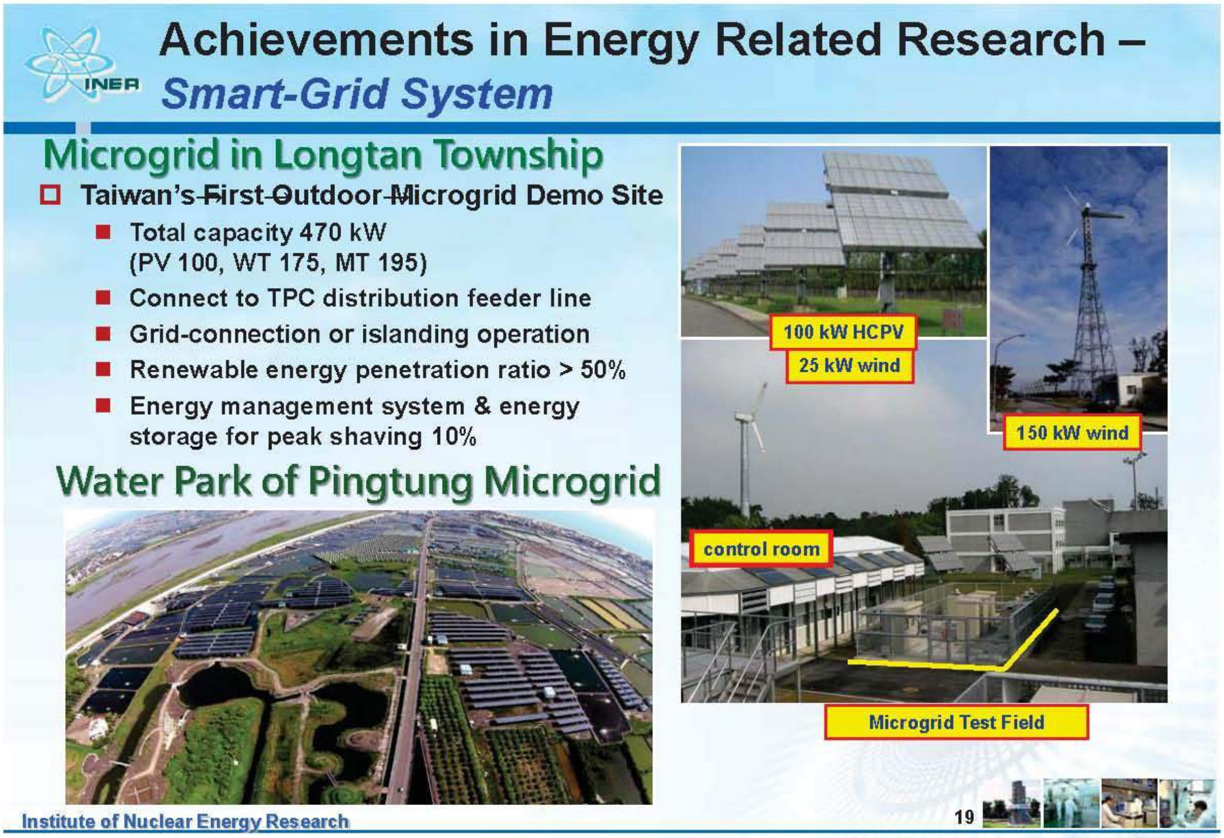
Total conversion technologies

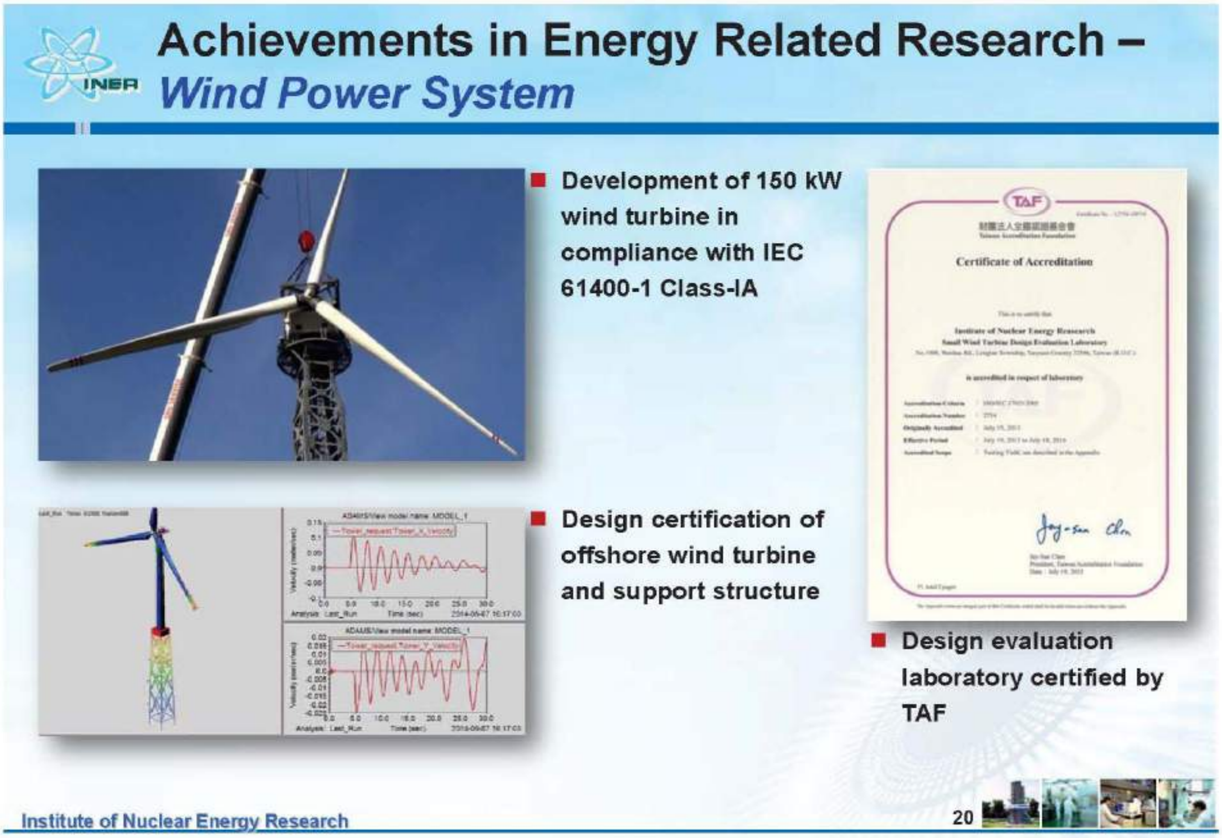



Achievements in Energy Related Research –
Solid Oxide Fuel Cell
High efficient, fuel-flexible, eco-friendly SOFC technology is pursued.
Technical Status Check
Cell Manufacturing
Stack Assembling
System Integration
Technical Transfer
Cell Testing
ASC type
MSC type
Tape Casting, or Atmospheric Plasma Spraying
Catalyst
Burner & Reformer
Heat Exchanger
Power Conditioning
Control DAS
Power System
BOPs
Stack
Cell
Powder
Oxide Powder (NiO, YSZ, LSM, etc.)
Raw Materials
Sealing & Stacking
Glass seals
Curing & Reduction
Assembled Stack
Metal Interconnect
Stack Testing
SOFC Technology – from Powder to Power
Institute of Nuclear Energy Research
16

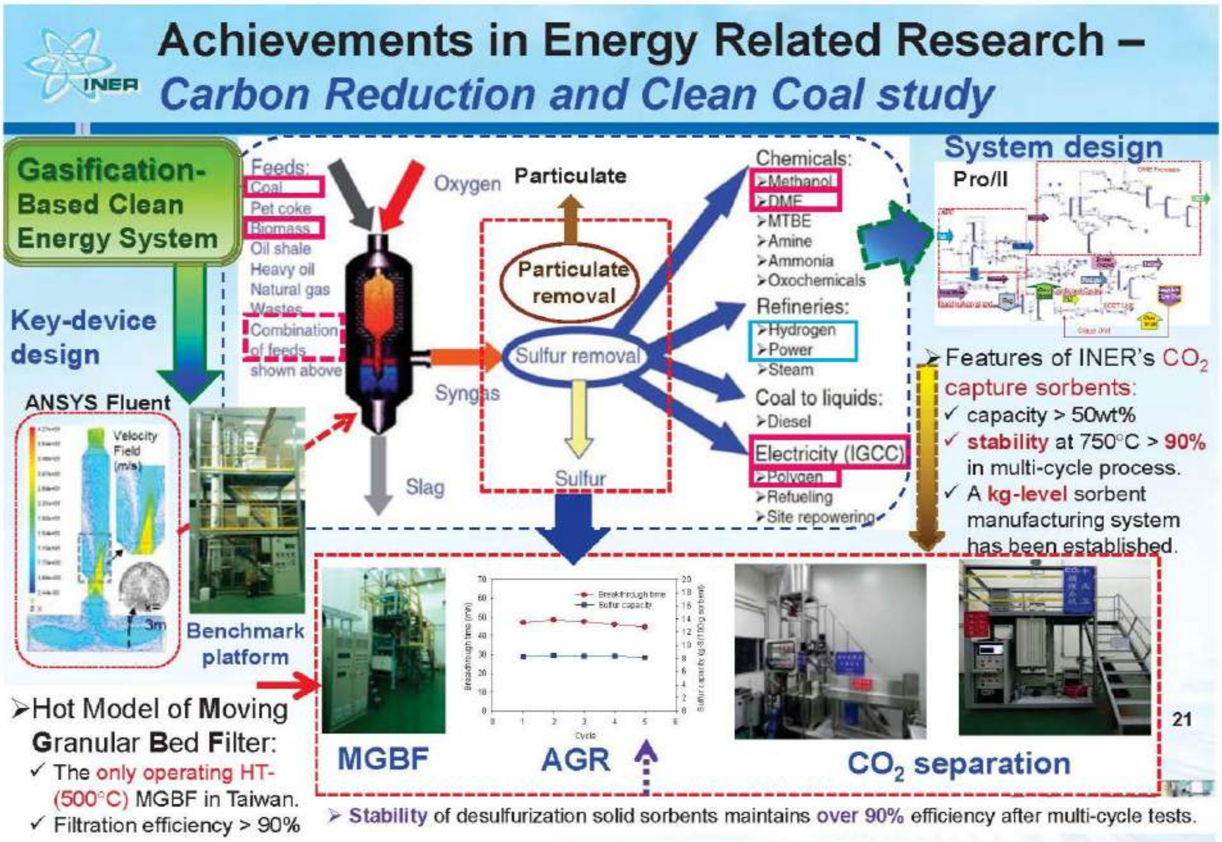

Achievements in Energy Related Research –
Energy Storage System
Redox flow battery RD&D platform
single cell(2-6W)
100Ws short stack
1kW stack
2013
2014
Materials optimiztion ~ high current density with reasonable efficiency
single cell test platform
100W-3kW stack test platform
Stack and modular system design~ CFD and process simulation
5kW VRB Application Demonstration
Flow Battery R & D Test Zone
INER Micro-grid Energy Storage System Test & Application Site
Off/On grid integration PV~VRFB ESS with BMS/EMS
Institute of Nuclear Energy Research
17


Achievements in Energy Related Research –
Aviation Fuel
INER
Thermochemical / Biological Hybrid platform:
Thermochemical Biological
CO2 / Syngas → MeOH → Aviation Fuels
Tech.
Biological conversion,
Innovative synthetic microbes
Aviation Fuels
Low operation & capital costs expected.
Thermochemical converion,
Biomass → Syngas
→ MeOH/DME → Gasoline / Aviation Fuels
Innovative meso-pore catalysts
Aviation Fuels
High selectivity & blending ratio expected.
Catalysts & Processes
MDtG catalysts & processing
Gasoline
Long life : >20 day per cycle & >1 year lifetime.
100% drop-in fuels!
Gasifier CO2 capture Gas cleaning
Active StMD catalysts
MeOH & DME
High syngas conversion : 92% of theoretical value
High yield : >2.0 g-DME/g-catalyst/h
500 kWth plasma gasifier
Syngas
Cold gas efficiency ~75%
Syngas heating value 5-15 MJ/Nm3
2006 2008 2010 2012 2014 2016
Year
Institute of Nuclear Energy Research
18

