福島核事故後歐洲核電廠壓力測試結果與法國核電發展情形

報告人: 原能會派駐法國 OECD/NEA 一等秘書 羅偉華

歐盟執行歐洲核電廠壓力測試情形與結果

2011 年 3 月 11 日芮氏地震儀規模 9.0 級的強震襲擊日本，並引發前所未見的超級大海嘯，在日本造成重大的破壞與人員的傷亡，並導致東京電力株式會社(TEPCO)的福島(Fukushima)核能電廠發生輻射外釋的嚴重事故，引起全世界對核安全的關注。

2011 年 6 月 20 日國際原子能總署(IAEA)在奧地利首都維也納舉行 IAEA 部長級核安全會議，並根據會議結論發表總計 25 條的宣言(詳如附件一)，其中的五個重點爲: **1**) 加強核安全標準; **2**)對所有核電廠進行安全審查，包括擴大國際原子能總署的同行評審計劃; **3**) 提高國家核監管機構的執行效益並確保其獨立性; **4**) 加強全球緊急應變準備和反應系統; 並 **5**) 擴大國際原子能總署在接收與傳播信息的角色。並強調增進有關核安全領域之雙邊、區域和國際合作，讓安全相關的技術和科技資訊能夠最自由的可能流通與廣泛的傳播，各國之間應就核安全的所有方面進行公開透明和最佳做法之交流。

國際間爲因應福島核事故對核能發電所造成的衝擊，多數國家已經宣布將根據眾所周知的福島核意外事故之事實爲基礎，對核電廠安全措施進行整體安全審查。爲此國際原子能總署(IAEA) 、歐盟(EU)國家與經濟合作暨貿易組織核能署(OECD/NEA)會員國就福島核事故之經驗與教訓已要求各會員國依據歐盟之歐洲核安全監管組(ENSREG)所提出之壓力測試(Stress Test)規範，對歐洲現有核電廠進行核安之整體安全測試，並對天然災害(如地震、海嘯、水災、風災)和多重災害之防範、核安法規之健全以及輔助電源進行加強作爲。歐盟進一步要求各國核安全監管機構至遲於 2011 年 6 月 1 日應將該壓力測試(Stress Test)規範送交核電業主，展開重新評估核電廠安全餘裕的三階段程序: **1**) 先期評估 -- 核電業主須回應壓力測試的問題，說明電廠在不同事件情境下的反應作爲，並要求分別於 8 月 15 日和 10 月 31 日提出進度報告及總結報告; **2**) 國家報告 -- 各國核安全監管機構應分別於 9 月 15 日和 12 月 31 日提出對核電業主進度報告及總結報告之各國審查報告，而各國總結報告之審查結果即爲國家報告; **3**) 同行審查(Peer Review) -- 該國家報告須經由同行審查之程序。

歐洲地區係屬相對穩定之古老地質板塊，地質調查資料顯示活動斷層相對較少，近數百年來歷史統計資料亦顯示地震發生頻率相對極少，而且許多擁有核電廠的歐洲國家地處內陸並未瀕臨大海洋，幾乎沒有發生海嘯的經驗，其所處情況與位於環太平洋地震帶的我國和日本有所差異，倒是暴雨引發之水災與龍捲風等風災乃是較爲顯著之天然災害。因此，歐洲之核電廠普遍在防震安全設計基準上較我國和日本在核監管法規上之要求等級爲低。

歐盟之歐洲核安全監管組(ENSREG)於 2012 年 4 月 25 日提出對歐洲核電廠執行之壓力測試同行審查報告(詳請參閱附件二)，由來自 24 個歐洲國家及加拿大、美國、日本、阿拉伯聯合大公國、克羅埃西亞等國家以及歐盟執行委員會(European Commission)之 80 位專家分組進行審查，共計完成 17 份國家報告(包括 15 個歐盟會員國和瑞士，以及烏克蘭)之審查作業並提出各別核電廠之弱點和建議加強改善措施。歐盟之歐洲核安全監管組(ENSREG)和歐盟執行委員會(European Commission)隨之於 4 月 26 日發布壓力測試與同行審查作業共同宣言

(詳請參閱附件三) 。同行審查報告的綜合主要結論與建議有以下 4 項，俾提供歐洲國家進行整體核安全改善作爲:

- 參考國際原子能總署(IAEA)現有的核安全準則，並加入歐盟已有的評估自然災害和超出安全設計基準範圍情形之最佳專業知識，來發行西歐核監管機構協會(WENRA)之天然災害評估準則 (包括地震、水災、極端天氣情況);
- 強調應定期執行定期安全審查的重要性(至少每 10 年一次);
- 實施各項認可的措施 (諸如: 設置於堅固掩體內之儀器、車載式儀器、緊急應變中心) 以保護核電反應器圍阻體的完整性;
- 採取必要之措施 (諸如:防範氫氣爆炸之通風過濾排氣系統) 盡量減小自然災害造成的危害，並限制其後果之擴大。

2012 年 10 月 4 日歐盟執行委員會(European Commission)正式發布對歐洲 68 個核電廠 145 座反應器機組之壓力測試結果報告(詳請參閱附件四)，該壓力測試結果報告除了強調前述 4 項主要結論與建議外，並提出數百項改善措施需要緊急補強(報告中指出，其中有 54 座核電反應器機組對地震風險的考量不足，有 62 座機組對水災風險的考量不足，有 121 座機組應裝置或改善廠內之地震儀器，有 32 座機組尚未裝設圍阻體通風過濾排氣系統，有 81 座機組需增置嚴重事故救援裝備，有 24 座機組尚未建置備份緊急控制室，有 79 座機組須補強嚴重事故管理導則，有 57 座機組須補強緊急操作程序書……等)，俾改善歐洲 145 座核電反應器機組的安全，在未來幾年「必須投入 100 億至 250 億歐元 (約 130 億至 320 億美元) 經費」，並希望核電廠更新改善計畫能於 2015 年前在監督下完工。有鑑於福島核事故之經驗與教訓和壓力測試結果報告所獲得之歐洲核電廠弱點和建議加強改善措施，歐洲議會(European Parliament)最大的歐洲人民黨(European People's Party, EPP Group) 將推動修訂歐洲核安全指令 (Europe's Nuclear Safety Directive) 把"強勢卻合理的最低核安全標準"納入法規。(相關新聞請參閱附件五、六)

法國核電發展情形

核工業在法國是非常先進的，三個法國公司 - AREVA集團，法國天燃氣 Suez 集團和法國電力公司 EdF - 是全球在核工業領域競技場中最重要的球員，而且國家仍在這三個公司中持有大量的股份。

在法國，EdF 公司在全國19個廠址經營著58個核電反應器機組，目前正在法國 Flamanville建設一座歐規壓水式反應器(EPR)大型核電廠，並且另規劃將在 Penly再建設一座 EPR核電廠，是全球最大的核電反應器聚集地之一。EdF 與 AREVA公司設計、維護與運營核電反應器，並對核反應器進行除役。最近該二公司已在英國、美國和中國等地對這些國家的核能計畫進行了重大的投資。

日本福島核事故發生後，當時法國總理立即下令對該國所有的58個核電反應器機組進行安全審查。法國核安全監管機構(ASN)則依據歐盟之歐洲核安全監管組(ENSREG)提出的壓力測試(Stress Test)規範對核電廠安全措施進行整體安全審查。經審查結果，ASN表示法國所有的核反應器機組基本上是安全的，但基於安全的理由堅持它們必須在安全上加以升級。"沒有人能保證在法國永遠不會發生核意外事故，"ASN 的主席 Mr. LACOSTE 曾經表示。他說，"必須盡一切努力來避免發生這樣的意外事故，唯一旦事故發生發生則須減輕其後果，而且 "我們必須具備足夠的能力來管理它們。" (相關新聞請參閱附件七、八)

雖然，法國新任總統歐朗得(Mr. Francois Hollande)將兌現其競選諾言，於2016年底關閉法國最老的有2個較小型核電反應器機組的 Fessenheim核電廠，並加強發展再生能源，將目前佔全國總電力供應量比率75%的核電於2025年縮減至50%。在此同時，總統歐朗得仍然同意繼續Flamanville大型 EPR核電廠的建設工程，亦未阻止規劃在 Penly建造另一座 EPR核電廠，因此法國未來仍將繼續維持運營58個核電反應器機組，而其核電供應能量卻將是有所提升的，不減反增。(相關新聞請參閱附件九)

核能發電乃是法國重點發展科技(包括航太、軍事、核能、生技等)之一，並且核技術與核電輸出是該國年度出口收入的主要來源之一。核能發電並不會排放溫室氣體CO_2，因此核電可視爲“準潔淨能源”。核電供應了法國充足且價廉的電力需求，並對週邊仰賴電力進口的國家如德國、瑞士、盧森堡等提供電力供應服務，賺取大量外匯。再者，法國民眾對核能發電的接受度頗高，反核團體的訴求影響有限，所以無論從當前的核能危機中可獲得什麼樣的教訓，法國是不可能背棄核能的，此乃傳承自受崇敬的前總統戴高樂(Mr. Charles de Gaulle)的遺產和菁英政治的影響，並且在幾十年來的政治主流中已廣泛地被政治家們所接受。綜上所述，職的看法是，法國仍將持續發展核電並搭配發展再生能源，積極建構智慧型電網(Smart Grid)朝增加核電出口比例的方式，俾達到上述階段性政策目標。

[附錄]

附件一、“2011年6月20日維也納舉行之國際原子能總署部長級核安全會議宣言_ Declaration by the IAEA Ministerial Conference on Nuclear Safety in Vienna on 20 June 2011”中英對照版一篇。

附件二、“2012年4月25日對歐洲核電廠執行之壓力測試同行審查報告_ Peer Review Report: Stress tests performed on European nuclear power plants” 報告一篇。

附件三、“2012年4月26日壓力測試與同行審查作業共同宣言_ Stress tests and Peer Review Process Joint statement of ENSREG and the European Commission”報告一篇。

附件四、“歐洲核電廠壓力測試結果報告_ COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT- on the comprehensive risk and safety assessments ("stress tests") of nuclear power plants in the European Union and related activities {SWD(2012) 287 final}”, European Commission, 3 October 2012 報告資料一篇。

附件五、“歐核電廠補強 需砸數百億美元” 2012年10月3日法新社新聞(中央社翻譯)資料一份。

附件六、***NucNet*** “Stress Tests Show ‘*Urgent Measures*’ are Needed on Nuclear Safety, 4 October 2012”、“MEPs Call for ‘*Ambitious But Reasonable*’ EU Safety Directive, 3 October 2012”、 “Europe Continues Work On Revised Nuclear Safety Directive, 21 June 2012” 新聞資料共3篇。

附件七、***NucNet*** “France’s Regulator Calls For ‘*Rapid Increase*’ In Plant Robustness, 29 June 2012”新聞資料一篇。

附件八、“法國將對‘不可思議的’ 意外事故做好準備”, ***Inside NRC*** - Platts: 9 May 2011 翻譯新聞一篇。

附件九、***World Nuclear News*** “France to debate '*energy transition*', 21 November 2012”、“Four years left for *Fessenheim*, 17 November 2012” 新聞資料共二篇。

Declaration by the IAEA Ministerial Conference on Nuclear Safety in Vienna on 20 June 2011

2011 年 6 月 20 日維也納舉行 之國際原子能總署部長級核安全會議宣言

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譯者摘要: 國際原子能總署部長級核安全會議宣言的五個重點爲: **1**) 加強核安全標準; **2**)對所有核電廠進行安全審查，包括擴大國際原子能總署的同行評審計劃; **3**) 提高國家核監管機構的執行效益並確保其獨立性; **4**) 加強全球緊急應變準備和反應系統; 並 **5**) 擴大國際原子能總署在接收與傳播信息的角色。

We, the Ministers of the Member States of the International Atomic Energy Agency (IAEA), gathered in Vienna in light of the serious consequences of the nuclear accident at the Fukushima Daiichi Nuclear Power Station caused by the Great East Japan Earthquake and Tsunami to direct, under the leading role of the IAEA, the process of learning and acting upon lessons to strengthen nuclear safety, emergency preparedness and radiation protection of people and the environment worldwide,

鑒於日本東部大地震和海嘯所引發之福島第一(Fukushima Daiichi)核電廠事故所造成的嚴重後果，我們 — 國際原子能總署(IAEA)會員國的部長們 — 聚集在維也納，在 IAEA 的領導下，指導在所獲得之經驗教訓的基礎上開展學習和採取行動進程，俾加強全世界性的核安全、緊急應變準備，以及對人類與環境的輻射防護，

1. Express sympathy for and solidarity with Japan in connection with the unprecedented earthquake and tsunami of 11 March 2011, which caused much loss of life and severe damage, and the accident at the Fukushima Daiichi Nuclear Power Station; and emphasize the resolve of the international community to continue to assist Japan in its efforts to mitigate and overcome the consequences of the disaster and the accident;

   爲2011年3月11日日本所發生前所未見的地震和海嘯，以及福島第一核電廠的核事故導致重大的生命損失與嚴重的損害，對日本方面表示同情和聲援; 並強調國際社會的決心，將繼續協助日本努力減輕和克服此次災難和事故所造成的後果;

2. Recognize the efforts of the international community to enhance knowledge in nuclear safety and radiation protection and strengthen international standards in nuclear safety, emergency preparedness and response and radiation protection of people and the environment and the need to draw the lessons from the accident at the Fukushima Daiichi Nuclear Power Station;

