公務出國報告

（出國類別：參加研討會）

參加第 20 屆太平洋盆地核能會議
(PBNC 2016)
出國報告

服務機關：行政院原子能委員會、行政院原子能委員會放射性物料管理局、行政院原子能委員會核能研究所

姓名職稱：李綺思副處長、洪子傑科長、周鼎副研究員、郭子傑技正、熊大綱技士、藍泰蔚技士、黃朝群技士

派赴地區：中國大陸

出國期間：105 年 4 月 05 日至 105 年 4 月 10 日

報告日期：104 年 6 月 6 日

摘　　要

太平洋盆地核能會議(Pacific Basin Nuclear Conference)為太平洋核能學會(Pacific Nuclear Council)每兩年舉辦一次之國際研討會，邀請對象為環太平洋盆地核能使用國家，本會議自 1976 年以來已經舉辦了 19 次，2016 年輪由中國核學會舉辦。

本次會議的特點包含：

一、邀請超過 30 位國際專家、學者就 1) 全世界核能發電技術新進展、2) 核燃料循環及 3)核能安全等三項大會議題進行討論。

二、超過 80 位專家就八項專題進行學術交流，包含 1)核融合技術、2)新一代核能技術發展成就、3)核電廠運轉安全及年限管理、4)核電廠興建與零組件製造、5)鈾原料供應及新燃料發展、6)用過核燃料處理與廢棄物處置、7)輻射照射處理及 8)公共接受議題等。

三、約 362 篇論文投稿，就 10 項技術專題進行報告，包含 1)核能安全與核子保安、2)核電廠運轉及維修、3)核子反應器及新建機組、4)廢棄物處置、5)核能元件供應鏈及品質保證、6)核燃料循環、7)核能新技術及新應用、8)公共接受與核能教育、9)經濟與成本降低、10)輻射醫療及生物效應。

四、核能學科卓越研究獎(針對核能學科之學生)。

五、與中國核能工業展(the China International Nuclear Industry Exhibition)共同舉辦，讓與會者可在參加研討會之餘，抽空參加位於會場隔壁之核能工業展，瞭解目前全世界核能工業發展現況。

本次會議本會主要係參加 2016 年太平洋盆地核能會議(PBNC 2016)，除參加主辦單位辦理之大會議題及專題，並就赴會前投稿相關專題之論文進行發表，並與與會相關專家學者進行討論，會後並參訪北京清華大學高溫氣冷核子反應器，瞭解目前中國大陸最新一代核能技術。

透過參加核能國際研討會，可供本會瞭解目前太平洋盆地核能國家核能發展現況、各國就新一代核能技術所衍生之可能核能安全措施、核子事故緊急應變與民眾溝通等相關議題，以精進我國對於相關議題之作法。

目　　錄

壹、出國目的

本此出國目的係參加第 20 屆太平洋盆地核能會議(PBNC 2016)，除參加大會安排之大會議題及專題外，並由本會人員就相關技術議題進行論文發表，期透過與相關專家學者研討，以拓展我國核能安全管制、輻射防護、核子事故緊急應變及民眾溝通等之觀點：

一、 參加第 20 屆太平洋盆地核能會議(PBNC 2016)；

二、 參訪北京清華大學高溫氣冷核子反應器；

貳、出國行程

本次出國行程含往返共計六日，行程表如下：

日　期	行 程 內 容	地　點
04 月 05 日（二）	啟程（桃園市→北京市）	北京市
04 月 06 日（三）	參加第 20 屆太平洋盆地核能會議	北京市
04 月 07 日（四）	參加第 20 屆太平洋盆地核能會議	北京市
04 月 08 日（五）	參加第 20 屆太平洋盆地核能會議	北京市
04 月 09 日（六）	參加第 20 屆太平洋盆地核能會議	北京市
04 月 10 日（日）	上午參訪北京清華大學高溫氣冷核子反應器 下午返程（北京市→桃園市）	桃園市

參、過程紀要

本次出國係各業務處及所屬機關（核能管制處、輻射防護處、核能技術處、放射性物料管理局）依相關赴大陸計畫辦理，時間安排於 105 年 4 月 5 日至 10 日，連同參訪與路程共 6 天。計有原能會核能管制處李綺思副處長、熊大綱技士、輻射防護處郭子傑技正、核能技術處洪子傑科長與黃朝群技士、放射性物料管理局藍泰蔚技士、核能研究所周鼎副研究員等共 7 人參與。

本次研討會主題範圍涵蓋 3 項大會議題、8 項專家議題、10 項技術專題交流，最後藍員另參訪北京清華大學高溫氣冷核子反應器。

一、大會議題（Plenary Session）

（一） 全世界核能發電技術新進展(New Progress of the World Nuclear Power Technology)

1. 第一位講者為 Ms. Lee McDonough，任職於英國能源及氣候變遷部門之核能發展辦公室，她就英國最新核能政策(Overview of UK New Nuclear Policy)進行介紹。英國目前共有八座核能發電廠商轉中，核能發電占英國整體電力共 16%，未來英國將持續興建採用新技術之核能電廠，估計到 2030 年，核能發電比例將占整體發電比例之 30 至 35%，英國之所以要繼續使用核能發電之原因主要係為了達成英國整體減碳達 40 億噸之目標。英國目前對於核能發電產業是非常歡迎的，英國已向中國大陸商談欣克利角 C(Hinkley Point C, HPC)核能發電廠之興建計畫，將採用中國大陸自主研發之先進中國壓水式反應器(ACP1000)，目前已簽約完成，估計將有約 700 萬英國人受惠，同時將帶動當地經濟活動。核能發電雖然可帶來英國經濟發展與減碳排放量的目標，但經過了美國三哩島核子事故、前蘇聯車諾比核子事故與日本福島核子事故後，確認核子事故發生是有可能的，但在核能發電技術的不斷進步與創新之後，英國相信將可大幅降低核子事故發生之可能性。

Ms. Lee McDonough 報告

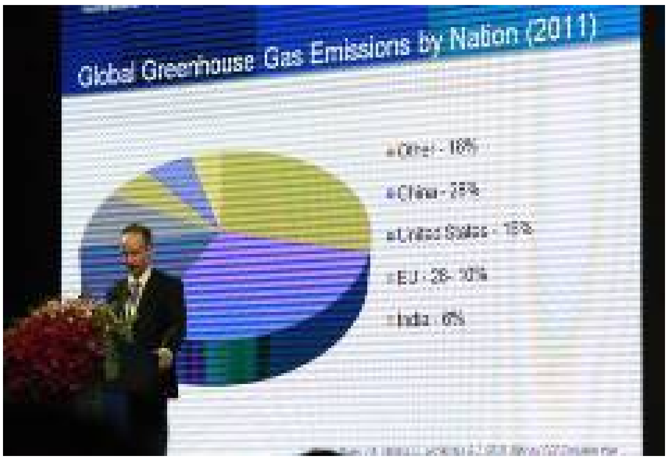
2. 第二位講者為 Mr. Herve Machenaud，任職於法國電力公司擔任執行副總裁，他的簡報介紹高品質的運轉技術才能確保核能安全(Nuclear Safety Mainly Depends on High-quality Operation)。日本福島事故之後，引起了全球核能產業界、政府與環保團體之間對於核能安全爭論，核能產業界為了賡續拓展核能發展，已經將現行的核電機組技術推進至第三代核電技術，標榜採用新的安全設備可避免核子事故發生，然而當談到安全的議題時，僅專注在技術方面是不對的。日本福島核子事故的發生主要是因為操作過程中錯誤的決策及運轉團隊僵化的思考模式所造成。再先進的技術均無法克服所有的狀況，尤其是人為因素所造成的錯誤。日本福島核子事故後，我們可以很明確的瞭解到核能電廠的運轉安全關鍵仍在運轉員身上，為了達到較高的核能安全等級，運轉員必須熟稔所有的操作設備，更重要的是，透過熟練的作業程序，獲得廣泛的深度防禦經驗。法國電力公司已經建立有關核能電廠安全運轉之經驗回饋機制，作為邁向更高一級核能安全境界之基石。

Mr. Herve Machenaud 報告

3. 第三位講者為 Mr. Jorge Spitalnik，任職於世界工程組織聯盟(World Federal of Engineering Organizations, WFEO)，並擔任總裁，他也是美洲核能學會，拉丁美洲分會的前理事長。他就在聯合國氣候綱要公約UNFCCC締約國大會(COP-21)中核能的角色(Nuclear Energy in the Context of the COP-21 Climate Change Agreement)進行報告。1998 年京都協議書中雖然未納入以使用核能來降低碳排放量選項，但是許多核能工業國家仍然認為核能是非常重要且現階段最適合達到低碳目標的手段，因此努力想將核能納入未來新的協議中。繼京都協議書後，全世界為了對抗氣候變遷，於 2015 年在巴黎召開聯合國氣候綱要公約 UNFCCC 締約國大會(簡稱巴黎協議)，該協議未將核能排除於經濟有效的低碳排放的手段，而且協議是各締約國所承諾事項，因此無論利用哪種能源作為低碳排放方法均可接受，巴黎協議訂有一些科學、技術等之要求，用以確保締約國能夠確實根據事實證據、科學知識及工程上可行的條件，達到低碳排放量的要求，目前許多核能工業國家認為，如果不使用核能，現階段無法實現最低成本效益的能源，因此在巴黎協議簽署後，核能仍將是多數國家用以達到減碳排放的重要選項之一。

Mr. Jorge Spitalnik 報告

4. 第四位講者為 Mr. Danny Roderick，任職於西屋電力公司，擔任總裁職務。他就核能發電：創新與清淨空氣的經濟發展動力(Nuclear Power：An Economic Engine of Innovation and Clean Air)進行報告。西屋公司迄今之主要業務領域為發電設備、輸變電設備、用電設備和電控制設備、電子產品等共 4000 多種產品。其中以發電設備、輸變電設備尤具特色。目前全世界用電需求是年年增長，尤以非經濟合作暨發展組織(Organization for Economic Co-operation and Development，OECD)國家為甚，能源需求大幅提升伴隨而來的就是溫室氣體排放的問題，依據美國橡樹嶺國家實驗室於 2015 年發表的相關研究顯示，2011 年全世界溫室氣體排放比例，中國大陸就佔了 28%，遠高於美國 16%及歐盟 10%。核能現階段為替全世界帶來綠色生活的選項之一，全世界的電力目前有大約 11 %的電力是透過核能發電，而且核能發電幾乎零碳排放量，這表示未來若利用核能發電來達到巴黎協議的要求，是有可能達成目標的。目前西屋公司與全世界五成核能使用國家有過合作，同時在美國，將近十分之一的綠色生活歸功於西屋公司的技術。西屋公司將持續為降低溫室氣體排放與讓全世界人民享用低價、安全與可靠的能源做出努力。目前全世界各國大都為對抗氣候變遷帶來的災害做努力，尤其是在許多進行減碳中的國家、期望汰舊基礎設施的國家、經濟發展中的國家等，他們大多仰賴核能技術以達到國家的目標，目前將近 66 部與西屋公司合作的機組正在興建中，未來核能可為全世界低溫室氣體排放目標做出一定貢獻。



Mr. Danny Roderick 報告

5. 第五位講者為 Mr. Preston Swafford，任職於加拿大 SNC-Lavalin 公司擔任執行副總。他就加拿大最新 CANDU 反應器與可永續利用核燃料循環貢獻介紹(The Advanced Fuel CANDU Reactor & its Contribution to a Sustainable Fuel Cycle)進行說明。SNC-Lavalin 創立於 1911 年，該公司提供包括採礦冶金、石油天然氣、基礎設施與能源等工程總包及工程管理服務，並替客戶整合所有服務以提供客戶從融資到營運以及維護等相關細項解決方式的能力。加拿大與中國大陸早在 1990 年代起迄今已有多年合作的歷史，其中位於秦山核能電廠的 CANDU 反應器計畫就是一個極為成功的典範。另外還成功進行等效天然鈾燃料(Natural Uranium Equivalent，NUE)的開發。CANDU 反應器是當前可充分利用新一代核燃料循環所有階段的核子反應器，不僅可供使用的國家獲得獨立的能源來源，也可以用過核燃料當作燃料來取得能源。SNC-Lavalin 公司目前已替全世界核能使用國家提供用過核燃料處置的方案。在中國，SNC-Lavalin 公司與中國國家核電技術有限公司(China National Nuclear Corporation)合作開發 Advanced Fuel CANDU Reactor TM (AFCR)。AFCR 是第三代核子反應器，發電量高達 740MWe 級的傳統式重水反應器，可充分利用再循環的鈾燃料，未來也可以中國大陸境內的釷礦作為燃料。目前這項技術在中國大陸封閉型燃料循環計畫中之輕水式用過核燃料再處理技術中扮演很重要的角色。這樣技術不僅帶來國家能源獨立性，同時也可替核能使用國家達到巴黎協議所要求的減少碳排放量的目標。

Mr. Preston Swafford 報告

6. 第六位講者為 Mr. Bernard Bigot，任職於法國國家核融合實驗用核子反應器計畫主任，同時也是法國原子能委員會前主任委員，他就國際熱核實驗用核子反應器(International Thermonuclear Experimental Reactor，ITER)計畫進行跨洋報告。法國自從在 2016 年 11 月簽署 ITER 計畫以來，ITER 計畫就扮演著核融合試驗的關鍵角色。ITER 的組件有超過 80%都已就緒，目前進度在於真空管以及熱屏蔽的製造。反應器的研究與設計雛形已經送到廠址進行相關測試，目前 22 個中國研究機構與企業刻正進行相關機組組件設計與製造，核融合將是跨時代最新的減碳排放量的技術，可供未來新一代核能發電永續利用的重要選項之一。

Mr. Bernard Bigot 跨洋報告

7. 第七位講者為 Mr. Sun Qin (孫勤)，任職於中國核工業集團(China National Nuclear Corporation，CNCC)擔任董事長。他就華龍一號(HPR1000)－帶領中國大陸核電技術走向全世界之先驅者(HPR1000：Pathfinder of China’s Nuclear Power Going Abroad)進行報告。中國大陸目前已經是全世界核能工業發展最快速的地方，核能不僅能減少溫室氣體排放的問題，也是最佳的能源選項之一，在未來核能的前景依舊看好。中國大陸不斷地在增進核能領域的科學研究能力，並發展中國大陸自產核電機組華龍一號(HPR1000)。華龍一號是第三代壓水式核能發電機組，具有高度核能安全的設計，包含主動與被動式安全系統，嚴重事故防止與緩和對策，並強化天然事故防護措施。日本福島核子事故後，華龍一號已經將相關事故肇因納入設計考量，可避免重蹈覆轍。華龍一號目前已應用於福清核能電廠的第五、六號機組，並在 2015 年五月時開始施工建造，日後將逐步在中國大陸數個新建核能電廠中普及。除中國大陸境內將大量採用華龍一號的機組外，中國大陸並積極拓展海外市場，目前多個先進國家如英國、法國等均對於華龍一號表達高度興趣，華龍一號的輸出對於中國大陸來說是一項嶄新的突破，未來華龍一號將成為中國大陸核能技術輸出最具指標性的意義。

Mr. Sun Qin 報告

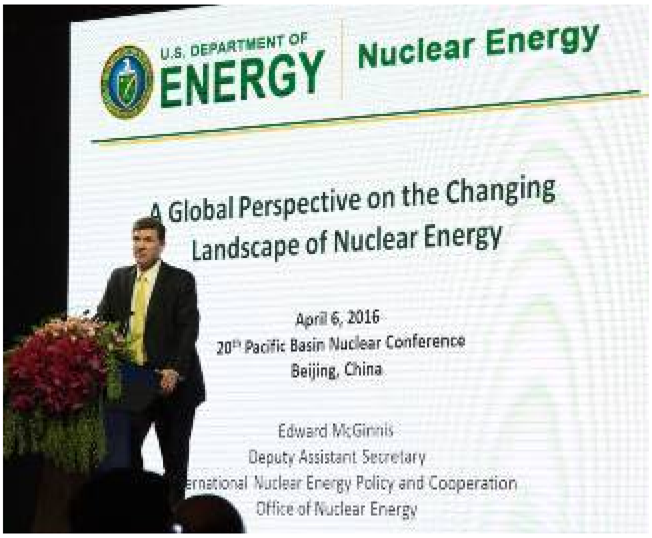
8. 第八位講者為 Mr. Lee Jong Ho，任職於韓國水利與核電公司(Korea Hydro & Nuclear Power，KHNP)擔任執行副總。他就韓國的能源三元困境與核能(Energy Trilemma and Nuclear Energy in Korea)進行報告。任何國家在決定能源政策時，須考量到能源的三元困境，包含能源安全、能源平等與環境永續。能源安全主要是有效處理國內能源供應與其他替代來源、國內能源基礎設施的可靠性、電力公司對於現在與未來相關要求遵行的能力。能源平等則是一般民眾對於使用能源的可接近性與可負擔性。環境永續則為致力發展低碳排放量的能源選項。能源安全、能源平等與環境永續的關係其實是無法兼顧的，因此如何巧妙平衡這三種是值得國家在做出能源政策時須好好思量的。韓國近年來大量進口能源與持續負擔著不平等的原料進口費用，因此發展核能對於現階段的韓國來說是一種可以平衡三元困境的手段且兼顧經濟競爭的能力。韓國是一能源孤島國家，95%的能源仰賴進口，在大量經濟快速成長下，對於能源需求與日俱增，因此韓國需發展核電以因應能量需求大幅提升的狀況。韓國目前核能發電佔總體發電量的 31.7%，目前核能產業在韓國均為國營事業，相關的核能科學研究機構也是國立的，為了達成巴黎協議，未來韓國將仰賴核能來降低碳排放量。

Mr. Lee Jong Ho 報告

9. 第九位講者為 Mr. Gu Jun (顧軍)，任職於中國核工業建設集團公司(China Nuclear Engineering and Construction Group Corporation)擔任經理。他就中國大陸核能電廠建造能力(Construction Capacity of Nuclear Power Plants)進行報告。中國大陸的核工業發展，端賴於中國大陸的核能電廠建設能力，包含施工過程安全、施工品質以及建廠時間表等等。中國核工業集團建設公司是全世界唯一可獨立提供完成核能電廠建造的公司，目前除肩負著中國大陸境內核能電廠核島區的興建，同時也進行輸出至國外的核能電廠核島區的建設工作。中國核工業建設集團公司歷經 30 年的努力，已經掌握了核能電廠興建的重要技術，並擁有許多經驗豐富的專業技術人員。目前所有已興建完成的核能電廠運作皆良好，中國核工業集團建設公司在全世界核能電廠建設方面已經達高水準的地步。

Mr. Gu Jun 報告

10. 第十位講者為 Mr. Ed McGinnis，任職於美國能源部核能辦公室，擔任國際核能與政策業務之副助卿 (Deputy Assistant Secretary)。他就核能發展前景的世界觀(A Globe Perspective on the Changing Landscape of Nuclear Energy)進行報告。日本福島核子事故後，全球核能產業仍然在發展中。根據國際原子能總署報告指出，目前全世界約有 437 座核能電廠運轉中，超過 66 座核能電廠興建中。世界核能協會(World Nuclear Association，WNA)預估在未來的 15 年內，仍然會有 184 部新機組出現。全球核能發展前景有賴一些驅動的因素，如為了解決溫室氣體排放的問題，為了國家能源安全以及在遠東地區、非洲、中東、中歐等地的經濟發展需求。核能是對抗全球氣候變遷的絕佳選項之一，因此美國已經準備好要與國際社會核能使用國家共同推動原子能和平用途、核能安全與核子保安。未來美國將賡續提升與促進全球核能安全與核子保安，並透過雙邊或多邊協議就核能研究、核能發展與核能安全應用等繼續合作。

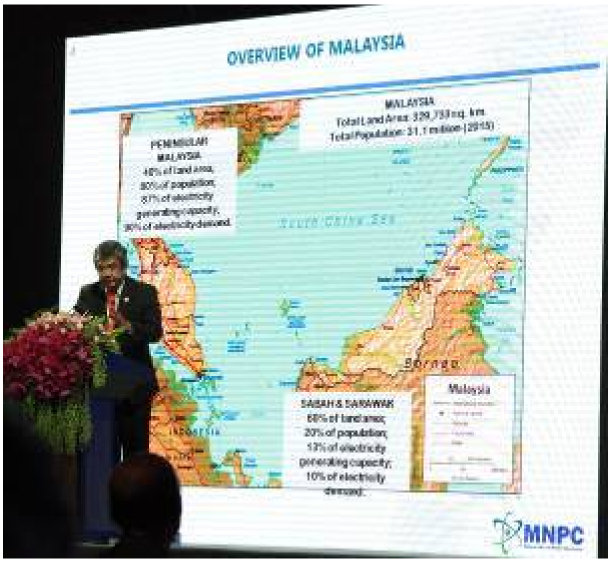


Mr. Ed McGinnis 報告

11. 第十一位講者原為 Mr. Wang Binghua，任職於中國電力投資集團(State Power Investment Corporation，SPIC)擔任董事長，惟另有要公，另請代理人進行報告。他就中國大陸自主研發之第三代核電機組目前進展(Progress of China’s Gen III Nuclear Power Self-reliance Program)進行報告。西屋公司推出之第三代非能動核電機組 AP1000(即 Advanced Passive PWR 的簡稱，其發電功率為 1000MWe)的技術經過中國大陸引進、消化與吸收後，已經被中國電力投資集團通盤掌握關鍵技術，並自主創新研發現為全世界最大的第三代非能動式核電機組 CAP1400，首部機組將於 2016 年下半年進行澆灌混凝土作業(FCD)。CAP 系列的第三代核電機組將替中國大陸帶來寶貴的經驗，最終將有助於全世界核電發展版圖之拓展。