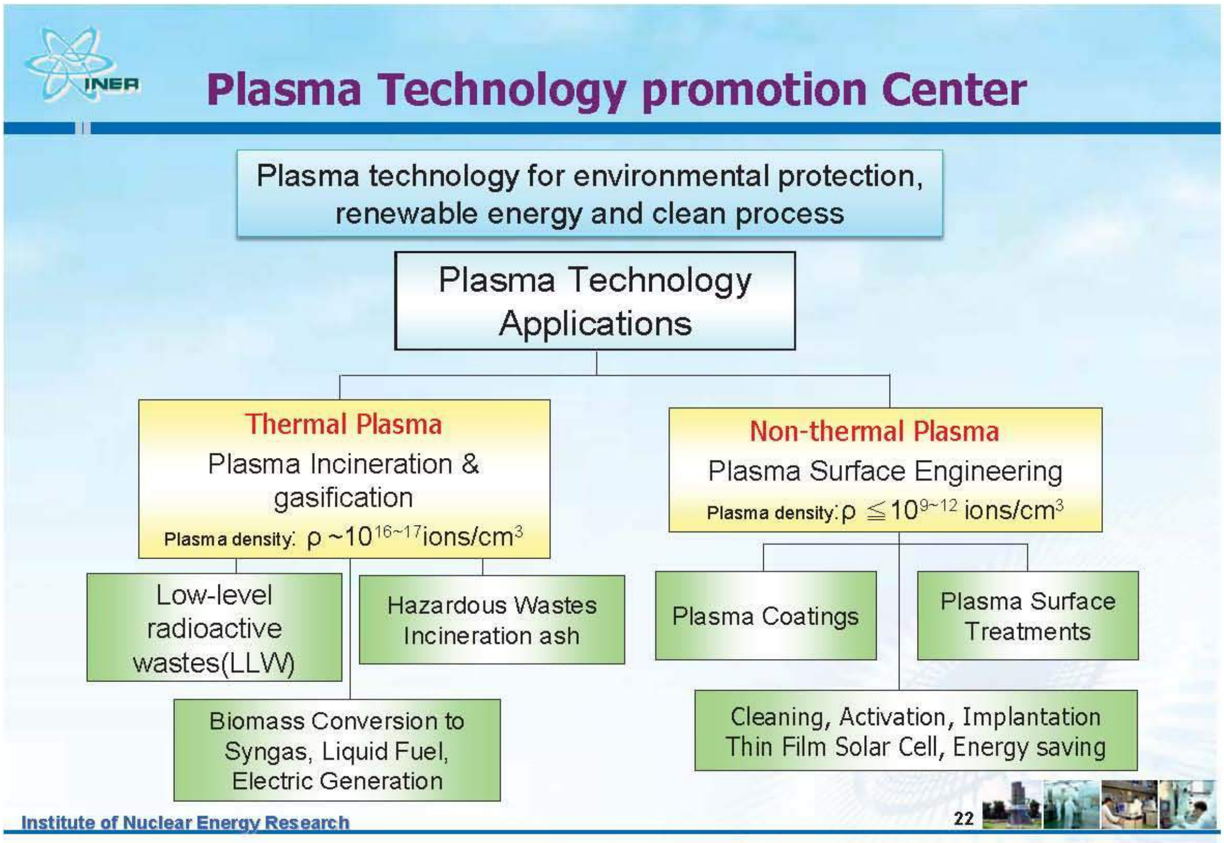

Achievements in Energy Related Research –
Smart-Grid System
INER
Microgrid in Longtan Township
Taiwan's First Outdoor Microgrid Demo Site
Total capacity 470 kW (PV 100, WT 175, MT 195)
Connect to TPC distribution feeder line
Grid-connection or islanding operation
Renewable energy penetration ratio > 50%
Energy management system & energy storage for peak shaving 10%
Water Park of Pingtung Microgrid
100 kW HCPV
25 kW wind
150 kW wind
control room
Microgrid Test Field
Institute of Nuclear Energy Research
19



INER
Achievements in Energy Related Research –
Wind Power System
Development of 150 kW wind turbine in compliance with IEC 61400-1 Class-IA
Design certification of offshore wind turbine and support structure
TAF
Certificate of Accreditation
Design evaluation laboratory certified by TAF
Institute of Nuclear Energy Research
20



INER
Achievements in Energy Related Research –
Carbon Reduction and Clean Coal study
Gasification-Based Clean Energy System
Feeds:
Coal
Pet coke
Biomass
Oil shale
Heavy oil
Natural gas
Wastes
Combination of feeds shown above
Oxygen
Particulate
Particulate removal
Sulfur removal
Syngas
Slag
Sulfur
Chemicals:
➢Methanol
➢DME
➢MTBE
➢Amine
➢Ammonia
➢Oxochemicals
Refineries:
➢Hydrogen
➢Power
➢Steam
Coal to liquids:
➢Diesel
Electricity (IGCC)
➢Polygen
➢Refueling
➢Site repowering
System design
Pro/II
Key-device design
ANSYS Fluent
Velocity Field (m/s)
3m
Benchmark platform
➢Features of INER's CO2 capture sorbents:
✓ capacity > 50wt%
✓ stability at 750°C > 90% in multi-cycle process.
✓ A kg-level sorbent manufacturing system has been established.
➢Hot Model of Moving Granular Bed Filter:
✓ The only operating HT-(500°C) MGBF in Taiwan.
✓ Filtration efficiency > 90%
Breakthrough time
Sulfur capacity
Cycle
MGBF
AGR
CO2 separation
21
➢ Stability of desulfurization solid sorbents maintains over 90% efficiency after multi-cycle tests.


INER
Plasma Technology promotion Center
Plasma technology for environmental protection, renewable energy and clean process
Plasma Technology Applications
Thermal Plasma
Plasma Incineration & gasification
Plasma density: ρ ~10^16~17 ions/cm^3
Non-thermal Plasma
Plasma Surface Engineering
Plasma density: ρ ≦10^9~12 ions/cm^3
Low-level radioactive wastes(LLW)
Hazardous Wastes Incineration ash
Biomass Conversion to Syngas, Liquid Fuel, Electric Generation
Plasma Coatings
Plasma Surface Treatments
Cleaning, Activation, Implantation
Thin Film Solar Cell, Energy saving
Institute of Nuclear Energy Research
22


INER
Plasma Coating Technology
Far Eastern Ti-Gold Technology Inc.
Super Coater
Generation I (1995-1998)
Generation II(1998-2001)
Generation IV(2007-2009)
Φ1800 × L4500
Multiple Planar CAD
Column CAD
Hybrid CAD
Over 30 planar CAD plasma sources and 2000A in total arc current
Good for deposition of complicated shape and large volume of working pieces
One plasma source over 8m in length and 1000A in arc current
Good for deposition of high uniformity of larger plane area of working pieces
Modified multiple Planar CAD together with 5m-long column CAD plasma sources
Good for deposition of all kinds of shape of working pieces
Institute of Nuclear Energy Research
23

Exclusive coater with front gate of 5 meter in length

NH48MV

2 tons work pieces available per batch

Feature
- Multiple modified planar CAD plasma sources together with high power pulse DC bias
- Equipped with Pulse DC driving Nitride

Screw-rod for plastic extrusion
Extending the life period at least Three times

- Adhesion force over 70 N for TiN film with thickness of 3 um on plasma nitride steel

Conclusions

INER followed the steps of the most National Nuclear Laboratories of the world. We extend our research fields to Green Energy during the past 15 years.

Taiwan's Bureau of Energy (BOE) rises the renewable target by 25% to 17.3Gw in 2030, which raises the share of renewables in national power mixes is estimated to be more than 26% (now 5%). PV 8,700Mw, Off-shore Wind Power 4,000Mw.

INER will switch to "Ministry of Economic and Energy Affairs" and change our name to "Institute of Energy Research, InER" after the new Organizational Act to be approved by Legislation Yuan in the near future.


Thank you for your Attention !

Wind Power Research and Development at INER

Presented by
Dr. Chin-Cheng Huang
Director, Mechanical and System Engineering Program
October 2015

INER Institute of Nuclear Energy Research

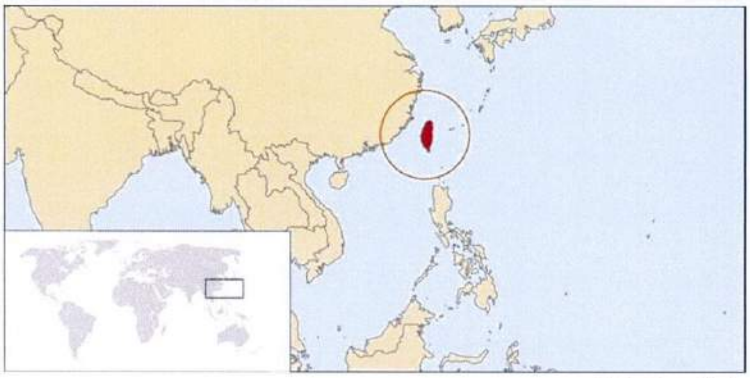
Outline

- Geography of Taiwan
- Wind resources in Taiwan
- National target for wind power
- Research and development of wind power in Taiwan and at INER
- Some important research topics on wind power

Institute of Nuclear Energy Research

1

Geography of Taiwan



All pictures from wikipedia

- Taiwan is located south east to China between Japan and Philippines.
- Taiwan is mostly mountainous in the middle and east, with gently sloping plains in the west. Penghu island is one of large off-islands in Taiwan.

Wind resources in Taiwan

- According to the international website, 4Coffshore.com, showing the abundant wind resources on the Taiwan Strait.

10 Year Global Wind Speed Rankings

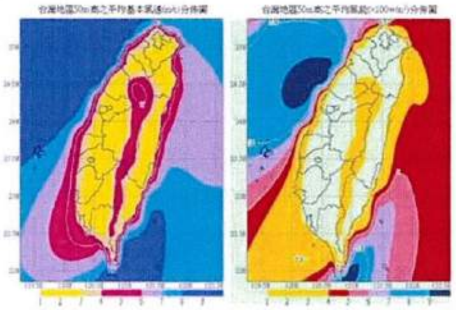
1 2 3 4 5 6 7 8 9 10 ...

Rank	Project	Sea	Cty	Status	Speed (m/s)
1*	Fujian Pingtan Datang Changjiangao 200MW offshore Wind Farm	South China Sea			12.11*
1	Putian Pinghai bay offshore project phase D-E	Taiwan Strait			12.11
1	Pingtan experimental zone 300MW offshore wind power project	South China Sea			12.11
4	Fujian Putian Shicheng Yugang Offshore Wind Farm	Taiwan Strait			12.06
5	Longyuan Putian Nanri Island 400MW project - Phase 1 - 16 MW Prototype	Taiwan Strait			12.04
5	Putian Pinghai bay offshore Wind Farm demonstration project phase 2-250MW	Taiwan Strait			12.04
5	Putian Pinghai bay offshore demonstration project phase A	Taiwan Strait			12.04
5	Longyuan Putian Nanri Island 400MW project - Phase 2 - 190MW	Taiwan Strait			12.04
10	Zhanghua 1-1 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 1-2 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 1-6 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 3-3 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 1-7 - Development Zone	Taiwan Strait			12.03
15	Zhanghua 3-1 - Development Zone	Taiwan Strait			12.02
15	Zhanghua 3-2 - Development Zone	Taiwan Strait			12.02
15	Taizhong 2 - Development Zone	Taiwan Strait			12.02

Source: 4Coffshore

Wind resources in Taiwan-onshore

- Superior on-land wind farms are mostly located in the northwestern and southwestern coasts. The full load hours can be 2500~3200 hours per year.
- Penghu island is one of the best wind areas with annual average wind speed ~ 9 m/sec, higher capacity factor of 45%