   認知到國際社會爲增進核安全與輻射防護知識、加強核安全、緊急應變準備與反應和對人類與環境輻射防護領域之國際標準所做的努力，以及需要從福島第一核電廠事故中汲取經驗教訓的必要性;

3. Recognize that some States consider nuclear power as a viable option in meeting their energy needs, while other States have decided not to use or to phase out nuclear energy;

認知到有一些國家認爲核電是可作爲滿足其能源需求的一個可行選項，而也有一些其他國家已經決定不使用或逐步停止使用核能;

4. Recognize that nuclear accidents may have transboundary effects and raise the concerns of the public about the safety of nuclear energy and the radiological effects on people and the environment; and emphasize the importance of adequate responses based on scientific knowledge and full transparency, should a nuclear accident occur;

認知到核事故可能造成跨越國境的影響，並引起公眾對核能的安全及輻射對人類與環境影響的關切; 並強調如果真的發生了核事故，應根據科學知識和充分的信息透明度做出適切反應的重要性;

5. Underline that States with nuclear power programmes have a central role in ensuring the application of the highest standards of nuclear safety; and emphasize the responsibility of these States for providing a timely, transparent and adequate response to nuclear accidents in order to minimize their consequences;

重點強調擁有核電計劃的國家應在確保適用最高核安全標準方面發揮其核心作用;並強調這些國家有責任對發生之核事故提供及時、透明和適當的應對措施，俾盡最大努力減小事故之後果;

6. Emphasize the importance of implementing enhanced national and international measures to ensure that the highest and most robust levels of nuclear safety are in place, based on IAEA safety standards, which should be continuously reviewed, strengthened and implemented as broadly and effectively as possible and commit to increase bilateral, regional and international cooperation to that effect;

強調依據國際原子能總署安全標準執行經過加強的國家與國際處置措施的重要性，以確保落實最高和最強勢水平的核安全，並應不斷審查、加強和儘可能廣泛地且有效地施行國際原子能總署安全標準，以及承諾爲此而增進雙邊、區域和國際合作;

7. Commit to strengthening the central role of the IAEA in promoting international cooperation and in coordinating international efforts to strengthen global nuclear safety, in providing expertise and advice in this field and in promoting nuclear safety culture worldwide;

承諾加強國際原子能總署在促進國際合作，與協調國際間加強全球核安全的努力、提供核專業領域知識與建議、以及在促進全球核安全文化方面的核心作用;

8. Encourage the close cooperation and coordination among the relevant intergovernmental and non-governmental organizations on nuclear safety related matters;

鼓勵各相關政府間組織和非政府組織在核安全相關問題上進行密切的合作和協調;

9. Stress the importance that the IAEA should be further enabled to meet the high level of public expectation to provide timely, factually correct and objective information and assessments of nuclear accidents and their radiological consequences;

強調應進一步增強國際原子能總署能力的重要性，俾滿足公眾對其應及時提供符合事實的客觀信息，以及有關核事故和其放射性影響後果評估意見之高度期望;

10. Welcome the reports submitted by Japan and the IAEA International Fact-Finding Mission to Japan, which include preliminary assessments of the accident at the Fukushima Daiichi Nuclear Power Station;

歡迎日本和國際原子能總署派往日本的國際實況調查團所提交的報告，其中包括對日本福島第一核電廠事故的初步評估報告;

11. Stress the need to receive from Japan and the IAEA a comprehensive and fully transparent assessment of the Fukushima Daiichi Nuclear Power Station accident in order for the international community to be able to draw and act upon the lessons learned, including a review of IAEA safety standards that are relevant to the accident, in particular those pertaining to multiple severe hazards;

強調需要從日本和國際原子能總署收到對日本福島第一核電廠事故之全面和充分透明的評估結果，俾使國際社會能夠汲取所獲得的經驗教訓並在這些經驗教訓的基礎上採取行動，包括審查原子能總署裡與此次事故相關的安全標準，特別是那些涉及多重嚴重危害的安全標準;

12. Underline the benefits of strengthened and high quality independent international safety expert assessments, in particular within the established IAEA framework, through periodic reviews and evaluation missions assessing national regulatory frameworks, emergency preparedness and response and nuclear power plant operation in order to ensure continuous improvement of the safety of nuclear installations on the basis of internationally agreed rules and procedures;

重點強調國際安全專家所作出經加強的高品質獨立評估報告之效益 — 特別是在既定之國際原子能總署框架內，通過定期審查和其評審訪問團對國家監管框架、緊急應變準備和反應，以及核電廠運作情況的評估，俾於國際商定之規則和程序的基礎上持續改進，以確保核設施安全;

13. Encourage States with operating nuclear power plants to conduct, as a response to the accident at the Fukushima Daiichi Nuclear Power Station, comprehensive risk and safety assessments of their nuclear power plants in a transparent manner;

鼓勵擁有正在營運核電廠的國家以公開透明的方式對其核電廠進行全面性的風險和安全評估，作爲對日本福島第一核電廠事故的應對;

14. Emphasize the responsibility of the nuclear industry and operators in the implementation of nuclear safety measures and call upon them and their associations to fully support and actively contribute to international efforts to enhance nuclear safety by, inter alia, furthering transparency and prioritizing safety considerations;

強調核產業界和營運者在執行核安全措施方面的責任，並呼籲他們及其所屬協會全力支持並積極促進加強核安全之國際努力，尤其是，進一步提高透明度和優先考慮安全因素;

15. Commit to further strengthening the authority, competence and resources of national regulatory authorities, including through appropriate technical and scientific support and to continuously ensure their effective independence;

致力於進一步加強國家監管當局的權威、能力和資源，包括透過給予適當技術上的和科學上的支援，並持續確保其有效獨立性;

16. Reiterate the importance of universal adherence to and the effective implementation and continuous review of the relevant international instruments on nuclear safety, consider the possibility of strengthening the international legal framework in this area; and recognize the Agency's enhanced efforts to that effect;

重申普遍遵守和有效執行以及持續審查核安全相關國際工具的重要性，考慮在這一領域加強國際法律框架的可能性，並認知到國際原子能總署爲此已加強了努力;

17. Underline further the importance of adequate, prompt and continuous information sharing in the case of an accident, transparency and exchange of best practices among States in all aspects of nuclear safety;

進一步重點強調在發生核事故的情況下，適當、迅速和持續之信息共享的重要性，各國之間應就核安全的所有方面進行公開透明和最佳做法之交流;

18. Underline that the freest possible flow and wide dissemination of safety related technical and technological information enhances nuclear safety, which is essentially technical in nature and of global concern; and note the role that innovative technologies can play in improving nuclear safety;

重點強調讓安全相關的技術和科技資訊能夠最自由的可能流通與廣泛的傳播，可以加強基本上屬於技術性質並爲全球所關注的核安全問題; 並注意到創新技術可以在提升核安全方面扮演的角色;

19. Emphasize the need to improve national, regional and international emergency preparedness and response to nuclear accidents, including through the possible creation of rapid reaction capacity and the development of training in the field of crisis management at the regional and international levels, as well as to strengthen cooperation among national authorities, technical safety organizations, operators and among relevant intergovernmental and non-governmental organizations; and call for a strengthened role of the IAEA in emergency preparedness and response by promoting and possibly expanding existing IAEA response and assistance capabilities;

強調需要加強國家、區域和國際之核事故緊急應變準備和反應的能力，包括透過在區域和國際層级建立可能的快速反應能量和發展危機管理領域的培訓，以及加強國家監管機關、技術安全組織、營運者與各相關政府間組織和非政府組織之間的合作; 並呼籲通過促進和可能地擴大現有國際原子能總署的反應和援助能力，來加強國際原子能總署在核事故緊急應變準備和反應領域的角色;

20. Underline the need for States operating nuclear power programmes and the IAEA to promote capacity building, including education and training for both regulators and operators;

重點強調目前正營運核電計劃的國家和國際原子能總署需要促進其能力建設，包括對監管者和營運者的教育和培訓;

21. Underline the need for States planning to embark on a nuclear power programme to create an appropriate nuclear safety infrastructure based on IAEA safety standards and relevant guidance and assistance, using, among others, effective IAEA technical cooperation mechanisms for supporting the safe and secure use of nuclear technologies;

重點強調正在規劃從事核電計劃的國家有必要依據原子能總署的安全標準與相關導則和協助爲基礎，來建立一個適當的核安全基礎架構，其中包括，利用國際原子能總署支持運用核技術安全和保安之有效技術合作機制;

22. Recognize the need for a global nuclear liability regime that addresses the concerns of all States that might be affected by a nuclear accident with a view to providing appropriate compensation for nuclear damage;

認知到需要制定一個全球性的核損害賠償責任制度，俾解決所有可能會受到核事故影響國家所關切的問題，以期對核損害做出適當的賠償;

23. Request the IAEA Director General to prepare a report on the June 2011 IAEA Ministerial Conference on Nuclear Safety and a draft Action Plan, building on this Declaration and the conclusions and recommendations of the three Working Sessions, and the expertise and knowledge available therein; and to promote coordination and cooperation, as appropriate, with other relevant international organizations to follow up on the outcomes of the Conference, as well as facilitate consultations among Member States on the draft Action Plan;

請國際原子能總署署長以本”宣言”和三個工作組會議的結論和建議，以及其中所載之專業技術和知識爲基礎，編寫一份關於 2011 年 6 月國際原子能總署部長級核安全會議的報告和一項”行動計劃(草案)”; 並爲促進協調與合作酌情與其他相關的國際組織共同貫徹本次會議的成果，以及促進會員國之間對此”行動計劃(草案)” 的磋商;

24. Request the IAEA Director General to present this report and the draft Action Plan covering all the relevant aspects relating to nuclear safety, emergency preparedness and response and radiation protection of people and the environment, as well as the relevant international legal framework, to the IAEA Board of Governors and General Conference at their forthcoming meetings in 2011;

請國際原子能總署署長將這份報告和涵蓋了與核安全、緊急應變準備和反應、對人類與環境的輻射防護有關之所有相關方面，以及有關國際法律框架的”行動計劃(草案)”提交於國際原子能總署理事會和會員大會在 2011 年即將召開的會議;

25. Call upon the IAEA Board of Governors and the General Conference to reflect the outcome of this Conference in their decisions and to support the effective, prompt and adequately resourced implementation of the Action Plan.

呼籲國際原子能總署理事會和會員大會在其決議中反映本次部長級核安全會議的成果，並支持有效率的、迅速的和提供適當的資源來執行本”行動計劃”。

Post-
Fukushima
accident

Peer review report

Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

Executive Summary

General context

Following the severe accidents which started in the Fukushima Dai-ichi NPP on 11 March 2011, the European Council of 24/25 March 2011 requested that a comprehensive safety and risk assessment, in light of preliminary lessons learned, be performed on all EU nuclear plants. The request of the Council included "stress tests" performed at national level complemented by a European peer review. This was the first time that such a multilateral exercise covering over 140 reactors in all EU countries operating nuclear power plants was considered. The Council invited the European Nuclear Safety Regulators Group (ENSREG) and the European Commission to develop the scope and modalities for the stress tests with the support of the Western European Nuclear Regulators' Association (WENRA). WENRA drafted the preliminary stress tests specifications in April. Consensus on these specifications was achieved by ENSREG and the European Commission on 24 May 2011. The Commission and ENSREG agreed that the work on the stress tests should be carried along two parallel tracks; a safety track to assess how nuclear installations can withstand the consequences of various extreme external events and a security track to analyse security threats and incidents due to malevolent or terrorist acts. The work on security is carried out by an Ad hoc Group on Nuclear Security composed of Member States experts and is outside the scope of this report. The specifications of the peer review as well as a working paper on the transparency aspects of the EU stress tests were agreed upon at the 11 October 2011 ENSREG meeting.

Stress tests and peer review organisation

The safety track of the stress tests and peer review focus on three topics which are directly derived from the preliminary lessons learned from the Fukushima disaster and confirmed by the IAEA missions following the accident and reports from the Japanese Government. Natural initiating events, including earthquake, tsunami and extreme weather, the loss of safety systems and severe accident management are the main topics for review. The stress tests and peer review assess these topics in a three step process. The first step requires the operators to perform an assessment and make proposals for safety improvements, following the ENSREG specifications. The second step is for the national regulators to perform an independent review of the operators' assessments and issue requirements, whenever appropriate. The last step is a European peer review of the national reports submitted by regulators.

The objectives of the peer review were to assess the compliance of the stress tests with the ENSREG specifications, to check that no important problem has been overlooked and to identify strong features, weaknesses and relevant proposals to increase plant robustness in light of the preliminary lessons learned from the Fukushima disaster.

The 15 European Union countries with nuclear power plants as well as Switzerland and Ukraine performed the stress tests and were subjected to the peer review. The operators submitted their final assessments on 31 October 2011 and the regulators submitted their final national reports on 31 December 2011. The peer review started on 1 January 2012.

The peer review was managed by a Board that consisted of seven senior regulators from EU countries and an EC senior manager. Each national regulator was invited to nominate one expert for each of the three topical areas. Most of the experts were experienced regulators. Knowledgeable scientists or consultants designated by regulators also participated. The European Commission also nominated experts. There were over 70 reviewers from 24 European countries participating in the peer review. Observers from several non-EU countries (Canada, Croatia, Japan, UAE and USA) as well as the IAEA also attended.