Mr. Wang Binghua 代理人報告

12. 第十二位講者為 Mr. Jamal Khaer Ibrahim，任職於馬來西亞核電公司，擔任總裁。他就發展核電對於馬來西亞能源安全重要性(Nuclear Power Towards Ensuring Energy Security in Malaysia)進行報告。核電在 2009 年 1 月時，首次被馬來西亞納入可能的能源選項之一，但僅限於馬來西亞半島。馬來西亞擁有豐富的天然氣資源，因應經濟快速發展，用電比例漸增，因此開始進口煤礦進行發電。馬來西亞目標於 2020 年時之 GDP 可達 5.5%。因此馬來西亞於 2010 年時訂定十年經濟轉變計畫，並於 2011 年 10 月啟動。該計畫包含 12 項馬來西亞關鍵經濟發展領域，含括石油、天然氣與能源方面，核電發展即為 12 項領域之一。馬來西亞未來的目標為建造一座具有雙機組且總發電功率高達 2000MWe 的核能電廠，馬來西亞相當注重民眾對於核能接受程度，因此有關民眾接受的計畫也是未來執行重點，另國際間對於核能安全最新作法均會納入法律訂定框架中，對於選址部分也會充分聆聽民眾的意見。在 2011 年，馬來西亞首相府下設置了馬來西亞核能發展組織，並由該組織成立馬來西亞核電公司。2016 年至 2020 年，馬來西亞將持續有關核能管制與安全相關法律之建立並設立獨立的原子能監管機構，制定核能管制基礎發展計畫與 10 年期的核能民眾溝通計畫及核能政策，以確保未來馬來西亞能源安全。



Mr. Jamal Khaer Ibrahim 報告

13. 第十三位講者為 Mr. Zhang Weiqing，任職於中廣核公司(China General Nuclear Power Corporation，CGNPC)擔任董事長。他就抓住機會與強化合作，共同驅動全球核能發展(Joint Efforts to Drive Global Nuclear Power Development by Seizing Opportunities and Deepening Cooperation)主題進行報告。核能是一種高效率、發展成熟且具有高度經濟競爭性的乾淨能源，同時對於降低全球溫室氣體排放也扮演很重要的角色。中國大陸目前已可自主化生產製造第三代核能發電機組，具有新進且可靠的製造技術，有完整的核電機組零組件製造鏈與高度經濟效益，模組化的建造方式可讓建廠過程更加快速。中國大陸高度支持核電發展，鼓勵相關企業成為合作夥伴，為全世界減碳目標作出最大的努力。中廣核公司歡迎同儕或國際夥伴共同合作，讓核電發展邁向高峰。

Mr. Zhang Weiqing 報告

（二） 核燃料循環與核能安全(Nuclear Fuel Cycle and Nuclear Safety)

1. 第一位講者為 Mr. Tim Gitzel，任職於加拿大卡梅科公司(世界上最大的鈾交易上市公司，在 2013 年是世界第三大鈾生產商，佔世界產量的 14%)擔任總裁與執行長。他就現今天然鈾礦市場的挑戰與機會(Challenges and Opportunities of Today’s Uranium Market)進行報告。日本福島核子事故已經五年過去了，鈾礦業的發展仍然遭受很大的阻力。日本方面的進展仍然非常緩慢，而且低廉的鈾礦價格讓投資人不願意投入資金進行先進的產品研發。有些國家已經選擇離開或放緩核能發展的腳步，同時全世界仍然在搶救金融海嘯後的經濟。然而，在過去經過的每一天，卡梅科公司仍然積極的發展鈾礦市場。由中國大陸或印度主導的能源市場，對於乾淨能源的需求與日俱增，卡梅科公司預期未來將有更多的鈾礦開採需求，因此卡梅科公司的現今的策略就是專注在公司一級資產管理以面對目前市場的困境，並隨時做好滿足鈾礦需求訂單的準備。

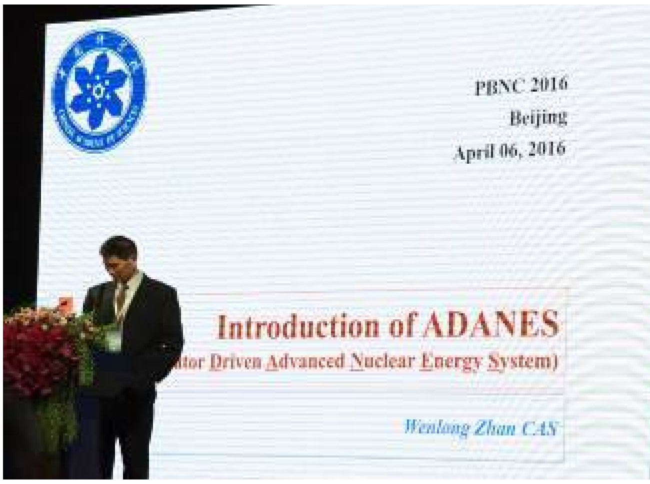
Mr. Tim Gitzel 報告

2. 第二位講者為 Mr. Zhan Wenlong (詹文龍)，任職於中國科學院(Chinese Academy of Science，CAS)擔任副院長。他就加速器驅動先進核能系統介紹(Introduction of Accelerator Driven Advance Nuclear Energy System)進行報告。目前核能發電的發展面臨最主要問題之一是用過核燃料的處理。用過核燃料是經受過輻射照射、使用過的核燃料，包含大量放射性分裂產物，為高階核廢料。其中有些分裂產物的半衰期極長，需經過幾萬甚至幾十萬年的衰變，其放射性才能降到天然背景值。如何縮短這類核種的半衰期？加速器驅動次臨界系統（Accelerator Driven Sub-critical System, ADS）被國際公認為是高階核廢料最有前景的處理技術。其工作原理是，利用加速器產生的高能強流質子束轟擊重核產生高能高通量中子作為外源來驅動由用過燃料組成的次臨界爐心中的易裂材料（fissile）發生持續的連鎖反應，使長壽命放射性核種最終變為非放射性或短壽命放射性核種，並維持核分裂反應進行。它可以縮短用過核燃料中某些過於長壽的放射性核種的壽命，同時處理這些核種產生的熱量還能作為能源，實現用過核燃料的再利用。

中國大陸發展中的 ADANES 則是先進 ADS，可永續利用分裂能的新方法，其程序包含用過核燃料再循環和 ADANES 爐。依設計，再處理過的用過核燃料（氧化物或碳化物）可移除一半以上的分裂產物，特別是鑭系（lanthanide）分裂產物，以高溫揮發分裂產物，再以稀土產物的方式萃取鑭系分裂產物。ADANES 爐設計來嬗變（transmute）和增殖（breed）用過核燃料，並產生核分裂能源。利用加速器產生的高能離子轟擊散裂靶產生高通量、高能中子，驅動次臨界爐心運轉，讓易裂燃料的利用率高於 95%。因為爐心是次臨界，ADANES 爐更安全，讓用過核燃料再利用，且更經濟。所以使用 ADANES 的觀念，可實現封閉型核燃料循環（closed fuel cycle），使分裂能可使用數千年，而核廢料的數量只有傳統核能電廠的 4%，且放射性核種壽命小於 500 年。中國大陸 ADANES 的發展分四期，目前正進行第一期。中國科學院已經與中國廣核集團（中廣核）簽約合作，ADANES 將在廣東省惠州市

建設示範堆，並預計以 20 年左右時間實現商業化。

經過 4 年的研發，已在實驗室測試核燃料再循環。有些關鍵材料，如使用 SiCf/SiC 混合物做為燃料護套的方法已經用於研發。下一期中規模測試將於 5 年內在新的基地進行。ADANES 爐包含高功率線性加速器（LINAC）、轟擊散裂靶（spallation target）及次臨界爐心。25MeV 線性加速器原型機還須運轉微調至最佳狀態。新觀念的轟擊散裂靶為顆粒狀流體靶，高能高強度中子由上向下照射，產生的熱能由流體帶走，其功率約為 10~100MW。原型機測試已驗證符合原設計 500℃，無放射性的條件。次臨界爐心為可滋生快中子爐，目前進行 3 種不同冷卻劑（鉛鉍共熔合金 LBE、顆粒氣體和雙相流蒸汽）之研究實驗，以尋求最佳穩定性及經濟性。



Mr. Zhan Wenlong 報告

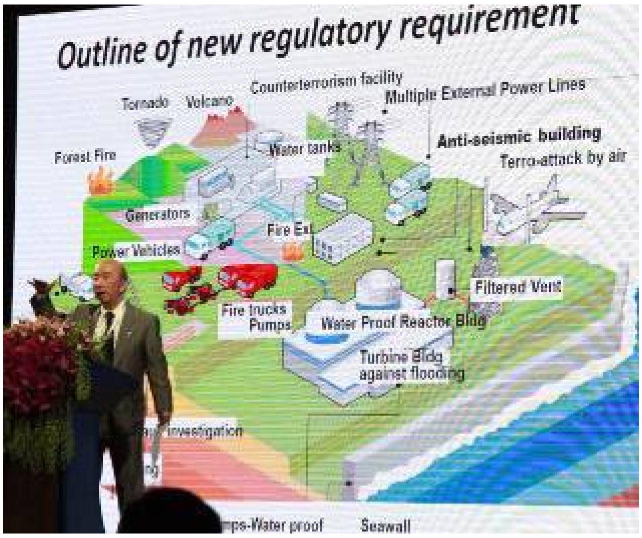
3. 第三位講者為 Mr. Philippe Varin，任職於法商阿海珐公司擔任總裁。他就法商阿海珐(AREVA)公司未來將與中國大陸在核燃料週期處理方面成為策略型合作夥伴(A Fuel Cycle Operation-based Forward-looking New AREVA, Willing to Raise French-Chinese Fuel Cycle Cooperation to the Level of a Strategic Partnership)報告。法國核能工業重整風正在進行，因此阿海珐在公司重組的過程中，成立新的部門專責核燃料循環作業，包含鈾礦開採、鈾礦轉化、鈾礦濃縮、用過核燃料再處理、用過核燃料貯存、相關後勤作業、拆除以及相關的核燃料循環工業等。中國大陸核工業的蓬勃發展促使了中國大陸成為阿海珐公司的關鍵合作夥伴，彼此在核燃料循環方面的合作，從鈾礦供應拓展到大型的用過核燃料再處理廠的建造。中國大陸與法國雙方對於核燃料循環的合作已有共識，未來法商阿海珐公司與中國大陸中國核工業集團(China National Nuclear Corporation，CNNC)將發展為策略型合作夥伴，中國核工業集團將成為阿海珐公司的少數的利害關係人(Stakeholders)。

Mr. Philippe Varin 報告

4. 第四位講者為 Mr. Liu Wei(劉偉)，任職於中國核電工程公司(China Nuclear Power Engineering，CNPE)擔任總裁。他就中國大陸在封閉型核燃料循環後端工業發展現況(Present Status of the Back end of Close Nuclear Fuel Cycle in China)進行簡報。中國大陸目前對於核能的發展策略分為三個階段，第一階段為壓水式核子反應器(PWR)、第二階段為快滋生式核子反應器(FBR)，最終目標為核融合核子反應器，同時確定要發展封閉型核燃料循環，並做出明確的方針－必須有效且安全的發展核能。到目前為止，中國大陸有全世界規模最大的核子反應器機組正在興建中。然而在中國大陸發展核能的兩項瓶頸為如何將鈾礦資源的充分利用以及如何降低核廢料的產量。為了解決這兩項問題，中國大陸必須趕快進入核能發展策略的第二階段，即以快滋生式核子反應器為基礎的閉式核燃料循環的相關研究與設施的興建顯得格外重要。作為目前中國大陸快滋生式核子反應器的唯一設計公司，中國核電工程有限公司刻正進行相關研發工作，以實現快滋生式核子反應器的最佳化設計目標。在用過核燃料循環再處理部分，中國核電工程有限公司主導再處理的科學與技術計畫，並興建用過核燃料再處理廠。中國核電工程有限公司也獨立研發設計 HPR1000(華龍一號)，即屬第三代壓水式核子反應器的技術，透過華龍一號計畫示範型機組的興建過程，致力於實現標準化與獨立核電技術的大規模發展。快滋生式核子反應器與封閉型核燃料循環可藉由製造混合氧化物核燃料(Mixed oxide fuel，MOX fuel)生產線來實現，最後利用發展核能，達到低碳與永續發展的目標將會被實現。

Mr. Liu Wei 報告

5. 第五位講者為 Mr. Kazuaki Matsui，任職於日本能源綜合工業研究所(Institute of Applied Energy，IEA)擔任技術顧問。他就日本核能現況與未來(Japan Nuclear Today and Tomorrow)進行報告。自 2011 年福島核子事故發生迄今已過了 5 年，無人因輻射曝露而死亡，但是放射性物質外釋卻造成了將近數十萬人的疏散，同時破損的福島核電廠的除役工作已經啟動，預期尚需數十年的作業。在日本，約有 50 座核能電廠已經停機進行檢查，同時檢視是否符合國際最新的核能安全法規與要求，目前已有 4 座反應器符合並重新啟動運轉。日本政府被要求調整與更新在 2010 年制訂的能源政策，要求降低核能發電的比重，並須符合低碳排放量的要求。然而，要達到低碳排放量的要求，無疑必須透過核能取代燃煤、油與天然氣的發電方式。在這個世紀末，最新發展的核能技術的優點(如非能動安全停機設計，可確保廠區全黑時仍可將爐心安全停機)將被尋求零碳排放量的國家重新探索與討論。



Mr. Kazuaki Matsui 報告

二、專家議題（Panel）

本次會議主辦單位安排了八項專家議題，包含 1)核融合技術的挑戰與進展(Achievement and Challenge in Nuclear Fusion)、2)新一代核能技術的新進展(New Achievements in Advanced Nuclear Energy)、3)鈾礦資源發展現況、鈾礦供給與新燃料發展(Uranium Resource Development，Uranium Supply and New Fuel Development)、4)核電廠興建與零組件製造(NPP Construction and Component Manufacture)、5) 輻照工業和技術的新發展(New Progress in Irradiation Procession Industry and Technology)、6)核電廠運轉安全與年限管理(NPP Operation Safety and Life Management)、7)用過核燃料處理和放射性廢棄物管理（Spent fuel and Treatment and Waste Management）、8)公眾接受度與核能知識教育管理(Public Acceptance and Nuclear Knowledge Management)。本會職責為確保核能及輻射安全，爰擇相關議題參與，說明如次：

（一）新一代核能技術的新進展(New Achievements in Advanced Nuclear Energy)

1. 第一位講者為 Mr. Christophe，任職於法國原子能與替代能源委員會(Commissariat a l'Energie Atomique)核能部擔任主任。他簡報為何需要發展第四代核子反應器(Why Generation IV reactors？)。在第四代核子反應器國際論壇中，法國核安與輻防中心(The Institute for Radiation Protection and Nuclear，IRSN)指出在 2014 年只有鈉金屬冷卻式快中子反應器(Sodium Cooled Fast Reactor，SFR)設計概念，在具有足夠的實驗經驗與成果下可能被實現。這項說法是確實的，因為截至目前為止，共有 19 座鈉金屬冷卻式快中子反應器在不同國家運轉中，且不斷有運轉經驗進行回饋中；目前有兩座新的鈉金屬冷卻式快中子反應器即將運轉，俄羅斯的 BN800(已於 2015 年底商轉，發電功率 800MWe)及印度的原型快滋生式核子反應器(Prototype Fast Breeder Reactor，PFBR，發電功率 500MWe，預計 2016 年底運轉)，而且，在法國、俄羅斯、韓國及日本等國家仍有許多相關的專案計畫持續進行中。

   為何這麼多國家對於第四代核子反應器有高度的興趣呢？首先，我們回顧目前鈾燃料製造狀況，我們假設當鈾礦價格高漲前，仍可使用約 100 年的鈾礦作為輕水式核子反應器的燃料來源。當第四代核子反應器只需以用過核燃料當作燃料，這意味著

這一型的反應器燃料來源，將不再需要鈾礦開採及鈾礦濃縮的產業。

接著，對於第四代核子反應器，鈽是很重要的，而鈽的取得可透過輕水式核子反應器用過核燃料的再處理即可取得，這麼一來將可以大幅減少核廢料的容量。鈉金屬冷卻式快中子反應器可以同時進行多重核燃料循環作業，因此可將混合氧化物核燃料(MOX)與再處理過的用過核燃料一同當作燃料使用。在核能安全議題方面，鈉金屬冷卻式快中子反應器有許多優點，如爐心壓力低、具有較大的熱慣性、鈉金屬的有效熱傳導特性、利用空氣進行冷卻、不需要冷卻水等。以法國的鳳凰號核子反應器及超級鳳凰號核子反應器為例，對於周遭環境衝擊非常的小，且環境輻射劑量率非常的低。最後，為了核能永續發展，輕水式核子反應器、封閉型核燃料循環及鈉金屬冷卻式快中子反應器均扮演著關鍵的角色。

2. 第二位講者為 Mr. Sun Yuliang，任職於北京清華大學核能與新能源研究所擔任副所長。他的簡報介紹北京清華大學高溫氣冷核子反應器(HTGR)發展現況(Status of HTGR Technology Development in China)。北京清華大學高溫氣冷核子反應器示範模組是一項嶄新的核能發電技術，獲得中國大陸政府大力支持。這項技術不但可以確保核能安全，同時也可將餘熱進行利用。目前 HTR-10 之實驗型反應器已經於北京清華大學建置完畢，用來進行相關的研發工作、工程設計、安全評估與認證、設備製造與電廠興建、核電廠試運轉與正式運轉等。之後，工業示範型核能電廠(HTR-PM)正在興建中，設計為雙機組、雙蒸汽產生器模組共同驅動一蒸氣渦輪機，發電力為 200MWe。目前正在進行機組安裝，預計於 2017 年竣工。

3. 第三位講者為 Mr. Song Danrong，任職於中國核動力研究設計院擔任首席工程師。他的簡報為介紹 ACP100 技術與經濟觀點(ACP100 Technical & Economic Aspects)。Mr. Song Danrong 首先介紹小型模組化反應器(Small Modular Reactor, SMR)在中國大陸的進展。ACP100 是小型壓水式核子反應器，其發電功率為 100MWe，為中

國核工業建設集團推出的小型核子反應器，模組化壓水式反應器適用於分散式發電，ACP100 還能設置於船上成為浮動核電站，不須需透過漫長興建過程，只需將浮動電站船入港接電即可供應電力，遇到緊急事故或是戰亂，可以迅速駛離，具高度機動性與便利性。

4. 第四位講者為 Mr. Qiu Zhongming，任職於上海核工程研究設計院擔任助理總裁。他的簡報介紹 CAP1400 技術的發展(The Development of CAP1400 Technology)。中國大陸自主研發之先進非能動壓水式核子反應器(發電功率 1400MWe 級，簡稱 CAP1400)是上海核工程研究設計院在將非能動安全特性概念納入壓水式反應器改良研發工作中的一項研發項目。目前 CAP1400 已經是國際間第三代壓水式核子反應器之領航者，透過發展 CAP1400 的過程，中國大陸對於核子反應器設施研發及技術已有大幅進步，同時提升了中國大陸核工業設計、測試與製造程度。

5. 第五位講者為 Mr. Chris Colbert，任職於美國 NuScale Power 公司擔任策略長。他的簡報介紹 NuScale Power 公司發展先進小模組輕水式反應器近期成果(NuScale’s Recent Achievements in the development of its Advanced Small Modular Light-Water Reactor)。當全世界正在訴求低碳排放量時，NuScale Power 公司擁有的技術正好可派得上用場，並且讓客戶負擔得起也用得安心。NuScale Power 公司發展的小模組輕水式反應器在單一發電設施中設置，最大可同時安裝 12 個小模組輕水式反應器。同時因其輕巧的特點，大幅縮短興建期程，可大幅節省建造成本。每個小模組輕水式反應器可提供 50MWe 的發電量，在單一發電設施中最大發電量可達 600MWe。NuScale Power 公司目前正向美國核管會(NRC)申請執照，未來將與美國猶他州聯合市政電力系統公司(UAMPS)執行首部小模組輕水式反應器興建計畫。

6. 第六位講者為 Mr. Eric Loewen，任職於美國奇異公司擔任首席工程師。他介紹兼具核燃料再利用、非能動式安全設計及可快速部署的 PRISM 核子反應器 (PRISM: Recycling. Passive Safety. Rapid Deployment)。當核能使用國家開始在意如何對核廢料進行循環再

利用時，核工業可趁機展示在核燃料再循環技術的領先地位，透過進步型快中子反應器(Advanced fast reactors)，將用過核燃料再作為發電燃料進行燃燒。進步型快中子反應器具有高經濟價值，可大幅降低燃料成本與減少核廢料的產生。PRISM 核子反應器是一種第四代鈉金屬冷卻式快中子反應器，PRISM 的技術將使用過核燃料當作燃料的技術成真。此外，PRISM 的技術不僅可以減少核廢料的量，也可讓核廢料貯存的時間從數十萬年縮短到數百年。PRISM 已經簡化成模組化設計方式，可在電廠廠址外先進行模組化興建，並可利用過飽和蒸汽汽機來達到大的發電效率。PRISM 使用革命性的安全設計特點來降低超過設計基準事故的可能性，這些特點包含將核子反應器設置在地下，具有非能動氣冷式(passive air-cooling)能力。在燃料設計方面，金屬燃料設計提升安全性，效率性與可製造性，另外，PRISM 的設計提供抗震 1g 的能力。目前全世界對於 PRISM 的技術都表達高度興趣，尤其是中國大陸。目前奇異公司向美國 NRC 提出的設計審查申請部分，NRC 表示後續發照程序應不是問題。

7. 第七位講者為 Mr. Hadid Subki，任職於國際原子能總署核能部擔任技術領導人及計畫經理。他的簡報介紹國際原子能總署會員國在小模組核子反應器技術科技研發的進展 (Advances in Small Modular Reactor Technology Developments in IAEA Member States)。國際原子能總署有一項計畫，目標是提供會員國對於小模組核子反應器科技的整合、發展與實現。這項計畫目標是同時協助發展小模組核子反應器的專家，未來可能使用小模組核子反應器的國家就小模組核子反應器安全設計方面的問題提供協助與解決。小模組核子反應器發展的動力，主要是為了讓核子反應器使用拓展到更多的使用族群，並取代老舊式化石燃料發電機組。小模組核子反應器可透過非能動式安全設計強化核能安全，並讓更多的使用者負擔得起。每一小模組核子反應器的設計可提供發電量高達 300MWe。目前全球約有 50 種小模組核子反應器的設計概念，這些小模組核子反應器大多處於不同發展階段，部分小模組核子反應器的設計目標是要在短期間完成並興建。這些短程發展的小模