Source: Bureau of Energy

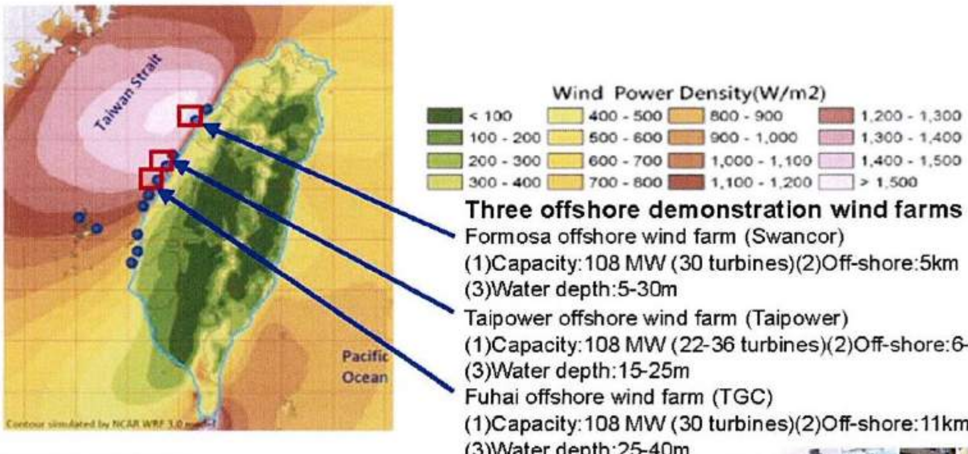
Average wind speed and wind power density at elevation 50m

Source: Bureau of Energy

Onshore wind power plants in Taiwan

Wind resources in Taiwan-offshore

• Shallow Water (5~20 m)	• Deep Water (20~ 50 m)	• Deeper Water (> 50 m)
➢ Area: 1,779.2 km² ➢ Potential: 9 GW ➢ Feasible: 1.2 GW	➢ Area: 6,547 km2 ➢ Potential: 48 GW ➢ Feasible: 5 GW	➢ Potential: 90 GW ➢ Feasible: 9 GW



Three offshore demonstration wind farms

Formosa offshore wind farm (Swancor)
(1)Capacity:108 MW (30 turbines)(2)Off-shore:5km
(3)Water depth:5-30m

Taipower offshore wind farm (Taipower)
(1)Capacity:108 MW (22-36 turbines)(2)Off-shore:6-8km
(3)Water depth:15-25m

Fuhai offshore wind farm (TGC)
(1)Capacity:108 MW (30 turbines)(2)Off-shore:11km
(3)Water depth:25-40m

National target of wind power for Taiwan

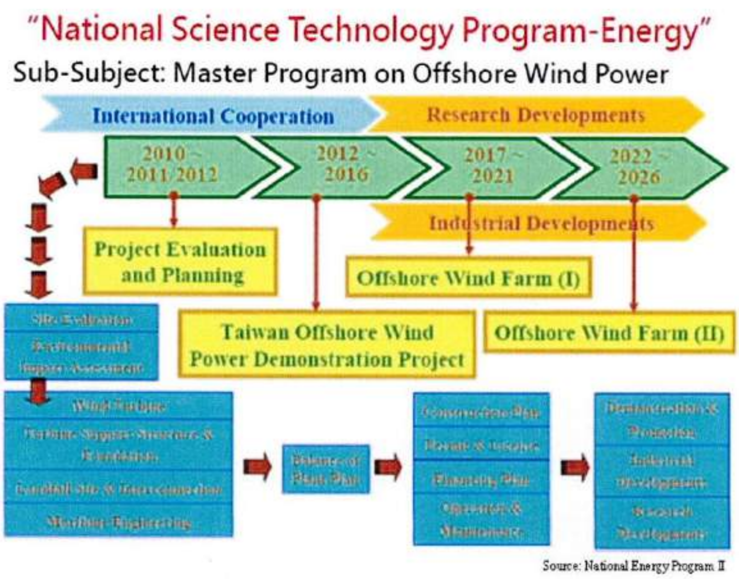
- According to the Bureau of Energy, the latest national target for wind power development can be shown in the table below (as of July, 2015).
- Hopefully, there will have first demonstration offshore wind turbines installed in two demonstration offshore wind farms, Fuhai offshore wind farm and Formosa offshore wind farm, respectively.

	2013	2016	2020	2025	2030
Onshore Accum.MW (units)	614 (311)	737 (370)	1,200 (450)	1,200 (450)	1,200 (450)
Offshore Accum.MW (units)	0	>12 (4)	520 (104)	1,520 (304)	4,000 (800)
MW (units)	614 (311)	750 (374)	1,720 (554)	2,720 (754)	5,200 (1,250)

Revised from BOE

Timeline for offshore wind research and development

- For development of offshore wind, the government(MOST) has formed national program to support the offshore wind R&D from 2010.
- The offshore wind program widely covers many different areas which are urgent and important to the offshore wind demonstration projects in Taiwan.



Source: National Energy Program II

Research and development on Wind Power at INER

- INER is a multidisplinary national laboratory and started small wind turbine research and development in 2006.
- The technology development for small wind is primarily on the mechanical system integration and self turbine development including aerodynamic design of blading, rotor system and dynamics, turbine integration, power testing, turbine test operation, etc.
- During the past decade, 400W, 25 kW, 150 kW from small to medium wind turbines have been developed and put into test operation at INER campus.
- Some joint research projects between universities and INER were performed on the self developed wind turbines.

Design of wind turbines and verification

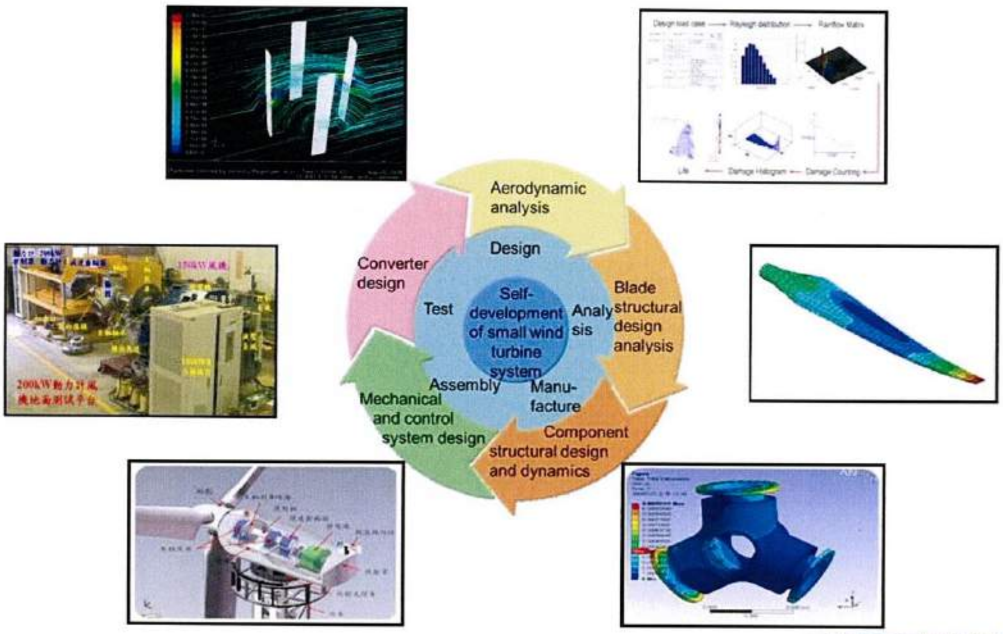
- INER is the only national laboratory with test wind park in Taiwan.
- Wind turbine technology team was recognized by TAF for design evaluation of small wind turbines.
- In 2013, INER helped Hi-VAWT with DS-3000 design report which was successfully certified by Class NK of Japan. The small VAWTs have been exported to Japan.


25 kW wind turbine


150 kW wind turbine


Wind turbine assembly

Technology development for wind turbine design and verification



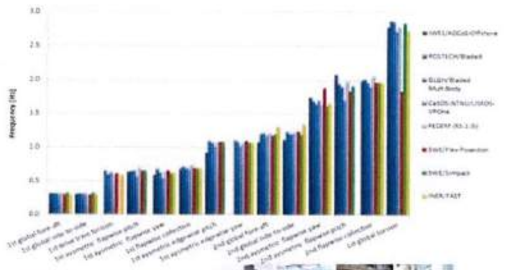
Offshore wind research and development at INER

- In 2012, INER joined the national offshore wind program of Taiwan
- The primary objective of the national offshore wind program is to support the demonstration offshore wind projects and localization of offshore wind technology by integration of research institutions, academia and industry.
- INER has been involving in the integrated dynamic load analysis of offshore wind turbine subjected to extreme external conditions such as typhoon, earthquake, etc.
- INER has also joined the IEA Task 30 OC5 as an observer since May of 2015, to get involved in the international activities of simulation and test on offshore wind and also get more technical information to improve the load simulations.

Offshore wind research and development at INER (Cont'd)

- With the OC3/OC4 technical reports, INER has finished the comparisons of load analysis results for NREL 5MW reference turbine subjected to some load cases for both of turbines with monopile and jacket support structures.
- Collaborate with SWE, Stuttgart university on the integrated load analysis for offshore wind turbine and support structures.
- At present, this work is ongoing for load analysis for offshore wind turbine system subjected to local environmental conditions such as typhoon, earthquake, etc.

Source: NREL



Institute of Nuclear Energy Research

12

Some important research topics on wind energy

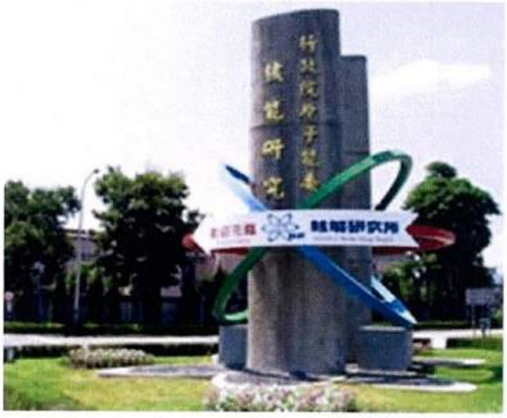
- Re-examination of the adequacy of use of the international design standards on the design of wind turbine in Taiwan. Specially, impact of harsh environments of typhoon, earthquake, etc. on local design guidelines for offshore wind system needs to be studied.
- Load simulation and load measurement are crucial for the offshore wind turbine design, operation and maintenance. Development for the combined technology is also very important for determination of regional design load cases, necessary component design strength, load mitigation, etc. against the harsh environments in Taiwan.
- Structural integrity and reliability assessment technologies are also to be developed in the near future at INER.

Institute of Nuclear Energy Research

13

INER

Thank you for your attention
Welcome to INER !



Institute of Nuclear Energy Research

14

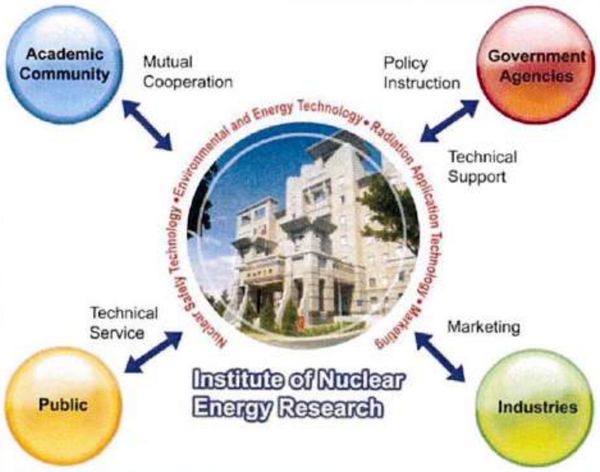
R&D Activities for biorefinery Technology at INER

Wen-Song Hwang

Chemistry Division
Institute of Nuclear Energy Research, AEC

Institute of Nuclear Energy Research (INER)

- INER was founded in 1968, currently under the administration of Atomic Energy Council (AEC), Taiwan.
- Will be renamed Institute of Energy Research, under the administration of Ministry of Economic and Energy Affairs (MEEA), Taiwan, after government organizational restructure.



- Organization was founded as the sole national research institute for nuclear science and technology studies.
- Research has been extended to the development of carbon-free energy, low-carbon energy, and industrial radiation applications.
- Special focus on research of renewable and new energy area.