The peer review itself started with a desktop review of the national reports. Each reviewer had access to all the reports and could generate written questions to the national regulators. Over 2000 questions were generated. Following the desktop review, all peer reviewers met in Luxembourg on Sunday 5 February, for a full two week topical review. The review was structured by the 3 topics of the stress tests: natural hazards, loss of safety systems and severe accident management. The experts were grouped in 3 topical teams. Each topical team was composed of approximately 23 reviewers. Each of the 17 countries subjected to the peer review had to make a presentation to each of the three topical teams, to answer the written questions as well as additional questions asked during presentations. In-depth discussions on the results of the topical reviews were then performed within each of the teams until a consensus was reached. The findings of the review were shared between the 3 teams at the end of the process. Finally, the results of the review were grouped country by country in order to produce draft country reports.

In March 2012 a series of country reviews began. Each country subjected to the peer review was visited by a team of eight peer reviewers for three or four days. Complementary discussions were held in order to obtain appropriate answers to the questions left open after the topical review as well as clarification on important issues. A plant selected by the review team was also visited in each country. The reports drafted during the topical reviews were completed using additional information obtained during the visits. They were discussed within the teams in order to reach a consensus and finalised. The national regulator had the opportunity to make remarks but the final decision belonged to the review team. The 17 country reports are included as annexes to this report. They were used by the peer review Board to refine the preliminary conclusions drawn from the topical reviews and to write this report.

Transparency and an opportunity for public involvement have been objectives from the beginning. In pursuit of these objectives, the national reports have all been made public in English and most in the national language. The final peer review report with the country review annexes is also available publicly. The ENSREG and the peer review Board hosted a public meeting in January 2012 to inform the stakeholders and seek comments. Suggestions were collected on a public website in January 2012 and were later considered during the peer review process. Comments related to specific countries or reactors were forwarded to the responsible national regulators. Overall the public input has improved the stress test peer review process. Comments received in the public meeting influenced the structure of the final report. An additional public meeting is planned for 8 May 2012 in Brussels to present the results and answer questions.

<u>Main results of the peer review</u>

The peer review concluded that all countries have taken significant steps to improve the safety of their plants, with varying degrees of practical implementation. In spite of differences in the national approaches and degree of implementation, the peer review showed an overall consistency across Europe in the identification of strong features, weaknesses and possible ways to increase plant robustness in light of the preliminary lessons learned from the Fukushima disaster. As a result of the stress tests, significant measures to increase robustness of plants have already been decided or are considered. Such measures include provisions of additional mobile equipment to prevent or mitigate severe accidents, installation of hardened fixed equipment, and the improvement of severe accident management, together with appropriate staff training measures. In many cases, important modifications are being prepared for the near future. Details about national situations, as well as recommendations to national regulators, can be found in the attached country reports.

The peer review also identified four main areas of improvement to be considered at the European level, as presented in the following paragraphs.

<u>European guidance on assessment of natural hazards and margins</u>

Overall, the compliance with the ENSREG specification was good with regard to design basis for earthquake and flooding. However there was a lack of consistency identified with respect to natural hazards where significant differences exist in national approaches and where difficulties were encountered with beyond design margins and cliff-edge effects assessments. Therefore:

The peer review Board recommends that WENRA, involving the best available expertise from Europe, develop guidance on natural hazards assessments, including earthquake, flooding and extreme weather conditions, as well as corresponding guidance on the assessment of margins beyond the design basis and cliff-edge effects.

<u>Periodic Safety Review</u>

The peer review demonstrated the positive contribution of periodic safety reviews as an efficient tool to maintain and improve the safety and robustness of plants.

In the context of the peer review, this finding is especially relevant for the protection of installations against natural hazards. Therefore:

The peer review Board recommends that ENSREG underline the importance of periodic safety review. In particular, ENSREG should highlight the necessity to re-evaluate natural hazards and relevant plant provisions as often as appropriate but at least every 10 years.

Containment integrity

The Fukushima disaster highlighted once again the importance of the containment function, which is critical, as the last barrier to protect the people and the environment against radioactive releases resulting from a nuclear accident. This issue was already extensively considered, as a follow-up of previous accidents, and possible improvements were identified. Their expeditious implementation appears to be a crucial issue in light of Fukushima accident. Therefore:

Urgent implementation of the recognised measures to protect containment integrity is a finding of the peer review that national regulators should consider.

The measures to be taken can vary depending on the design of the plants. For water cooled reactors, they include equipment, procedures and accident management guidelines to:

- depressurize the primary circuit in order to prevent high-pressure core melt;
- prevent hydrogen explosions;
- prevent containment overpressure.

Prevention of accidents resulting from natural hazards and limiting their consequences

The Fukushima disaster has also shown that defence-in-depth should be strengthened by taking into account severe accidents resulting from extreme natural hazards exceeding the levels taken into account by the design basis and current safety requirements applicable to the plants. Such situations can result in devastation and isolation of the site, an event of long duration, unavailability of numerous safety systems, simultaneous accidents of several plants including their spent fuel pools, and the presence of radioactive releases. Therefore:

Necessary implementation of measures allowing prevention of accidents and limitation of their consequences in case of extreme natural hazards is a finding of the peer review that national regulators should consider.

Typical measures which can be considered are bunkered equipment to prevent and manage severe accident including instrumentation and communication means, mobile equipment protected against extreme natural hazards, emergency response centres protected against extreme natural hazards and contamination, rescue teams and equipment rapidly available to support local operators in long duration events. Such possible measures, as identified by the peer review, are detailed in the report.

Future actions

The peer review Board recognises that full understanding of the Fukushima accident will be a long-term process extending over several years, possibly a decade. The peer review has demonstrated the benefit of sharing between national regulators the results of the stress tests and ideas for strengthening safety and robustness of plants. In the spirit of continuous improvement for safety, the peer review Board considers that a follow-up of the actions resulting from the present stress tests as well as future assessments would be beneficial. Such a follow-up should be organised in the frame of the existing arrangements, rather than creating new ones.

One of the important results of the public interaction is a strong demand for a European initiative on off-site emergency preparedness. This subject was not part of the mandate of the peer review. However, the Board recognises importance of off-site emergency preparedness in Europe, as a follow-up of the Fukushima disaster.

Finally, it should be mentioned that performing such a peer review was a challenge and required very significant resources from the participating countries. In that sense, it should be considered as an exceptional exercise, which cannot be reproduced frequently. Notwithstanding, it was judged very positively by most of the participants and is expected to contribute to enhancing safety in Europe and in each European country.

1 INTRODUCTION

1.1 Mandate by the European Council and ENSREG specifications

The nuclear accident that occurred at the Fukushima Dai-ichi nuclear power plant in Japan, following the earthquake and tsunami of 11 March 2011, raised considerable attention on nuclear safety, worldwide.

While initiatives were taken in Member States by Governments and Safety Authorities, the European Commission and EU national nuclear safety regulators launched a process to carry out EU-wide risk and safety assessments of nuclear power plants ("stress tests"). The initiative was supported by the European Parliament and endorsed by the European Council (EU Council) at its meeting of 24 – 25 March 2011[1]. In its request the EU Council asked ENSREG and the Commission to carry out the assessment by *independent national authorities and peer review; their outcome and any subsequent measures that will be taken should be shared with the Commission and within ENSREG and should be made public.* The EU Council also stated that the *EU will request that similar "stress tests" be carried out in neighbouring countries and worldwide, regarding both existing and planned plants.*

The Commission and ENSREG agreed that the work on the stress tests should be conducted in two parallel tracks, as defined by the ENSREG and European Commission (EC) specifications[2]:

- A Safety Track to assess how nuclear installations can withstand the effects of extreme events. A detailed specification is annexed to the ENSREG declaration.
- A Security Track to analyse security threats and the prevention of, and response to, incidents due to malevolent or terrorist acts. The work on security is carried out by an Ad hoc Group on Nuclear Security composed of experts from the Member States, with the participation of the Commission and is outside the scope of this report.

1.2 Stress tests process and objectives

ENSREG initially defined a "stress test" as a targeted reassessment of the safety margins of nuclear power plants in the light of the events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident. As such, the main aim of stress tests is to assess the safety and robustness of nuclear power plants (NPPs) with regard to the preliminary lessons learned from Fukushima.

For this purpose, they go beyond the safety evaluations made during the licensing process and periodic safety reviews (PSRs).

Stress tests are conducted on a voluntary basis by the participating countries following a three-step process:

1. Assessment by the nuclear operators (licensees) during the period June – October 2011,
2. Review by national authorities (regulators) by end 2011, and
3. European peer reviews from January 2012 until April 2012.

In the first step, operators have analysed the robustness of their plants against the ENSREG specifications and proposed improvements. They reported mainly on the following topics:

- Topic 1: Initiating events: earthquakes, flooding and extreme weather conditions,

[1] EUCO 10/11 (paragraph 31)

[2] http://ec.europa.eu/energy/nuclear/safety/doc/20110525_eu_stress_tests_specifications.pdf (Declaration of ENSREG, 13 May 2011).

- Topic 2: Loss of safety systems: issues related to loss of power or ultimate heat sink; or a combination of both, as a consequence of any event, and
- Topic 3: Severe accident management (SAM)

In the second step, national regulators evaluated the work of the operators and eventually imposed additional requirements on them. The regulators summarised the situation in national final reports. These reports were submitted to the EC by 31 December 2011.

In the third step, a team of peer reviewers have reviewed the national reports and presented a set of conclusions and recommendations. This report summarises and provides an overview of the whole process.

1.3 Peer review objectives

The ENSREG requirements [2] noted that a transparent EU-wide review was needed in order to enhance credibility and accountability in the national stress tests performed by the 17 participating countries[3] and summarised in their national reports.

The peers reviewed the comprehensiveness and the consistency with standards of the approaches taken by the operators and the national regulators in their work.

1.4 Purpose of the present report

The results of the peer reviews are summarised in this report. The purpose of this report – as prepared by the peer review Board is threefold:

a) To describe the peer review process,
b) To provide ENSREG with the outcome of the peer review process,
c) To present the main results in terms of strong features, weak points, identified measures already taken at national level as well as indicating areas to be considered for possible further improvements.

2 DESCRIPTION OF THE PEER REVIEW PROCESS

2.1 General approach

The main purpose of the final national reports is to evaluate the safety assessments performed by the operators as well as proposed measures for possible improvement and if necessary identify additional needed improvements.

The peer review teams reviewed the 17 final national reports according to the following methodology:

- First, the peer reviews were conducted on a topical basis, assessing the national reports in the three topical areas (extreme natural hazards, loss of safety systems, and severe accident management issues). In the course of these topical reviews, three expert teams analysed the contributions from all countries on the particular topic.
- Next, the results for each of the topical reviews were incorporated into draft country reports for each country. These draft country reports, including lists of complementary questions to be clarified, were then finalised during specific country visits by dedicated country review teams.

[3] **15 EU Member States** (Belgium, Bulgaria, Czech Rep., Finland, France, Germany, Hungary, Lithuania, Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom) and **2 Neighbouring Countries** (Switzerland, Ukraine).

ENSREG and the EC agreed on the composition of the peer review teams, consisting of experts from nuclear and non-nuclear Member States and participating neighbouring countries, as well as from the EC (Directorate-General for Energy and the Commission's Joint Research Centre (JRC)):

- Each of the three topical review teams comprised 20-30 experts, with a team leader, a deputy team leader and two rapporteurs. Members of the team whose national facilities were under review were not part of that specific review. Observers from Canada, Croatia, Japan, the UAE, the USA and the International Atomic Energy Agency (IAEA) also participated.
- The six country review teams, visiting 17 countries, each comprised eight experts, including a team leader and a rapporteur. The EC provided the rapporteur and one member in each review team.

A peer review secretariat was also created with the support of the JRC of the EC.

2.2 Project organisation

2.2.1 Board

ENSREG and the EC decided to establish a peer review Board to provide adequate supervision, ensure consistency and provide a report to ENSREG on the peer review process. The Board comprises:

- A Chairperson (Ph. Jamet – France),
- A Deputy Chairperson (A. Gurgui – Spain),
- A project manager with the task of ensuring overall coordination of the activities (P. Krs – Czech Republic),
- Three team leaders of the topical reviews (D. Shepherd (UK) for Topic 1, E. Liszka (Sweden) for Topic 2 and J. Misak (Slovak Republic) for Topic 3,
- A representative of non-nuclear Member States (A. Molin – Austria), and
- A representative of the European Commission (M. Garribba – Directorate-General for Energy).

2.2.2 Review teams

The peer review experts proposed for participation in topical and country reviews were nominated by the participating countries and the EC, and communicated to the peer review secretariat:

- Each Member State, each fully participating neighbouring country[4] and the European Commission, had the right to nominate one expert for each of the three topical review teams.
- The qualifications of the experts were decided by the nominating parties; information on the experts background was provided to facilitate the composition of balanced country review teams.
- In nominating their participants for the topical review teams, countries also indicated whether their nominees could serve as team leaders or deputy team leaders.
- The appointment of topical review team leaders and deputy team leaders was agreed by ENSREG and the EC.

The country review teams were assembled by the peer review secretariat on the basis of the persons suggested and the countries to be visited by each team. The composition of each team was then confirmed by the peer review Board and the respective country.