組核子反應器形式為整合型壓水式核子反應器(iPWR)，目前僅有阿根廷、中國與俄羅斯聯邦正在興建中。在中國，高溫氣冷核子反應器的設計為以兩部熱功率 250MWth 的機組產生電功率 200MWe，目前正在興建中，預計 2018 年正式上線服役。在阿根廷，自然循環式整合型壓水式核子反應器原型機(CAREM-25)即將運轉，最遲在 2018 年 10 月可上線服役，可提供發電功率約 31MWe。在俄羅斯聯邦部分，KLT-40S，以壓水式核子反應器為底的浮動船型發電站將在 2016 年興建，並在 2019 年併聯發電，這一類型的發電站之所以受歡迎的原因主要是具有機動性。在中國大陸，ACP100 型也是一種整合型壓水式核子反應器，發電功率可達 100MWe；工業示範型機組計畫將在福建省興建，熱功率為 310MWth。在韓國，進步型系統整合式核子反應器(System-integrated Modular Advanced Reactor，SMART)，也是一種整合型壓水式核子反應器，其發電功率可達 100MWe，在 2012 年已獲得韓國核能安全與保安委員會(Nuclear Safety and Security Commission)的設計許可證。在 2015 年 9 月，韓國與沙烏地阿拉伯已簽署在沙烏地阿拉伯興建 SMART 的協議。在美國，NuScale Power 公司備妥該公司設計許可申請書，預計在 2016 年最後一季向美國核能管制委員會提出設計許可申請書。NuScale Power 公司設計的部分，是一種自然循環式的整合型壓水式核子反應器，由 12 個小模組核子反應器組成，每個模組可提供電功率為 50MWe。國際原子能總署近期出版了關於討論水冷式小模組核子反應器安全設計考量的技術文件，這部分主要是汲取了日本福島核子事故經驗後所提出。這份文件提供未來加入小模組核子反應器研發行列之技術人員、使用國家有關強化深度防禦的基本概念、方法與手段。

8. 第八位講者為 Mr. Kevan D. Weaver，任職於美國 TerraPower 公司擔任總裁。他的簡報介紹先進核能技術的新進展 (New Achievements in Advanced Nuclear Energy)。核能的使用一種可信賴的、規模可調整的選項，核能可以有效對抗氣候變遷與碳排放所帶來的空氣污染，甚至，可確保國家的能源安全。法國已經證實

核能可有效大規模取代化石燃料的能源,在 20 年內將可成功將燃煤方式轉換成核能。使用核能可符合零碳排放量的要求，在未來勢必為全球能源使用策略思考的選項之一。TerraPower 公司目前正在研發一種行波核子反應器(Traveling Wave Reactor，TWR)，這是一種利用金屬鈉冷卻的快中子核子反應器，可充分利用核燃料，不需要再進行再處理作業。TWR 可在重新回填燃料運轉，燃料可使用耗乏鈾燃料、天然鈾、低濃度鈾等。TWR 最終的運轉模式，就是以耗乏鈾燃料當燃料，因此 TWR 最後不會有核廢料產生。自 2006 年下半年，TerraPower 在超過 50 個機構共同合作努力下，已經完成概念性的工程設計。目前的願景就是希望在 2020 年興建完成第一部機組並運轉，到 2030 年時，將可提供乾淨、零碳排放的能源。

（二） 核電廠興建與零組件製造(NPP Construction and Component Manufacture)

1. 第一位講者為 Dr. Corey McDaniel，目前擔任美國 Idaho 國家實驗室核能科技國際與商業合作的經理人。他首先簡介 Idaho 國家實驗室的基礎硬體設施，並提出 GAIN(Gateway for Accelerated Innovation in Nuclear, GAIN)的倡議，他指出著眼於核能是未來能源組合很重要的一部分，必須引進創新科技以滿足低碳世界的需求，尤其全球核能需求正在增加，美國的領先科技對於國家安全及外銷市場的滲透都極為重要。他除了介紹 IDAHO 實驗室目前專注的研究領域，並且特別簡介了小型模組化反應器(Small Modular Reactor, SMR)的進展，說明 Idaho SMR 無碳電力計畫(Carbon Free Power Project (CFPP))，將使用 12 個 50MWe NuScale modules (合計 600MWe NPP)發電，IDAHO 仍積極尋求國際上對於 SMR 各項研究計畫的合作機會。

2. 第二位講者為 Mr. Bill Poirier，任職於西屋電力公司擔任副總裁。他的簡報介紹目前世界上有八部核能機組正在興建使用西屋公司 AP1000 反應器，其中四部在中國，另四部在美國。

3. 第三位講者為 Mr. Herve Hottelart，任職於 AREVA 亞洲區擔任副總裁。他的簡報則以 AREVA 公司如何納入中國核能產業供應鏈為題發表演說，隨著中國核能工業的發展，中國有越來越多的合格供應商進入這個市場，而既有的供應商也逐漸成熟，但是在中國採購仍有品質、工期可信度、語言與溝通技巧、規範標準及相關文件、詳細設計等方面的挑戰。

4. 第四位講者為 Mr. Jose Maria Zubimendi，任職於德國 ENSA 核能商業部擔任副總經理。他的簡報以新一代反應器先進科技與國際合作為題發表演說，介紹第三代反應器 AP-1000 泵殼的困難銲接技術(複雜幾何與多種材質的銲接)、第四代反應器-礫石床反應器(4th generation PBMR Reactor)壓力容器的製造研究、第四代反應器-鈉反應器(4th generation Sodium Reactor)的製造研究，他認為核能工業界面對與日俱增的安全要求、科技、品質及成本上的多方挑戰，現今新一代反應器需要發展先進的製造能力，從組件的製造階段

就能確保安全。

5. 第五位講者為 Mr. Norbert Dudek，任職於亞洲超重機集團(Terex Cranes-Asia)擔任副總裁，他的簡報介紹核能電廠新建階段常使用的重物吊裝施工安全。

6. 第六位講者為 Dr. Ron Oberth，任職於加拿大核工業集團擔任執行長。他的簡報介紹加拿大身為核能的先進國家，擁有六十年核能科技發展的經驗，率先研發出加壓重水反應器(CANDU)，每年核能產值達 70 億加幣，提供 3 萬個就業機會，且為世界第二大鈾製造生產國。他並舉安大略省電力結構為例，核能佔 62%，水力 24%，風力 4%，剩餘才用油或天然氣發電。此外，並說明加拿大核能業界如何積極參與各項國際合作。

7. 第七位講者為 Mr. He，任職於中國核電工程擔任副總工程師。他的簡報介紹創新應用關鍵技術安裝壓水式反應器(PWR)的主要設備，達成節省興建工期的目標，這些創新突破技術包括：主要管路的自動銲接、3D 模擬安裝（含精確尺寸量測建構 3D 模型、安裝施工邏輯以及同步應力分析等功能）、發展水下無重力狀態的精準檢測技術（含抗輻射及抗電磁干擾）以及特殊工具的發展等四大突破，隨後這些創新技術被實際應用在福建寧德核電廠、紅沿河核電廠、台山核電廠、陽江核電廠、防城港核電廠等 13 部機組，每部機組施工期約可節省 60 日。

8. 第八位講者為 Mr. Wang，任職於上海核能工程公司擔任副總經理。他的簡報以 AP-1000 設備組裝與電廠興建-轉變與挑戰為題發表演說，他提到第三代反應器 AP-1000 具有被動式安全的設計，在中國首次興建時，面對適用新的準則與技術要求，對於設備組裝及現場施工的廠商構成許多挑戰，透過中國-美國聯合逐一檢視這些困難，終於克服了障礙，包括：銲材、銲接與熱處理、反應器冷卻泵浦、爆破閥、安全相關電纜、設備品質試驗、模組化施工、等等技術議題，他並且認為第一部 AP-1000 機組的興建，可以提供寶貴而豐富的施工經驗，回饋給後續興建的機組。

（三） 輻照工業和技術的新發展(New Progress in Irradiation Procession Industry and Technology)

本專題邀請的專家及來賓包括國際原子能總署（IAEA）輻射應用專家 Sunil Sabharwal 先生、國際輻照工業協會(IIA)總經理 Paul Wynne 先生、加拿大 Nordion 公司主任 Richard Wiens 先生、加拿大 Mevex 公司總裁 David Brown 先生、比利時 IBA 公司亞太市場和銷售副經理 Evan Xu 先生、中國同輻股份有限公司副總經理張錦榮先生、施潔醫療技術有限公司中國區業務總監 Erik Jia 先生、藍孚高能物理技術股份有限公司副總裁彭偉先生及北京大學第一醫院核子醫學科主任王榮福先生等，共同就輻照工業和輻射加工技術的新發展發表自己的觀點並進行討論，包括加馬、電子束和 X 光三個輻照工業的發展前景、游離輻射的應用、研究與技術轉移等。與會的專家及來賓分享輻射的各種應用實例，例如在醫療器材和食品工業，加馬輻射是殺死細菌和有害微生物的一個有效工具；輻照技術還可應用於測量和清除河流中的污染物，以及測試和改變材料的特性，從而改進材料的結構和彈性等。因本專題部分專家超過時間，無法完整介紹，擇要說明如次：

1. 國際原子能總署（IAEA）輻射應用專家 Sunil Sabharwal 先生認為：原子能和輻照技術的應用過去以來一直在為提高工業效率、節能和保護環境作出貢獻。原子能和輻照技術在許多方面已經成為品質或技術革新的重要方法之一。通過 IAEA 的合作研究計畫和技術援助計畫傳授這些技術的經驗，對許多國家的經濟發展都有一定程度的貢獻。從已開發國家的經驗得知，適當而正確地應用原子能和輻照技術可創造許多實際效益。不論是現在或未來，輻照工業和技術的應用將有助於提升開發中國家相關工業的生產效能。

2. 北京大學第一醫院核子醫學科主任王榮福先生表示：放射性同位素在檢查和治療上的應用是診療醫學的重要進程，也是提升醫療品質的趨勢之一。例如核子醫學技術應用於癌症診斷，主要是腫瘤位置的偵測、區別腫瘤為良性或惡性、診斷腫瘤是否復發以及轉移的可能性。事實上核子醫學與其他臨床醫學都有一定程度的

關聯，例如腫瘤科、骨科、內科、新陳代謝科及泌尿外科等，若能加強各臨床科室間的經驗交流與學習，並提升核子醫學與分子影像技術在醫學領域應用，相信核子醫學領域將會有更多的技術創新與突破。

3. 本論壇還探討輻照技術的創新應用，例如保護文化資產及製造新型環保塑材等，並探討這些技術如何促進或提升產值。同時論壇也認為即使全球經濟成長趨緩，輻照工業及技術之應用應不會受到的太大影響，仍可保持一定程度的進步與發展。在場的專家及來賓對於原子能與輻照技術發展成一項新興科技，在工業、農業、醫療衛生、食品及環境保護等方面有廣泛用途，並能促進經濟效益和社會效益等，都抱持樂觀及肯定的態度。

（四） 核電廠運轉安全與年限管理(NPP Operation Safety and Life Management)

1. 第一位講者為來自美國 Idaho 國家實驗室的 Dr. McCarthy。他的簡報簡介美國能源部的輕水式反應器持續性研究計畫(Light Water Reactors Sustainability Program, LWRS)，她以 2014 年美國電力結構為例，核能發電雖然僅佔整體發電量的 19%，其中，若單獨來看非排碳能源的部分，核能卻佔非排碳能源的 62.9%，水力發電佔 19.9%，太陽能/風力/地熱等佔 17.1%。她認為輕水式反應器是美國國家的重要資產，過去 20 年以來，輕水式反應器提供了近 100GWe 的低碳低成本電力，且可見的未來，美國不太可能快速新建足夠多的電廠，填補輕水式反應器的除役以及對新的潔淨電力需求，因此推動輕水式反應器的延役相關研究，以提供材料老劣化的科學基礎。

2. 第二位講者為世界核能發電者協會同行審查小組召集人 Mr. Dawes。他的簡報簡介世界核能發電者協會的設立宗旨與協助協會會員提升運轉中核電廠安全所做的努力。

3. 第三位講者為來自於加拿大的加壓重水反應器業主集團(CANDU Owners Group, COG)董事長兼執行長 Mr. Dermarker。他的簡報則以 CANDU 加強合作以達成卓越的表現為題發表演說，他提出基於借鏡其他工業界的經驗學習(例如航空業)，對核能業界創新改革的重要性，包括：提升安全、增進可靠度、強化人力績效、降低成本並改進品質控制等。但面對日本福島事故的危機，我們必須依然保持警惕，研議如何處置超越設計基準的事件，包括：系統設備硬體方面的改善以及對於人力與組織方面的強化，例如訓練、情境模擬、基於知識庫的決策工具以及在困難時刻採取行動步驟的優先次序，他進一步認為唯有各個領域的從業人員通力合作，才能達成最佳化表現。

4. 第四位講者為美國西屋公司資深副董事長 Mr. Howell。他的簡報則以描繪核能工業的下一個 60 年為題發表演說，首先提到截至 2014 年，美國核管會(USNRC)已經核准 74 座電廠的 20 年延役申請，而後介紹西屋公司的遠景，包括：以盡可能低成本的方式，

滿足後福島事故各項管制與安全要求；透過可預測的縮短大修工期以確保長期經濟可行性；投資對運轉具有關鍵性的系統組件，達成長期資產管理的目標。

5. 第五位講者為來自英國的 Mr. Lewis。他的簡報介紹了如何應用壽命管理達成低成本運轉的經驗，包括：高效能運轉、縮短大修工期、降低維護成本、降低庫存及低輻射曝露等。

6. 第六位講者為 Mr. Oh，他的簡報特別介紹了非營利組織 CSA group 與其因應福島事故後新發展的五項規範標準及修訂七項既有的規範標準。五項新訂的規範標準中，其中有三項標準業已發行，包括：核能緊急應變管理計畫的一般要求、超越設計基準事故的要求、核燃料與放射性物質濕式貯存等。

（五） 用過核燃料處理和放射性廢棄物管理（Spent fuel Treatment and Waste Management）

1. 第一位講者為 Mr. Dixon，任職於世界核運輸研究所(World Nuclear Transport Institute, WNTI)擔任特別顧問。他的簡報介紹 WNTI 後端運送工作小組：目前工作概述和我們工業面對的未來挑戰 (WNTI Back End Transport Working Group：overview of our current work and the coming challenges facing our industry.)。WNTI 在 2008 年建立的工作小組主要致力於後端材料，包括放射性廢棄物、用過核燃料及除役物件的運送作業。WNTI 後端運送工作小組的目標是：

(1) 確認潛在負面影響放射性廢棄物、用過核燃料的安全性或效率的議題。
(2) 使用成員的知識或經驗以獲得這些議題的全盤認識及發展其工業定位。
(3) 向涉及第七類運送作業的相關單位傳遞學習經驗。

WNTI 扮演了業界和管制機關的橋樑角色，由上而下向工業界提供法規的解讀和詮釋，並編撰運送實務模範案例文件，由下而上則將工業界操作實務和經驗學習回饋到管制機關。WNTI 後端運送工作小組已經在工業界、利益團體及管制機關關注的各個議題耕耘了 6 年，目前正在進行中的議題包括了核電廠除役的運輸，為此 WNTI 編撰了「運輸大型物件及特殊處理」的內容概要說明書，將有關工業界的實務經驗、運輸路線規劃、及有關民眾資訊的事件的處理都編入其中。此外多功能護箱(Dual Purpose Casks, DPC)議題，WNTI 正在研究多功能護箱是否足以因應後端工作的多個選項如再處理、中期水池貯存、乾式貯存、最終處置等。運輸法規方面則進行定期的檢視，重點包括經過長期貯存後在運輸方面的差異分析(gap analysis)及包件的老化管理等，預計在 2018 至 2019 年提出運輸法規的草擬版本。

2. 第二位講者為 Mr. Gerd-Michael，任職於德國 RWE 電力公司擔任資深專案經理。他的簡報介紹在核電廠除役及廢棄物管理方面 RWE 的經驗（RWE’s experience in decommissioning of nuclear power plants and Waste Management）。德國 RWE 的核電廠除役經驗

包括 Kahl(BWR)、Gundremmingen-A(BWR)、Lingen-A(BWR)及 THTR300(Thorium high temperature reactor)等核電廠，這構成了 RWE 在除役和廢棄物管理經驗的基礎，Kahl 目前已完全除役回復成綠地、Gundremmingen-A 則大部分除役已完成，僅剩圍阻體殘留、Lingen-A 及 THTR300 則安全關閉中，預計明年將開始除役。Gerd-Michael 先生談到電廠除役必須彈性管理，視各電廠情況不同採用不同的拆除策略，在電廠的拆除策略上有現址拆除(將模組於安裝地拆除)；在其他地點拆解模組並在現場進行處理；在其他地點拆解模組並交由外部協力廠商進行處理等作法，而透過現場和離場拆解、處理的交互選用達成了彈性管理的目標。

燃料管理方面，RWE 採取在電廠關閉後燃料棒直接從反應器移出至燃料池作進一步的冷卻作法，經過大約 5 年時間，燃料棒將移到不鏽鋼護箱之中，再移至中期貯存設施使用專門之貯存容器貯存。廢棄物管理方面，無害的可利用物質依情況採不處理、去污或熔融處理後，無限制釋出或回收再利用，不可利用的廢棄物則於掩埋場丟棄，此部分占了除役廢棄物的 95%；只有 5%會成為放射性廢棄物，其視情況進行固化後進入最終處置場。Gerd-Michael 先生最後提到除役設備的選用原則，為了將廢棄物體積縮減至最小，因此超高壓縮機、乾燥機等的處理設備選用就十分重要，但處理過的廢棄物還要符合未來最終處置場的接收標準。拆解設備方面，原則上選用構造簡單易於維修並且有效率的設備，安全、易於使用及重量輕便也必須考量，在個人輻射防護上的安全措施例如負壓式帳蓬等尤其重要。測量設備的選擇則必須選用經過管制機關認可並能適用於清潔範圍偵測的設備。

3. 第三位講者為 Mr. Kee. Chan. Song，任職於韓國原子能研究機構(Korea Atomic Energy Research Institute, KAERI)擔任用過燃料科技管理主任。他的簡報介紹 KAERI 在高溫處理過程技術的研發（Pyroprocessing Technology Development at KAERI）。在能源的保安和全球暖化的因素下，核能逐漸變成穩定能源的選項，韓國目前核能約能提供 1/3 的電力，但計畫在 2035 年前提升到 41%。韓國在長期用過核燃料的選項上包含直接處置、境外再處理、水溶液

再處理(aqueousreprocessing)等選項，然而直接處置要求有大量的處置空間、境外再處理有運輸和分離鈽的問題、水溶液再處理則有分離鈽的累積疑慮，因此涉及高溫處理過程(Pyroprocessing)的用過核燃料循環就成為選項之一。高溫處理過程的概念是群回收(group recovery)，因此鈽元素不會被單獨分離，從而有助於防止核武擴散。鈽以及其他核種佔用過核燃料的 1.4%，將回收利用，並與部分自用過核燃料回收的鈾進行混合，製成鈉冷式快中子反應器(sodium-cooled fast reactor,SFR)的燃料，鈽以及其他核種將在快中子反應器中燃耗並轉換成其他核種。此外，鍶跟銫一般被認為是用過核燃料主要的熱負載，也將在高溫處理過程中回收分離貯存並加以處置，而鍶跟銫的移除則能夠大大降低處置場的負擔。高溫處理過程的優點除了上述提到，還包括可減少高放射性廢棄物的體積，並減少高放射性廢棄物衰變至天然鈾礦強度所需時間，此係快中子反應器會將超鈾元素燃燒轉換成短半衰期或穩定之核種之故。

4. 第四位講者為 Mr. Wang Ju，在中國大陸核工業北京地質研究院(Beijing Research Institute of Uranium Geology) 擔任副院長。他的簡報介紹中國大陸在高放射性廢棄物地質處置計畫現況:更新至2016（Geological Disposal Program for High Level Radioactive Waste in China：update 2016）。Wang Ju 首先介紹中國核能發展情形，在 2020 年以前，中國大陸核反應器的裝機容量將達到 28GW，同時另外有 30GW 的反應器裝機容量正在建造中。目前估計全部 58 部核子反應器所產生的用過核燃料將達到 14,000 噸，針對如此龐大數量的用過核燃料，中國大陸的政策是輕水反應器所產生的用過核燃料將先進行再處理，然後進行玻璃固化及最終處置。2006 年中國大陸原子能機構(CAEA)、科技部、國家環境保護部發布了高放射性廢棄物最終地質處置的長期研發計畫，包含三個階段，2006-2020 年為高放處置場址選址和實驗室研究。2021-2040 年第二階段為地下現址測試。2041-2050 年第三階段為處置場建造。高放處置場址選址自 1986 年開始，1989 年選出六個適合興建高放處置場址的區域，並進一步地選出了北山場址，處置主要概念採

用豎井隧道模型(shaft-tunnel Model)、多重障壁及處置窖方式，處置場則設置於花崗岩層的飽和區，而廢棄物的最終型態則為玻璃固化的高放射性廢棄物。2016 年選出了地下實驗室的場址。地下實驗室的目的主要為對深地質環境進行特性調查，執行全尺寸試驗、技術研發、人員訓練及國際合作、民眾溝通等目的，而北山處置場的地下實驗室目前正進行場址調查工作，預計於 2020 年興建完成。

北山場址目前已經完成 27 個鑽孔，另外有 6 個深鑽孔正在施工中。而關於提供緩衝材料的 GMZ膨潤土庫則位於內蒙古一帶，其膨潤土的蘊含量約達 160 百萬噸，此外，大規模的試驗原型設施已經建造完成，可在模擬的處置條件下研究 GMZ膨潤土行為。談到未來 5 年的工作重點， Wang Ju 先生表示重點將落在地下實驗室的場址特性調查、設計及建造，高放處置場址的選址、工程設計和工程障壁的研究、其他則包括關鍵核種行為以及安全情節的評估等項目。

（六）公眾接受度與核能知識教育管理(Public Acceptance and Nuclear Knowledge Management)

本專題講員有九位：法國核能協會（SFEN）秘書長 Valerie Faudon 女士、韓國原子能安全防護學會主席 Kune Y Suh 博士、美洲核能學會（ANS）主席 Gene Grecheck 先生、中國核能電力公司（CNNP）公眾溝通資深經理 Yue Zuo 先生、中國廣核集團公司（CGN）駐泰國代表 Yunli Liu 先生、Potomac 通訊集團合夥人 Laura Hermann 女士、馬來西亞核電公司（MNPC）核電發展計畫主任 Jamal Khaer Ibrahim 先生、加拿大核能協會（CNA）主席 John Barrett 博士、IAEA 核能部副秘書長辦公室溝通顧問 Ayhan Evrensel 先生。各講員的演講內容摘要如下：