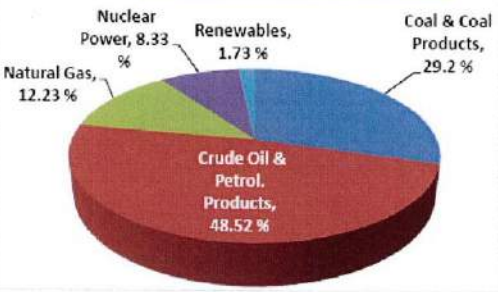
"Professionalism, Innovation, and Safety"
------Institute's core values

1

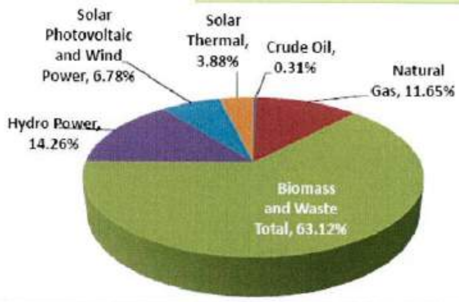
Energy Usage and Supply in Taiwan

- **Highly dependent on imported energy:**
  98.04% of energy sources are imported, only 1.96% from indigenous energy
- **Major reliance on fossil fuels (89.94 %)**
- **Biomass, the largest resource, accounts for 63 % of indigenous energy (1.96%) in Taiwan**

Total energy supply in Taiwan
148 million KLOE(2014)



Indigenous energy in Taiwan
2.9 million KLOE (2014)



Source :http://www.tbeia.org.tw/frnEnd/news/news_detail.aspx?id=17

2

Biomass Energy Industry in Taiwan

- **Biomass power**

2013 Installed capacity		In 2030
Waste	• City 624 MW • Industry 5MW	
Agriculture & Forestry	• Biogas 19MW • Agro-waste 92MW	
Total	740MW	950MW

- **The city waste will be decreased due to well garbage sorting and efficient resource recovery , and the biogas from sewage sludge and animal feces will be promoted in the future.**
- Aim to reach **950MW in 2030.**
- Construction of Refuse Derived Fuel (RDF-5) plant and co-located with paper manufacturer was operated well in Taiwan.

24 Waste incinerator power plant: 624MW

Biogas power plant 19 MW

RDF-5
180,000 ton/year

RDF-5 CHP plant

Source :http://www.tbeia.org.tw/frnEnd/news/news_detail.aspx?id=17

3

Biofuel policy in Taiwan

□Bioethanol

- E3 gasoline has been used in government vehicles in Taipei since 2007.
- 14 gas stations in Taipei and Kaohsiung city provide E3 gasoline since 2009.
- Source: Highly dependent on imports.

□Biodiesel

- B1 biodiesel was implemented nationwide in 2008, later increase to B2 in 2010.
- Source: Transesterification of kitchen waste oil and plant oil

E3 gasoline.

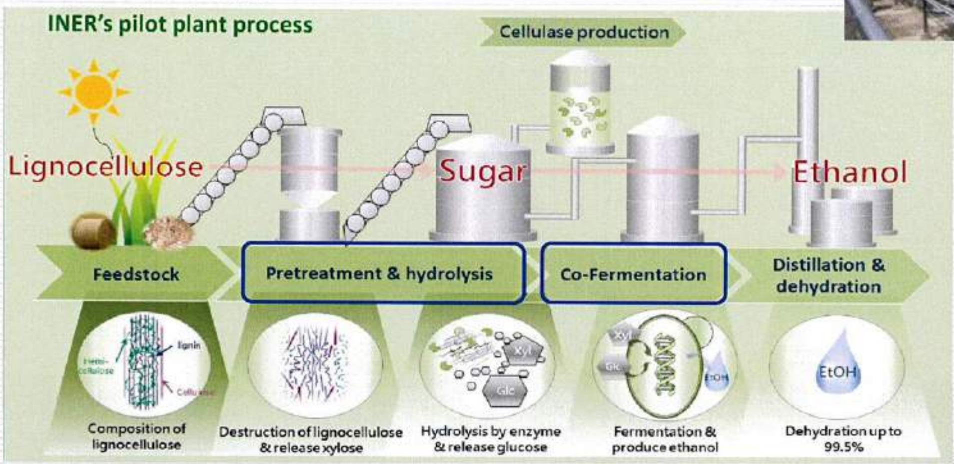

First manufacturer of biodiesel

2007	2008	2010	2025	2030
• E3 gasoline in Taipei	• B1	• B2	• B10 • E3 gasoline nationwide implementation.	• E10 gasoline • Biofuels account for 10% of transportation fuels

4

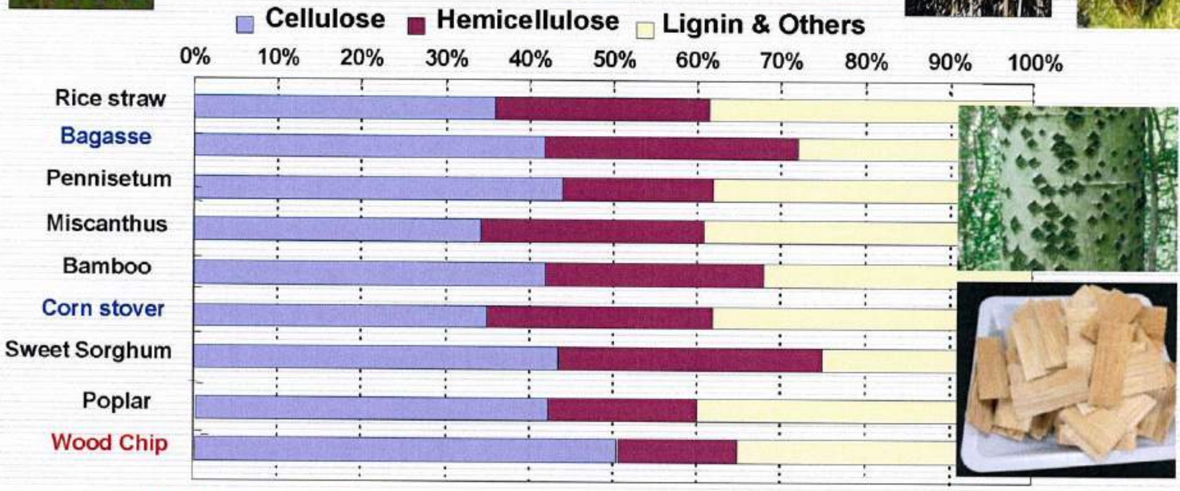
Cellulosic Ethanol (Biochemical Conversion)

□ INER has been dedicated to develop cellulosic ethanol technology since year 2005, and a leading and unique pilot plant with a capacity of 1 ton biomass fed per day was built to validate the applicability of cellulosic ethanol production at massive scale.



5

Cellulosic Ethanol of INER – Feedstock collection



➔Approximately 60% can be converted to fermentable sugars

6

INER Milestone

Bioenergy Technology Emerging Abroad

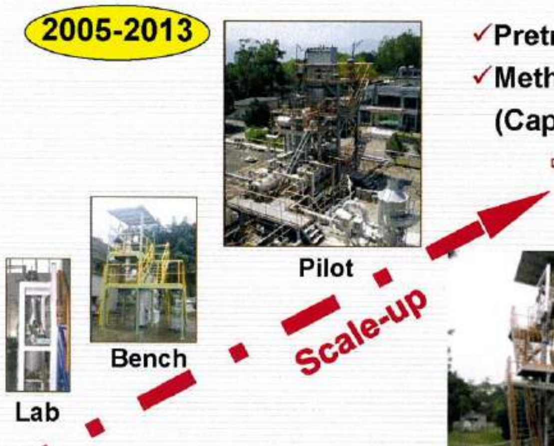
- INER's Cellulose-to-Ethanol Technology Transferred to Malaysian
- Business model of "Co-location construction" design was provided
- New biofuel plant construction co-located with the existing plywood plant by using waste wood chips as raw material for of biofuel production.

The agreement of technology transfer signed on May 14th 2015 by the Director-General of INER, Dr. Yin-Pang Ma(left) and Mr. Lin Tsai-Rong, the president and representative of Cymao, Malaysia.

7

Pretreatment Technology Development

2005-2013



2013-

✓Pretreatment **process improvement**
✓Methodology of **scale-up engineering**
(Capacity: 100-300 ton/day)

⇨ Establish **computational fluid dynamics (CFD) simulation models** according to the results of pilot plant tests

□ **Features:**

- Diverse lignocellulosic feedstocks
- Input solid/liquid ratio can be up to 40% ~ 50%
- Xylose concentration can be 40 g/L, glucan recovery > 80%
- Enzymatic hydrolysis conversion of the solid residue can be > 80%

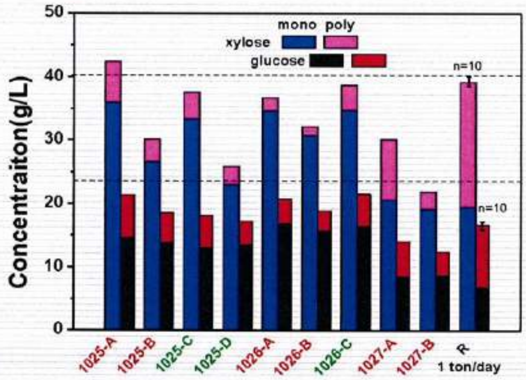
□ **Acid-Catalyzed Steam Explosion system** has reached the threshold of commercialization (Taiwan patents I340192, I346723, I369944 , I364427, I392544; US patent 8,080,128B2)

8

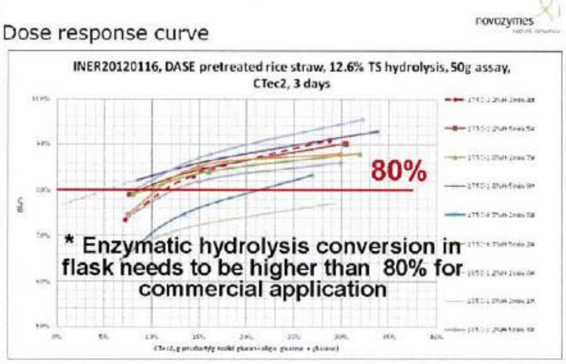
Cooperation between INER and Novozymes Company

➢ INER's acid-catalyzed steam explosion pretreatment system has reached the threshold of commercialization (Taiwan patents I340192, I346723, I369944 , I364427, I392544; US patent 8,080,128B2):

- Input solid/liquid ratio can be up to 40% ~ 50%
- Xylose concentration can be 30 ~ 40 g/L, glucan recovery > 80%
- Enzymatic hydrolysis conversion of the solid residue can be > 80%