In the appointment of the country review teams, the principle followed was that each team has two reviewers for each topic of the topical review. This ensures consistency and continuity from the topical to the national parts of the review.

[4] i.e. Switzerland and Ukraine.

The list of reviewers is included in appendix 2.

2.2.3 EC support

Facilities, organisational and financial support was provided by the EC for the peer reviews and the Board meetings in Brussels and Luxembourg. Thirteen experts from the EC (Directorate-General for Energy and JRC) participated in the topical and the country reviews. The EC JRC provided the peer review secretariat.

2.3 Project implementation and schedule

2.3.1 Pilot phase

A peer review pilot exercise was performed on 7 and 8 December 2011 at the EC Directorate-General for Energy premises in Luxembourg. This exercise comprised the review of one example national report, covering the three above topics. UK, Germany and Finland volunteered to submit a draft national report each on one topic for the pilot review.

Given the complexity and the time scale of the peer review phase, the pilot phase was designed to test all the subsequent phases of the peer review process and allow their smooth management. The pilot phase identified a number of adjustments needed in the process while concluding that the process is realistic and the given time schedule, although very ambitious, is achievable.

2.3.2 Desktop review

A desktop review was performed by each participating expert on all national reports or a subset of them (each national report was reviewed by at least 3 experts) during the period 1 – 20 January 2012.

Written questions were sent by each expert to the secretariat and to the respective country. The secretariat then compiled and grouped questions and sent them to all reviewers of the respective topic and to the respective countries, with the aim of facilitating the discussion during the topical review meetings in February. **In total, more than 2000 questions were received from reviewers in preparation of the topical reviews[5].** Individuals responsible for drafting the country report prepared the first version of the country report.

2.3.3 Topical reviews

Over the period 5-17 February 2012, the topical reviews were performed at the EC premises in Luxembourg. Three national reports were presented each day (in parallel for the three topical review groups), followed by question and answer sessions.

Groups of experts from the national regulators of the 17 participating countries presented their respective national reports for each specific topic and answered the questions sent in advance (originating from the desktop review) and those raised spontaneously during the meeting.

On the basis of these discussions, topical country summaries were improved and agreed upon within the respective groups.

Next, topical country summaries were assembled and harmonised across countries and topics in order to produce one draft topical review report for each of the three topics. These documents included not only a summary of the respective issues per country, but also highlighted corresponding strengths and weaknesses identified by the national regulators or the peer review teams.

Similarly, the topical country reviews were used to develop draft country-specific reports, including lists of complementary questions and issues to be clarified during the country reviews.

2.3.4 Country reviews

Six teams of varying composition were set up to visit each of the 17 participating countries during March 2012 and perform a more detailed review of the country report. In order to maintain a clear link

[5] See Annex.

with the topical reviews, teams included two reviewers who attended the topical review for each topic, a team leader and a rapporteur. To prevent any conflict of interest, the reviewers were not allowed to originate from a country which the team would be reviewing. Teams have been constructed also taking into account the preferences of each Member State in peer reviewing the report of other Member States.

Draft country reports were sent to each country at the end of the topical review phase. E-mail or phone discussions on the reports started before the country review took place in order to prepare the country visit and ensure full mutual understanding of the issues to be reviewed.

Country reviews focused on questions, comments, and recommendations identified during the topical review. The purpose of the visit was to examine and resolve issues identified during the earlier stages of the process. In order to guarantee rigor and objectivity, the national regulator under review was asked to allow access to all necessary information by the peer review team, subject to the required security clearance procedures. Staff and facilities were also made available to the visiting team to discuss the open issues. A visit to a NPP selected by the review team was organised in each country in order to provide complementary information on some aspects of the implementation and results of the stress tests.

2.3.5 Identification of final conclusions

The peer review process led to final conclusions being reached concerning the consistency of the exercise, the common issues identified through the topical reviews as well as country-specific issues that are detailed in the country reports attached to this report. The last chapter of this report contains the conclusions reached by the peer review Board.

The present report summarises the results and conclusions of the peer review. It includes 17 country reports as annexes.

3 TRANSPARENCY AND PUBLIC INVOLVEMENT

3.1 Background and framework

The EU Council of March 2011 requested that all necessary information be provided to the public and that the outcome of the stress tests and any necessary subsequent measures to be taken should be made public.

Being aware that full transparency, combined with this opportunity for public involvement, would contribute to the stress tests being recognised by European citizens, ENSREG decided that national regulatory authorities should be guided by the "principles for openness and transparency"[6] as adopted by ENSREG in February 2011 and that these principles should also apply to the stress tests (Annex I to the Declaration of ENSREG of May 2011[7]).

The means of ensuring full transparency and also providing an opportunity for public involvement were finalised in October 2011 and have subsequently been published[8].

3.2 Information on the ENSREG web site

ENSREG decided that information about the stress tests would be made available on a dedicated location on its website. The site includes information about the background and specifications, the stress test process, the timetable as well as the composition of peer review teams. In addition, information on peer review progress has been provided by two monthly updates for February and March 2012.

National reports (both progress reports and final reports) have been made available in a timely manner as was the report to the EU Council by the EC.

[6] HLG_p(2011-14)_57 – 'Principles for Openness and Transparency'.
[7] HLG_p(2011-15)_66 – 'Scope and modalities for comprehensive risk and safety assessments'
[8] HLG_p(2011-16)_80 – 'Transparency aspects in the implementation, reporting and follow-up of the stress tests'

This report, including the country-specific peer review reports, will also be available on the ENSREG website.

ENSREG also recommended that the operator reports be published, provided that this does not jeopardize other interests, for example security, recognised in national legislations or international obligations, in line with Annex I of the "Declaration of ENSREG". Many operators followed this recommendation.

Furthermore, comprehensive information relevant for public involvement is presented and regularly updated, including presentations, the summary and conclusion of the January public event.

3.3 Participation of Board members in national and other meetings

ENSREG stated that, at the national level, regulators should consider how to engage the public by organising a structured and comprehensive information process. During the January public event, members of the public noted that local events would be more effective than a large public event in Brussels. As such, in the view of the peer review Board, organisation of local public events sponsored by the national regulatory authorities was a good idea. Such events took place in a number of countries. Members of the peer review Board offered to take part and were therefore invited to some of the public events.

In addition, members of the peer review Board made a number of presentations at various other meetings at national, European and international levels.

3.4 Suggestions raised by the public on the Web site, answers and contributions to the peer reviews

A number of questions and suggestions were posted on a public website in the period 1 - 20 January 2012. They were published on the ENSREG website and far more questions and suggestions were raised during the public event held on 17 January 2012, in Brussels.

A summary of these questions and suggestions as well as pertinent answers was compiled by the end of January and published on the ENSREG website. The main issues were:

- public involvement;
- off-site emergency preparedness;
- security issues, airplane crash in particular; and
- the stress test peer review process.

The ENSREG website will be open again from 25 April to 6 May to collect comments on this report.

3.5 Main output and conclusions of the interactions of the European stakeholders at the beginning of the process, contribution to the peer reviews

The January public event associated with the stress tests peer review was well attended. There was sufficient time for question and answer sessions which permitted an open and constructive discussion. Participants used the opportunity to express their views on the process, to share comments, to express their expectations of the ongoing process. They also extensively discussed with representatives of the organisations that played a role in developing and organising the stress tests and peer reviews, including the EC, ENSREG, WENRA and the peer review Board.

The chairman of the public event summarized the main conclusions which were also published on the ENSREG website. He highlighted the unique character of the stress tests. The decision to conduct European stress tests in a coordinated way has generally been appreciated. Topics addressed in the scope of the stress tests and stress test specifications were generally well received, however, he noted scepticism remaining regarding topics not included in the stress tests and its specifications. The stress tests execution has been globally welcomed. It was recognised that operators and regulators have provided extensive analyses. They have respected the given deadlines and published their respective reports, providing comprehensive information to all interested parties, including means for public participation. He also noted that the independence of the review process was questioned. Many participants expressed high expectations with regard to the outcome of the peer review. In particular the peer review Board and ENSREG were expected to establish a common and consistent European dimension in the evaluation of the stress tests results. It was expected that the outcome of the stress tests would be validated against existing international standards for nuclear safety and the WENRA reference levels, where applicable. Finally, a need for continuous improvement beyond the stress tests was unanimously recognised, while views differed on the pertinent priorities.

The present report contains a number of recommendations for future actions to address major issues in this regard. It also takes into account suggestions and comments provided by European stakeholders.

3.6 Presentation of final conclusions to European stakeholders

This report and its findings in particular, will be presented at a second public event to be held in the first half of May 2012. This period was selected late enough to enable members of the public to review this report before the public event and early enough for the outcome of this second public event to be reflected in the European Commission's final report to the European Council.

4 GENERAL QUALITY OF NATIONAL REPORTS AND NATIONAL ASSESSMENTS

4.1 Compliance of the national reports with the topics defined in the ENSREG stress tests specifications

In general terms, all the national reports addressed the three topics defined in the ENSREG stress tests specifications.

For topic one, natural external hazards, ENSREG identified three areas of investigation - earthquake, flooding and extreme weather. Although most national reports address the design basis for earthquake (DBE) and flooding (DBF) reasonably well, very few assess cliff-edge situations in the manner requested by ENSREG. This is possibly because of the short timeframe of the stress tests exercise. Many countries indicated that future work in this respect is either ongoing or is planned in the near future. Several national reports noted that addressing cliff-edge effects for flooding is not necessary. This was accepted by the peer review for external flooding if it can be demonstrated that such flooding is practically impossible due to local geography. The peer review identified that a systematic assessments along the lines proposed by ENSREG is worthwhile. The peer review Board recommends that WENRA, involving the best available expertise from Europe, develop guidance on natural hazards assessments, including earthquake, flooding and extreme weather conditions, as well as corresponding guidance on the assessment of margins beyond the design basis and cliff-edge effects.

For the topic two, the reports covered all areas prescribed by the ENSREG specifications - loss of offsite power (LOOP), station blackout (SBO) and loss of ultimate heat sink (UHS), plus combinations thereof. In all cases, national reports extensively assessed the plant responses to specific events, also indicating the margins (time) available until specific remedial measures need to be undertaken. The stress tests confirmed that all the countries rely on well developed regulatory requirements, in line with IAEA standards and guidance. Nevertheless, differences in plant design bases lead to particular differences in response to events evaluated. The peer review process offered a good opportunity for experts from participating countries to understand such differences and utilise lessons learned for identification of further improvements.

The information provided in the national reports on topic three, severe accident management, addressed the topics of the ENSREG specifications in full. National reports describe existing accident management and on-site emergency arrangements, as well as measures for further enhancement of the provisions. However, their presentation and level of detail does not always follow the format proposed by ENSREG.

4.2 Adequacy of the information supplied, consistency with the guidance provided by ENSREG

All participating countries submitted reports on the conduct and regulatory assessment of their respective national stress tests on time. As mentioned above, there were differences in approach, both in the methodology of various investigations and in the form of reporting. Nevertheless, this is to be expected since the ENSREG stress tests exercise is novel and was conducted over a deliberately compressed timescale. Taking account of the circumstances, these variations were considered acceptable, and did not impact the outcome of the stress tests. The main constraint was the time available for each phase of the stress tests process and the regulatory review of its results. All countries reported that a number of activities were still ongoing or are to be launched in the very near future.

The information provided was, in general, very good. In some cases, in particular for countries with numerous plants and different designs, summary information was provided in the national report, with detailed, plant level information usually being available in the operator reports. Nevertheless, it could be concluded that the information provided fulfilled the guidance established by ENSREG and allowed for a comprehensive peer review.

Participating countries fully cooperated with the European peer review process during the topical peer reviews and country visits. Peer review experts made very effective use of the topical discussions organised in Luxemburg from 5 to 17 February and the seventeen country visits that took place from 11 to 31 March, to complete the reviews and obtain the information and evidence needed for drawing concise conclusions from the Fukushima event at the European level.

4.3 Adequacy of the assessment of compliance of the plants with their current licensing/safety case basis for the events within the scope of the stress tests

Plant compliance with their current licensing bases was reviewed both by the operators and the regulatory bodies during the national phase of the stress tests, drawing in part on their regular safety assessment activities. The stress test peer review process demonstrated that although countries used different approaches, all the national reports provided evidence of compliance of the plants with their current licensing/safety case basis. Development of updated IAEA safety standards and WENRA reference levels (RLs) over the last decade also promoted a significant shift towards greater consistency between the European countries in terms of general acceptance criteria. Nevertheless, areas for modification of existing RLs or the development of enhanced RLs were identified.

As a general conclusion, there was no indication that any of the plants reviewed within the stress tests did not comply with its licensing basis. , Concerning minor deviations from regulatory requirements that were found, in particular when performing regulatory inspections, standard regulatory procedures were applied in line with legislative framework.

Stress test peer review process results clearly indicate that particular attention needs to be paid to periodic safety reviews as an important and powerful tool for regular reassessment of plant safety status.

Many national reports identify explicit work to demonstrate ongoing compliance with reviewed nuclear installation safety cases. In such a compressed timescale, it is difficult for the peer reviewers to obtain a sense of compliance or otherwise. It was only possible to obtain a snapshot from the peer review country visits and it is therefore recommended that national regulators consider how best to ensure that specific requirements (e.g. IAEA safety standards and WENRA reference levels) for all three topical areas under investigation are adequately maintained. Specific proposals are given in Chapters 5, 6 and 7 and summarised in the final conclusions of this report. The lessons learned, to date, from the Fukushima event (the analysis of the event continues) have in all countries led to modified or additional safety requirements on specific issues. This process is currently ongoing and in most cases is included in the normal process between regulator and licensee.