1. 第一位講者為 Faudon 女士，簡報主要在介紹 2015 年 12 月在巴黎舉行的「聯合國氣候綱要公約 UNFCCC」第 21 次締約國大會（COP21）的會議成果。依據政府間氣候變遷小組（IPCC）的估算，COP21 所通過的全球減碳協議，若要達成在 2050 年將全球升溫限制在 2°C 的目標，至少 80%的電力必須來自低碳能源。這是一個巨大的挑戰，而核能是 IPCC 認可有效減緩溫室氣體效應的選項，其溫室氣體排放量和再生能源不分上下。COP21 會期中，全球 150 個核能相關組織成立了「Nuclear for Climate 倡議」，推廣讓世界認知核能是對抗氣候變遷的解決方案之一，Faudon 女士簡述此倡議的目標及行動計畫等。最後 Faudon 女士以下一次 COP22 將有更嚴峻的挑戰做為結論。

2. 第二位講者為 Suh 博士，他的簡報先闡明核能在能源及氣候解決方案上的重要性，然後強調核能的發展需要解決人的關係，所以他倡導 NOAH（Nuclear Odyssey Alongside Humanity）的觀念，關注於人性，讓科學家更親和，讓人道主義者更滿意，讓反核人士更和諧，作為核能溝通的目標。

3. 第三位講者為 Grecheck 先生，他的簡報在介紹近年來 ANS 在公眾溝通和推廣行動上的成果，包括網頁、部落格和社群網站的經營等。此外，ANS 也為國會議員的幕僚和助理舉辦核能研討會，為中小學教師舉辦核能研習營等。2015 年 ANS 和世界各國 150 個科學社團加入「Nuclear for Climate 倡議」，致力於正確核能資訊的傳播與教育。

4. 第四位與第五位講者分別為 Yue Zuo 先生和 Yunli Liu 先生，分別介紹中國核能電力公司（CNNP）和中國廣核集團公司（CGN）在核能宣導上的作法與經驗，例如在車諾堡事故後，中廣核的大亞灣電廠就受到香港居民的抗議。而在福島事故後，全國的核能計畫都遇到阻力，必須採取更主動的策略，讓公司的政策與資訊更透明，而實際的溝通方式則必須更有創意。

5. 第六位講者為 Hermann 女士，她的簡報則由傳播從業人員的角度來看世界各國核能公眾溝通的特性，解釋不同政府的形式、文化的因素、公眾討論方式的影響，也調查並評估對不同利害關係人的實務做法。結論是善用從過去經驗學習到的課題，可以讓後續的計畫更順利。

6. 第七位講者為 Ibrahim 先生，他的簡報介紹馬來西亞推廣核能的歷史與遭遇到的困難。馬來西亞在 2011 年成立官方機構推動實現第一座核能電廠的計畫，包括 10 年期的核能溝通方案、建立核能管制法規、建立獨立原子能管制機構等。

7. 第八位講者為 Barrett 博士，他的簡報介紹加拿大的核能公眾接受度。加拿大所有大型核能計畫都必須得到公眾的接受。取得在地社區和勞工團體的認同很重要，因為他們可以影響政治領袖。以加拿大而言，就成功地讓原住民社區和勞工從大型核能計畫獲得相當大的利益，取得他們的支持。Barrett 博士強調：公眾對風險的接受度，取決於公眾對政府或電力公司掌控風險能力的信心。

8. 第九位講者為 Evrensel 先生，他的簡報則強調與利害關係人溝通的重要性。核能計畫的規劃初期，就要考慮到利害關係人的參與。IAEA 的安全標準文件（Safety Standards）就已詳細敘述政府、管制機關、電力公司及承包商在與利害關係人溝通上的責任。利害關係人在整個核能利用的生命週期（從建廠到除役）的支持，是國家基礎建設能永續發展的基石。在 IAEA 為核能新興國家編寫的協助建議文件（The IAEA Milestones Approach）中，利害關係人溝通即是 19 項關鍵議題之一。

三、技術專題（Parallel Technical Track）

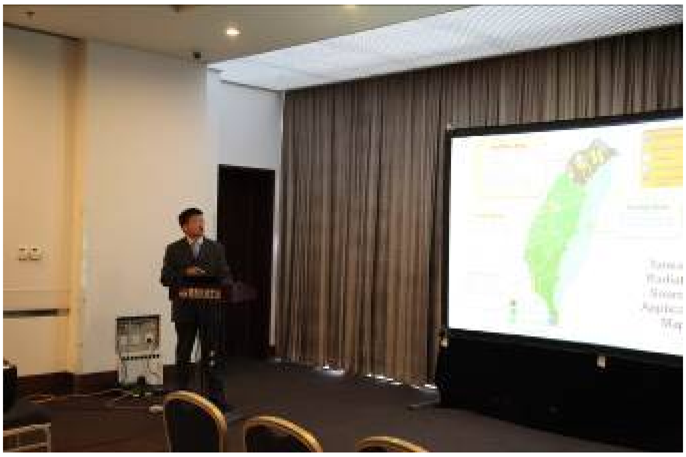
主辦單位安排 10 項技術專題領域，包含 1)核能安全與核子保安、2)核電廠運轉及維修、3)核子反應器及新建機組、4)廢棄物處置、5)核能元件供應鏈及品質保證、6)核燃料循環、7)核能新技術及新應用、8)公共接受與核能教育、9)經濟與成本降低、10)輻射醫療及生物效應。本次僅就本會與會發表人員所參加專題進行說明：

（一） 核能安全與核子保安(Safety and Security)

1. 郭子傑技正發表「輻射防護雲化服務系統簡介(THE RADIATION PROTECTION CLOUD SERVICE SYSTEM IN TAIWAN)」

「輻射防護」分組研討會主席為中國核電工程有限公司反應堆工藝研究所所長毛亞蔚女士。輻射防護處郭子傑技正報告題目為「輻射防護雲化服務系統簡介」，內容主要是介紹我國輻射源的輻射安全管制已進入雲化服務時代，本會同仁與業者可以使用 Internet Explorer、Google Chrome、FireFox 等網頁瀏覽器，全面提供「無紙化」之線上申辦及審核服務，包括放射性物質、可發生游離輻射設備、進出口簽審等證照申辦、定期申報、屆逾期 Email 通知及安全審查等輻射源安全管制業務。此外，雲化服務系統可讓使用者以個人電腦、平板電腦及智慧型行動電話等裝置，隨時隨地獲得優質穩定的網路線上服務，不但可以大幅節省政府成本，亦可落實環保政策，以提升輻防服務及管制效能。

報告結束後與在場之來賓交換意見，其中一位外國人士詢問本會有多少人使用輻射防護雲化服務系統？郭員回答就任職之輻射防護處而言，目前約有 20 位同仁在使用此系統執行輻射安全管制業務。分組研討會結束後與在場來賓交換意見，主席毛亞蔚女士表示她專長於核電工程與研究，對於核電以外的輻射應用接觸較少，藉由此簡報可對台灣輻射源的應用與管制有所瞭解。法國電力公司(EDF)中國研發中心研發工程師宋雨婷小姐認為輻射源管制和核電廠運作相似，其設計都需要精密地規劃，並從科學的角度執行有系統的管理，才能全盤掌握生命週期(Life Cycle)，也就是「從搖籃到墳墓」 (Cradle to Grave)的觀念，如此才能確保輻射源的安全管控。



郭子傑技正發表「輻射防護雲化服務系統簡介」

2. 黃朝群技士發表「後福島事故台灣核子事故緊急應變及整備介紹 (LESSONS LEARNED FROM FUKUSHIMA-APPLIED TO EMERGENCY PREPAREDNESS IN TAIWAN)」

日本福島核子事故後，原能會立即就國內三座院轉中核能電廠進行核能安全總體檢作業，聚焦於核能安全、輻射防護與緊急應變整備等三方面。經檢視日本福島核子事故後，原能會將之歸類為五個應學習的課題：1)複合式災害應變、2)受害者觀點、3)運用新科技、新事證、4)減災、5)資訊透明與民眾溝通。為了避免重蹈日本的覆轍，原能會從三方面著手：1)機制改進與法規修訂、2)境外與國際合作、3)整備作業的精進。

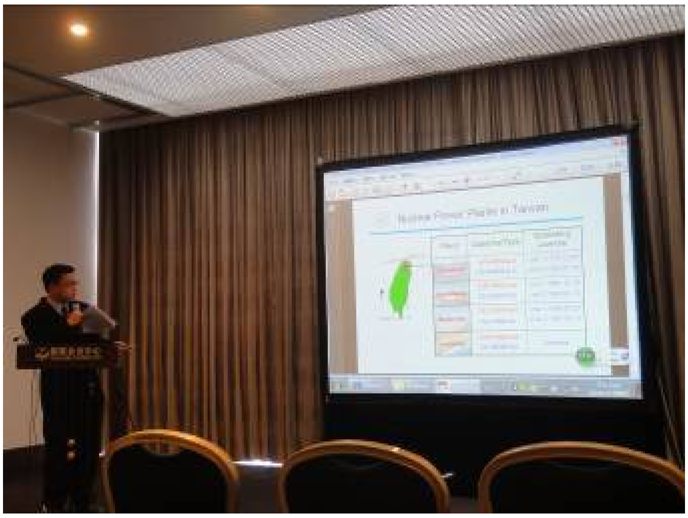
機制改進與法規修訂方面，原能會已經著手進行核子事故緊急應變相關法規命令、行政規則的修訂作業，並基於雙機組事故計算，擴大緊急應變計畫區(Emergency Planning Zone，EPZ)至八公里，最後則是強化核能電廠因應嚴重天然災害引發核子事故應變能力。

境外與國際合作方面，原能會已經修正核子事故分類通報及應變辦法、核子事故中央災害應變中心作業要點、並增訂境外核災處理作業要點，另一方面，原能會已強化輻射劑量評估與分析能力與大氣擴散模式、向美國引進空中輻射偵測技術與增列海上輻射偵測作業。

整備作業的精進方面，原能會要求台電公司必須符合美國核管會(NRC) Near-Term Task Force Report (NTTF)有關人員與通訊議題的建議要求事項。台電公司目前已經制定出斷然處置導則，若核子事故非常嚴重，必須要水注入反應器，確保放射性物質不會大量外釋。台電公司也就緊急應變場所的耐震或免震棟部分進行相關改進措施。為了確保 EPZ 內所有民眾可以在 45 分鐘內 100%聽到核子事故警報聲音，台電公司已增設多處警報站。配合緊急應變計畫區擴大，設置更多的環境輻射監測站。在碘片發放部分，原能會已經預先規劃發給 EPZ 內民眾兩天分的碘片用量，另外兩天分的用量存放在 EPZ 所在之地方政府指定區域，此外原能會與國防部攜手合作建置南北各一處之國家碘片儲存庫，可提供核子

事故期間需要額外碘片的因應作業。在緊急應變作業溝通聯繫部分，原能會已經建立核子事故緊急應變作業平台，供核子事故期間，緊急應變人員相互通報、聯繫與訊息傳遞用，若事故惡化到全面緊急事故或複合式災害引發核子事故時，原能會應變團隊將前往位於新店大坪林中央災害應變中心執行應變，並以應變管理資訊雲端服務(EMIC)與相關進駐機關(單位)及地方政府進行相互通報、聯繫與訊息傳遞。在疏散方面，階段性下風向疏散模式將是中央災害應變中心指揮管下達決策時之重要參考，學生與照護之家民眾將優先進行疏散，目前預防行疏散作業已規劃完成。原能會也持續進行資訊透明及民眾溝通作業，並舉辦園遊會傳達輻射防護概念。最後，原能會透過每年辦理的核安演習進行所有整備精進作業的成效驗收。

文末提到原能會認為應謙卑地面對天然災害，持續精進核子事故緊急應變與整備能力，並透過資訊透明與持續溝通以贏回民眾對於政府的信賴。



黃朝群技士發表「後福島事故台灣核子事故緊急應變及整備介紹」

3. 熊大綱技士發表「以安全管制的觀點介紹台灣運轉中電廠耐震餘裕評估(SEISMIC MARGIN ASSESSMENT OF THREE OPERATING NUCLEAR POWER PLANTS IN TAIWAN FROM REGULATORY PROSPECTIVE)」

台灣位處環太平洋地震帶上，地震發生頻繁，核能電廠的耐震安全議題特別受到社會各界的關注。是以我國核能電廠規劃建廠之初，即參照美國核能法規相關要求進行非常嚴謹的地質調查與電廠選址作業，並針對廠址與周遭環境歷史記載曾發生最嚴重的地震進行調查，作為廠址安全與電廠耐震設計之依據。核能電廠重要系統設備所在的反應器廠房建築是座落於岩盤上，可進一步降低核能機組受地震危害之風險。論文首先簡介核一/二/三廠反應器、圍阻體基本型式以及建廠之初設定的安全停機地震(safe shutdown earthquake, SSE)分別為 0.3g/0.4g/0.4g(g：地球重力單位)。

其次談到有鑑於民國 96 年與 98 年經濟部中央地質調查所將山腳斷層與恆春斷層暫列為第二類活動斷層，且研判該兩斷層有向海域延伸之可能性，另一方面亦基於 96 年日本柏崎刈羽核電廠因地震造成機組停機事件之經驗回饋，原能會為進一步確保核能電廠之運轉安全，遂於民國 98 年要求台電公司規劃執行「核能電廠耐震安全再評估精進作業方案」(以下簡稱耐震精進案)，其內容包括：「海域、陸域地質調查」、「地震危害度分析與設計地震檢討」、「核電廠各安全相關結構、系統及組件(SSCs)耐震餘裕檢討及適當補強作為」等階段，要求台電公司分階段執行，並將執行結果提報本會進行審查。

有關海、陸域地質調查部分，台電公司已於 101 年 6 月底完成初步調查成果，並於 101 年 11 月中旬提出調查結果。經本會聘請專家學者協助，已經完成審查，並提出安全評估報告上網公告。依據目前調查結果顯示，山腳斷層長度已由原先概估的 50.6 公里（即陸域 34 公里，海域概估 16.6 公里），進一步往外海延伸，總長度達 74 公里，同時不排除有繼續往外海延伸之可能性；恆春斷層陸域段呈現斷層帶，可分為東恆春斷層與西恆春斷層，東、西恆春斷層並在恆春半島南灣入海前交會，若自海口村起

算，海域、陸域總長度至少有 41 公里，兩條斷層長度均遠超過當初經濟部中央地質調查所公布的長度。本會基於安全保守性決策，已先行要求台電公司保守假設山腳斷層延伸至棉花峽谷(即海陸域總長度 114 公里)之條件下，進行耐震能力評估，倘若評估結果耐震餘裕不足，即應進行耐震補強。

地震危害分析與耐震餘裕評估及補強作業：強震來襲時，對於核能電廠而言首重能夠安全停機，並適當冷卻，使反應器維持在安全狀態。台電公司基於前述山腳、恆春斷層新事證地質調查結果與保守假設斷層長度，提出地震危害度分析結果與進行耐震評估之基準地震，經本會聘請專家學者進行審查，決定核一/核二/核三廠進行耐震評估之基準地震分別為 0.51g/0.67g/0.72g，約為各廠原安全停機地震之 1.7~1.8 倍，其可完全涵蓋新事證之地震危害度分析結果，並據以進行耐震餘裕評估與補強。

隨後介紹台電公司採用美國多數核電廠執行過的耐震餘裕評估方法，依據前述評估基準地震，重新檢視每部機組兩串安全停機相關結構、設備之耐震能力。針對耐震強度不足的設備組件，台電公司已於 103 年 6 月完成設備更新或補強改善作業。經補強後，將可使核一、二、三廠於發生原建廠設計地震之 1.7~1.8 倍的強震時，仍有兩條安全停機路徑可以使用，使機組可以安全停機與維持穩定冷卻。

文末則提到核能電廠耐震安全乃屬持續性之管制作業，本會仍將管制追蹤台電公司依據美國核電廠實務採用的資深地震專家會議(SSHAC level3)的程序，執行機率式地震危害度分析，確保核能安全。

熊大綱技士發表「以安全管制的觀點介紹台灣運轉中電廠耐震餘裕評估」

（二）公眾接受度與核能知識教育管理(Public Acceptance and Nuclear Knowledge Management)

藍泰蔚技士發表「台灣放射性廢棄物管理之民眾參與 (Public Participation In Radioactive Waste Management In Taiwan) 」，主要係講述到目前為止台灣經多年所累積經驗，有關放射性廢棄物的民眾參與。

簡報首先介紹台灣的放射性物廢棄物管制現況、及廢棄物管理之政策，使聽者對管制背景有一個概略的輪廓，其後講述蘭嶼平行監測的措施，如環島每 500 公尺的輻射監測、環境樣品的採樣、即時連線顯示幕等，有助提升民眾對輻射安全的信心。第二個重點則是落在乾貯設施的民間訪查行動，約 20 個來自利益團體、地方政府機關、學者專家及非政府環保團體代表等就乾式貯存設施興建品質等面向進行訪查。最後則提到乾貯設施聽證辦理情形，切實依照行政程序法辦理預備聽證及聽證盡可能地蒐集民眾意見，並於聽證終結後獲致 5 項重要結論。

結束簡報說明後，接受現場提問，為關於簡報內談到的蘭嶼平行監測、民間訪查、辦理聽證等是否有法律的明確依據？對於提問部分，藍員答覆蘭嶼平行監測、民間訪查此兩項民眾參與措施並無法律明文規定管制機關須辦理，惟基於放射性廢料管理方針所揭示應溝通宣導，厚植放射性廢料管理之根基，及依政府資訊公開法第 6 條規定，與人民權益攸關之施政、措施及其他有關之政府資訊，以主動公開為原則，並應適時為之。遂辦理以上民眾參與措施，以促進人民對公共事務之瞭解、信賴及監督。聽證則係為放射性物料管理法所明定，另依行政程序法對聽證程序要求辦理之。

藍泰蔚技士發表「台灣放射性廢棄物管理之民眾參與」

四、 參訪北京清華大學高溫氣冷核子反應器

本次研討會提供的參訪活動之一是北京清華大學核能與新能源技術研究院(Institute of Nuclear and New Energy Technology，INET)10MW 高溫氣冷實驗性反應器行程，開始參訪前由北京清華大學接待人員介紹北京清華大學核能與新能源技術研究院管理現況，以及高溫氣冷核子反應器的主要特性。

核能與新能源技術研究院成立於 1960 年，為中國大陸最先進核能教育及研究基地之一，也是教育體系裡最大的研究機構，目前有 400 位教職員，包含 1 位中國科學院(Chinese academy of sciences)成員及 2 位中國工程院(Chinese academy of engineering)成員。此次參訪之設施 HTR-10 是 1992 年由中國大陸政府核准建造，1995 年開始建造，2000 年第一次達到臨界，2003 年全功率運轉後開始對電力網絡輸出電力。HTR-10 具有低能量密度特性，在不使用電力及冷卻劑的情況下仍保有適當的核反應度之負溫度係數，並透過自然機制，利用水和空氣循環，依靠熱傳導、對流等移除衰變熱並散發到空氣中，藉此達成反應器的固有安全。

HTR-10 除了作為高溫氣冷核子反應器的技術展示和試驗的平台，也是現在唯一運轉中的球床式高溫氣冷核子反應器，其模組化的設計，可做為商業用反應器的技術基礎。安全性方面，HTR-10 的設計具有固有安全性，2004 年在國際原子能總署和其他國際專家的見證下，在失去氦氣循環和失去廠外電力供應的情形下，對 HTR-10 進行安全停機之試驗，結果燃料溫度不超過設計基準，無爐心熔毀，也無大量之裂變產物釋出。未來發展方面，簡報中提到高溫氣冷核子反應器具固有安全性，複數個模組可合併使用同一個汽渦輪，數個高溫氣冷模組也能共用其他的輔助系統，加以壓力容器、石墨、金屬等組件均能模組化製造，降低建造人力成本與建造週期，因此高溫氣冷核子反應器具有相當經濟競爭力。

簡報完成後，解說人員引導參觀 10MW 高溫氣冷實驗性反應器的 1:8 模型，一邊進行設施模型的解說。解說人員說明 HTR-10 的設計具有固有安全性，在設計基準的事故情境下，核種的釋出非常有限，技術上不需要廠外的緊急應變措施。基於其安全性，更可縮減選址的限制要

求。解說人員更進一步說明反應器之設計及發電機制，反應器爐心和蒸汽產生器採分離式設計，以氦氣作為冷卻劑，以石墨作為減速劑(moderator)及爐心結構。高溫氣冷核子反應器的發電機制係以氦氣循環流在反應器爐心加熱至攝氏 750 度後，通過蒸氣產生器產生高溫蒸氣，高溫蒸氣再進入汽輪發電機發電，而反應器爐心、蒸氣產生器和主氦風機三者則構成高溫氣冷核子反應器的主系統。反應器的氦氣出口溫度可以達到攝氏 750 度，可產生攝氏 570 度的過飽和蒸氣，因此可延伸應用到其他工業程序，如熱化學產氫、汽電共生、海水淡化、石油精煉、煤液化(coal liquefaction)等產業，延伸其商業價值。

HTR-10 的燃料也經過特別設計，燃料元件為全陶瓷包覆顆粒球型(Tristructural isotropic，TRISO)，其由彌散在石墨基體中的大量包覆顆粒燃料組成，每個包覆在二氧化鈾核芯外包覆了四層耐高溫材料，具有良好的耐高溫性能，在設計基準的事故條件下，其最高溫度始終不會超過其安全限值攝氏 1620 度，並且能限制放射性物質的釋放。

圖1、燃料元件結構示意圖

圖2、高溫氣冷核子反應器燃料循環示意

球型燃料透過循環管路進入反應器爐心後，藉由重力自然向下移動進入循環管路離開反應器爐心，而此一循環管路設計可進行新燃料的補充，檢測燃料元件有無破損、移除破損燃料、測量燃料的燃耗，以及移出達到一定燃耗標準的用過燃料等功能。

設施模型解說完畢後，便進入實驗室參觀反應器實體，由於核能與新能源技術研究院的政策是採取技術保護的宗旨，因此實驗室內是禁止拍照的。解說人員引導我們參觀主氦氣風機的軸承試驗。由於主氦風機是負責將反應器爐心產生的熱量通過蒸發器帶走，而主氦風機安裝在 70

kg/cm^2 壓力下的反應器一迴路冷卻劑壓力腔內，轉速範圍約為 800~4200r/min。高溫氣冷核子反應器一迴路的冷卻劑是高純氦氣，對雜質有嚴格的限制，該軸承要求不可使用軸承潤滑劑。主氦風機設計使用年限為 40 年，又安裝在壓力容器內維修困難，故而須嚴格要求軸承的使用年限。實驗條件模擬主氦風機的軸承運作環境，設計在純氦氣環境溫度為攝氏 150 度，壓力在 70 kg/cm^2，無使用軸承潤滑劑情況下進行，軸承轉動的誤差範圍須控制在 3mm 以下，解說人員提到該軸承已經成功通過轉動 492 萬圈之測試，顯示了在核能領域方面，中國大陸在自製軸承技術能力的突破。