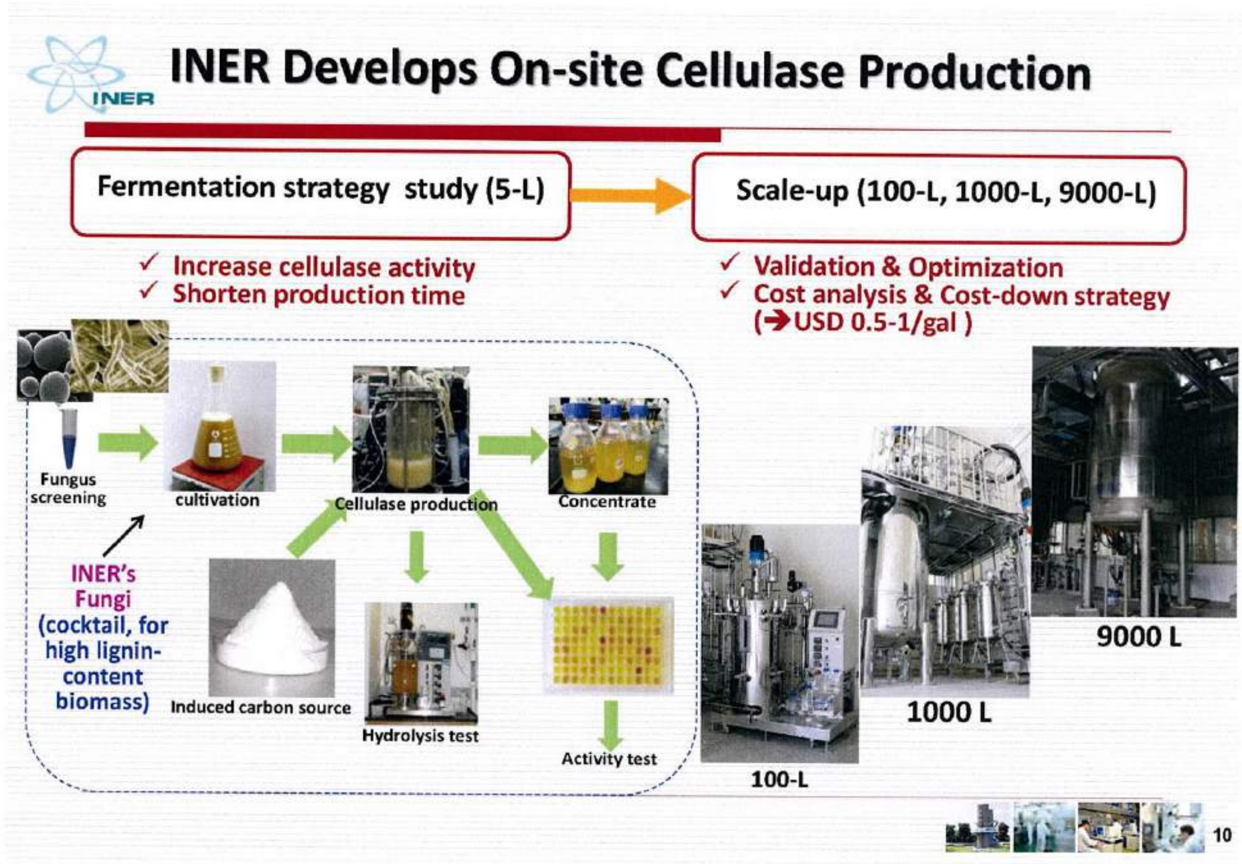


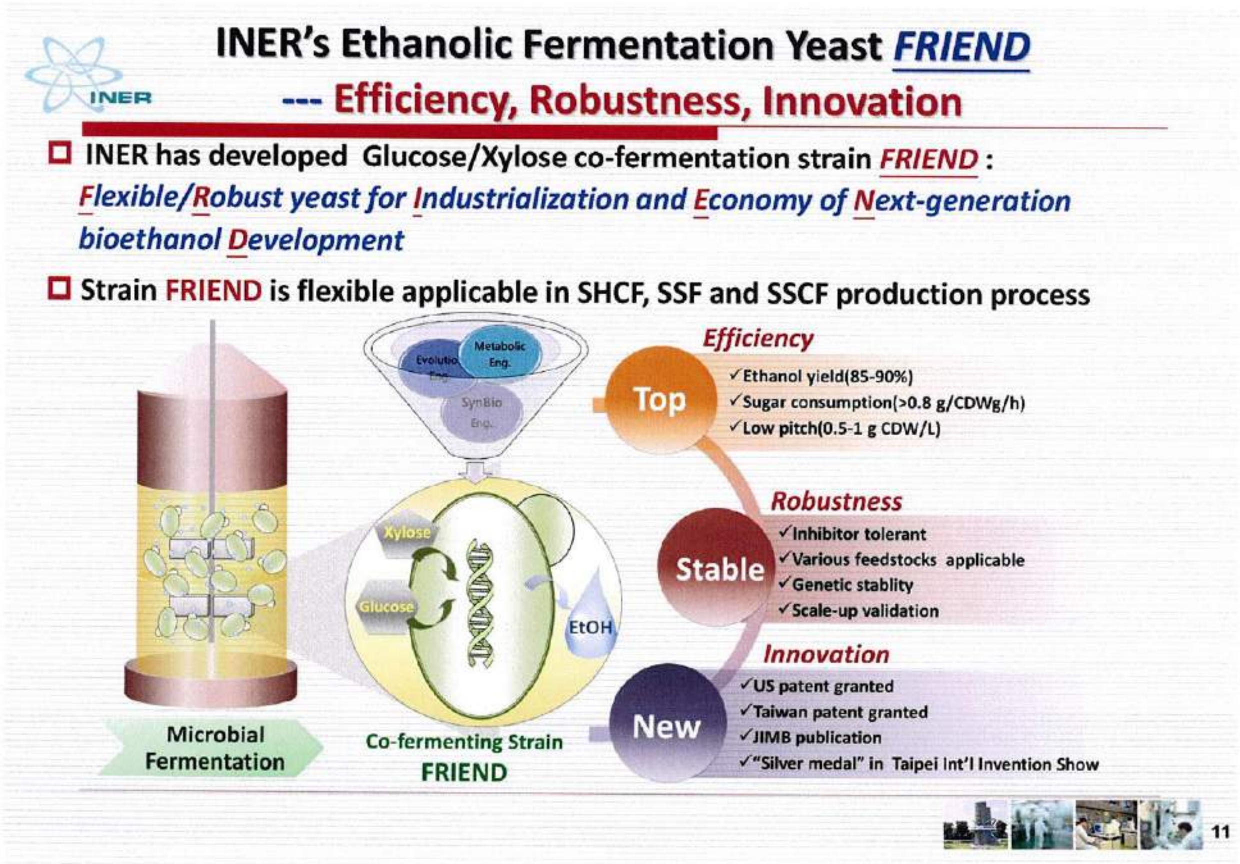
Rice straw hydrolysate obtained after pretreatment system of the pilot plant



Evaluation of enzymatic hydrolysis of the pretreated rice straw by Novozymes

9


INER
INER Develops On-site Cellulase Production
Fermentation strategy study (5-L)
Scale-up (100-L, 1000-L, 9000-L)
✓ Increase cellulase activity
✓ Shorten production time
✓ Validation & Optimization
✓ Cost analysis & Cost-down strategy
(➔USD 0.5-1/gal)
Fungus screening
cultivation
Cellulase production
Concentrate
INER's Fungi (cocktail, for high lignin-content biomass)
Induced carbon source
Hydrolysis test
Activity test
100-L
1000 L
9000 L
10


INER
INER's Ethanolic Fermentation Yeast FRIEND
--- Efficiency, Robustness, Innovation
INER has developed Glucose/Xylose co-fermentation strain FRIEND :
Flexible/Robust yeast for Industrialization and Economy of Next-generation bioethanol Development
Strain FRIEND is flexible applicable in SHCF, SSF and SSCF production process
Metabolic Eng.
SynBio Eng.
Xylose
Glucose
EtOH
Microbial Fermentation
Co-fermenting Strain FRIEND
Efficiency
Top
✓Ethanol yield(85-90%)
✓Sugar consumption(>0.8 g/CDWg/h)
✓Low pitch(0.5-1 g CDW/L)
Robustness
Stable
✓Inhibitor tolerant
✓Various feedstocks applicable
✓Genetic stablity
✓Scale-up validation
Innovation
New
✓US patent granted
✓Taiwan patent granted
✓JIMB publication
✓"Silver medal" in Taipei Int'l Invention Show
11

Extension of CE Technology to Biorefinery

- INER's R&D now focuses on biorefinery technologies such as depolymerization of lignocelluloses, cellulase production and recombinant strains to produce advanced biofuels and bio-based chemicals.
  - ✓ Bio-polymer (Lactic acid)
    - > 99% optical purity L-lactic acid & D-lactic acid
  - ✓ Drop-in fuels
    - Fatty acid & fatty alkane, hydrocarbons fuel
  - ✓ Bioplastics (Bio-FDCA)
    - Building block for PET or PEF
  - ✓ Butadiene precursor
    - Important industrial chemical used as a monomer in the production of synthetic rubber.
  - ✓ Lignin derivatives
    - Carbon fiber

12

Gasification-Based Clean Energy System

Syngas → Clean-up: Particulate removal; Sulfur removal; CO_2 separation → ✓Chemical ✓Refinery ✓Electricity

Hot Model of Moving Granular Bed Filter:

- ✓The only operating HT-MGBF (@500°C) in Taiwan.
- ✓Filtration efficiency > 90% at elevated temp.

➢Acid Gas Removal: Stability of desulfurization solid sorbents maintains over 90% during multi-cycle tests.

CO_2 capture sorbents:

- ✓Capture capacity > 50wt%
- ✓Stability > 90% in multi-cycle process at 750°C.
- ✓A kg-class sorbent manufacturing system has been commissioned.

13

Decarbonized of syngas from biomass derived syngas

INER

- Carbon neutral is an important item for sustainability of using carbonaceous feedstock as fuel.
- The gas cleanup technology including acid moisture, S, Cl has been tested using kW scale reactor as test rig.
- The **sorbent Ca/Al material capture 50 wt% CO_2 at 750˚C** under syngas composition of 17.7%H_2, 28.9%CO, 4.5%CH_4, and 25.0%CO_2 (air balance).
- Most of **impurities in gaseous stream are removal to sub-ppm level**, which is benefit for utilization of high purity syngas for advanced application such as solid oxide fuel cell.

gasification → Raw syngas → S-filter → Cl^-, NH_3 removal → Polishing guard bed → Filter → Clean syngas

Gasification


Syngas tank


Syngas cleanup


CO_2 capture

SOFC 14

INER

Thank You for your attention

15

附錄 4:核研所風能技術發展現況

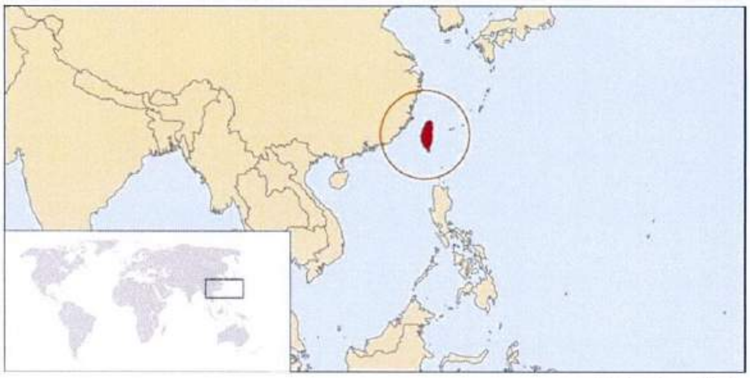
Wind Power Research and Development at INER

Presented by
Dr. Chin-Cheng Huang
Director, Mechanical and System Engineering Program
October 2015
INER Institute of Nuclear Energy Research

Outline

- Geography of Taiwan
- Wind resources in Taiwan
- National target for wind power
- Research and development of wind power in Taiwan and at INER
- Some important research topics on wind power

Geography of Taiwan



All pictures from wikipedia

- Taiwan is located south east to China between Japan and Philippines.
- Taiwan is mostly mountainous in the middle and east, with gently sloping plains in the west. Penghu island is one of large off-islands in Taiwan.

Wind resources in Taiwan

- According to the international website, 4Coffshore.com, showing the abundant wind resources on the Taiwan Strait.

10 Year Global Wind Speed Rankings

1 2 3 4 5 6 7 8 9 10 ...