4.4 Adequacy of approaches used to evaluate margins and robustness of plants

For topic one, natural external hazards, the peer review process noted the generally sound approach to demonstrating an appropriate design basis but identified that the evaluation of margins beyond design basis (BDB) is not consistent in participating countries. A few countries have adopted established approaches for seismic margins and have quantified the inherent robustness of the plant beyond the design basis. However, the majority have made only a general claim that margins exist and therefore there is no information on the basis of which to consider effective potential improvements. ENSREG was clear regarding the approach proposed for flooding, where incremental increases and associated assessments of acceptability and improvements were detailed. Only a small number of countries have done this. The approach to margins for extreme weather demonstrated even more variability, probably because the existing guidance is less well developed. Despite these uncertainties, the majority of national reports identified significant and worthwhile improvements from the approaches adopted.

In topic two, loss of electrical power and loss of the ultimate heat sink and the combination thereof, scenarios were assessed in the topical review regardless of their cause or frequency. In practically all cases, the plant response assessment was properly undertaken for all situations required by ENSREG specifications. In most instances, the loss of UHS (as well as the combination of the SBO and loss of UHS) was enveloped by the SBO event. This leads to some aggravating situations for plants in which the design concept relies on multiple layers of AC power or multiple sources of water. For those, plants selected to define a SBO for two cases, partial and full loss of alternating current (AC) power. This was found to be a correct way of following the ENSREG specifications. The lack of a clear and unambiguous common terminology (such as definition of ultimate as opposed to alternate heat sink) was an issue related with the assessment of the heat sink. Some countries considered additional sources of water (like dedicated wells, or nearby lakes), others considered a possibility of residual heat transfer to the atmosphere as an alternative heat sink.

Discussions during the topical reviews allowed for clarification of differences in the assumptions, methodologies and presentation of results. It was then concluded that the safety margins and cliff-edge effect determination for losses of safety systems were generally in line with ENSREG specifications.

Robustness for Topic 3, severe accident management, can mainly be thought of in terms of the sufficient time available before the occurrence of important events which escalate the severity of the accident (e.g., core damage, vessel and containment failure). Another measure of robustness is the level of the redundancy, diversity and independence of provisions in place to prevent or limit radioactive releases to the environment. The national reports address in a fairly uniform way the hardware, procedural and human provisions available, their extent, the level of preparedness including, verification and validation of SAMGs, strategies for implementing specific accident mitigation measures, etc. Nevertheless, the SAM provisions differ, as those are closely related with the plant type and design, but also with the historical developments in specific countries. In practically all the national reports the need for further analysis is identified as necessary prerequisite for incorporating all lessons learned from the Fukushima event in the severe accident management area.

4.5 Regulatory treatment applied to the actions and conclusions presented in the national reports

National reports include specific information with regard to the involvement of individual regulators in the process, in particular on the actions of the authorities related to the stress tests and on their conclusions. In all cases, the national regulatory authorities, sometimes supported by their technical support organisations (TSOs), reviewed the assessments undertaken by the licensees. The regulatory actions included dedicated inspections, decisions/orders given, assessments of and in some cases regulatory approval, necessary improvement/remediation measures and their planned schedules. In addition to the actions of the operators, regulatory organisations launched their own investigations related to the Fukushima event. Furthermore, all regulatory authorities may refocus their activities, for example, to include specialised inspections. Long-term changes may be needed depending on the findings from the final assessment of the accident and the lessons learned from it.

The national regulators screened information coming from Japan and international organisations such as the IAEA. In many countries, immediate national checks were performed even before the ENSREG stress tests specifications were developed and were agreed on. Some of the governments demanded reports on the results of such quick checks before summer 2011. On the other hand, there are countries which decided for a more gradual approach where the final decisions on programs and measures to be implemented in response to the Fukushima event will be made after comparison with the EU stress test peer review results.

All regulatory bodies have taken very seriously the stress tests process at the national level, and in certain cases have already assessed specific new proposals presented by the operators. A large number of previously scheduled activities have been accelerated and decisions have been issued by the regulatory authorities identifying further safety improvements resulting from the stress tests process. According to the national reports, national regulators have been highly pro-active in identifying improvements and areas for further analyses.

5 EUROPEAN PLANTS ASSESSMENT RELATIVE TO EARTHQUAKES, FLOODING AND OTHER EXTREME WEATHER CONDITIONS

5.1 Description of the present situation of plants at the European level

5.1.1 Regulatory basis for safety assessment and regulatory oversight

A variety of regulatory approaches are adopted for protection against external events. Most countries adopt a prescriptive approach, in which regulations specify details of how safety cases are to be produced and detailing hazard parameters resulting in a DBE or similar. Other countries adopt a high-level, goal-setting approach, in which more discretion is left to the operator, provided that they justify the approach adopted. Either approach can lead to a satisfactory safety case but demonstration is only adequate if the national regulator and/or operator determine that external events are assessed with the appropriate level of conservatism.

IAEA guidance suggests that a minimum 0.1g horizontal peak ground acceleration should be adopted for seismic loading, where a detailed hazard assessment may indicate a lower level for design or re-assessment. This default level has not yet been fully adopted in a small number of instances. However where this is the case there are local plans to address the deficiency. It is recommended that this be taken into consideration by regulators when reviewing seismic hazards for future PSRs.

Most countries have demonstrated an adequate approach to seismic and flooding design bases, given that regulators consistently require this. However the assessment of margins beyond the design basis (BDB) is far more variable since this is not generally a regulatory requirement. Very few countries have determined cliff-edge effects and the associated protection improvements in the manner envisaged by ENSREG. The situation with regard to extreme weather is even less satisfactory. Some countries demonstrated a capability based on recent historic data, which is less demanding than good practice would dictate. In general there was little evidence of assessing margins BDB.

5.1.2 Main requirements applied to this specific area

A good practice adopted by IAEA member states and used by the peer review is that external events should be addressed by designing to the hazard level consistent with a 10,000 year return period, i.e. a frequency equivalent to 10^{-4} per annum. Many countries adopt this level for new designs, while a large number of countries adopt it for re-evaluation of older designs. However a small number have not adopted this level for re-evaluation/back-fitting, in some cases since they judge that it is not feasible to define the characteristics of the earthquake at such remote frequencies. It is recommended that regulators consider how to determine consistency in ensuring that all plant reviews/back-fitting with regard to external hazards safety cases, achieve this level of demonstration.

The main issue of hazard reassessments is to identify the need for appropriate modifications to NPPs. Either deterministic or probabilistic methods can be used, but should be consistent with IAEA guidance.

Towards the end of the peer review process, IAEA issued guidance on meteorological design basis parameters which will be expected to form a focus for development of extreme weather assessments in the near future[9].

5.1.3 Technical background for requirement, safety assessment and regulatory oversight

External events safety cases ideally should have elements of both deterministic and probabilistic approaches. The deterministic approach requires definition of a review level loading analogous to a design basis loading. The national reports indicate that there is a significant level of agreement, underpinned by IAEA and other guidance, for this level to be consistent with a frequency of 10^{-4} per annum. A small number of countries adopt a more conservative approach using a frequency of 10^{-5}.

Because of the high level of uncertainty regarding natural events, it is helpful and logical to complement the deterministic assessment with probabilistic safety analysis (PSA). Although seismic PSA is a well-developed technique it was apparent from the peer review that it is not universally implemented for older plants and it is recommended that national regulators should consider ensuring that seismic PSAs are included in the PSR process. For natural hazards other than seismic and flood the PSA process is not as well-developed and alternative approaches to determining margins and identifying potential plant improvements may be more appropriate, although at least one country appears to successfully include extreme weather in its PSA. The requirements for potential plant improvements derived from either the deterministic or probabilistic methods should be consistent. In both cases the objective should be to determine opportunities for plant improvement.

The stress tests specifications did not consistently result in relevant information in the national reports concerning regulatory oversight. However it can be reliably inferred that hazard safety cases are appropriately regulated, although it was difficult to determine how oversight is continued into plant operation. From the national reports that did address this aspect it is apparent that effective inspections can be undertaken to ensure that equipment is properly installed and maintained and it is recommended that all national regulators should consider establishing programmes for such inspections, particularly for temporary and mobile equipment and tools used for mitigation of BDB external events.

5.1.4 Periodic safety reviews

It was clear from the national reports that PSRs are well-established throughout the participating countries and they have formed the basis for continuous plant improvements, as well as for regular re-assessment of the licensing basis. In most cases, a reassessment of the external hazard is part of the PSR process. PSRs including re-assessment of the seismic hazard were found to be particularly strong safety features since such repeated periodic updates make it possible to take advantage of advances in science and technology. It is recommended that regulators should consider how to strengthen the PSR process by developing a more consistent approach to the determination of hazard levels and margins for external events, at least every 10 years and whenever necessary.

5.1.5 Plant compliance with current requirements

All national reports provided good evidence of compliance with design-basis requirements for earthquake and flooding. BDB is less clear, partially because methods are not as mature and readily

[9] Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations - IAEA Safety Standards Series No. SSG-18;Published Thursday, December 01, 2011.

available, and partially because the regulatory requirements are less clear, as discussed above. For extreme weather even the design-basis is not clear, however new IAEA guidance9 was issued near the end of the stress test process and this may provide the initiative for more consistency to be developed within the participating countries.

It is also considered valuable for the ongoing compliance of plants to be rigorously validated by regulators and it is recommended that regulators, together with operators, should consider how to develop standards to address qualified plant walkdowns with regards to earthquake, flooding and extreme weather – to provide a more systematic search for non-conformities and correct them (e.g. appropriate storage of equipment). This plant-based activity would benefit from clear labelling of qualified equipment.

5.2 Assessment of robustness of plants at the European level

5.2.1 Approach used for safety margins assessment

There are well-established practices for assessing seismic margins BDB, referred to as seismic margin assessment. This appears similar to a deterministic method although the acceptance criteria are derived from probabilistic fragility assessments. Alternatively, similar fragilities can be implemented in a seismic PSA. Many countries have adopted one of these approaches and used them to determine potential improvements. However, nearly half the countries participating in the stress tests did neither and cited generic potential margins in response to the ENSREG specifications.

Assessment was made more complicated by different nomenclature used in international guidance, such as SL1, SL2, DBE, etc. Whatever approach is adopted it is clear that the primary objective should be to determine potential plant improvements and this should be the focus of the work.

For flooding, ENSREG was very explicit about the approach to be adopted to assess margins – presume increases in flood level BDB and determine cliff-edge responses and potential improvements to address them. Only a small number of countries have done this. In many cases the national report argues that the possibility of a significant flood BDB is very remote and can be discounted. Nevertheless many of these countries still identify possible improvements. It is accepted that at some sites, due to the inherent physical geography, any cliff-edge effect resulting from an external flooding, caused by rising water level, can be practically eliminated. However it is recommended that national regulators in all countries that have not considered incrementally increased flood levels and associated potential improvements consider requesting the operators to do so.

As mentioned above, it is recommended that WENRA, involving the best available expertise from Europe, should consider how to determine a consistent approach to margin assessments for external events – probably best done through the provision of more advice regarding the scope of periodic reviews and/or in conjunction with the work of agencies such as IAEA. It would, in particular, be appropriate to encourage further development of consistent approaches to extreme weather.

Where BDB studies have been carried out effectively, relevant improvements have been identified and it is important that the regulators in those countries that did not comply fully with the ENSREG specifications should consider how to complete such an assessment.

5.2.2 Main results on safety margins and cliff-edge effects

In general, the seismic design basis is satisfactorily determined on the basis of events consistent with a 10^{-4} per annum return frequency. This is consistent with good practice and international guidance. However there are some countries where the acceleration levels consistent with the perceived 10^{-4} per annum return frequency are very low. In these circumstances, IAEA guidance suggests that a minimum 0.1g horizontal peak ground acceleration (PGA) should be adopted. This has not been the case in a small number of instances.

The science of seismic hazard assessment and the availability of relevant knowledge continues to improve and it is important that the loading be determined realistically. It is therefore recommended that regulators should consider how to encourage wider discussion regarding good practice for determining the seismic hazard design basis, in order to ensure that the design level and any indicated margin is meaningful in all cases.

Where BDB studies have been carried out effectively relevant improvements have been identified and it is important that the regulators in those countries that did not comply should consider how to complete such an assessment.

The safety margin evaluations that have been reported demonstrated that the evaluation of margins can be effective in identifying plant improvements for increased robustness. The reports also identified significant improvements implemented following PSRs.

For a number of plants, some of the extreme weather loadings are claimed to be encompassed by different events that are judged to require higher levels of plant or structural resistance. On a case-by-case basis this may be judged to be an acceptable approach but the equivalence of the loading has to be demonstrated.

All European countries have determined that a tsunami is either not a realistic threat for the existing plant sites or is encompassed by other flood initiators. Generally, the DBF has been addressed effectively and demonstrated to be adequate. However only a small number of countries have assessed flood margins in the manner that ENSREG specified, i.e. assuming incremental increases in flood level and seeking cliff-edge effects and potential improvements. Many countries have made cases that BDB flooding is an extremely low frequency event and therefore did not evaluate the condition. Even so, many of these countries identified some improvements after subjective consideration. Examples include increased height of openings into protected rooms, provision of additional temporary flood protection dams or volumetric protection of safety-related rooms. The peer review concluded that a systematic assessment of margins along the lines proposed by ENSREG is worthwhile unless there is overwhelming evidence that BDB flooding is an extremely infrequent event. It is recommended that regulators consider pursuing an assessment in-line with the ENSREG specifications where this has not yet been done.