此次參訪，解說人員強調高溫氣冷核子反應器因為其固有安全性和經濟競爭力，市場潛力大，並且透過 HTR-10 證明其技術可行性，另一方面，中國大陸也積極研發關鍵零組件的自製技術，以形成完整的供應鏈，預備向國際推廣高溫氣冷核子反應器技術。

肆、心得與建議

心得：

一、 中國大陸因官方政策指示大力推動核能產業，有關核能發電自核燃料開發、機組零組件製造技術、施工模組化等均有驚人的進展，中國大陸從早先的引進國外核能技術，乃至於日後自主研發並推陳創新，最後將輸出核電興建技術至國外，可見當官方能源政策非常明確時，將可吸引廠商投入資源全力開發。

二、 中國大陸除大力發展核能發電技術外，核廢料處理亦有進展。核廢料目前是眾多使用核電國家棘手的項目。在考量能源永續利用及環境友善，中國大陸亦致力於發展核廢料再處理技術，另中國大陸有豐富之鈾礦資源，促使中國大陸對於封閉型核燃料循環技術發展亦有顯著進展，此點相較於我國國情亦是不同的，我國目前核燃料全仰賴進口，且在國際的壓力下，無法發展核燃料再處理技術，同時民眾對於核廢料最終處置場所選址亦有諸多疑慮及考量，均考驗著我國政府在這方面處理的智慧。

三、 本次參與會議深刻感受到中國大陸產官學界積極發展核能發電的企圖心，除了因應中國大陸蓬勃發展的核能電廠興建工程實務各方面的困難挑戰，透過產官學聯合平台發展出許多特殊技術性的突破以之外，並積極以國家的力量，對外加強行銷中國國產的核子反應器—華龍 1 號，一切的目標似乎著眼在因應全球氣候變遷時代，世界各國對減碳的需求，以及中國大陸國內日益嚴重的霾害問題。

四、 此次開會，中國大陸對核電發展路線明確，2020 年以前，中國大陸核子反應器的裝機容量將達到 28GW，同時另外有 30GW 的反應器裝機容量正在興建中。此外，快中子實驗性反應器、高溫氣冷實驗性反應器的相繼完成，顯示中國大陸在打入核能產業供應鏈上的努力不遺餘力，此次參訪北京清華大學核能與新能源技術研究院的實驗室，解說人員更提到中國大陸正朝關鍵零組件自主化的目標邁進，例如高溫氣冷實驗性反應器的主氦風機軸承等在測試環境下已通過測試，距離自主生產又更接近一步。

建議：

一、 為與國際接軌，精進核安管制與輻射防護作為，我國仍應踴躍出席太平洋盆地核能會議。

二、 面對積極發展核電的中國大陸與南韓，至今仍未放棄核能發電的日本，以及有意發展核能發電的馬來西亞與越南，建議持續加強與鄰近國家核能安全的管制技術交流，並以我國長期以來優良的核電安全管制實務經驗，對區域性周邊國家核能發電的安全，善盡國際一份子的責任。

三、 我國的核電廠即將邁入除役階段，建議可多吸取國際經驗，確立最有利的除役策略，並參採國際間專案管理的方式，對所有除役廢棄物進行嚴謹的管理，以確實達成除役放射性廢棄物之減量目標，同時管制單位未來勢必面對除役廢棄物的外釋或放行申請，建議與已有除役經驗之國際官方單位互相交流監督經驗及管制重點，為將來除役管制預做準備。

附件一：第 20 屆太平洋盆地核能會議議程

PBNC2016 Initial Agenda at a Glance

Tuesday, April 5

15:00 Conference Registration

18:00 Conference Reception

Wednesday, April 6

Opening Ceremony &Keynote Address

(Joint with the 14th China International Nuclear Industry Exhibition (Nuclear Industry China, NIC2016))

Chair: Mr. LI Guanxing
President of Chinese Nuclear Society (CNS)
Ms. Mimi Limbach
President of Pacific Nuclear Council (PNC)

09:00 **Congratulatory Remarks: Mr. XU Dazhe**
Chairman of China Atomic Energy Authority

09:10 **Welcoming Remarks: Ms. Mimi Limbach**
President of Pacific Nuclear Council (PNC)

09:20 **Welcoming Remarks: Mr. SUN Qin,**
Chairman of PBNC2016, Chairman of China National Nuclear Corporation (CNNC)

09:30 **Congratulatory Remarks: Ms. Kim Rudd**
Parliamentary Secretary to the Canadian Minister of Natural Resources, Canada

09:40 **Congratulatory Remarks: Mr. Christophe Xerri**
Director, Division of Nuclear Fuel Cycle and Waste Technology, International Atomic Energy Agency

09:50 **Congratulatory Remarks: Mr. ZHANG Qin,**
Vice President and Executive Secretary of China Association for Science and Technology (CAST), Secretary of the leading Party group

10:00 **Keynote Address: Mr. MA Kai**
Vice Premier of State Council (TBC)

10:15 Coffee Break

Plenary Session 1A:
New Progress of the World Nuclear Power Technology

Chair: Mr. SHEN Lixin, Deputy Secretary General of Chinese Nuclear Society (CNS)
Mr. Kune Y Suh,
Vice-President of Pacific Nuclear Council (PNC)

10:45 **Ms. Lee McDonough,**
Director, Office for Nuclear Development, Department of Energy & Climate Change, UK

11:00 **Mr. Hervé Machenaud**, Vice Executive President, Electricite de France (EDF), France

11:15 **Mr. Jorge Spitalnik,**
Former President, the Latin American Section of American Nuclear Society (ANS), President of World Federation of Engineering Organizations (WFEO)

11:30 **Mr. Danny Roderick**, President of Westinghouse Electric Corp.

11:45 **Mr. Bernard Bigot**, Director-General of ITER

12:00 **Mr. Preston Swafford**, Executive Vice-President of SNC-Lavalin

12:15 Conference Luncheon

Plenary Session 1B:
New Progress of the World Nuclear Power Technology

Chair: Mr. ZHAN Wenlong, Vice-President of Chinese Nuclear Society (CNS)
Ms. Valerie Faudon, Secretary General of France Nuclear Energy Society (SFEN)

13:30 **Mr. SUN Qin**, Chairman of China National Nuclear Corporation (CNNC)

13:45 **Mr. LEE Jong-Ho**, Executive Vice-President of Korea Hydro & Nuclear Power Co. (KHNP)

14:00 **Mr. ZU BIN**, Vice-President of China Nuclear Engineering Group Corporation (CNEC)

14:15 **Mr. Ed McGinnis**, Deputy Assistant Secretary for International Nuclear Energy and Policy, Office of Nuclear Energy, U.S. Department of Energy (U.S. DOE)

14:30 **Mr. WANG Binghua**, Chairman of State Power Investment Corporation (SPIC)

14:45 **Mr. Jamal Khaer Ibrahim**, Director, Nuclear Power Programme Development, Malaysian Nuclear Power Corporation (MNPC)

15:00 **Mr. HE Yu**, Chairman of China General Nuclear Power Corporation (CGN)

15:15 Coffee Break

Plenary Session II:
Nuclear Fuel Cycle and Nuclear Safety

Chair: **Mr. LI Guanxing**, President of Chinese Nuclear Society (CNS)
Mr. Gene Grecheck,
President of American Nuclear Society (ANS)

15:45 **Mr. Tim Gitzel**, President& CEO of Cameco (Canada)

16:00 **Mr. ZHAN Wenlong**, Vice President of Chinese Academy of Sciences

16:15 **Mr. Philippe Varin**, President of AREVA (France)

16:30 **Mr. LIU Wei**, President of China Nuclear Power

Engineering Co., Ltd. (CNPE)

16:45 **Mr. Kazuaki MATSUI**, Advisor of the Institute of Applied Energy (IEA)

17:00 **Wrap-up: Mr. LI Guanxing**, President of Chinese Nuclear Society (CNS)

Thursday, April 7

08:30--10:00 **Parallel Technical Sessions**

10:00-10:30 Coffee Break

10:30-12:00

Panel I: Achievement and Challenge in Nuclear Fusion

Chair: Mr. LIU Yong, President of Southwestern Institute of Physics

Panelists:

Mr.LUO Delong, Head, ITER China Domestic Agency, Director-General, China International Nuclear Fusion Energy Program Execution Center, Ministry of Science and Technology

Mr. Mohamed A. Abdou, Director, Center for Energy Science and Technology Advanced Research, University of California, Los Angeles (UCLA)

Mr. Ki-Jung JUNG, Director General, ITER Korea

Mr. Makoto Sugimoto, Director, Department of ITER Project, Naka Fusion Institute, Sector of Fusion R&D, Japan Atomic Energy Agency

Mr. A.J.H. (Tony) Donné, EURO fusion Programme Manager

12:00 Conference Luncheon

13:30-15:00

Panel II: New Achievements in Advanced Nuclear Energy

Chair: Mr. TIAN Jiashu, Deputy Chief Engineer of China National Nuclear Corporation

Panelists:

Mr. Christophe Behar, Director of the Nuclear Energy Division, chairman of GIF (Generation IV International Forum), President of SFEN

Mr. SUN Yuliang, Deputy Director of the Institute of Nuclear and New Energy, Tsinghua University

Mr. SONG Danrong, Chief Designer, Nuclear Power Institute of China

Mr. QIU Zhongming, Chief Information Office and Assistant President of Shanghai Nuclear Engineering Research & Design Institute

Mr. Chris Colbert, Chief Strategy Officer NuScale Power, LLC

Mr. Eric Loewen, Chief Engineer, Advanced Plants, GE Hitachi Nuclear Energy

Mr. Hadid SUBKI, Technical Lead and Project Manager, IAEA Department of Nuclear Energy

Mr. Kevan D. Weaver, Director, Technology Integration, TerraPower, LLC

13:30-15:00

Panel III: Uranium Resource Development, Uranium Supply and New Fuel Development

Chair: Ms. Agneta Rising, Director-General of the World Nuclear Association (WNA)

Mr. Zheng Mingguang, Senior Vice President of State Nuclear Power Technology Corp.

Panelists:

Mr. Kirk Schnoebelen, Head of Sales, Urenco

Mr. ZHOU Rongsheng, Deputy Chief Engineer of URC, China General Nuclear Power Corporation

Ms. WANG Ying, Executive Director& Chief Executive Officer, CNNC International Ltd.

Mr. Jim Brennan, Senior Vice President, Engineering, Westinghouse Electric Corporation

Mr. Vincent Maureaux, Senior Vice President, Commercial and Business Development, Mining and Front-End Asia, AREVA

15:00-15:30 Coffee Break

15:30-17:00 **Parallel Technical Sessions**

Friday, April 8

08:30-10:00 **Parallel Technical Sessions**

10:00 Coffee Break

10:30-12:00

Pane IV: NPP Construction and Component Manufacture

Chair: Mr. ZU Bin, Vice-President of China Nuclear Engineering Group Corp.

Panelists:

Mr. Corey McDaniel, Manager of International and Commercial Cooperation, Nuclear Science and Technology, Idaho National Laboratory (INL)

Mr. Bill Poirier, Vice President,
China Projects, Westinghouse Electric Corporation

Mr. Herve Hottlart, Vice President,
Manufacturing and Supply Chain, AREVA Asia

Mr. José M. Zubimendi, Vice President
Nuclear Business of ENSA

Mr. Norbert Dudek,
Vice President and General Manager, Terex Cranes-Asia

Mr. Ron Oberth, President and CEO,
Organization of Canadian Nuclear Industries (OCI)

Mr. HE Guowei, Deputy Chief Engineer of
China Nuclear Power Engineering Co., Ltd (CNPEC)

Mr. WANG Mingdan,
Deputy General Manager, State Nuclear Power
Engineering Company. Ltd, Shanghai

10:30-12:00

Panel V: New Progress in Irradiation Procession Industry and Technology

Chair: **Mr. Keneth Hsiao**, General Manager of CGN
Dasheng Electron Accelerator Technology Company

Panelists:

Mr. Sunil SABHARWAL,
Radiation Processing Specialist, International Atomic
Energy Agency (IAEA)

Mr. Paul Wynne, General Manager,
International Irradiation Association (IIA)

Mr. Richard Wiens, Director, Strategic Supply,
Nordion Inc. (Canada)

Mr. David Brown, President of Mevex

Mr. Evan Xu, Deputy Manager Asia-Pacific
Marketing & Sales, IBA

Mr. Erik Jia, China Operation Director,
Sterigenics

Mr. Jingrong Zhang, General Manager, CNNC
China Isotope & Radiation Corp.

Mr. Wei Peng, Vice President, Vanform Corp.

Mr. WANG Rongfu, Director of Medicine
Department of Peking University First Hospital

12:00 Conference Luncheon

13:30-15:30 **Parallel Technical Sessions**

15:30 Coffee Break

16:00- 17:30

Panel VI: NPP Operation Safety and Life Management

Chair: **Mr. Wang AN**, General Manager of Suzhou
Nuclear Power Research Institute (SNPI)

Ms. Kathryn McCarthy, Deputy Associate
Laboratory Director, Idaho National Laboratory (INL)

Panelists:

Mr. Chris Dawes, Peer Review Team Leader,
WANO London

Mr. Fred Dermarker, President and CEO of the
CANDU Owners Group

Mr. Randall Lewis, General Manager for
Rolls-Royce Nuclear Services UK

Mr. David Howell, Senior Vice President,
Operating Plants Business, Westinghouse Electric Corp.

18:00 **Gala Banquet**

Saturday, April 9

08:30-10:00

Panel VII: Spent Fuel Treat and Waste Management

Chair: **Mr. YE Guoan**, Vice-President of
China Institute of Atomic Energy

Panelists:

Mr. Trevor DIXON, Master Mariner and
Specialist Advisor, World Nuclear Transport Institute

Mr. Jean Pierre Gros, Asia Senior Vice
President of the AREVA Back End Business Group

Mr. Gerd-Michael Burow, Senior Project
Manager, RWE Technology International GmbH

Mr. Kee. Chan.Song, Vice President for
Nuclear Fuel Cycle, Korea Atomic Energy Research
Institute (KAERI)

Mr. Christophe POINSSOT, Head of the
Radiochemistry & Processes Department Nuclear
Energy Division, French Atomic and Alternative
Energies Commission CEA

Mr. Kazuhiro Suzuki, Senior Managing
Director, Nuclear Damage Compensation and
Decommissioning Facilitation Corporation (NDF)

Mr. ZHANG Zhenhua, Deputy General
Manager, Qinshan Nuclear Power Group

Mr. WANG Ju, Vice President of the Beijing
Research Institute of Uranium Geology (BRIUG)

10:00 Coffee Break

10:30-12:00

Panel VIII: Public Acceptance and Nuclear Knowledge Management

Chair: Ms. Mimi Limbach,
President of Pacific Nuclear Council (PNC)
Ms. Valerie Faudon, Secretary General, SFEN, France

Panelists:

Mr. Kune Suh,
President& CEO, Philosophia Inc., Chairman, Korea Atomic Safety Protection Institution

Mr. Gene Grecheck, Principal, Grecheck Consulting LLC, President of American Nuclear Society

Mr. ZUO Yue, Senior Manager for Public Communication, China National Nuclear Power Co.Ltd

Mr. LIU Yunli, Chief Representative in Thailand, China General Nuclear Power Corporation

Ms. Laura Hermann,
Partner, Potomac Communications Group

Mr. Jamal Khaer Ibrahim, Director, Nuclear Power Programme Development, Malaysia Nuclear Power Corporation

Mr. John Barrett, President and CEO of the Canadian Nuclear Association

Mr. Ayhan Evrensel, Communication Adviser, Office of the Deputy Director General, Department of Nuclear Energy, International Atomic Energy Agency

Sunday, April 10

Time: Morning
One person, one tour
Maximum Number: 50
First come, first served basis

Technical Tour I: China Experimental Fast Reactor
Location: China Institute of Atomic Energy

Technical Tour II: High Temperature Gas Cooled Reactor
Location: Institute of Nuclear and New Energy Technology, Tsinghua University

附件二：行政院原子能委員會同仁發表論文集

一、郭子傑技正發表部分

PBNC 2016
Beijing, China, April 5-9, 2016

THE RADIATION PROTECTION CLOUD SERVICE SYSTEM IN TAIWAN

KUO Tzu-Chieh
Atomic Energy Council of Executive Yuan, Taiwan

HUANG Jehn-Ying
Atomic Energy Council of Executive Yuan, Taiwan

TSAI Chin-Hsien *Atomic Energy Council of Executive Yuan, Taiwan*

KEYWORDS: radiation protection, cloud service, the private sector, radiation safety regulation, paperless

ABSTRACT: In Taiwan, regulation of sources, for radiation safety, has entered the cloud-service stage. A cloud system could provide an interactive information service platform for competent authority, i.e. Atomic Energy Council, and private sectors, for the purpose of strengthening the quality and safety of radiation practices. The Radiation Protection Cloud Service System has been building since 2013, supposed to be completed by 2016. Mostly used web browsers such as Internet Explorer, Google Chrome and Firefox, etc., are all supported to access the System. The goal of paperless processing, involving in applications (for sectors) and verifications (for regulators), is to be achieved. The on-line services that the System would provide cover import/export signed review of radioactive material and equipment capable of producing ionizing radiation, as well as license application, regular declaration of sources, due and/or overdue notification by e-mail, and radiation safety review, etc. In addition, the System would also provide Open Data for the public for information inquiry and/or application.

Electronic Government is a proactive policy for facilitating public services in Taiwan. The Cloud Service System could not only allow end users such as private sectors, radiation workers and regulators to access the on-line services with stable network performance, anytime and anywhere by the use of personal computers (PC), tablet PC and smart phone devices, etc., but save remarkably governmental resources, as well as achieve the goal of reducing carbon emissions, so as to enhance the efficiency and effectiveness of radiation safety regulation.

1. INTRODUCTION

According to Ionizing Radiation Protection Act in Taiwan, the owners of medical and non-medical radioactive materials and ionizing radiation equipment should apply for licenses and/or certificates from competent authority, the Atomic Energy Council (AEC), and operators should obtain Radiation Safety Certificate or receive radiation protection training and obtain related proof for operating those materials and equipment. In addition, radiation practices such as in production, purchase, import, export, installation, use, cease of use, transfer and abandonment of those equipment and materials should apply for approval from AEC before starting the practices. In order to protect radiation safety of the radiation workers and public, AEC has made efforts to regulate the certificate/license and permit of radiation practices, related workers and radiation protection personnel.

With increasing of import/export application and approval of radioactive materials and equipment capable of producing ionizing radiation from the private sectors, to take care of both the prerequisite of radiation safety and public interests, besides simplifying the application procedure, AEC adopted electronic process and constructed the import/export application and approval system and radiation protection regulation information system in 2007. The instant application and approval procedure provide the private sectors with the most efficient service. These systems provide import/export application and approval of radiation sources, and registration of registration-category radiation equipment online, replacing paper applications as done in the past.

2. APPLICATIONS OF ATOMIC ENERGY IN TAIWAN

The consumer applications of atomic energy are extensive in Taiwan, including applications of radiation sources for use in nuclear power generation, medical institutions, and academic research, industry, agriculture and police agencies.

In Taiwan, currently there are about 15,000 private sectors using radiation sources, about 30,000 licenses for radiation use, and about 25,000 relevant certificates for radiation workers, radiation protection organization, radiation protection services and medical radiation exposure quality assurance etc. Annual applications for approval are about 32,000 in number: in those, the use of medical radiation-related cases accounted for the largest of such radiation practice application. Figure 1 shows radiation application map in Taiwan. As of the end of 2015, the numbers of certificates and licenses issued by AEC are summarized in the following Table 1.

3. THE RADIATION PROTECTION CLOUD SERVICE SYSTEM

Electronic government is a proactive policy for facilitating public services in Taiwan. In streamlining application procedures on radiation practices permits, reducing application cost and time, AEC is establishing an advanced information service platform- the Radiation Protection Cloud Service System, which has been built since 2013 and will be completed by 2016. The advanced system uplifts the function of AEC Radiation Protection Regulation Information System by connecting through it so that import/export information of radioactive materials and radiation equipment can access automatically and are input once only through a single platform for the whole application process, reducing paperwork and facilitate civil service. The cloud-service system provides instant checking and approval functions, strengthening safety control of radioactive materials and equipment capable of producing ionizing radiation, and ensuring effective management on import/export and usage of radiation sources.

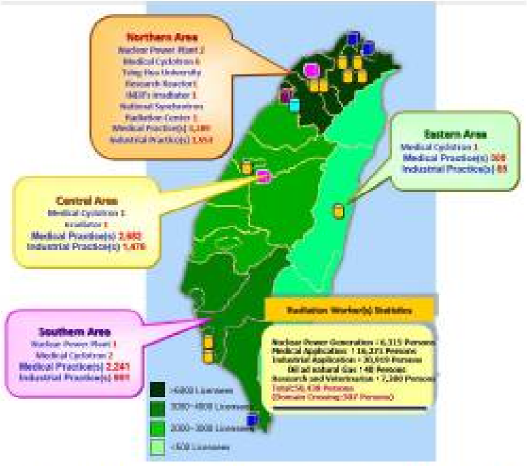


Figure1. Taiwan's Radiation Source(s) Application Map

Licenses, Registration and Certificates	Category	Quantity
License and Registration of Radioactive Material	Permission	485
	Registration	3,225
License and Registration of Equipment Capable of Producing Ionizing Radiation	Permission	557
	Registration	24,952
Radiation Safety Certificate for Radiation Worker	5,293	
Certificate of Operator (Including High-Level Radiation Facilities and Manufacturing Facilities)	141	
Certificate of Radiation Protection Personnel	Senior Radiation Protection Officer	966
	Radiation Protection Officer	1,492

Table1. Statistics of Relevant Licenses and Certificates (Compiled Date: 2016/01/05)

The Radiation Protection Cloud Service System provides radiation related practices with online filing and reviewing application document of import/export of radioactive materials and ionizing radiation equipment, and in association with General Bureau of Custom Tax application and processing network system processes each import/export application. It has provided 24-hours a day service. Over 90 percent of import/export application cases have been automatically checked and approved through the system. Through cross-referencing the import/export information to its corresponding information on the Radiation Protection Regulation System, the inventory records of radiation sources can be done instantly and correctly. To take account of radiation safety, the cloud-service system simplifies the application process of ionizing radiation equipment certificate for registration. At the same time, the private sectors, which possess or make use of sealed radioactive materials, shall report the status of radioactive materials through the system monthly. Thus, AEC can effectively and fully monitoring the whereabouts of radioactive sources and their status.