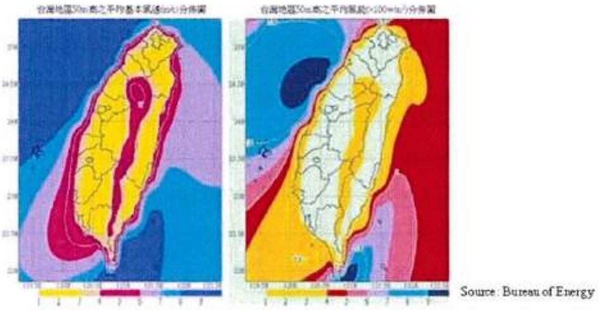
Rank	Project	Sea	Cty	Status	Speed (m/s)
1*	Fujian Pingtan Datang Changjiangao 200MW offshore Wind Farm	South China Sea			12.11*
1	Putian Pinghai bay offshore project phase D-E	Taiwan Strait			12.11
1	Pingtan experimental zone 300MW offshore wind power project	South China Sea			12.11
4	Fujian Putian Shicheng Yugang Offshore Wind Farm	Taiwan Strait			12.06
5	Longyuan Putian Nanri Island 400MW project - Phase 1 - 16 MW Prototype	Taiwan Strait			12.04
5	Putian Pinghai bay offshore Wind Farm demonstration project phase 2-250MW	Taiwan Strait			12.04
5	Putian Pinghai bay offshore demonstration project phase A	Taiwan Strait			12.04
5	Longyuan Putian Nanri Island 400MW project - Phase 2 - 190MW	Taiwan Strait			12.04
10	Zhanghua 1-1 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 1-2 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 1-6 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 3-3 - Development Zone	Taiwan Strait			12.03
10	Zhanghua 1-7 - Development Zone	Taiwan Strait			12.03
15	Zhanghua 3-1 - Development Zone	Taiwan Strait			12.02
15	Zhanghua 3-2 - Development Zone	Taiwan Strait			12.02
15	Taizhong 2 - Development Zone	Taiwan Strait			12.02

Source: 4Coffshore

Wind resources in Taiwan-onshore

- Superior on-land wind farms are mostly located in the northwestern and southwestern coasts. The full load hours can be 2500~3200 hours per year.
- Penghu island is one of the best wind areas with annual average wind speed ~ 9 m/sec, higher capacity factor of 45%

Onshore wind power plants in Taiwan

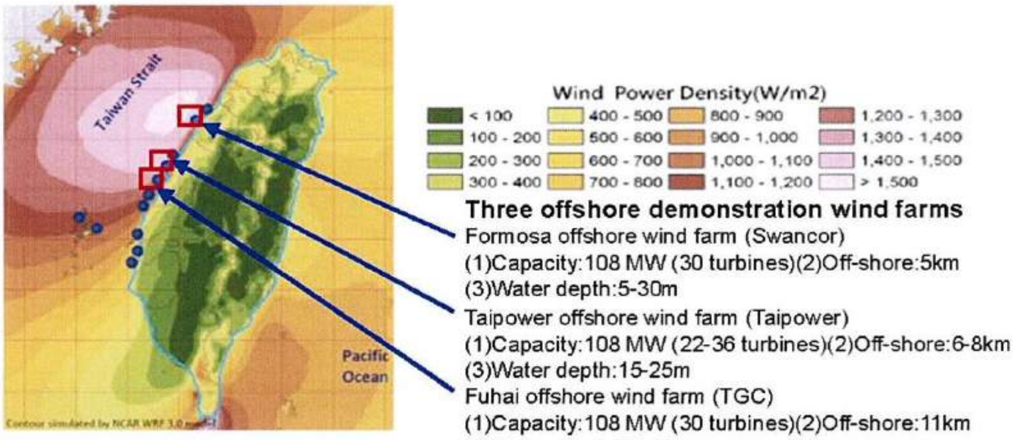


Source: Bureau of Energy

Average wind speed and wind power density at elevation 50m

Wind resources in Taiwan-offshore

• Shallow Water (5~20 m)	• Deep Water (20~ 50 m)	• Deeper Water (> 50 m)
➢ Area: 1,779.2 km² ➢ Potential: 9 GW ➢ Feasible: 1.2 GW	➢ Area: 6,547 km2 ➢ Potential: 48 GW ➢ Feasible: 5 GW	➢ Potential: 90 GW ➢ Feasible: 9 GW



Three offshore demonstration wind farms

Formosa offshore wind farm (Swancor)
(1)Capacity:108 MW (30 turbines)(2)Off-shore:5km
(3)Water depth:5-30m

Taipower offshore wind farm (Taipower)
(1)Capacity:108 MW (22-36 turbines)(2)Off-shore:6-8km
(3)Water depth:15-25m

Fuhai offshore wind farm (TGC)
(1)Capacity:108 MW (30 turbines)(2)Off-shore:11km
(3)Water depth:25-40m

National target of wind power for Taiwan

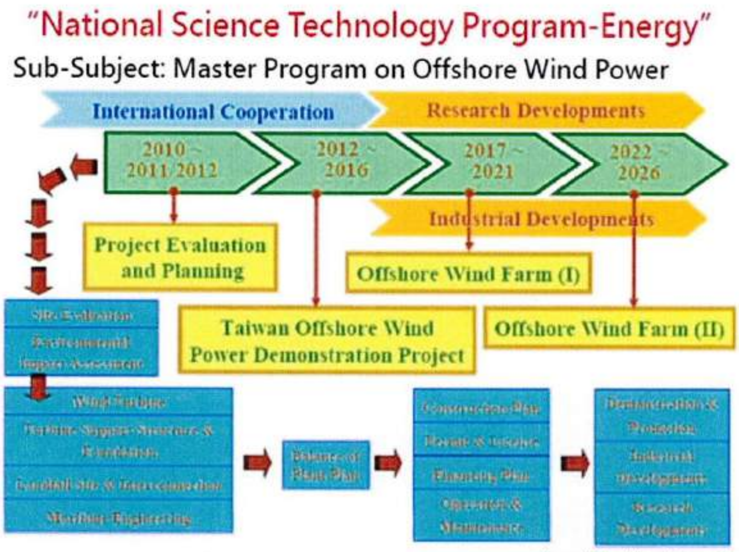
- According to the Bureau of Energy, the latest national target for wind power development can be shown in the table below (as of July, 2015).
- Hopefully, there will have first demonstration offshore wind turbines installed in two demonstration offshore wind farms, Fuhai offshore wind farm and Formosa offshore wind farm, respectively.

	2013	2016	2020	2025	2030
Onshore Accum.MW (units)	614 (311)	737 (370)	1,200 (450)	1,200 (450)	1,200 (450)
Offshore Accum.MW (units)	0	>12 (4)	520 (104)	1,520 (304)	4,000 (800)
MW (units)	614 (311)	750 (374)	1,720 (554)	2,720 (754)	5,200 (1,250)

Revised from BOE

Timeline for offshore wind research and development

- For development of offshore wind, the government(MOST) has formed national program to support the offshore wind R&D from 2010.
- The offshore wind program widely covers many different areas which are urgent and important to the offshore wind demonstration projects in Taiwan.



Source: National Energy Program II

Research and development on Wind Power at INER

- INER is a multidisplinary national laboratory and started small wind turbine research and development in 2006.
- The technology development for small wind is primarily on the mechanical system integration and self turbine development including aerodynamic design of blading, rotor system and dynamics, turbine integration, power testing, turbine test operation, etc.
- During the past decade, 400W, 25 kW, 150 kW from small to medium wind turbines have been developed and put into test operation at INER campus.
- Some joint research projects between universities and INER were performed on the self developed wind turbines.

Design of wind turbines and verification

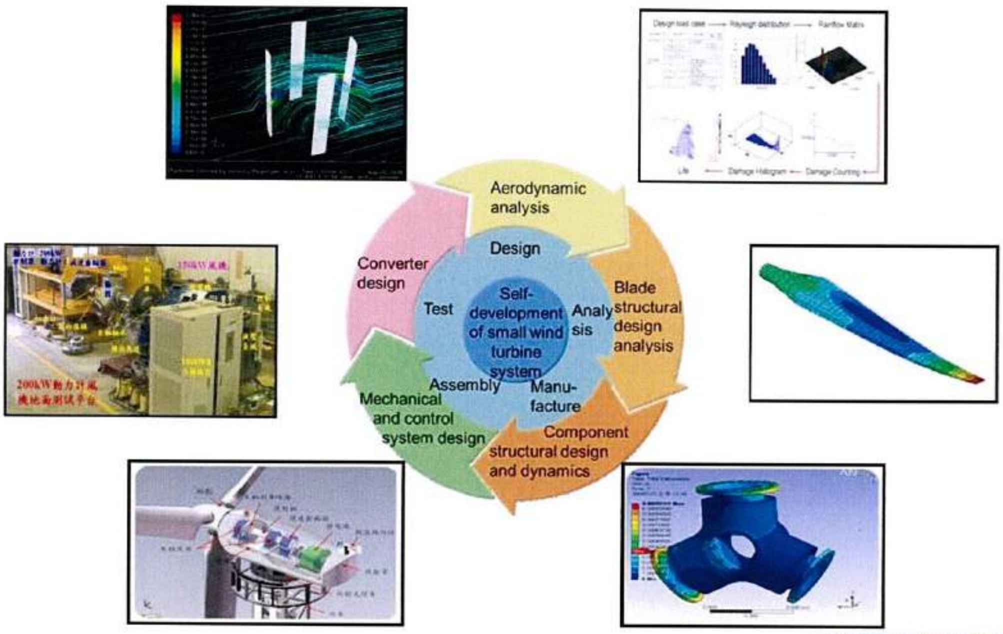
- INER is the only national laboratory with test wind park in Taiwan.
- Wind turbine technology team was recognized by TAF for design evaluation of small wind turbines.
- In 2013, INER helped Hi-VAWT with DS-3000 design report which was successfully certified by Class NK of Japan. The small VAWTs have been exported to Japan.


25 kW wind turbine


150 kW wind turbine


Wind turbine assembly

Technology development for wind turbine design and verification



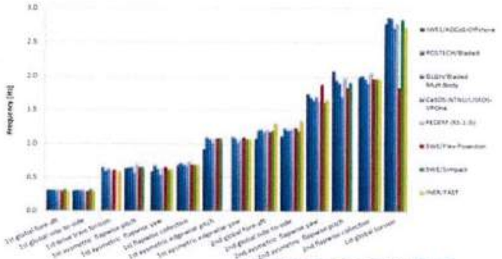
Offshore wind research and development at INER

- In 2012, INER joined the national offshore wind program of Taiwan
- The primary objective of the national offshore wind program is to support the demonstration offshore wind projects and localization of offshore wind technology by integration of research institutions, academia and industry.
- INER has been involving in the integrated dynamic load analysis of offshore wind turbine subjected to extreme external conditions such as typhoon, earthquake, etc.
- INER has also joined the IEA Task 30 OC5 as an observer since May of 2015, to get involved in the international activities of simulation and test on offshore wind and also get more technical information to improve the load simulations.

Offshore wind research and development at INER (Cont'd)

- With the OC3/OC4 technical reports, INER has finished the comparisons of load analysis results for NREL 5MW reference turbine subjected to some load cases for both of turbines with monopile and jacket support structures.
- Collaborate with SWE, Stuttgart university on the integrated load analysis for offshore wind turbine and support structures.
- At present, this work is ongoing for load analysis for offshore wind turbine system subjected to local environmental conditions such as typhoon, earthquake, etc.

Source: NREL



Institute of Nuclear Energy Research

12

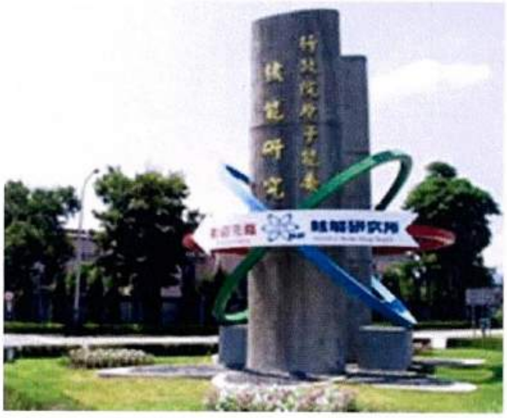
Some important research topics on wind energy

- Re-examination of the adequacy of use of the international design standards on the design of wind turbine in Taiwan. Specially, impact of harsh environments of typhoon, earthquake, etc. on local design guidelines for offshore wind system needs to be studied.
- Load simulation and load measurement are crucial for the offshore wind turbine design, operation and maintenance. Development for the combined technology is also very important for determination of regional design load cases, necessary component design strength, load mitigation, etc. against the harsh environments in Taiwan.
- Structural integrity and reliability assessment technologies are also to be developed in the near future at INER.

Institute of Nuclear Energy Research

13

Thank you for your attention
Welcome to INER !



Institute of Nuclear Energy Research

14

附錄 5:核研所生質精煉技術發展現況

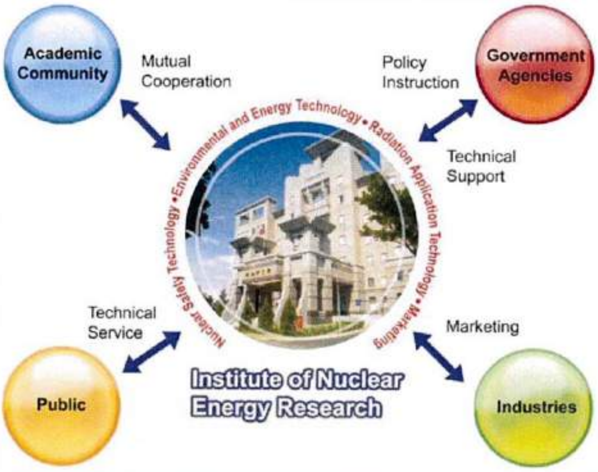
R&D Activities for biorefinery Technology at INER

Wen-Song Hwang

Chemistry Division
Institute of Nuclear Energy Research, AEC

Institute of Nuclear Energy Research (INER)

- INER was founded in 1968, currently under the administration of Atomic Energy Council (AEC), Taiwan.
- Will be renamed Institute of Energy Research, under the administration of Ministry of Economic and Energy Affairs (MEEA), Taiwan, after government organizational restructure.