5.2.3 Strong safety features and areas for safety improvement identified in the process

In general the requirements of the DBE and DBF are satisfied appropriately by qualified structures, systems and components (SSCs) and topological arrangements. Many SSCs are either demonstrated to have margins beyond DBE or are claimed to have moderate margins by virtue of robust DBE design. Such approaches are augmented by the adoption of separation and redundancy with regards to BDB hazards.

Over one third of the European plants have adopted a "hardened core" philosophy to provide an additional independent sub-set of safety related SSCs capable of withstanding earthquake and flooding events significantly BDB.

The protected volume approach is noted as an effective way of demonstrating flood protection for identified rooms or spaces.

Where an adequate case has not been demonstrated, the majority of countries have identified future work either to assess margins or establish them by means of modifications.

Most countries have plans to provide rugged mobile equipment to perform the necessary safety functions if the permanent systems were to be impaired. It is recommended that the design for storage of such equipment should take account of external events at the design and beyond design levels to ensure appropriate availability in the event of being required. Similar considerations apply for external hazard robustness of on-site centres for SAM.

The extent of work to assess hazard cases and improve plants arising from PSRs is noteworthy and many countries have demonstrated adequate robustness on the basis of earlier work done to satisfy the PSR process. It is recommended that regulators should encourage consolidation of the PSR process to include assessment of margins against external events, including regular reviews of the design and beyond design hazards.

With regard to hazards, particularly seismic, it would appear that techniques and available data are still developing. It is recommended that regulators should consider co-operation with other agencies in order to develop a consistent approach across Europe, taking account of updates in methodology, new findings and any relevant information from continuous research on active and capable faults in the vicinity of NPPs.

Many, but not all NPPs have permanently installed seismic monitoring and alarm systems. Information from such systems enables operators to make informed judgements regarding whether or not to continue operation following a seismic event. Clearly such decisions should be based on appropriate procedures and training. It is recommended, where they do not currently exist, that regulators consider requiring seismic monitoring systems and appropriate procedures and training,

It was evident that the approach to secondary effects of seismic events, such as flood or fire arising as a result of the event, is not always addressed consistently. It is recommended that the national regulators should clarify such requirements for future assessments.

Some countries refer to weather alert systems. Advance warning of deteriorating weather is often available in sufficient time to provide the operators with useful advice and it is recommended that national regulators should seek to ensure that appropriate communications and procedures are developed by all operators.

5.2.4 Possible measures to increase robustness

Most countries have not completed a formal margins assessment or PSA for the seismic hazard. The peer review concludes that the potential benefit is substantial and recommends that national regulators should consider requiring such analyses where they have not been completed.

In some countries the original seismic design was based on very low accelerations. All countries accept that modern standards require a design level based on a 10^{-4} per annum frequency of occurrence. However the hazard determination is not always consistent with modern standards and understanding and it is recommended that national regulators consider requesting a re-appraisal of hazards against modern standards, as part of the PSR process.

For flood the peer review concluded that a systematic assessment of margins along the lines proposed by ENSREG is worthwhile, unless there is overwhelming evidence that BDB flooding is not feasible. It is recommended that regulators consider pursuing such assessments where they have not yet been completed.

There is substantial variability regarding approaches to extreme weather, partly arising from a lack of clarity with respect to regulatory requirements, but also a lack of available established methods. It is recommended that regulators consider promoting a European-wide debate on the benefits of a more systematic approach to extreme weather challenges and a more consistent understanding of the possible design mitigation measures.

5.2.5 Measures already decided or implemented by operators and/or required for follow-up by regulators

For external event safety cases it is difficult to identify generic physical mitigation measures, since the approach to improve margins is plant-dependent. However, all countries have identified further work in response to the stress tests, or associated work arising from the Fukushima event and it is recommended that ENSREG continues to promote discussions within the community to ensure maximum benefit within Europe. Concerning extreme weather, application of the latest IAEA guidance [10] (issued in 2011) is likely to assist in this respect.

5.3 Peer review conclusions and recommendations specific to this area

All national reports have identified significant and worthwhile potential improvements with programmes extending over several years. It is recommended that national regulators consider the following:

1) Driving all plant reviews/back-fitting with respect to external hazards safety cases to the 10^{-4} per annum/0.1g minimum peak ground acceleration.

2) That in all countries that have not considered incrementally increased flood levels and associated potential improvements they should consider requiring the operators to do so. When carried out at the right level, the exercise is practicable and can easily provide valuable insight into effective and realistic improvements.

3) Strengthening the PSR process by encouraging a more consistent approach to the determination of margins for external events, including external event PSAs (including seismic) and regular reviews of the design and beyond design hazards.

4) That with regard to hazard definition, techniques and data are still developing. WENRA, involving the best available expertise from Europe, should develop guidance on natural hazards assessments, including earthquake, flooding and extreme weather conditions, as well as corresponding guidance on the assessment of margins beyond the design basis and cliff-edge effects.

5) Clarifying requirements for the approach to the secondary effects of seismic events, such as flood or fire arising as a result of the event, in future assessments.

6) That the protected volume approach is an effective way of demonstrating flood protection for identified rooms or spaces.

7) How best to ensure that specific operational requirements of external events safety cases are adequately maintained. Regulators and operators should consider developing standards to address qualified plant walkdowns with regards to earthquake, flooding and extreme weather – to provide a more systematic search for non-conformities and correct them (e.g. appropriate storage of equipment, particularly for temporary and mobile plant and tools used to mitigate BDB external events). This plant-based activity would benefit from clear labelling of qualified equipment.

8) That some countries have proposed to develop a "hardened core" of selected safety systems protected against extreme hazards.

9) That the design for storage of mobile equipment to perform necessary safety functions should take account of external events at the design and beyond design levels, to ensure appropriate availability in the event of being required following a significant external event. Similar considerations apply for external hazards robustness of on-site centres for SAM.

10) Installation of seismic monitoring systems and development of associated procedures and training for those NPPs that currently do not have such systems.

11) That some countries refer to weather alert systems. Advance warning of deteriorating weather is often available in sufficient time to provide the operators with useful advice and national regulators should ensure that appropriate communications and procedures are developed by all operators.

6 EUROPEAN PLANTS ASSESSMENT RELATIVE TO LOSS OF ELECTRICAL POWER AND LOSS OF ULTIMATE HEAT SINK

6.1 Description of present situation of plants across Europe

6.1.1 Regulatory basis for safety assessment and regulatory oversight

The majority of countries recognise that the IAEA standards form a good general basis for continuous improvement with respect to the LOOP, SBO and loss of UHS. The national regulatory requirements for this area are generally in line with the IAEA safety standards. However, these national regulatory requirements and regulatory oversight are country-specific. Even so, the underlying safety principles are universal and consist of a comprehensive system of safety objectives with basic safety goals and safety requirements with respect to defence in depth principles and ensuring critical safety functions. Some countries are more specific or apply additional requirements to various levels of defence in depth and diversity for both electrical power supply and residual heat removal. There can also be slight differences in practical application in specific areas, such as systems safety classification, based on an internal logic according to the country-specific situation, or the historical development of the country's nuclear activities and of the country-specific plant design. In order to harmonise and apply good regulatory practices in European countries and in order to learn from each other, WENRA developed reference levels designed to further improve the level of nuclear safety and regulation in the member countries. Implementation of the WENRA reactor safety Reference Levels (RLs) began in 2007. It should be noted that these levels are relatively general and do not provide detailed requirements in the area of topic 2.

6.1.2 Main requirement applied to this specific area

In addition to the general safety requirements discussed above, specific requirements and regulatory guides are applied in different countries, covering the areas of electrical power system and UHS requirements. In particular, for electrical systems more detailed safety requirements are available and in some countries the guidelines are well developed, comprising a more detailed level of technical requirements. These provide the operator with more detailed specifications concerning the design basis and the safety requirements pertaining to electrical systems and components. In line with the principle of continuous improvement of nuclear safety, the most recent requirements are applied to existing plants insofar as is practicable.

Safety requirements regarding the UHS are more general and are addressed in terms of redundancy and diversity. It is difficult to identify specific requirements, such as for the provision of an alternate diverse UHS function, and there is no evidence of the existence of such detailed guidance with regard to this particular function.

6.1.3 Technical background for requirement, safety assessment and regulatory oversight

As defined in the ENSREG specifications, the deterministic approach has been applied as the main approach for the preparation of the national stress tests reports. Nevertheless, complementary information from both the deterministic and probabilistic assessments has been used in the national reports and in discussions, where relevant, as this is reflected in regulations and regulatory guidance in the majority of the countries. Operational experience feedback was also provided, as in some cases it is taken into account and required by the regulations. In addition, the safety impact of plant retro-fits, modernisation programs and accumulated improvements achieved over time, has been demonstrated with corresponding PSA results. The adoption of WENRA reactor safety RLs and the use of deterministic analysis together with level 1 PSA, and in many countries level 2 PSA, is also an important part of the position and requirements presented in the national reports.

6.1.4 Periodic safety reviews

The PSR as a tool for regulatory oversight appears to be universally accepted and applied in European countries with a basic period of 10 years for all operating plants. The scope and the frequency can vary slightly depending on a country's specific practice; however they are on the whole in line with IAEA guidance. In some cases, the regulatory body has adapted the PSR process in order to increase efficiency and to ensure adequate implementation times, as well as to ensure the safe long-term operation of plants.

6.1.5 Compliance of plants with current requirements

The national reports were not required to provide a particular or explicit statement related to conformity with the national requirements. However, it appears from the topical review that the majority of regulators carried out the necessary checks to ensure that the plants are in compliance with the national requirements, but the process has focused on the technical scope of the stress tests and the issues highlighted by the Fukushima accident. The lessons learned up to now from the accident (obviously without any in-depth analysis) have led in several countries to more stringent or additional safety requirements on specific issues. This process is currently ongoing and in most cases involves a dialogue between the regulator and the operator.

6.2 Assessment of robustness of plants at the European level

This chapter of the report addresses the response to the ENSREG specifications for LOOP and loss of the ultimate heat sink (UHS) and the combination thereof. These scenarios were assessed, regardless of their cause or frequency. The combination of these scenarios with additional failure assumptions is beyond the scope of the ENSREG specifications for Topic 2, although in the topical review, the possible impact was considered as part of the discussions.

6.2.1 Approach used for safety margins assessment

The aim of the EU stress tests as a targeted reassessment of the safety of nuclear installations was to evaluate the effects of extreme natural events included in the design basis and beyond.

<u>Issues recognised during the stress tests regarding terminology</u>

– ultimate heat sink (UHS) and alternate ultimate heat sink:

The term “alternate UHS” was interpreted differently in various countries. Most countries considered a diverse source of cooling medium (water from ponds, wells, etc.) as an alternate UHS, but some countries also considered secondary or primary feed-and-bleed into (ultimately) the atmosphere, or the use of emergency condensers, as an alternate UHS.

– loss of off-site power (LOOP) and station blackout (SBO):

The term ‘SBO’ was interpreted differently in several countries. Most countries considered SBO as “complete SBO”, but some countries considered “loss of the protection for design basis accidents”.

A clear and unambiguous common terminology in this regard would enhance transparency and comparability. However, the peer review ensured that the evaluation was performed on the substance of the underlying safety assessment rather than on the basis of terminology alone.

<u>Design safety margins</u>

Design provisions are among the cornerstones of safety analysis and a description of them was required in the national reports. As the ENSREG stress tests specifications define a deterministic approach, in which event sequences are postulated regardless of their plant-specific occurrence frequency, the robustness of the design provisions to prevent their occurrence is not easily estimated, rated or quantified.

Without embarking on a probabilistic approach, a qualitative means of indicating the level of robustness of specific design provisions to ensure safety functions can still lie in the definition of the level of robustness, as practiced in some countries. Examples are: level of redundancy (no redundancy, single failure criterion, n+2 criterion, or more), level of diversity, etc.

Cliff-edge effects and coping times

The main measures required by the ENSREG stress tests specifications are cliff-edge effects and their coping time determination. These cliff-edge effects were provided in the report in most cases, or were obtained during the peer review. In most cases, a conservative approach is applied to calculating the coping times associated with identified cliff-edge effects. This conservative approach sometimes results in relatively short coping times. However, the real coping times available might be longer (sometimes even considerably so). A direct and objective comparison of such values would require the adoption of the same level of conservatism for associated assumptions and calculations. Nevertheless, the basic safety criterion here is to identify cliff-edge effects and when they occur, but also to indicate provisions to prevent these cliff-edge effects or to increase plant robustness. Consequently, part of the stress tests results was a demonstration that adequate measures in the form of plant modifications can and will be taken within the coping time, regardless of the level of conservatism adopted.

Comprehensiveness of safety assessment

In general, it is recognised that the national reports and the country presentations made during the topical review tried to provide a comprehensive safety assessment. Where some (or parts) of the installed systems that are credited in a plant-specific safety case might not satisfy all state-of-the-art requirements (often for historical reasons), it is ensured that sufficient defence in depth is provided by other systems.