Figure2. Framework of the Radiation Protection Cloud Service System

Besides import/export signed review of radiation sources, the Radiation Protection Cloud Service System provides e-control of information on license application, regular declaration of sources, due and/or overdue notification by e-mail, and radiation safety review, with convenient application and processing service. The system also provides the function of inquiry of application status and previous application records. In addition, the Radiation Protection Cloud Service System would also provide open data for the public for information inquiry and/or application. Mostly used web browsers such as Internet Explorer, Google Chrome and Firefox, etc., are all supported to access the system which could allow end users such as private sectors, radiation workers and regulators to access the on-line services with stable network performance, anytime and anywhere by the use of personal computers (PC), tablet PC and smart phone devices, etc. By the same time, the Radiation Protection Cloud Service System provides multiple fee payment service, including cashing, remittance, check payment, and the inter-bank monetary service. Licensees can print the web page payment voucher and go to convenience stores, banks, postal office counters, ATM and on-line banks to transfer payment to the designated accounts of AEC.

Figure3. Design Concept of the Radiation Protection Cloud

Service System

With the Radiation Protection Cloud Service System establishing, AEC provides nonstop online service for radiation practices application and approval of radiation sources, shortening processing time from seven days to one, as well as enhance the efficiency and effectiveness of radiation safety regulation. Taking into account added benefits, such as non-paper service, AEC estimates that the government and the private sector will save about one million papers each year, to achieve the goal of reducing carbon emissions. In addition, data related to radiation sources, once established in the system, can be used for the whole regulation process, reducing management costs of the applicants. To sum up, the Radiation Protection Cloud Service System provides with online application process through network instead of paperwork, and improves the efficiency of radiation safety regulation. Both the government and the private sectors will benefit from this practice.

Figure4. Service Goals of the Radiation Protection Cloud Service System

4. CONCLUSIONS

Integration of online web service with clouds computing information system is the ongoing trend in the globe. Policies of replacing road walking by cloud walking as well as of paperless services are crucial for a country to uplift its competitiveness. Therefore, for accommodating to the trend, AEC is currently executing a 4-year renew project named "Radiation Protection Cloud Service System", purposed to uplift service quality of administration for radiation protection associated businesses. In 2015, the 2nd term of the 4-year project has ended. For licensees better understand the renewed scope within the term-II, AEC has sponsored seven workshops, located separately in the Northern, Central, Southern and Eastern parts of Taiwan, to announce the upcoming online service items, including application for permit of radioactive materials and equipment capable of producing ionizing radiation, etc. The main targets of the workshops are the radiation protection managing personnel in all lines of trade, medical units, governmental units, and research institutions. In whole, the participants showed hearty response and appreciation about what AEC has served for the licensees. AEC expects the system to promote administrative effectiveness and efficiency for radiation safety management while improving international trading simultaneously, will continue enhancing preventative control and risk management of radiation sources, and will actively assist the private sector in improving radiation protection practice - which in turn will protect the public and the environment as a result. all lines of trade, medical units, governmental units, and research institutions. In whole, the participants showed hearty response and appreciation about what AEC has served for the licensees. AEC expects the system to promote administrative effectiveness and efficiency for radiation safety management while improving international trading simultaneously, will continue enhancing preventative control and risk management of radiation sources, and will actively assist the private sector in improving radiation protection practice - which in turn will protect the public and the environment as a result.

AUTHOR'S INFORMATION

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二、熊大綱技士發表部分

PBNC 2016
Beijing, China, April 5-9, 2016

SEISMIC MARGIN ASSESSMENT OF THREE OPERATING NUCLEAR POWER PLANTS IN TAIWAN FROM REGULATORY PROSPECTIVE

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Taiwan, R.O.C.

KEYWORDS: geological survey, active fault, seismic hazard analysis, review level earthquake, seismic margin assessment

ABSTRACT: In year 2009, before the 2011 Fukushima nuclear event, the Atomic Energy Council (AEC), the nuclear regulatory authority in Taiwan, requested the Taiwan Power Company, the operator of three operating Nuclear Power Plants (NPPs), to perform a comprehensive seismic safety re-evaluation considering the new nearby active faults and follow-up enhancement to comply with the license condition. The seismic safety re-evaluation began with the geological survey of land and marine region near the NPPs and the characteristics investigation on active faults, the seismic hazards analysis was then performed to determine the Review Level Earthquakes (RLEs) for each NPP for the Seismic Margin Assessment (SMA) and the reinforcement of seismic resistance of structures, systems and components (SSCs) to meet with the plant RLE requirement.

The 2-year geologic survey activities started in 2010, the major working items included bathymetry survey, offshore and onshore geophysical survey, remote sensing image identification for fault lines, deep and shallow borehole investigation for active faults, and supplementary investigation of site characteristics (e.g., shear wave velocity profile, static and dynamic physical properties test for soil and rock). The geologic investigation both on land and marine regions related to the newly identified active Sanchiao fault and Hengchun fault has also been conducted. In addition to the geological aspect, seismic activity around the faults has also been revisited. Then, the seismic hazard analysis based on the updated data was submitted to AEC for review. The 0.51g, 0.67g and 0.72g RLEs for Chinshan, Kuosheng, and Maanshan NPPs, were conservatively decided by AEC based on the deterministic seismic hazard analysis result. In the SMA, two alternative shutdown paths for each unit were determined and those SSCs in the shutdown paths with High Confidence of Low Probability of Failure (HCLPF) fragility values less than RLE were identified, and reinforcement of seismic resistance on those SSCs has been completed in mid-year 2014. As the result, the seismic safety for the three operating NPP has been ensured, and re-evaluation of seismic hazard by probabilistic seismic hazard analysis is still ongoing in parallel to further verifying the seismic safety of NPPs.

1. INTRODUCTION

There are three operating Nuclear Power Plants (NPPs) in Taiwan, namely Chinshan, Kousheng and Maanshan, and with two units at each site. Chinshan NPP and Kousheng NPP are located in Northern tip of the Island, while Maanshan NPP is located in the Southern tip of the Island. Chinshan and Kousheng NPPs are 28 and 22 kilometers away from major city (Taipei), while Maanshan NPP is about 110 kilometers away from major city (Kaohsiung). All the NPPs are owned by Taiwan Power Company (TPC).

The Taiwan Island is located at the Circum-Pacific seismic zone, so earthquake is a major challenge/concern for the NPP's operation. During the site selection period, it is strictly required for TPC to meet the Appendix A in US 10 CFR100 seismic and geologic siting requirement. And the design basis earthquakes (OBE and SSE) had been adequately evaluated and were detailed documented in the Final Safety Analysis Report (FSAR) of every plant. Table 1 summarizes the basic design features of these three operating NPPs.

TABLE 1 Design features of operating NPPs in Taiwan

Plant name	Chinshan	Kuosheng	Maanshan
Reactor Type Vender	BWR-4 GE	BWR-6 GE	PWR Westinghouse
Containment	Mark-I (Steel)	Mark-III Reinforced Concrete	Large, Dry Post-Tensioned Reinforced

		(with steel liner)	Concrete (with steel liner)
Thermal Power (MWt)	1804	2943	2822
Electrical Power (MWe)	636	985	951
Operating Basis Earthquake (OBE)	0.15 g	0.2 g	0.2 g
Safe Shutdown Earthquake (SSE)	0.3 g	0.4 g	0.4 g
Date of Commercial Operation	12/06/1978 07/16/1979	12/28/1981 03/15/1983	07/27/1984 05/18/1985

2. NEW GEOLOGIC EVIDENCE

In according to a special report issued in July 2007 by the Taiwan Central Geological Survey (CGS), the existing 34 km long Sanchiao fault, which lies between Chinshan NPP and Kuosheng NPP, was temporarily re-categorized as an active fault of the second category - the late Pleistocene active fault. By the definition, fault of this category is a fault which has ceased moving for more than 10,000 years, but the movement had been observed or with the evidence of seismic activity during the past 100,000 years and has a potential for reactivation. The length of Sanchiao fault could be even longer if its marine extended segment is included. The shortest distances from the fault to the Chinshan NPP and the Kuosheng NPP are 7 km and 5 km respectively.

Later on, the CGS issued another special report in December 2009. In that report, the Hengchun fault, the shortest distance to Maanshan NPP is 1km, was also temporarily re-categorized as an active fault of the second category.

Although there was no historical record showed any significant earthquakes directly induced by these two active faults in at least the past 100 years, the declaration of these new active faults may challenge the current licensing basis and the previous seismic assessment result in the FSAR of the three NPPs. It also indicates that the potential seismic hazards for these operating NPPs may be larger than those previously estimated.

The preliminary assessment suggested that a 7.3 Richter magnitude based on 50.6 km fault length (including 34 km on land and 16.6 km marine extension) is a maximum potential earthquake for the Sanchiao fault. The results of this assessment reveal that the peak horizontal accelerations at the base rock of the Chinshan and Kuosheng reactor buildings were 0.20g and 0.27g respectively, which were still lower than the design values of 0.3g and 0.4g for each safe shutdown earthquake (SSE) of the plants.

About the same time, Apart from the new geologic evidences mentioned above, the Niigataken-Chuetsu-Oki (NCO) earthquake, a Mw 6.8 earthquake, attacked the nearby Kashiwazaki-Kariwa NPP in 07/16/2007. AEC noticed that all 7 units' design earthquakes were exceeded and all units had been shut down for several years for repair and restart.

Based on the above mentioned information, in year 2009, the AEC requested TPC to perform a comprehensive seismic safety re-evaluation considering the new nearby active faults and follow-up enhancement to comply with the license condition for the three operating NPPs. The seismic safety re-evaluation began with the geologic survey of land and marine region near the NPPs and the characteristics investigation on active faults, the seismic hazards analysis and the site effect analysis were then performed to determine the Review Level Earthquakes (RLEs) for each NPP for the Seismic Margin Assessment (SMA) and the reinforcement of seismic resistance of structures, systems and components (SSCs) to meet with the plant RLE requirement..

3. GEOLOGIC SURVEY PLAN

Due to the awareness of potential risks from the new active faults near the three operating NPPs as well as the lack of confirmed accurate data on the length (especially the marine extended segment) and other focal mechanism parameters of the Sanchiao fault and Hengchun fault, the geologic survey particularly focused on the Sanchiao and the Hengchun faults, and both the inland and marine segments near the NPPs have been comprehensively investigated.

The geologic survey, started from 2010, was a 2-year plan submitted by TPC after being reviewed and approved by AEC. The primary objective is to gather the fault parameters as well as the updated sites soil characteristics for the seismic hazard analysis afterwards. Therefore, the major contents of the geologic survey included bathymetry survey, offshore and onshore geophysical survey, remote sensing image interpretation for fault line, deep and shallow borehole investigation for active faults, and supplementary investigation of site characteristics (shear wave velocity profile, static and dynamic physical properties test for soil and rock, etc.). In addition, historical and modern seismological data were also collected to relocate earthquake hypocenters.

The preliminary results from the geologic survey showed that Sanchiao fault length is 74 km (including 34 km on land and 40 km marine extension) and may extend further 40km along the offshore extension, up to 114 km in total by extremely conservative estimation, while Hengchun fault is around 40 km. Therefore, another extended geologic investigation (also known as the phase II geologic investigation) of geologic survey requested by AEC was launched. Figure 1 and 2 showed the current investigation results of the possible fault extension.

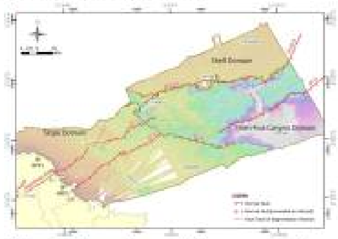

FIG. 1 Sanchiao fault and possible extended segment in marine area (source from TPC)

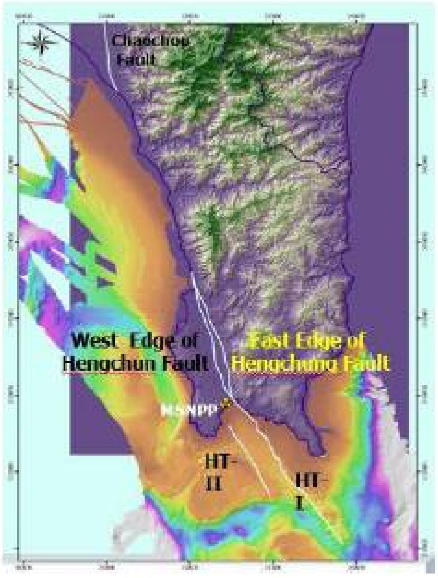

FIG. 2 Hengchun fault and possible extended segment in marine area (source from TPC)

4. REVIEW LEVEL EARTHQUAKE AND SEISMIC HAZARD ANALYSIS

The seismic margin methodology was developed in early 90s under the Individual Plant Examination of External Events (IPEEE) program and was designed as a rather quick method to demonstrate that the plant has sufficient margin above the safe shutdown earthquake (SSE) and to locate any plant vulnerabilities which might impede the plant seismic shutdown capability (reference 2). The first step of SMA is to specific an appropriates review level earthquake (RLE) considering the new faults threat and the RLE should be no less than 1.67 SSE for each NPP. The RLE was determined by deterministic seismic hazard analysis (DSHA) or the probabilistic seismic hazard analysis (PSHA) considering new evidence of active fault based upon those important parameters provided by the geologic survey, latest codes and technical methods.

By using the updated available preliminary geologic survey results, TPC submitted the DSHA and PSHA report to AEC for approval. However, after a deliberate review, due to the insufficient understanding of fault parameters such as slip rate and recurrence interval, the AEC decided to adopt the DSHA results considering the maximum potential earthquake induced by Sanchiao fault and Hengchun fault with the assumed length of 114 km and 41km respectively. It was noted that the ground motion prediction equations (GMPEs) or known as the term attenuation relationships used in the DSHA were the Next Generation Attenuation (NGA) reported in a special publication of the Journal Earthquake Spectra in 2008.

After the regulatory review, 0.51g, 0.67g and 0.72g were conservatively specified as the final RLEs for Chinshan NPP, Kuosheng NPP, and Maanshan NPP, The RLEs were according to the DSHA result with extra standard deviations to account the seismic uncertainties. Figure 3~5 illustrate the comparison of 1.67SSE and DSHA output of Chinshan, Kuosheng and Maanshan NPP respectively.

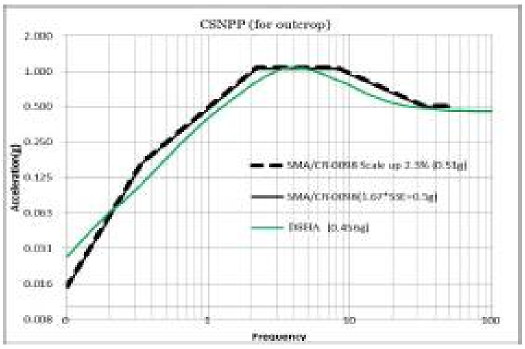

FIG. 3 RLE for Chinshan NPP (at foundation level outcrop)

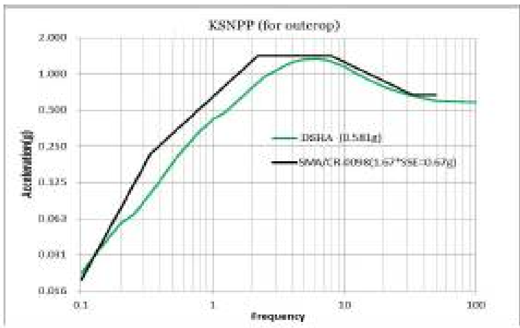

FIG. 4 RLE for Kuosheng NPP (at foundation level outcrop)

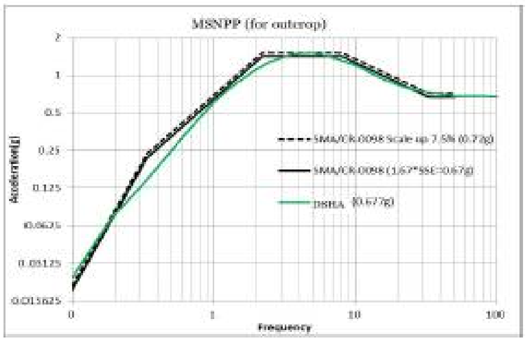

FIG. 5 RLE for Maanshan NPP (at foundation level outcrop) (FIG. 3, FIG.4, and FIG.5 modified from TPC)

5. SEISMIC MARGIN ASSESSMENT

The SMA of this paper adopted the EPRI NP-6041-SL, Rev 1 "A Methodology for Assessment of NPP Seismic Margin" methodology. Two success shutdown paths were selected for each unit, and the seismic walk-down on SSCs and the HCLPF fragilities calculation in the shutdown paths were conducted. Then SSCs with HCLPF values less than RLE were identified, and the reinforcement of seismic resistance on these SSCs (mostly are motor control center cabinets, masonry walls, and main control room ceilings) of three operating NPPs has been completed in the middle of the year 2014. With the reinforcement, it is ensured that the shutdown paths for each unit have the capability of bringing the plant to a stable condition (cold shutdown) and last for at least 72 hours when RLE occurring. Table 2 is the statistics of reinforcement of seismic resistance on SSCs in three operating NPPs.

TABLE 2 Reinforcement statistics of seismic resistance on SSCs in three operating NPPs (data from TPC)

Plant	Number of Equipment	Number of Relay	Reinforced			
			Equipment	Relay Chatter	Seismic Interaction Item	
Chinshan	1469	530	11	14	Masonry Wall and Main Control Room ceiling	
Kuosheng	1211	1094	20	23	-	-
Maanshan	1368	816	23	1	-	-

6. CONTINUOUS REGULATATORY OVERSIGHT

The 2007 NCO earthquake and 2011 Great East Japan earthquake have told us the possibility of unexpected large earthquake could challenge the seismic safety of NPPs even the NPPs have designed against earthquake. To keep up with the advancement of the technology, more sophisticated analytical methods and new standards are required to be adopted to investigate the plant seismic safety. Besides, new geologic/seismic evidences also challenge the original design adequacy. Hence, the seismic safety of the NPP is required to be revisited and improved continuously. This paper demonstrated that Taiwan have adopted the new geologic survey evidence to accomplish the latest SMA, and have finished the associated seismic upgrades, and thus to assure that should a unlikely beyond design earthquake occurs, the plant should be able to safe shutdown and maintain in a safe shutdown state.

At present, the re-evaluation of PSHA following Senior Seismic Hazard Analysis Committee (SSHAC) level 3 process as well as the Probabilistic Fault Displacement Hazard Analysis (PFDHA) of Sanchiao and Hengchun Fault are ongoing to verify further the seismic safety of Taiwan NPPs.

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三、藍泰蔚技士發表部分

PBNC 2016
Beijing, China, April 5-9, 2016

PUBLIC PARTICIPATION IN RADIOACTIVE WASTE MANAGEMENT IN TAIWAN

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KEYWORDS: ENVIRONMENTAL RADIATION MONITORING, PUBLIC OBSERVATION, PUBLIC HEARING

ABSTRACT: The Atomic Energy Council of Taiwan has recognized public acceptance would be the most beneficial measure towards further development of radioactive waste management. Three related public acceptance activities have been launched to enhance public confidence, including (1) a public hearing on the installation license of a dry storage facility, (2) an environmental radiation parallel monitoring program at the Lan-Yu LLW storage site, and (3) a public observation program on the construction of the spent fuel dry storage facility. Results have shown that these public acceptance activities were advantageous to improve the confidence of local residents neighboring the radwaste facilities.

1. INTRODUCTION

There are four twin unit nuclear power plants (NPPs) in Taiwan, three of these NPPs are in operation and the other NPP is under construction. The government has decided to defer the operational tests for the fourth NPP in 2015. All NPPs are owned and operated by a state-run company, the Taiwan Power Company (TPC). During 40 years of operation, around 750,000 55-gallons drums of LLW (Low Level Waste) will be produced from three NPPs, and 5,000 tons of spent fuel will be generated from three NPPs.

To enhance the management of radioactive waste in Taiwan, Atomic Energy Council (AEC) implemented the "Radioactive Waste Management Policy" to protect people, secure ecological and environmental quality, and avoid disadvantages as well as burdens to present and future generations. According to the policy, the management strategy of LLW is "Minimize, solidify, store safely and facilitate the final disposal program." In the case of HLW, the management strategy of spent fuel is "Spent fuel pool storage for the short term, on-site dry storage for the midterm, and promote final disposal for the long term." The above strategy is flexible, can be adjusted to cope with international developments.

For conducting radwaste management policy, a firm organization framework was established to govern the safety of spent fuel and radioactive waste management as shown in Fig. 1. The TPC, under the supervision of the Ministry of Economic Affairs (MOEA), is the primary waste generator and operator of nuclear facilities, including NPPs, and the Lanyu LLW storage site. The AEC is the regulatory authority. The Fuel Cycle and Materials Administration (FCMA), a subsidiary of AEC, is in charge of regulatory enforcement of radioactive waste management. The Environmental Protection Agency is responsible for Environmental Impact Assessment evaluation. Independence of regulatory functions from other organizations are thus in line with "the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management".

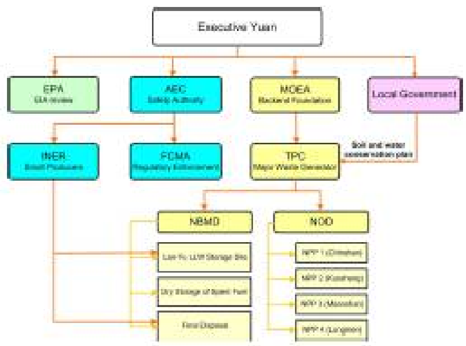

Figure 1 Organizational Structure for Radioactive Waste Management

2. MANAGEMENT OF LOW LEVEL RADIOACTIVE WASTE IN TAIWAN

2.1 Treatment

Due to the improvement of treatment technology and the efforts to minimize the radioactive waste in each NPP, the production of the LLW shows a declining trend year by year as shown in Fig. 2. The LLW production had reached 12,000 drums in 1983, but now only is around 200 drums of solidified LLWs generated by 3 operating NPPs since 2010. The contribution to the declining production of LLW is from utilizing a High-Efficiency Solidification Technologies (HEST) system, which was invented by the Institute of Nuclear Energy Research (INER) in Taiwan. The HEST system includes two key technologies, PWRHEST and BWRHEST. PWRHEST was implemented at Maanshan NPS (PWR) in 1998, and solidified waste has been reduced from 400~500 drums to 20~30 drums per year. BWRHEST was implemented at Kuosheng NPS (BWR) in 2006. The large amount of around 300~500 drums/yr of solidified waste was reduced to ~60 drums annually.