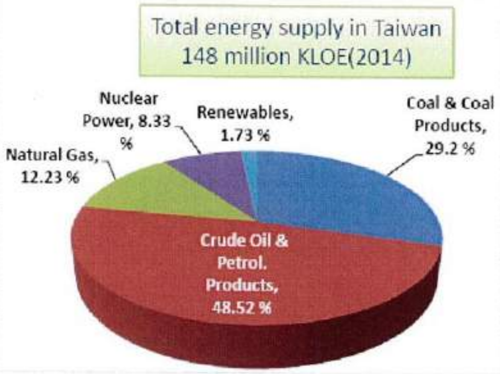
- Organization was founded as the sole national research institute for nuclear science and technology studies.
- Research has been extended to the development of carbon-free energy, low-carbon energy, and industrial radiation applications.
- Special focus on research of renewable and new energy area.

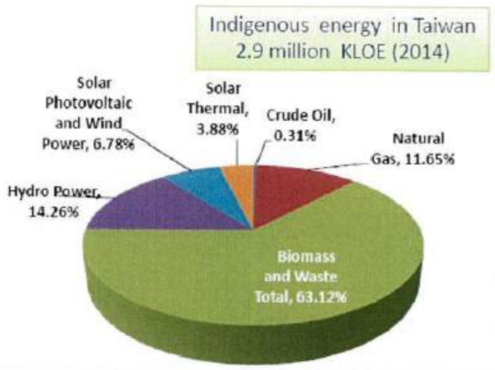
"Professionalism, Innovation, and Safety"
------Institute's core values

1

Energy Usage and Supply in Taiwan

- **Highly dependent on imported energy:**
  98.04% of energy sources are imported, only 1.96% from indigenous energy
- **Major reliance on fossil fuels (89.94 %)**
- **Biomass, the largest resource, accounts for 63 % of indigenous energy (1.96%) in Taiwan**





Source :http://www.tbeia.org.tw/frnEnd/news/news_detail.aspx?id=17

2

Biomass Energy Industry in Taiwan

- **Biomass power**

2013 Installed capacity		In 2030
Waste	• City 624 MW • Industry 5MW	
Agriculture & Forestry	• Biogas 19MW • Agro-waste 92MW	
Total	740MW	950MW

- **The city waste will be decreased due to well garbage sorting and efficient resource recovery , and the biogas from sewage sludge and animal feces will be promoted in the future.**
- Aim to reach **950MW in 2030.**
- Construction of Refuse Derived Fuel (RDF-5) plant and co-located with paper manufacturer was operated well in Taiwan.

24 Waste incinerator power plant: 624MW

Biogas power plant 19 MW

RDF-5
180,000 ton/year

RDF-5 CHP plant

Source :http://www.tbeia.org.tw/frnEnd/news/news_detail.aspx?id=17

3

Biofuel policy in Taiwan

Bioethanol

- E3 gasoline has been used in government vehicles in Taipei since **2007**.
- 14 gas stations in Taipei and Kaohsiung city provide E3 gasoline since **2009**.
- Source: Highly dependent on imports.

E3 gasoline.

Biodiesel

- B1 biodiesel was implemented nationwide in **2008**, later increase to B2 in **2010**.
- Source: Transesterification of kitchen waste oil and plant oil

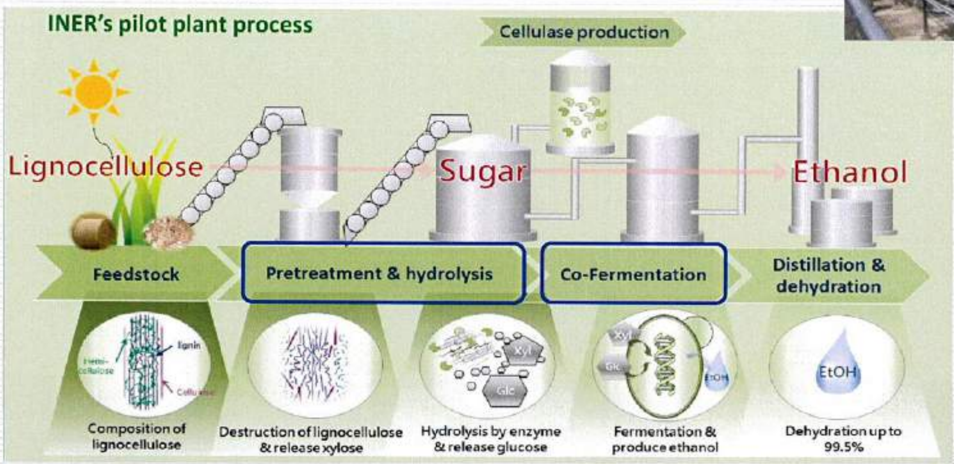

First manufacturer of biodiesel

2007	2008	2010	2025	2030
• E3 gasoline in Taipei	• B1	• B2	• B10 • E3 gasoline nationwide implementation.	• E10 gasoline • Biofuels account for 10% of transportation fuels

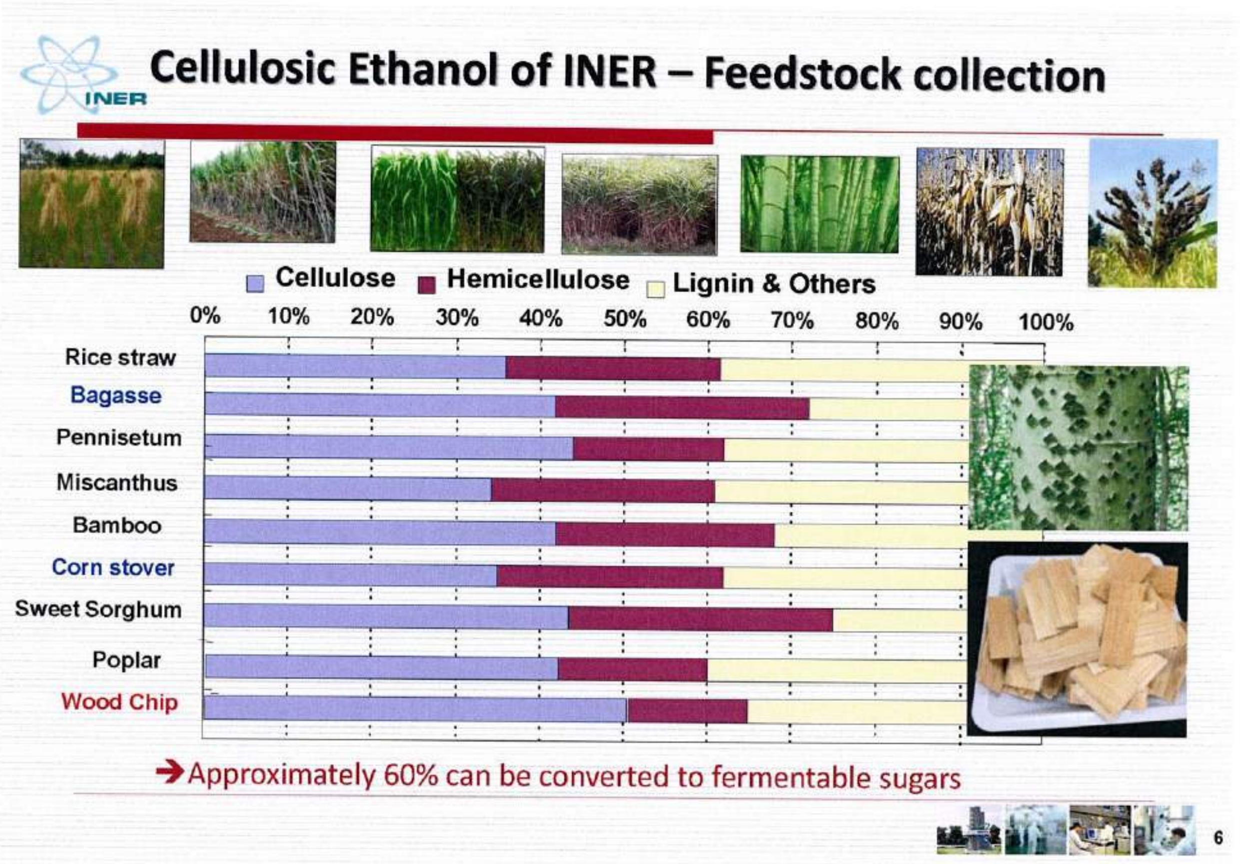
4

Cellulosic Ethanol (Biochemical Conversion)

- INER has been dedicated to develop cellulosic ethanol technology since year 2005, and a leading and unique pilot plant with a capacity of 1 ton biomass fed per day was built to validate the applicability of cellulosic ethanol production at massive scale.



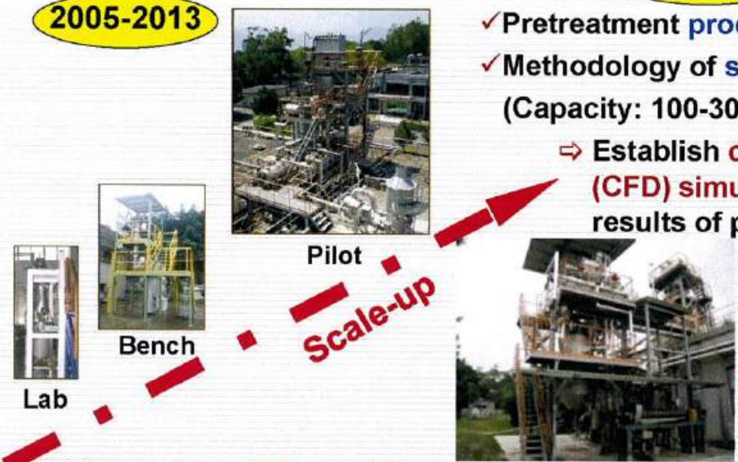
5


INER
Cellulosic Ethanol of INER – Feedstock collection
Cellulose
Hemicellulose
Lignin & Others
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Rice straw
Bagasse
Pennisetum
Miscanthus
Bamboo
Corn stover
Sweet Sorghum
Poplar
Wood Chip
➔Approximately 60% can be converted to fermentable sugars
6


INER
INER Milestone
Bioenergy Technology Emerging Abroad
維酒精技術
INER's Cellulose-to-Ethanol Technology Transferred to Malaysian
Business model of "Co-location construction" design was provided
New biofuel plant construction co-located with the existing plywood plant by using waste wood chips as raw material for of biofuel production.
木片 Wood Chips
Wood chips
The agreement of technology transfer signed on May 14th 2015 by the Director-General of INER, Dr. Yin-Pang Ma(left) and Mr. Lin Tsai-Rong, the president and representative of Cymao, Malaysia.
7

Pretreatment Technology Development

2005-2013



2013-

✓Pretreatment **process improvement**
✓Methodology of **scale-up engineering**
(Capacity: 100-300 ton/day)
⇨ Establish **computational fluid dynamics (CFD) simulation models** according to the results of pilot plant tests

□ **Features:**

- Diverse lignocellulosic feedstocks
- Input solid/liquid ratio can be up to 40% ~ 50%
- Xylose concentration can be 40 g/L, glucan recovery > 80%
- Enzymatic hydrolysis conversion of the solid residue can be > 80%

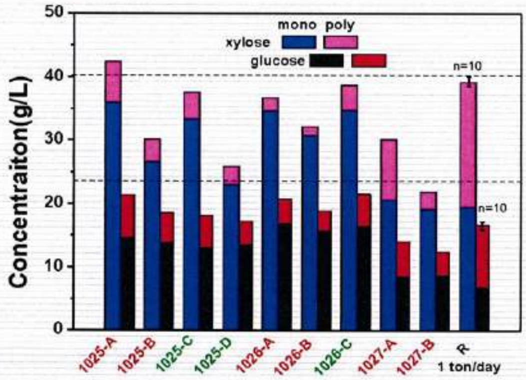
□ **Acid-Catalyzed Steam Explosion system**
has reached the threshold of commercialization (Taiwan patents I340192, I346723, I369944 , I364427, I392544; US patent 8,080,128B2)