Adequacy / level of detail in national reports

Large nuclear countries and/or countries with many plants of different designs tend to report on the basis of a design type, rather than providing a full set of plant-specific data and analysis results. This generated requests for clarifications during the topical reviews and, if necessary, during country visits.

6.2.2 Main results on safety margins and cliff-edge effects

In the EU there are a number of reactor designs, each with certain specific design features. Their safety margins depend on redundancy and diversity of equipment and associated defence in depth. However, for the purposes of the stress tests, these safety margins were assessed, for example, the coping time during which the core may uncover if countermeasures are not adopted. In considering such margins it should be noted that the electrical power supply and UHS are ensured by a number of redundant and diverse systems. Furthermore, in some plants, an extra layer of defence is provided by either stationary systems or mobile equipment that is qualified to operate in the anticipated external conditions. These defence systems help to ensure the required safety functions even if all standby safety-related equipment is lost.

Due to specific design features, some reactor designs are found to have greater margins than the others. However, the important factor to be considered is whether effective countermeasures can be implemented within the coping time to prevent core damage. For some cases a cliff-edge effect is apparent in that it appears that there may be insufficient time to implement countermeasures taking into account the ENSREG stress tests conditions. However, this does not necessarily mean that the cliff-edge effect would automatically lead to core damage due to the conservative approach used. Furthermore, the measures identified are intended to improve this situation.

The safety margins and cliff-edge effects have been calculated for various loss of safety function scenarios, as specified in the stress tests specifications. The LOOP, loss of all alternate-current power (SBO), loss of UHS, and SBO combined with loss of UHS have been analysed. The margins and cliff-edge effects arising from most critical situations are discussed below.

Reactor - LOOP

LOOP is considered to be within design basis for all plants and is managed through a range of redundant and diverse means. Typically, the power supply reaches the power plant via several independent power lines. In addition, in some plants, depending on their design and operational experience, there is a credible possibility of house load operation. If this fails, there are redundant standby emergency DGs, additional DGs, gas turbines, dedicated hydropower and other power plants which can power the electrical buses dedicated to plant safety. From the perspective of safety margins, the emergency power source (diesel/gas turbine generators) can typically provide power for about 72 hours (as per ENSREG stress tests specifications) to 8 days, and sometimes longer. This is based on the stocks of consumables (fuel, lubrication oil, gas etc.) available on-site. Beyond this, it is assumed that additional supplies would need to be brought in from off-site.

Reactor - SBO

The analysis has shown that in terms of safety margins, SBO is the limiting case for most of the reactor units. An isolated loss of UHS, which is typically water or the atmosphere, does not lead to fast reactor core heat-up, although it may be the limiting case in the longer term (availability of the cooling medium).

For a large pressurized water reactor (PWR) at power before the initiating event, SBO would typically lead to core heat-up after around 1-4 hours if no countermeasures were implemented. For a small PWR, core heat-up would take around 10 hours and for an advanced gas-cooled reactor (AGR) it would be greater than 10 hours, again assuming that no countermeasures were implemented. For some boiling water reactors (BWRs) designs SBO leads to core heat-up [10] within 30-40 minutes, if no countermeasures are adopted.

It was also observed that PWRs are susceptible to relatively fast core heat-up if the reactor is open a few days after shutdown (for refuelling). In this case core heat up is typically within the one to three hours range (without countermeasures). In particular coping times appear to be substantially reduced for mid-loop operation and it is recommended that regulators should encourage operators to find a way to minimise such operational conditions.

Spent fuel pools - SBO

The safety margins for spent fuel pools (SFPs), as well as spent fuel storage facilities (SFSFs) were also analysed. Generally, for SFPs the SBO is the most limiting scenario. Nevertheless, if water is available and it can be delivered to the SFP, evaporative cooling is effective and the condition is not critical.

For the worst case in which the entire core is unloaded into the SFP with no make-up, the fuel may uncover in about 7-9 hours. The analysis shows that for interim SFSFs that store fuel with low decay heat, the safety margins for both loss of UHS and SBO are in the range of several days, even if no countermeasures are adopted.

Batteries - SBO

Batteries play an important role in the SBO case because they ensure the minimum operability of some small equipment important to safety, the monitoring of plant parameters, and emergency lighting. It was observed that the typical battery design discharge time is in the range of 1-3 hours. However, through testing, some plants also confirmed that this discharge time is a conservative estimate and that realistically it is much longer, e.g. 6-9 hours.

[10] Core heat- up means that the temperature of the fuel exceeds the value given by safe operating limits and conditions. Consequently, at that point the first signs of fuel damage, such as loss of fuel rod cladding integrity, may be expected.

It is also noted that at some plants, direct current (DC) power can be ensured by recharging station batteries via small DGs, or even backup station batteries that can be connected to the DC bus via temporary cable connections.

Reactor coolant pump (RCP) seals - SBO

RCP seal integrity may be challenged in a SBO event during which cooling is lost. Typically, RCP seal integrity can be ensured for several hours without cooling. Some plants reported that RCP seals can retain their integrity for 24 hours. It was also reported that some RCP seal designs ensure integrity even without cooling.

Ventilation - SBO

It was also noted that loss of ventilation can be a limiting case in the longer term (several hours) because some equipment may suffer overheating and consequently fail.

Countermeasures

It should be emphasised that plants typically have countermeasures in place to cope with the above conditions, namely SBO and loss of UHS. The safety margins indicated above can be substantially increased, and cliff-edge effects may even be avoided. For example, using the diesel driven auxiliary/emergency feedwater pumps to feed the steam generators (feed & bleed), the total time before loss of fuel cladding integrity is more than 72 hours. This can be significantly increased with the systems already available on-site to about 8-10 days by using independent diesel driven pumps from the fire water system.

To cope with the SBO situation in BWRs (equipped with reactor core isolation cooling system (RCIC)), water availability for use in the RCIC systems is more than 20 hours. The steam is released into the wetwell and feeding can continue through the stationary or mobile diesel driven pumps. At some plants, the energy from the wetwell can be released via the containment filtered venting as the last resort scenario. However in this case it is necessary to verify (see 6.2.4) that valves fail in a position so that they are still operable in SBO conditions. This was not the case in the Fukushima accident.

Typically the demineralised water storage available on-site in condensate storage tanks is enough for 72 hours. The volume of cooling water available on-site is sufficient to ensure heat removal from essential consumers for more than 6-8 days.

6.2.3 Strong safety features

From the national reports and the peer review process, a number of strong safety features were identified in European NPPs. These are expected to be instrumental in preventing severe fuel damage in the reactor or spent fuel storage in the event of LOOP, SBO, loss of UHS or loss of UHS combined with SBO. These are available in some NPPs, but not necessarily all of them. Some of the safety features were due to the initial plant design, while in other cases, specific safety features were added through safety modernisation efforts over the years.

While strong safety features and their actual benefits are closely related to the design concept and/or particular solutions developed, many features might be of interest as add-on improvements. Nevertheless, some of the strong safety features in one of the designs may not be needed or even feasible in other designs, because similar functions are addressed in different ways. Still, plants that do not have specific features might consider adding them, as possible safety improvements, subject to specific needs and to compatibility with the original design.

The consideration of strong safety features is directly related to the specific event scenarios considered. In accordance with the concept of defence in depth, plants were originally designed with multi-layer protection. On some plants, safety features were later added to strengthen these multiple layers.

Safety features designed to minimise disruption following loss of power include the capability of the main generator to handle load shedding and house load stabilisation (which is regularly tested in some countries), multiple grid connections at different voltage levels including secure connections (e. g. underground cable) to a grid located at a certain distance. This is strengthened by arrangements (reported by some countries) in which the grid operator is contractually or otherwise obliged to ensure grid reliability as well as give power restoration priority to a NPP. Site-specific robust safety features include direct and/or dedicated connection (separate from the grid or the plant's own switchyard) to a nearby hydro or a gas power plant, having a black start capability.

For the scenarios with complete and unrecoverable LOOP, all designs rely on multiple redundancies of dedicated and qualified power sources, mainly DGs and gas turbines. Strong safety features include qualification of equipment and its housing for a range of events including beyond design basis seismic events and beyond design basis floods, but also guaranteed and periodically verified availability of fuel and lubrication oil. Some designs include further layers of totally independent power sources (DGs), though often dedicated to specific functions (like battery charging) and not having full capacity like primary sources.

In the SBO scenarios analysed within the stress tests (which seem to be very unlikely on all of the NPP sites), all of the dedicated and emergency AC power sources are lost. In such cases, all the plants rely on safety-related DC sources (batteries) to enable operation of the control equipment (e. g. valve actuators), safety instrumentation and emergency lighting. The strong safety features identified include the high capacity of these batteries (up to 12 hours), load shedding procedures (to extend battery life time; up to 20 hours was reported) as well as regular and dedicated testing of batteries, to ascertain their capacity under accident conditions. One strong safety feature is permanent monitoring of the battery status, thus assuring full capacity when the need arises.

For a situation in which both AC and DC power becomes unavailable, positive safety features were mainly add-ons. Many plants reported having a range of mobile power sources, from DGs dedicated to charging batteries or powering specific pumps (e. g. feedwater or service water), usually a few hundred kW and mounted on a transportable skid, to trailer-mounted high-power DGs. Strong safety features for example include fuel tanks and cable spools mounted on a skid/trailer with a DG, as well as pre-established connections points, procedures on how to connect (and power specific busbar, operating switches and breakers to disconnect less important loads) and drills that encompass full sequences (from bringing a DG trailer to a location, to connecting and powering dedicated consumers). An important and sometimes overlooked positive safety feature is the practice of storing mobile equipment in areas that are resistant to the devastation that could be caused by a seismic event, flood or other internal or external impact.

For the SBO scenarios caused by devastation that is (often) beyond the original design basis, numerous plants decided to install a "hardened core" of equipment and organisational measures or bunker-based systems having their own power sources with dedicated fuel reserve, dedicated pumps with independent sources of water, their own instrumentation and controls. The design of a dedicated bunkered system varies, reflecting the needs of the original plant design, specific identified threats, etc. Single or multiple redundancies are to be found in these bunkers. Some of the bunkers are fully resistant to a range of external threats, while others have dedicated water supplies offering long-term independence. In all cases, bunker-based systems are separate and independent from the plant's safety systems.

To cope with losses of the main UHS, a variety of design features are being used. Positive features include multiple (and large) reserves of water such as dedicated tanks (e. g. seismic proof), large capacity pools (e. g. with spray-based heat removal from essential service water system), dedicated wells (with their own, independently powered pumps) as well as arrangements to obtain water from nearby lakes (using tanker trucks or fire hoses). Specially designed main cooling discharge channels that will retain large amounts of water if the UHS is lost, is among one of these positive features. A strong safety feature is to use the atmosphere as the UHS, for example with dedicated (safety class) cooling towers or spray ponds.

For the LOOP/SBO but also for the loss of the UHS scenarios, maintaining water injection to reactors and/or steam generators (SGs)/isolation condensers offers an ultimate means of cooling the core.

Varied and diversified systems for performing this function have been identified, including electric power-independent turbine driven pumps, arrangements for gravity feed (coupled with opening of selected valves), dedicated diesel driven pumps as well as pre-installed connections for external feed, such as from the on-site fire trucks. For use of the fire trucks, positive safety features identified include the pre-arranged connections, arrangements and drills for actual establishment of the connection for feeding of SGs.

Positive safety features were identified in relation to the SFPs. These include pools containing large volumes of water, design of pools to prevent drainage, robust construction, use of racks made of borated steel to enable cooling with fresh (unborated) water without having to worry about possible re-criticality. Other robust safety features include redundant and independent SFP cooling systems, dedicated external connection to provide the SFP feed, power-independent monitoring instrumentation as well as procedures and drills to restore SFP cooling and/or inventory being included in the plant emergency procedures.

All in all, the peer review concluded that many of European NPPs possess numerous strong safety features that would prevent accidents from occurring, even those initiated by a low-probability hazards. The strong safety features and their objectives vary across the designs, and are often dependent on the age of the design and the specific threats they are designed to address. While some of the strong safety features are inherent in the design (e. g. some reactors have very large quantities of water; some designs rely on physically diverse equipment; others on multiple redundancy and physical separation; some designs feature a leak-proof primary pump seal design, preventing losses of coolant), while others may, in certain circumstances, be replicated by the NPP operators elsewhere (something which, as discussed in following paragraphs, is already happening).

Thanks to prudent original designs and in particular to dedicated safety enhancements implemented over the years, European plants can as a whole be considered as having multiple strong safety features that would prevent deterioration, even in the very unlikely disaster scenarios such as those evaluated by the EU stress tests.

6.2.4 Areas for safety improvement and possible measures to increase robustness

As discussed in the preceding section, many positive safety features have been identified at plants throughout Europe. Some of those are inherent in the design (large volume of water in SGs, multiple layers of power sources, etc.), while others have been added as safety improvements over the years. These safety improvements might have been introduced to rectify the design deficiencies found, resolve the findings of the individual plant vulnerability analysis, or respond to new requirements that were issued while considering the “state of the art” requirements that are established within the PSR (which is mandatory for all NPPs in Europe).