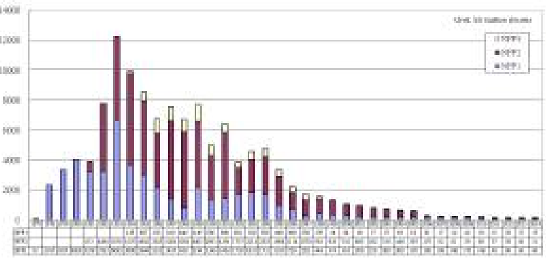

Figure 2 Annually Low Level Waste Generated from 3 NPPs in Taiwan

2.2 Storage

According to the law, all the LLW must be stored safely in storage facilities reviewed and approved by AEC. As of the end of 2014, the total amount of LLW was 205,392 drums. Most of those drums were stored at NPPs' air-conditioned, remote controlled and well-shielded storage facilities. However, 100,277 drums have been stored in the Lanyu storage site. The Lanyu LLW storage site is located at southeast tip of the Lanyu islet which is about 45 miles away from Taiwan. The Lanyu LLW storage site has 23 underground reinforce concrete trenches to store the LLW. Although it has stopped receiving waste since May 1966, the Lanyu storage site still needs to keep a good relationship with the local residents by participating in many communication activities.

2.3 Final Disposal

To specify siting procedures and ensure all the siting processes are open and transparent, AEC has promulgated the "Act on Sites for Establishment of Low-Level Radioactive Waste Final Disposal Facility" (siting act). This siting act also designated MOEA as the implementing authority, and MOEA assigned TPC as "site selection operator" in compliance with the siting act.

Having to shoulder the responsibility of site selection, MOEA and TPC were saddled with the siting act and had put a great effort into practicing these processes. Through years of site surveying to identify the potential sites, MOEA publicized these sites and published a "Report on the selection of recommended candidate sites" with special consideration for public comment. Later, MOEA announced Daren township and Hsiaochiou islet as the Recommended Candidate Sites (July, 2012). To comply with the self-determination as required by the siting act in a democratic fashion, the recommended candidate site must be approved by a local referendum and then may be listed as a candidate site. Due to the local government's reluctance hold this referendum, MOEA is still negotiating with the local government to hold a local referendum.

3. MANAGEMENT OF SPENT NUCLEAR FUEL DRY STORAGE IN TAIWAN

Periodically, about one-third of the nuclear fuel in an operating reactor needs to be unloaded and replaced with fresh fuel. Nuclear power plants must temporarily store this unloaded fuel, known as "spent fuel", in a water pool beside the reactor. Most of the spent fuel pools at the nuclear power plants in Taiwan are almost full, due to the limited capacity of the original design specifications. TPC has therefore begun looking for options to increase spent fuel storage capacity. The preferred option for increasing capacity is to store spent fuel in a dry storage facility.

3.1 Spent Fuel Dry Storage Licensing Program

In Taiwan, the dry storage facility is licensed in two steps: Construction License (based on the Preliminary Safety Analysis Report, PSAR) and Operating License (based on the Final Safety Analysis Report, FSAR). According to Article 17 of the Nuclear Materials and Radioactive Waste Management Act, the AEC must verify that the following four conditions are met before issuing a Construction License:

(1) The construction is consistent with the prescription of the relevant international conventions. The application documents shall meet the requirements of the IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (1997).

(2) The equipment and the facilities are sufficient to ensure safety and protect the public health. The PSAR review shall verify that the provisions for public health and safety are adequate.

(3) The environmental impact shall be in compliance with the standards put forth by all relevant laws, statutes and decrees.

(4) The technology, the management ability, and the financial guarantee of the applicant shall be sufficient to operate the facilities. TPC shall submit the financial guarantee report for ISFSI construction, operation, storage, and decommission. The Back End Management Foundation shall provide the letter of guarantee for funding of this project.

Even after the completion of facility construction, the facility may not be operated until the AEC has issued an Operating License. The construction engineering quality must be inspected, and the pre-operation test must meet standards of qualification. During the construction and operation of a dry storage facility, the AEC may inspect the facility at any time, and may ask the operator to submit relevant documents.

3.2 Licensing for the Chinshan Dry Storage Project

After performing a detailed study in 1990 on technical, safety, social, economic, and environmental impacts, the TPC decided to implement a dry storage program. It was constructed at the Chinshan NPS and has provided dry storage for 1,680 spent nuclear fuel assemblies. The combined capacity of this facility with the spent fuel pools has been sufficient to store all the spent nuclear fuel generated during Chinshan's 40-year licensed operation period.

In July 2005, TPC entrusted the INER to construct the Chinshan dry storage facility. After evaluation, INER decided to introduce concrete storage casks, INER-HPS, by means of a technology transfer from NAC International. In March 2007, TPC submitted an application for a Construction License to the AEC. After reviewing the documents, the AEC verified all regulatory requirements and issued the construction license in December 2008.

TPC started the manufacture of transportable storage canisters (TSCs) in September 2008 and all 25 TSCs were completed by August 2010. AEC inspected the Quality Assurance (QA) activities regarding TSC fabrication quarterly until completion. TPC commenced the site construction of the facility in October 2010. The concrete pad was completed in July 2012. AEC continues to perform the inspection of constructing activities monthly. The related inspection reports and technical documents are available at the AEC website to ensure transparency to the public.

TPC submitted the pre-operational test plan for approval in November 2011. AEC reviewed and then approved the pre-operational test plan in May 2012. TPC has completed the first stage pre-operational test (i.e. cold test). After checking that the test results met the limit conditions of operation (LCOs), AEC approved the test result report in September 2013, and agreed that TPC may carry out the second stage pre-operational test (i.e. hot test).

3.3 Licensing for the Kuosheng Dry Storage Project

The Kuosheng NPS has been operating for more than 30 years; the spent fuel pools are insufficient storage for spent fuel. TPC has decided to use dry storage to provide additional storage to fulfill the need of the 40 years of licensed operation of Kuosheng NPS.

The storage capacity of Kuosheng dry storage facility is designed for 2,400 spent fuel assemblies. The Environmental Impact Assessment (EIA) for the project was reviewed and approved by the Environmental Protection Agency (EPA) in January 2010. TPC invited bids for construction in November 2010, the joint winners of the bid were CTCI Machinery Corporation (Taiwan) and NAC International (USA). The two companies shall provide 27 MAGNASTOR concrete casks, capable of storing 87 spent fuel assemblies each.

TPC submitted an application for a construction license of the Kuosheng ISFSI to AEC in March 2012. Based upon the experience of the review of the Chinshan dry storage program, AEC completed the SAR review of Kuosheng ISFSI in September 2013. The reviewing conclusion of the SAR was found to be acceptable. After reviewing the documents submitted by TPC, AEC verified all regulatory requirements and issued the Construction License in August 2015.

4. PUBLIC ACCEPTANCE

The key issue for the decision making process of radioactive waste policy in Taiwan is public acceptance. In order to promote the public acceptance on regulatory measures of radwaste management, AEC encourage the public to participate in various regulatory activities, including public participation in environmental radiation monitoring at Lanyu, public observation during the construction phase of the spent fuel dry storage facility and a public hearing regarding the installation of the spent fuel dry storage facility, etc..

4.1 Public Participation in Environmental Radiation Monitoring

The weather of Lanyu islet is hot and humid, and the air quality is relative saline. An aboriginal tribe, the Tao tribe, has inhabited the Islet for generations. A low-level waste storage site at Lanyu Islet was established in 1981, where 23 storage trenches have been installed. The Lanyu storage site started to receive solidified LLW drums from 1982 to 1996. During this period, totally 97,672 drums of solidified LLW were stored at the site. However, during an inspection by the AEC, some of the drums were found corrosive damage. The AEC then requested TPC to implement the waste storage remediation program. The program was started in 2007 and completed in 2011; with additional 2605 drums, 100,277 drums of solidified LLW have been stored at the site.

Figure 3 The Lanyu Storage Site's Geography & Environment

AEC has established a real-time environmental radiation monitoring system in Taiwan, including several monitoring stations at Lanyu. AEC demanded TPC to install environmental radiation detector and to display the real-time radiation information at all villages so as to facilitate Lanyu local residents understanding the environmental radiation level around their living area immediately. All monitoring results have indicated that local radiation at Lanyu is much lower than the average of environmental background radiation in Taiwan.

Figure 4 Environmental Radiation Monitoring at Lanyu

Since 2008, the AEC has started a public participation program at the Lanyu environmental radiation monitoring program to relieve the radiation pollution concerns of the Lanyu local people. Each of the four developing phases ranges from expert's inspection to local residents involvement. A detailed description of each of the phases is as follows :

(1) 1st phase (2008 ~ 2010): AEC invited scholars and experts to visit the Lanyu storage site and inspect the facility operation, the results of which are reported to the Lanyu residents.

(2) 2nd phase (2011 ~ 2012): AEC invited environmental NGO delegates to visit the Lanyu storage site, and then the delegates shared their findings and participated in a discussion with the Lanyu residents.

(3) 3rd phase (2013 ~ currently): AEC invites Lanyu residents, local government officials, and Lanyu township representatives to participate in environmental radiation monitoring and sampling at Lanyu. Samples are then analyzed by an independent third party (NTHU) certified by the Taiwan Accreditation Foundation (TAF). Then NTHU sent the monitoring results and analysis report to the Lanyu township office for information disclosure. Furthermore, AEC has invited legislators to visit the Lanyu storage site to inspect radwaste conditions, and randomly selected a storage trench to check the radiation records. After visiting the storage site, the legislators also to monitor the environmental radiation along the route around Lanyu islet.

(4) 4th phase: AEC plans to commission well-trained Lanyu residents who volunteer to undertake sampling and radiation measuring tasks in the future. Samples will be analyzed by an independent third party certified by TAF, after which the third party will sent the monitoring results and analysis report to the Lanyu township office for information disclosure.

All participants were given a brief notice of concern regarding contamination of the sampling and detection tasks before carrying out activities. After that, participants measured environmental radiation, and took samples of water, soil, grass and agricultural products at all 6 villages at Lanyu.

The Soil Sampling Process

The Gross Sampling Process

All of the monitoring results from 2008 have shown that they are far below regulatory criteria and at the level of environmental background radiation. It indicates that the LLW storage site at Lanyu has not resulted in any radiation pollution. Now it is in the process of a health and safety assessment, including a health investigation for the Lanyu people, and a whole-body count for radiation for the Lanyu residents.

The public also participated in radiation monitoring on traffic routes along Lanyu Islet. Every 500 meters on the routes was monitored for its radiation level. These detection results have also shown that they are lower than the average of environmental background radiation in Taiwan.

Figure 5 Radiation Detection Every 500 Meters with Surrounding Route around Lanyu Island

4.2 Public observation program on the construction of the spent fuel dry storage facility

The licensing for a spent fuel dry storage facility needs much more consideration than just technical or regulatory decisions. Broad public consent and measures designed to gain public acceptance have become prerequisites for implementing ISFSI program. In order to enhance the confidence of the public, a Public Observation Program was initialized by AEC in 2011. AEC organized an Observation Team including 11 community delegates (village chiefs, directors of community associations, stakeholder representatives), 3 local government officials, 2 civil engineering experts, 4 environmental NGO delegates.

Public Observation Activities during the construction phase are performed periodically, including site visiting, environmental background radiation monitoring, and construction quality control. The activities for the Public Observation program were arranged by AEC. The observation members were invited to observe the construction quality of the SNF dry storage facility at Chinshan NPP. AEC and the utility company (TPC) would respond to concerns presented by the members at the meeting. During the Public Observation activity, the members will be arranged to check the radiation level at ISFSI site. Until now, there is no spent fuel stored in Chinshan ISFSI facility. The radiation level at ISFSI site was surveyed for background radiation and remained near natural background actually. These measured data can be a baseline for comparing the design criteria in SAR. Once the spent fuel has been stored in the ISFSI site, the radiation level will be compared with that of the background radiation to demonstrate the safety of the ISFSI. Up to now, 11 Public Observations have been held since May 2011.

Warehouse of Canisters and Dolly Survey

Concrete Overpack Construction Survey

Environmental Background Radiation Detection (1/2)

Environmental Background Radiation Detection (2/2)

The public opinions proposed by the public team members have been classified into 3 categories: safety, sustainable management, and feedback. Most of the public team members agreed that the spent fuel storage facility is safe under AEC supervision. They asked TPC to implement long-term monitoring of the safety of the facility, and that the monitoring data shall be accessible to the public. AEC demanded that the TPC must set up a comprehensive monitoring system (shown as Fig. 6) to reveal the monitoring information to the stakeholders. This system can serve as a communication platform between stakeholders and TPC. In addition, AEC requested TPC to disclose real-time monitoring data on the AEC Nuclear Duty Center after the spent fuel initial loading. This data includes temperatures, dose rates, hillside slope stabilities and ground water levels. The data regarding temperature of canisters and radiation levels at the site can also be displayed in real-time on the AEC website. With regards to sustainable management, the storage period was a priority issue concerned by the public due to the delay of repository program in most countries worldwide. AEC has required TPC to propose a centralized ISFSI to take over the spent fuels at this site as an alternative, if the licensed 40 years storage period has expired and the repository was not available. The alternative program is shown as Fig. 7. The most common issue is feedback subsidy. As a regulatory body, AEC encouraged the TPC to have more dialogue with the local communities to get a consensus on reasonable feedback. Furthermore, AEC has granted the local residents a whole-body count for radiation, instructed people in the community on radiation safety knowledge as well as usage of radiation monitoring instruments. Finally, AEC provided an instrument to each township which may be used to measure the local environmental radiation level in the community.

Radiation Lectures at Local Townships

Radiation Detection Instrument Provided to Each Township

Radiation Measurement by Local Residents(1/2)

Radiation Measurement by Local Residents(2/2)

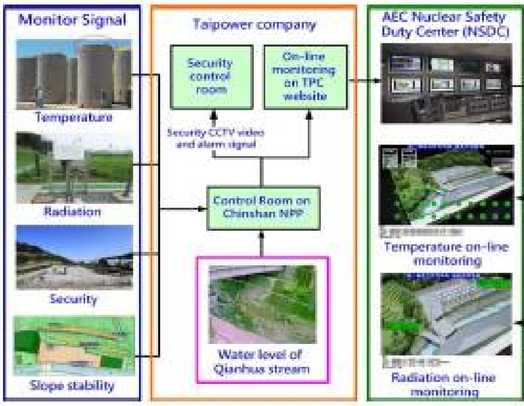

Figure 6 Monitoring System of the Dry Storage Facility at Chinshan NPP

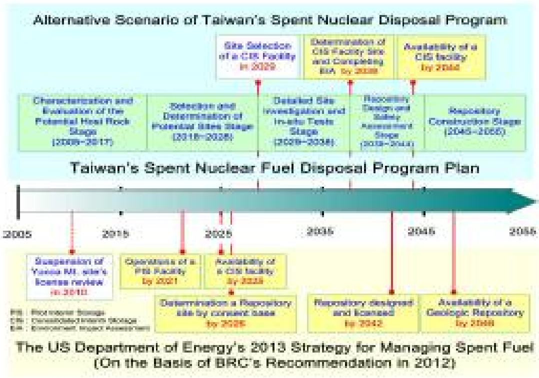

Figure 7 Alternative Program for Spent Fuel Disposal Program in Taiwan

4.3 Public Hearing

As mentioned before, the AEC accepted the application case for the Kuosheng NPP dry storage installation from TPC on Mar 15, 2012. According to the Articles of "Nuclear Materials and Radioactive Waste Management Act", AEC must hold a public hearing meeting for this application case. To process this public hearing meeting smoothly, AEC held a pre-hearing meeting on July 31 in the civic hall at Wanli township, close to the proposed installation's area to garner the opinion from the nearby residents. Around 20 issues of contention had been collected from the pre-hearing process meeting. These issues can be sorted to three categories, "Necessity of the facility", "Safety of facility" and "Energy policy, financial and credibility issues". Some key issues can be summarized as follows :

- May the Kuosheng's ISFSI become a final repository?
- Is the of subsidy fair to the host communities nearby the ISFSI?
- Can the safety of the community be guaranteed, in the event of an earthquake, tsunami, or landslide occurring at or near the site of ISFSI,?
- Can the spent fuel be retrieved safely after 40 years storage? Is there any plan to transport the loaded casks to a repository site?
- Is the cost of Kuosheng's ISFSI underestimated?
- Could the victims get compensation, if an accident occurs?

Later on, a hearing was held on August 10 aimed at reaching consensus upon these issues and took 10 hours to be complete. A total of 78 participants took part in the hearing, including 20 experts in related agencies, and 28 people from various domains such as Congress, the local communities and environmental groups. Most importantly, there were 6 issues adopted and became formal regulatory requests for TPC. These issues included many aspects as follows:

- The pre-operation of spent fuel dry storage facility (ISFSI) must include a mock simulation of the retrieval operation of spent fuel.
- The operator must make sure a facility available for retrieving spent fuel in the NPP's decommissioning plan.
- The maintenance and surveillance plan of the ISFSI shall include the monitoring of stress corrosion cracking (SCC) of the storage facility.
- Any new survey evidence of fault near the facility area is approved by AEC, the operator, TPC, must re-evaluate the seismic design of the ISFSI.
- The storage facility shall be decommissioned when the 40-years license expires.
- TPC should enhance outreach program and reasonably feedback to local communities for promoting the public acceptance.

5. CONCLUSIONS

Radwaste is an existing reality which must be well managed to ensure a sustainable environment, no matter the future is nuclear free or not in Taiwan. Radwaste management is not only technical but also social issue that needs patience and time to resolve. Public acceptance is the decisive factor in the success of radwaste management. Three related public acceptance activities have been launched to enhance public confidence by AEC, and results have shown that these activities were helpful to improve the confidence of local residents neighboring the radwaste facilities.

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四、黃朝群技士發表部分

PBNC 2016
Beijing, China, April 5-9, 2016

LESSONS LEARNED FROM FUKUSHIMA

- APPLIED TO EMERGENCY PREPAREDNESS IN TAIWAN

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ABSTRACT:

After Fukushima Daiichi accident in Japan, Atomic Energy Council (AEC) has conducted re-examination on three operating nuclear power plants in Taiwan immediately, focusing on nuclear safety, radiation protection and emergency preparedness. Lessons learned in five areas have been concluded from Fukushima accident: 1. Complex disasters, 2.Victim's viewpoint, 3.New technology, 4.Disaster prevention, and 5.Transparency and communication. In order to prevent from similar disaster occurs in Taiwan, AEC has improved capabilities and abilities of nuclear emergency preparedness and response through three aspects: 1.Mechanisms and regulations, 2.Cross-border and international cooperation, 3.Preparedness improvement.

For mechanisms and regulations, AEC has revised nuclear emergency response related acts, regulations and plans, expanded emergency planning zone (EPZ) based on two units accident. Enhance the national response mechanism for nuclear accident caused by severe natural disaster.

For cross-border and international cooperation, AEC has revised the guidelines for accident notification, introduced more agencies into emergency response mechanism and issued a new rule of the Response Guidelines for Cross-border Nuclear/Radiological Incidents. AEC also enhanced the abilities and capabilities on radiation dose evaluation and analysis, atmosphere dispersion model, aerial and maritime radiation detection and monitoring.

For preparedness improvement, AEC has required the licensees to fulfill the NRC's NTTF recommendations about Staffing and Communications. The licensees have developed the ultimate response guideline to inject seawater when necessary, and have improved (or are going to build) earthquake resistant/seismic isolated building for emergency response. More alert stations have been established to make sure all residents within EPZ will be notified within 45 minutes while nuclear accident occurs. More radiation monitoring stations also established within EPZ. For iodine tablet arrangement, AEC has introduced 3 layers concept, pre-distributed two-day's dose supply to residents within EPZ, another two-day's dose supply was kept by local government within EPZ, and two 'National Stockpiles' outside EPZ has been established for extra need. For emergency response information system, AEC had created nuclear emergency management platform system for nuclear response groups. If situation is getting worse to General Emergency or a complex disaster, AEC would activate emergency management information system to communicate with agencies at the Central Disaster Response Center. For evacuation, a staged-keyhole type evacuation was developed to support public protective action. Students and nursing people have first priority to evacuate; a pre-evacuation mechanism is in place for schools, nursing houses and hospitals. AEC also keeps on public communication with residents through all occasions, gathering and fairs. In order to verify above improved measurements, AEC conducts nuclear emergency exercise through tabletop exercise, onsite exercise and full participation exercise annually.

We should be humble in face of nature disaster, and keep on improving capabilities of emergency preparedness and response to reduce risk and mitigate consequence, and earn trust of residents through transparency and communications.

1. INTRODUCTION

Magnitude 9.0 earthquake occurred on north east off-coast of Japan on March 11th 2011, caused the tsunami stroke Fukushima Daiichi nuclear power plant, resulting the loss of the function of injecting water, core melted and radioactive materials released to atmosphere.

There are four nuclear power plants (NPPs) in Taiwan, Chinshan, Kuosheng, Maanshan, and Lungmen, information of the four NPPs are listed in Table 1. The construction permit of Lungmen was issued in 1999, and is deferred now. The electricity share of nuclear power in Taiwan is about 16.3% in 2014.