8

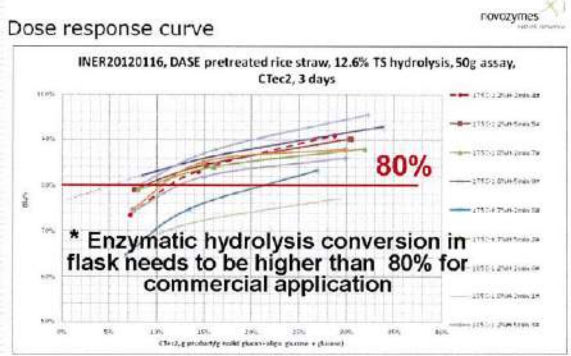
Cooperation between INER and Novozymes Company

➢ INER's acid-catalyzed steam explosion pretreatment system has reached the threshold of commercialization (Taiwan patents I340192, I346723, I369944 , I364427, I392544; US patent 8,080,128B2):

- Input solid/liquid ratio can be up to 40% ~ 50%
- Xylose concentration can be 30 ~ 40 g/L, glucan recovery > 80%
- Enzymatic hydrolysis conversion of the solid residue can be > 80%

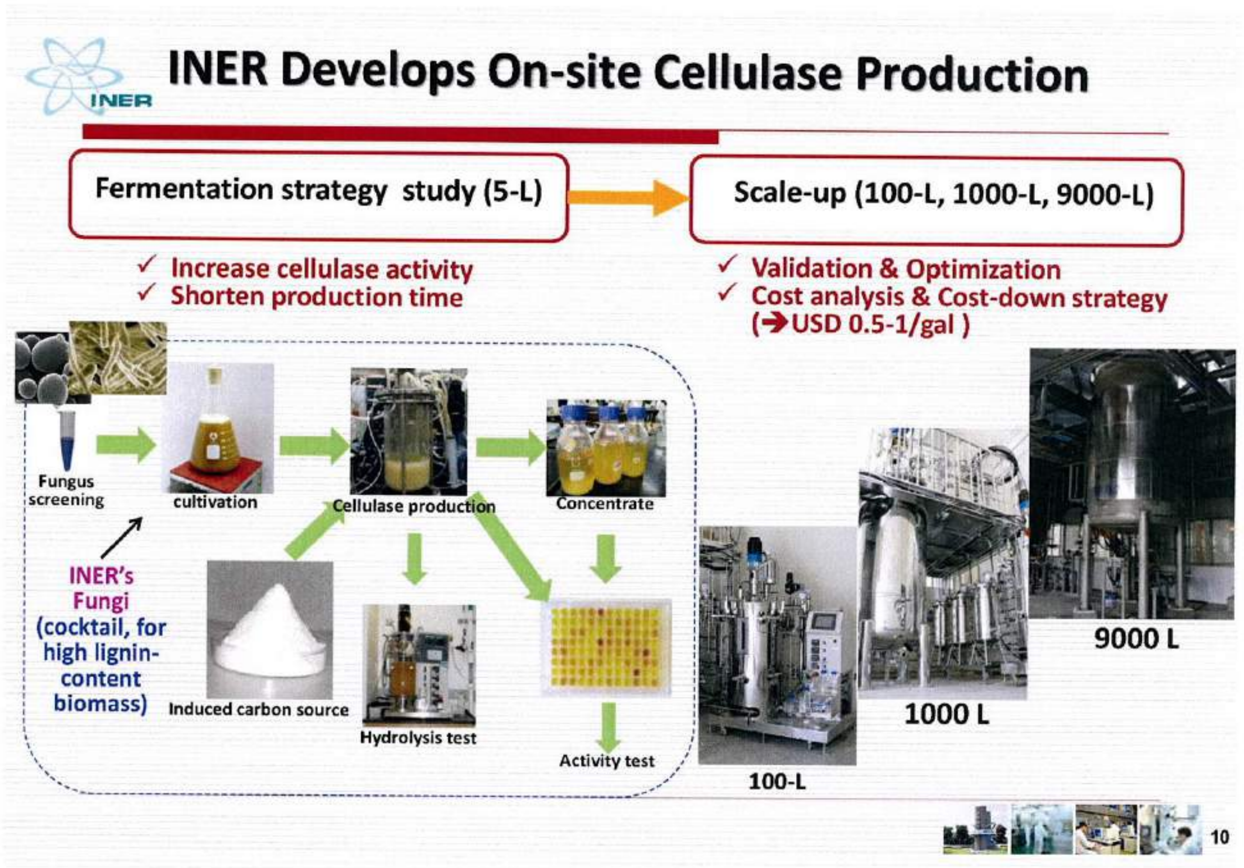


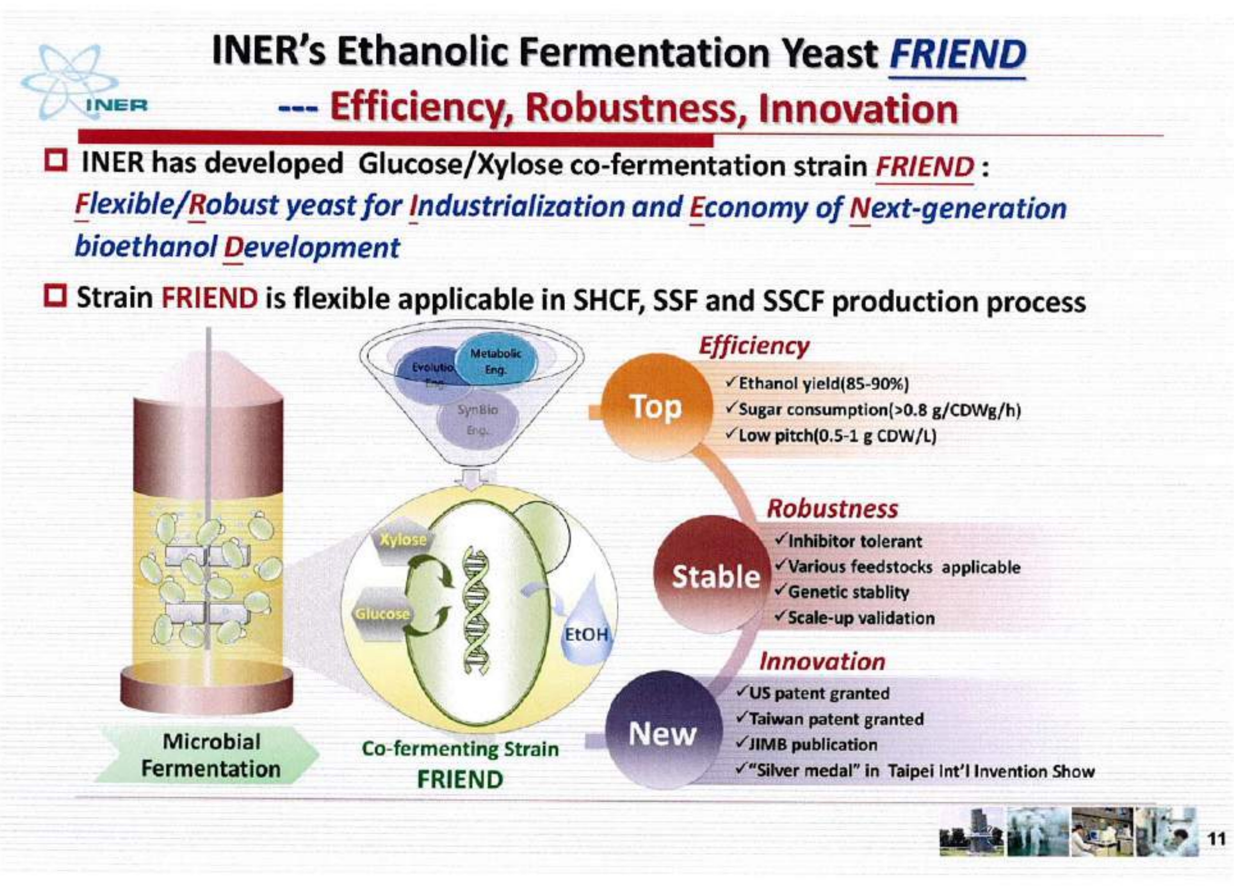
Rice straw hydrolysate obtained after pretreatment system of the pilot plant



Evaluation of enzymatic hydrolysis of the pretreated rice straw by Novozymes

9


INER Develops On-site Cellulase Production
INER
Fermentation strategy study (5-L)
Scale-up (100-L, 1000-L, 9000-L)
✓ Increase cellulase activity
✓ Shorten production time
✓ Validation & Optimization
✓ Cost analysis & Cost-down strategy
(➔USD 0.5-1/gal)
Fungus screening
cultivation
Cellulase production
Concentrate
INER's Fungi (cocktail, for high lignin-content biomass)
Induced carbon source
Hydrolysis test
Activity test
100-L
1000 L
9000 L
10


INER's Ethanolic Fermentation Yeast FRIEND
--- Efficiency, Robustness, Innovation
INER
INER has developed Glucose/Xylose co-fermentation strain FRIEND :
Flexible/Robust yeast for Industrialization and Economy of Next-generation bioethanol Development
Strain FRIEND is flexible applicable in SHCF, SSF and SSCF production process
Metabolic Eng.
SynBio Eng.
Xylose
Glucose
EtOH
Microbial Fermentation
Co-fermenting Strain FRIEND
Efficiency
Top
✓Ethanol yield(85-90%)
✓Sugar consumption(>0.8 g/CDWg/h)
✓Low pitch(0.5-1 g CDW/L)
Robustness
Stable
✓Inhibitor tolerant
✓Various feedstocks applicable
✓Genetic stablity
✓Scale-up validation
Innovation
New
✓US patent granted
✓Taiwan patent granted
✓JIMB publication
✓"Silver medal" in Taipei Int'l Invention Show
11

Extension of CE Technology to Biorefinery

INER

- INER's R&D now focuses on biorefinery technologies such as depolymerization of lignocelluloses, cellulase production and recombinant strains to produce advanced biofuels and bio-based chemicals.
  - ✓ Bio-polymer (Lactic acid)
    - > 99% optical purity L-lactic acid & D-lactic acid
  - ✓ Drop-in fuels
    - Fatty acid & fatty alkane, hydrocarbons fuel
  - ✓ Bioplastics (Bio-FDCA)
    - Building block for PET or PEF
  - ✓ Butadiene precursor
    - Important industrial chemical used as a monomer in the production of synthetic rubber.
  - ✓ Lignin derivatives
    - Carbon fiber

12

Gasification-Based Clean Energy System

INER

Syngas →

Clean-up
- Particulate removal
- Sulfur removal
- CO_2 separation

→ ✓Chemical ✓Refinery ✓Electricity

Hot Model of Moving Granular Bed Filter:
- ✓The only operating HT-MGBF (@500°C) in Taiwan.
- ✓Filtration efficiency > 90% at elevated temp.

➢Acid Gas Removal: Stability of desulfurization solid sorbents maintains over 90% during multi-cycle tests.

CO_2 capture sorbents:
- ✓Capture capacity > 50wt%
- ✓Stability > 90% in multi-cycle process at 750°C.
- ✓A kg-class sorbent manufacturing system has been commissioned.

13

Decarbonized of syngas from biomass derived syngas

- Carbon neutral is an important item for sustainability of using carbonaceous feedstock as fuel.
- The gas cleanup technology including acid moisture, S, Cl has been tested using kW scale reactor as test rig.
- The sorbent Ca/Al material capture 50 wt% CO_2 at 750˚C under syngas composition of 17.7%H_2, 28.9%CO, 4.5%CH_4, and 25.0%CO_2 (air balance).
- Most of impurities in gaseous stream are removal to sub-ppm level, which is benefit for utilization of high purity syngas for advanced application such as solid oxide fuel cell.

gasification

Raw syngas → S-filter → Cl^-, NH_3 removal → Polishing guard bed → Filter → Clean syngas

Gasification


Syngas tank


Syngas cleanup


CO_2 capture

SOFC 14

Thank You for your attention

15