Table 1 NPP Information in Taiwan

NPP	Chinshan		Kuosheng		Maanshan		Lungmen	
Reactor	I	II	I	II	I	II	I	II
Type	GE BWR4		GE BWR6		WH PWR		GE ABWR	
Maximum Capacity (MWt)	1804	1804	2943	2943	2822	2822	3926	3926
Operating License	Dec. 6th 1978	July 16th 1979	Dec. 28th 1981	Mar. 15th 1983	July 27th 1984	May 18th 1985		
Location	North of Taiwan		North of Taiwan		South of Taiwan		North Eastern of Taiwan	
Current Status	Operating		Operating		Operating		Deferred	

1.1 Safety Re-examination

After Japan's Fukushima Daiichi Accident, Atomic Energy Council (AEC) required Licensee -Taiwan Power Company (TPC) to re-evaluate each nuclear power plant's capability to cope with extreme natural disasters, including earthquake, tsunami, and flooding. The re-assessment comprises three parts: Nuclear Safety (focus of this part), Radiation Protection, Emergency Response and Preparedness. The results confirmed that there was no immediate danger at the three nuclear power plants in Taiwan, yet AEC requested the TPC to verify the capability of NPPs to respond both the design basis accident (DBA) and beyond-DBA accident. For emergency preparedness (EP) aspect, TPC was request to verify the capacities and capabilities of emergency plan of NPPs, whether adequate or not to cope with an accident like Fukushima Daiichi occurs in Taiwan.

There were two phases of re-examination, one is "near-term phase (dated before October 2011) "and the other is "mid-term phase (dated before August 2012)". AEC issued "The Near-Term Overall Safety Assessment Report for Nuclear Power Plants in Taiwan in Response to the Lessons Learned from Fukushima Daiichi Accident" at the end of first phase, mainly for the issues of beyond the design basis of most extreme natural events. Design provisions at the Fukushima Daiichi site appeared to only have been made to protect against a 5.7 meter high surge in sea level, and there was a huge tsunamis hitting this coast in the history of Japan. All NPPs of TPC should follow the same criteria to re-examine the design basis. In addition, TPC was required to demonstrate adequate protection in place for an extremely rare natural event, based on extrapolation from the historical record, and to show that there were no "cliff-edge" effects based on the specification of European Union (EU) stress test. Many areas of improvement had been identified in the issues of nuclear safety assurance. In August 2012, AEC issued "The Overall Safety Assessment Report for Nuclear Power Plants in Taiwan in Response to the Lessons Learned from Fukushima Daiichi Accident" at the end of mid-term phase, based on the preliminary conclusions and previously requirements. AEC referred the actions recommended by Nuclear Regulatory Commission of USA (NRC) to be taken without delay and the best international engineering practices considered in the nuclear industry by taking the nuclear regulatory cases into account to the min-term phase report.

The key areas of both reports included are the enhancement of capability to mitigate a prolonged station blackout (SBO), protection against tsunami hazards, spent fuel pool cooling, hydrogen detection and explosion prevention, severe accident management, protection against seismic hazards, critical infrastructure, and safety culture. Further stated in the following is related to emergency preparedness and response.

The severe disruption of the electrical grid, communications and transportation systems on Fukushima event was one of the important observations. It was a significant contributory factor to worsen the accident while the conditions lasted for several days. The reactor safety was reliant on the resilience of the local infrastructure in circumstances of extreme events affecting both the nuclear site itself and the surrounding area. TPC needed to enhance on-site accident management capabilities and incorporate the off-site resources. The interdependency on the resilience of nuclear plants and off-site infrastructure should be re-examined through the lessons learned from the Japan event. This might highlight the need for the enhancement of plant's sustainabilities for extended periods in terms of electrical power, coolants and necessary supplies. The Fukushima Daiichi accident in Japan showed the value of hardened on-site emergency response centers. AEC required TPC to prepare emergency response workplace at nuclear power plants by referring to the guidance of seismic isolation buildings of Japan, and completed relevant requirements as set forth in Recommendation 9.3 in the Near-Term Task Force (NTTF) report of NRC.

1.2 Missing Puzzles - Lessons Learned on EP

AEC greatly put focus on reports regarding to Fukushima events published by Japanese Government. Five lessons learned on emergency preparedness aspect was concluded from the report issued by Japanese government [1] and "The Overall Safety Assessment Report for Nuclear Power Plants in Taiwan in Response to the Lessons Learned from Fukushima Daiichi Accident": They are: 1.Complex disasters, 2.Victim's viewpoint, 3.New technology, 4.Disaster prevention and 5. Transparency and communication. For complex disaster aspect, we should be humble in face of natural disaster to do our best for emergency preparedness which means the accidents beyond design basis will be always on the priority list of emergency plan. The probability of nuclear accident should be reduced as low as possible through ways of safety improvement. The response mechanism of complex disaster should be introduced into our national response plan to reduce the damage impact from a nuclear accident resulted from severe natural disaster. And the systems for disaster prevention and consequence management should be updated and improved all the time. For victim's viewpoint aspect, some of the evacuees passed away during the nuclear crisis at Fukushima Daiichi because of inappropriate evacuation. The people with disabilities may be more vulnerable to hazards and consequences of a disaster than the general public. When evacuation is needed, authorities should have pre-existing procedures to ensure no one left behind. Arrangements should be in place to ensure that people with disabilities are able to follow evacuation orders issued by the authorities. This involves ensuring that departure, the journey and the arrival at destination can be conducted efficiently and safely. The children are also more vulnerable to hazards and consequences of a disaster than the public, especially for the radiological hazards form an accident. Children and people with disabilities should have the priority of evacuation. The residents within emergency planning zone (EPZ) may have higher risk of nuclear disaster than the people out of EPZ. The nuclear emergency notification system should be 100% coverage of resident. For new technology aspect, AEC have enhanced the abilities of dose evaluation, aerial radiation detection and monitoring, and cross-platform communication and information-sharing system for decision-making. For disaster prevention aspect, AEC have enhanced the safety of nuclear power plants where the radiation releases from in case of nuclear accident, including the requirement of FLEX and B.5.b of NRC, as mentioned above, Fukushima experience to improve on-site and off-site emergency preparedness plans, and so on. The ultimate goal is to prevent from radioactive materials released to the environment. For transparency and communication aspect, the general public in Taiwan lost faith on safety of nuclear power plants because of the Fukushima accident, we needed to make more efforts to regain trust from the public in Taiwan through more transparent and more open ways.

2. MECHANISM and REGULATIONS

2.1 Regulations amending

The Nuclear Emergency Response Act (NERA) is the foundation for nuclear emergency preparedness and response in Taiwan. The amendments of NERA has introduced lots of ideas from Fukushima experience and revised response mechanism regarding complex disaster and increased the responsibilities of TPC as well. Four years after the accident of Fukushima Daiichi nuclear power plant, this amendment has been submitted to the Legislative Yuan for examination in December 2015. Under NERA, the major regulation is the Emergency Response Basic Plan (ERBP) which has been revised in October 2014. For the Emergency Action Level in the revised ERBP, it starts one phase earlier, i.e., the national response mechanism shall be activated at Alert of nuclear accident, instead of Site Area Emergency. The precaution evacuation for schools and nursing houses also bring into the emergency preparedness and response plan. The TPC and local governments need to revise their emergency preparedness response plans accordingly. AEC also asked the TPC to adopt "The Overall Safety Assessment Report for Nuclear Power Plants in Taiwan in Response to the Lessons Learned from Fukushima Daiichi Accident" and NRC's NTTF recommendations into the emergency preparedness and response plan of nuclear power plant. AEC has completely revised emergency action levels (EALs) through technical papers of NRC [2], IAEA [3] and Nuclear Regulatory Authority of Japan (NRA) [4], and now is reviewing the public protective action guides (PAGs) with operational intervention levels (OILs).

2.2 EPZ expanding

The EPZ of each nuclear power plant in Taiwan was 5 kilometers before 2011 based on single unit accident. After Fukushima accident AEC considered multi-units (two units per plant in Taiwan) accident and more conservative PAG into EPZ calculation. It came out the result to expand EPZ from five kilometers to eight kilometers. Taiwan government announced the EPZ expansion for Chinshan, Kuosheng and Maanshan on October 27th 2011, and Lungmen in April 12th 2013. Basing on the expansion of EPZ, local government and TPC need to revise their emergency plan respectively.

2.3 Mechanism improvement

The ERBP was designed to cope with nuclear accident only in the past in Taiwan. The response mechanism was activated while TPC notifies AEC a nuclear accident at level of Alert or above. Then AEC will mobilize emergency response team which consists of senior directors and heads of AEC. The team also consists of technical groups as sub-teams. Accident Evaluation sub-team which is responsible for estimating possible progress of nuclear accident, Dose Evaluation sub-team which is responsible for evaluating environment dose rate around the accidental plant and provides PAG recommendations, Planning and Coordination sub-team is responsible for mobilizing the response members and sets up communicating and information device ready for response, News sub-team is responsible for publishing latest information and communicates with the general public and medias, and Administrative sub-team is responsible for supporting logistics support. If the nuclear accident progressed to Site Emergency, "National Nuclear Emergency Response Centre (National Centre)", which consists of emergency response related agencies, would be formed. Also "Radiation Monitoring and Assessment Centre (Monitoring Centre)" would be activated, whose members mainly from AEC and TPC to conduct dose estimation of off-site area, environment dose monitoring and environment sampling, and recommendations of public protective action to the National Centre. "Regional Nuclear Emergency Response Centre (Regional ERC)" which is formed by local governments would implement the public protective action orders by National Centre. "Nuclear Emergency Support Centre (Support Centre)" which is from the Army would support clean-up of personnel and vehicle, dose monitoring and other logistical support. The commander of National Centre was AEC chairman.

After the Fukushima accident AEC had revised ERBP plan to cope with complex disaster which meant natural disaster induced nuclear accident. Once a natural disaster, such as earthquake, tsunami, extreme rainfall and mudslide, combined with a nuclear accident were happening, the national emergency response team has more agencies get involved and the operation has been enhanced through multi central agencies coordination. And the timing to activate the nuclear emergency response mechanism has been elevated as one phase earlier, it means the response mechanism will be activated at level of Alert instead of Site Emergency before Fukushima Accident. If an Alert was notified to AEC from NPP, AEC emergency response team will be activated immediately, and National Centre will be formed soon after approved by AEC Chairmen, then the following response steps remain the same as previously described, and all staff of National Centre will move and merge into "Central Disaster Response Centre" to deal with complex disaster. The commander of Central Disaster Response Centre will be designated by Premier of Executive Yuan, and AEC chairman will be the co-commander.

3. CROSS-BORDER and INTERNATIONAL COOPERATION

In May 21 2014, AEC had completed new rule of the "Response Guidelines for the Cross-Border Nuclear/Radiological Incidents" to deal with a situation which a neighboring country NPP is experiencing an accident, radioactive materials may or may not impact Taiwan. In October 20th 2011, AEC signed an agreement with Mainland China called the "Cross-Strait Nuclear Power Safety Cooperation Agreement"; both sides have the responsibilities to notify the other side while a nuclear accident happens. AEC and National Nuclear Security Administration (NNSA), Department of Energy, USA, also signed a Statement of Intent between AEC and NNSA regarding nuclear and radiological incident response and emergency management capabilities. NNSA will provide technical support and experts' aid per AEC request once a nuclear accident happens in Taiwan.

AEC also enhanced capabilities on dose evaluation analysis and atmospheric dispersion model through a Nuclear Technical Project in the Taiwan's National Research Program on Energy from 2011 to 2014. The topics included long term of atmospheric dispersion trace model, platform establishing and benchmark, to strengthen the capabilities of dose evaluation analysis for a cross-border nuclear accident.

AEC enhanced aerial and maritime radiation detection and monitoring capabilities through setting up a system of maritime radiation detection with the Coast Guard Administrator. Together with aerial detection system, which is by from NNSA, both systems have been conducted functional test during annual nuclear emergency exercise.

4. EMERGENCY PREPAREDNESS IMPROVEMENT

In order to prevent from Fukushima accident happens in Taiwan, AEC has enforced preparedness improvement through following steps: 1.nuclear power plants emergency preparedness enhancements, 2.alert and notification system improvements, 3.radiation monitoring stations expansion, 4.iodine tablet arrangement, 5.emergency response information system, 6.evacuation strategy modification, 7.public outreach/communication, 8.nuclear emergency exercise.

4.1 Nuclear power plants emergency preparedness enhancements

First of all, TPC is required to fulfil the NRC NTTF recommendations about staffing and communications [5]. Secondly TPC should develop the ultimate response guidelines (URG) to inject seawater into reactor in order to prevent radioactive materials released to the environment during severe accident. Thirdly TPC should build an earthquake resistant (or seismic isolated) building for emergency response to provide the necessary foundation for disaster prevention activities in times of disaster.

4.2 Alert and Notification System Improvements

Because of EPZ expanded from 5 kilometers to 8 kilometers, TPC is required to review and adds more alert notification stations. These stations work together with the local village broadcast system, air-raid siren, TV, radio, vehicle broadcast, fishing broadcast radio, etc., to make sure one hundred percent coverage of the residents within EPZ could be notified within 45 minutes. In addition, Taiwan government also invited 3G mobile providers to set up a 'disaster message text broadcast system' to provide with text message delivery service through mobile phone to the public at the first time of accident.

4.3 Radiation monitoring stations expansion

Along with the EPZ expansion, more radiation monitoring stations were established, the radiation monitoring stations for Chinshan was increased from five to twelve, Kuosheng was increased from five to fourteen, Maanshan was increased from five to twelve. Also there are forty more mobile environmental radiation monitoring detectors with wireless connection were established. AEC had established the integrated environmental radiation information system to integrate data from these devices for protective action guides.

4.4 Iodine tablet arrangement

For iodine tablet arrangement, the concept of 3 layer defense was introduced, pre-distribution, local stockpiles, and national stockpile. Within EPZ, AEC had pre-distributed program that permanent residents had been provided a package of iodine tablets with two-day dose supply and the other two-day dose supply was kept by the local government. Outside EPZ, AEC established 'National Stockpiles' (about eight hundred thousand tablets) in 2012 for extra need in case of a nuclear accident. AEC has developed directions on the storage, distribution, replacement and disposal of iodine tablets which identify responsibilities and authorities for iodine tablet arrangements.

4.5 Emergency response information system (ERIS)

Real-time information is critical to emergency response. Emergency response information system is a common database for response groups, which provides geographical, real time information to responders. Response groups could communicate each other, publish information, deliver data and exchange information. In an accident of General Emergency or complex disaster, responders will use emergency management information system (EMIS) which was established by disaster prevention and management agency to communicate with other agencies in central government.

4.6 Evacuation strategy modification

After Fukushima nuclear accident, in order to prevent mass casualty due to large scale evacuation, AEC has took every scenario into consideration[6], for each scenario, an evacuation time estimate to complete a staged-keyhole evacuation is needed to support protective action decision-making. The evacuation-reception program considers different population segments: 1.permanent residents, 2. transportation dependent residents－permanent residents who do not have access to a vehicle, 3. special facility residents－residents of nursing homes and hospitals, etc, and 4.schools. Safety of children is the major task in an accident, while evacuation is needed in midweek daytime. In order to minimize traffic congestion, parents are urged not to pick up their children at school. All students attending the schools within EPZ will be evacuated to the 'host school' which is sixteen kilometers away from NPP to reduce the risk of radiation exposure. Students will remain at host schools until released to their parents or guardians through proper release procedures. Each school has a designated host school sixteen kilometers away in case of evacuation. Arrangements between school and host school are in place and school evacuation exercises have been conducted annually. AEC conducts annually evacuation survey on transportation needs for each school. Afterwards, local government's education department in coordination with fire department will continue making arrangement on evacuation vehicles, which is based on the survey data. Each school within EPZ should enact its own protective response plan, including standard operating procedure, evacuation routes, vehicles and host school and their contact information. Emergency information is prepared for parents; it provides information as what to do in an emergency, where the host school is, and how to contact with school.

4.7 Public outreach/communication

AEC continually communicate with residents and conducts survey within EPZ to provide most updated information about nuclear emergency and response. And to conduct outreach at focus groups meetings, seminar at schools, public meeting, and disaster preparedness fairs through all occasions within EPZ. AEC also works with local government to brief annual full-scale exercise to local community before exercise, and encourage the residents to attend the exercise.

Civilian of Taiwan lost their trust of government due to opaque policy and the failure nuclear safety experience of Fukushima nuclear accident. In order to regain trust of them, AEC had implemented some strategies: 1.setup "Post-Fukushima Safety Enhancement" website for the public, and show documents of peer-review, safety summary report and international meeting presentations which expose the regulation strategies about nuclear power plant to those who cared about nuclear safety issues can search them online easily. 2. Extend radiation safety knowledge through social networking sites such as Facebook to civilian. 3.To particularize nuclear emergency response preparedness tasks which had mentioned as previous and present to civilian about the latest plans which government had put eyes on them.

4.8 Nuclear emergency exercise

According to the "Nuclear Emergency Response Act", a full participation exercise should be conducted each year, it may include tabletop exercise and field operation drills. The processes and scenarios of each exercise would be different objectives, the fully participation exercise in 2015 in Taiwan is shown as bellow.

The "2015 Nuclear Emergency Exercise" took place in Shimen District of New Taipei city in northern Taiwan. Assuming an extremely heavy rain triggered by typhoon circulation for several days, and had caused flooding and landslides in some areas. It came with an earthquake induced that Chinshan had suffered loss of off-site power and backup cooling water system failure, resulting in releasing of radioactive materials to the environment. In order for ensuring public safety, the New Taipei City undertook relevant protective actions. Two-stage exercise were conducted: the first one was a table-top exercise that had been conducted on August 25th while the central government and local governments as well as TPC had activated and operated their emergency response centers simultaneously to examine the staffing at and communication between response units. The second one was a full-scale exercise that had been conducted on September 21st through 23rd to exercise the emergency plans of all responders.

The exercise began with an accident occurs, the emergency response units of Chinshan was activated right away to deal with the accident, then notified the authorities, and issued press release to inform the public of the latest situation. The scenario assumed that Chinshan had lost all AC power on site, backup 4.16KV power vehicles were called in to supply power for the emergency core cooling system. Moreover, the spent fuel pool water level was found decreasing due to failure of emergency sea water cooling system. Chinshan decided to extract water from nearby creek to ensure continued cooling of the spent fuels pool. Because the accident had lasted three days, it was becoming much difficult for the repair personnel to do their works, particularly in the night time. And it happened; workers were injured while fixing the out of order equipment. After preliminary first aid, they were rushed to hospital for further medical treatment.

When the nuclear accident continues to worsen to be at level of Alert, the National Centre, the Monitoring Centre, the Supporting Centre, the Regional Centre, the Response center of TPC, the Support Centre of Chinshan, the emergency response teams of AEC, all will be activated, respectively and correspondingly.

In 2014, all nuclear power plants in Taiwan were required to set aside an area for supporting helicopter's landing to cope with road interruption caused by earthquake or others. In the exercise, Chinshan applied to the National Airborne Service Corps, asking for bringing in heavy equipment to help with emergency repairing.

Based on the order from the National Centre, the Incident Command Centre of the National Centre had also been established at Kuosheng to integrate and allocate resources available for disaster relief in a prompt way.

The Monitoring Centre is responsible for conducting environmental radiation detection, evaluating the affected areas and predicting the potential scope of the accident. Accordingly, the center performed public dose evaluation and made appropriate recommendations for public protective actions. It also took samples of soil, grass and agricultural produces from the potentially contaminated area for radiological analysis according to the preset radiation detection plan. The Monitoring Centre asked military to send helicopters for aerial radiation detection, and to carry out large area radiation detection while situation was worsening and radioactive materials release was enlarging. Also, the coast guard was asked to send patrol ships to detect radiation, and to collect sea water and fish samples for preliminary analysis to fully understand the situation of radiological contamination. Moreover, water samples from the neighboring water treatment works was conducted to ensure drinking water free from radioactive contamination.

The accident notification was delivered to the general public through a pre-established emergency alert system within eight kilometers of EPZ surrounding the nuclear power plant, which includes village radio stations, vehicle broadcasting, text messaging, telephone, TV etc.... Once the alert is issued, traffic control shall be implemented to prevent persons or vehicles from entering affected area. In the meantime, the heads of affected villages and the police will urge the public to stay indoors. Residents should be sure to get theirs doors and windows closed during indoor sheltering. In the meanwhile, turning on the TV or radio for accident situation updated. Also strongly advised is to post a sign saying "I have been informed to take sheltering "at a prominent place on doors or windows, thus allowing the police and head of the village more time to notify other residents. The families having the disabled or elderly persons are recommended to clearly post a sign saying "I need help" on the windows and/or the door. Therefore, the police, the head of the village or social workers can give top priority to assist them for evacuation.

According the scenario, the nuclear accident happened during class time, teachers guided students to quickly enter classroom for sheltering, from where the evacuation buses arranged by the local government came to drive them to the "host school". On the way there, teachers explain to the students directions concerning public protection measures. Upon receiving evacuation order, parents may either go to school to pick up their children directly or meet them in the host school.

In order to enhance the awareness of public protection, particularly in the aspect of evacuation and reception, a precautionary evacuation drill for the public residing within 3 kilometers of the accident site was conducted this year. According to the New Taipei City's nuclear emergency plan, a screen station was established, according to the wind direction, at Chianshuiwon parking lot of Sanzhi District of New Taipei City, where radiation detection for people and vehicles were underway. A contamination free sticker was issued to whom without contamination. On the other hand, residents or vehicles exposed to radioactive contamination must go through decontamination process. Upon receiving evacuation notification, residents can choose to go either to their relatives or friends, or to the reception facility for temporary stay. In the reception facility the elderly care area, childcare area, pet service area, religious zone and information zone are in place to provide evacuees with good physical and mental care.

Although the risk of nuclear accident occurring is extremely low, we still need to let the response personnel know how to react effectively and do their rescue works efficiently in the case of a nuclear emergency. This is why we always plan and conduct the exercise in a very practical manner. Through the exercise, AEC would like to get more residents involved in the exercise, aiming to let them experience emergency response and preparedness measures undertaken by the governments in nuclear accidents. And it did work, more and more resident people within EPZ had jointed the fully participation exercise.

In the three-day "2015 Nuclear Emergency Exercise", not only verified the effectiveness of enhancement actions concerning the overall emergency plan of nuclear power plants, but also examined the operability of New Taipei City's regional public protection plan for nuclear accidents through full-scale field operation exercise. We hope the public can better understand the practices and efforts undertaken by the government in ensuring the nuclear safety. Once again, the risk of nuclear accident is very low, but we still need to be well prepared for it.

5. CONCLUSIONS

Although the safety design of nuclear power plants is defense in depth, however, unexpected disaster happened due to global climate change, beyond design basis accident would be happened, we should be humble in face of nature disaster, try our best to keep on improving capabilities of emergency preparedness and response to reduce risk and mitigate consequence. The support of civilian to nuclear energy is of great important, government should keep on communicating to residents within EPZ and stakeholders about nuclear safety procedure and protective actions, moderate open information to minimize civilian's worry.

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