Nevertheless, plant designers and operators had multiple choices and have chosen the solutions that are often specific to the design or specific site. Therefore different safety features are available to cope with similar scenarios. The strong safety features for one plant would not therefore necessarily be a similarly “strong” safety feature when transferred to another plant. The selection of features is ultimately specific to the plant/design and site and the advantages and drawbacks have to be carefully considered before any transfer.

Nevertheless, the review process identified the areas for safety improvements that are likely to be applicable to a wider range of plants operating in Europe. While some of them are already installed in plants, those plants on which they have not been implemented, subject to compatibility with the design concept and arrangements, should consider adding some. Such improvements and arrangements are expected to increase the robustness of the plants, even beyond the already high level of safety identified during the stress tests. It must be emphasised that the increased robustness might be achieved in a number of ways, so the safety improvements are not an all-inclusive list to be mandated for every plant. In fact, the safety improvements should most importantly complement the design features, support those that are strong and rectify any deficiencies identified.

Robustness of AC power supply

Enhancing the availability of both the on-site and off-site power supplies is an essential element of enhancing NPP robustness and its resistance to a variety of internal and external initiators. While many operators have already introduced specific arrangements, adding equipment and procedures to increase robustness, specific improvements might still be possible and in some cases justified. The safety improvements include enhancement of the grid, through agreement with the grid operator on rapid restoration of off-site power, but also through increasing and/or reinforcing off-site power connections or arranging for black start capability for co-located or nearby gas or hydro plants. This might include improved high-voltage insulators (in the switchyard or off-site) by replacing standard ceramic based items with plastic or other material that is resistant to a seismic event. Utilisation of generator load shedding to house load operation might increase robustness, but may also increase the specific risk of voltage regulation problems. Before introducing such arrangements the risks need to be properly understood. Further increases in robustness could be achieved by adding layers of emergency power (as some plants have done) but also by adding specific, independent, dedicated backup sources.

Availability of fuel and water stocks

The review during the stress tests revealed that many plants already possess stocks of fuel and water at the site that would ensure operation of safety systems (and mobile devices) for days without resupply. Nevertheless, in some plants, the fuel might be available but would require additional systems for transfer to the users (that might be unavailable, for example, due to a lack of power). A systematic review and, if necessary, improvements to the availability of fuel on-site and arrangements for resupply off-site will increase the robustness. Attention needs to be given to other consumables such as lubrication oil, which might be critical for large DGs. The same applies to the availability of water, firstly with regard to the physical availability in various man-made and natural storages, but equally important is to undertake a systematic assessment to ensure that equipment and means are available for providing water to locations and equipment where needed. The full chain considering equipment, procedures, surveillance and drills must be in place to ensure robustness.

Functional separation and independence

While in many cases identified and already rectified, the independence of important components from other systems (e. g. cooling water for pumps and DGs) is an important issue for increasing the robustness. Some plants introduced modifications (e. g. fire-water backup cooling for DGs), while others might consider safety improvements related to functional independence and separation. Another safety improvement is the provision of an alternate heat sink independent from the main AC power supply.

Provision of mobile devices for electrical power and water supply for makeup and cooling

Availability of mobile power sources or water supply means is a feature that will increase robustness, especially in situations that are (significantly) BDB, where plants' inherent robustness is challenged. Many plants already possess a variety of mobile devices including skid/trailer based DGs and pumps, dedicated fire trucks, etc., including the connection points and procedures on how to engage mobile units. Nevertheless, a systematic selection and acquisition of the equipment that would provide a variety of power and pressure levels and that is safely stored on-site and/or off-site will enhance robustness. The transportation and simple and fast connection of the mobile equipment, including its proper operation (considering fuel supply, independence but also organisation and procedures) shall be ensured by appropriate plant and site centric design and regular testing after installation. Considering the inclusion of mobile devices in a plant's safety-related surveillance might enhance the standby capability and thus increase robustness. It is essential that connection points for DGs, batteries, water injection points/piping (e. g. for SFP) are pre-established and have clear access.

Robustness of DC power supply (Batteries)

The DC power supply is, in almost all designs, an essential power source for monitoring and controls. Plant robustness, depending on the specifics of the design and arrangements, could be enhanced by improving the battery discharge time. Battery discharge time can be increased by upgrading the existing battery or changing its type (an additional benefit of which could be increased resistance to common-mode failures), by providing spare/replacement batteries or by implementing well-prepared load-shedding/staggering strategies. Regular real load testing and on-line monitoring of the status of the batteries might also add to robustness. Some plants have already increased robustness through dedicated recharging options (e. g. using portable generators).

Instrumentation and monitoring

In most cases, the instrumentation (and control) systems require an uninterruptible power supply (either directly DC or AC backed-up by batteries). In the event of a SBO and following discharge of the batteries, the instrumentation and the monitoring systems thus might become inoperable. Some plants, when introducing SA measures, undertook to install separate instrumentation and/or power sources to enable monitoring of essential parameters under any circumstances. Starting with verification of the availability of instrumentation in specific SBO and loss of DC sequences, safety improvements could be achieved and robustness strengthened by installing additional power sources and/or additional instrumentation that is based on simple physical principles (e.g. passive temperature , pressure readers).

Capability/strategy for handling accidents occurring simultaneously on all plants of the site

In a case of an event caused by an external hazard, multi-unit sites are especially vulnerable, as resources need to be shared. In some cases, the assessment of internal initiators did not consider that there were sufficient equipment and staff to cope with challenges on multiple units. Assuring preparedness and sufficient supplies for coping with events affecting all the units on a site would enhance robustness. Some plants reported implementing improvements in this respect (like adding mobile devices and fire trucks) and increasing the number of trained and qualified staff. Others should consider taking another look at their level of preparedness and introducing safety improvements.

Assured flow paths and access under SBO conditions

Losses of AC power, but even more so, DC power and instrument air may lead to a situation in which the operation of critical equipment (mainly valves) is no longer possible. In some cases, the equipment might default to a predetermined "safe state", but this safe state is not necessarily that required to ensure safety in a particular condition (e. g. containment isolation by fail-safe closure of feedwater valves will prevent secondary feed and bleed that use feedwater lines). Increased robustness may be achieved by enhancing and extending the availability of DC power and instrument air (e. g. by installing additional or larger accumulators on the valves), but also by ensuring that the state in which those valves fail on loss of actuation is carefully considered to maximise safety. Therefore the robustness could be enhanced by systematically analysing the consequences and, as necessary, changing the logic to ensure safety is carefully considered and maximised.

Many of the control elements could, as the ultimate choice, be operated by hand. However, SBO and/or loss of DC might lead to a blocked access if the turnstiles are electrically operated or electrically interlocked. A systematic review of the possibilities for access to critical equipment in power loss situations needs to be undertaken. Having access to critical equipment in all circumstances will increase the robustness of the plants.

Shutdown state risk/mid-loop operation

Although it was already well-known from various safety studies, the shutdown state and in particular mid-loop operation is, for many designs, the most unfavourable state in the event of SBO. Robustness could be increased through a systematic analysis of the shutdown state/mid-loop operation, in order to reduce or inhibit this operating mode and/or increase safety by adding dedicated hardware or procedures/drills. Use of other available water sources (e. g. from hydro-accumulators) may allow for longer operating time, thus increasing the robustness. Requiring the availability of SGs during shutdown operations but also the availability of feedwater in all modes up to cold shutdown (mode 5) would directly increase the robustness for some designs.

Other specific issues

Numerous areas for safety improvements that do not fall into any of the categories discussed above were identified and in some cases have already been implemented. Nevertheless, systematic investigation with introduction of specific improvements, if possible and if so justified, might further increase plant robustness. This includes considering the use of temperature-resistant (leak-proof) primary pump seals in some of the designs, enhanced ventilation capacity during SBO to ensure equipment operability, as well as analysis and enhancement of SFP integrity in overheating/boiling conditions. A related issue is the possibility of venting steam out of buildings, which might be of particular relevance in a case of boiling in the SFP. In the event of SBO, and in particular the loss of DC, the operability of the main control room (MCR), the emergency control room (ECR) and emergency control centre (ECC) might be compromised. As these are the key locations in which any actions to prevent escalation and/or mitigate the consequences will be undertaken, a systematic analysis and subsequent improvement would add to plant robustness.

6.2.5 Measures already decided or implemented by operators and/or required for follow-up by regulators

A range of measures have been identified by operators and regulators to provide increased protection for BDB events. Some of those were identified during regular PSRs, while others were defined within the stress tests framework. The majority of measures already decided and in some or many cases implemented, are related to the availability of power sources, i.e. the provision of mobile devices.

Many countries reported on other measures that are already implemented or being prepared for implementation, including enhancements of the heat sink function (increase robustness of the UHS or provision for alternate heat sink), measures to ensure cooling in the absence of AC power (e.g. primary or secondary feed and bleed), but also a variety of procedures to enhance the operability of specific equipment in adverse conditions. The countries also reported on the ongoing activities where more complex programmes of modifications are being developed, to be approved by the respective regulators and implemented in the next period.

Other measures already implemented or planned are related to SFP, to ensure water inventory or cooling. Nevertheless, additional measures were reported as under preparation, including provision for additional heat exchangers (e. g. submerged in the SFP), external connection for refilling of the SFP (to reduce the need for an approach linked to high doses in the event of the water falling to a very low level), etc. Further studies are in particular related to the integrity of the SFP and its liner in the event of boiling (which is a BDB condition for the SFP) or external impact.

The measures already identified and in many cases implemented include the guaranteed availability of fuel and lubrication oil for DGs or gas turbines, the means of transferring the fuel on-site (from storage tanks to day tanks) and similar. While the analysis is being carried out, additional analysis might be needed in some cases in order to optimise the operating times of these power sources. This is in particular relevant for mobile sources which would need to be resupplied, given that skid or trailer mounted tanks would only provide enough autonomy for a few hours, and in any case less than a day in most cases.

Identified as an issue by many plants, implementation has been decided on or initiated to reinforce the areas where the mobile equipment is stored. In some cases, mobile equipment, including fire trucks, is housed in fire stations that are often not resistant to a seismic event (or to a flood, but due to the slower nature of flooding, this is generally less of an issue). It has been decided that a significant fraction of European plants will implement a "hardened core" of equipment and organisational measures that is designed for significantly beyond design basis external hazards.

Many plants reported a need for dedicated diesel driven pumps for primary or secondary injection, for service water/ultimate heat sink or even for transfer of diesel fuel. In some cases the equipment was identified and procured. In other cases the acquisition of dedicated pumps, in particular including the construction of a dedicated, easy access and simple to operate connection point, and ensured availability of water in tanks or other sources (in which case a suction source needs to be assured) still need to be implemented. Related analyses are mainly to decide on the optimum size and number of these mobile pumps and to decide on positioning them in appropriate, secure locations.

As a general issue, the improvements related to the increased resistance to seismic events, floods or other extreme conditions might need to be evaluated and measures put in place. In some cases the original design basis of the plant might be reviewed. In such a case, the analysis of the possible impact on DGs, batteries, mobile equipment and its storage as well as fuel and water storage tanks needs to be undertaken. Any necessary improvements would need to be implemented.

With regard to the operability of control equipment (mainly valves) during the SBO, additional analysis is needed to ensure that cooling using natural circulation would not be interrupted. Depending on the outcome, additional or alternative means to operate control devices, in particular including the feedwater control valves and SG relief valves, main steam safety valves, isolation condenser flow path, containment isolation valves as well as depressurisation valves, might be needed.

An assessment of alternate/additional heat sinks has been undertaken. In some cases, a more detailed analysis might be required. As a consequence, actual measures might be needed that could for example include the air-cooled cooling towers, deep water wells on-site or in the vicinity and/or new or alternate fixed or temporary connections to reservoirs or other bodies of water.

In addition to hardware provisions, improvements might be related to procedures and preparedness for disrupted conditions. Some plants reported that battery load-shedding procedures were being considered. To develop a procedure that could be followed in the event of SBO, a systematic analysis of specific battery loads, considering different scenarios, could be undertaken. The same applies for the studies on how to refill the SGs using alternate means, such as gravity flow from the feedwater reheater or tanks, using other sources of water (for instance condensing towers in one design) or even fire tankers with fire truck-mounted pumps. All these might need specific arrangements, dedicated procedures and drills by the staff for implementation in emergencies.

Additional studies might be needed to assess operation in the event of widespread damage, for example, following an earthquake. This may identify the needs for different equipment (e. g. bulldozers) and plans on how to clear the route to the most critical locations or equipment. The logistics of the external support and related arrangements (storage of equipment, use of national defence resources, etc.) is another area that might need further studies, and possible improvements.

It is also noted that in some countries, the set of the most important improvement measures has been defined as a "hardened core" of equipment and organisational measures qualified to withstand beyond design basis events, although the degree to which they are qualified has not yet been decided. Analysis might be needed to define the full extent of equipment and measures in a "hardened core" of this type.

The action plans for further analysis and improvement measures have already been defined, or will shortly be drafted, in all countries. The general aim is to make improvements as soon as possible, with the initial focus on those measures that can be implemented quickly, thereby providing immediate benefit. The completion schedule of all aspects of the action plans will vary, depending on the agreed scope, the urgency of the measures and the general plans for future operation.

6.3 Peer review conclusions and recommendations specific to this area

In response to the ENSREG specifications, the following scenarios were considered:

- Loss of off-site power (LOOP)
- Station blackout (SBO)
- Loss of ultimate heat sink (UHS)
- Loss of the primary UHS combined with SBO

These scenarios have been assessed regardless of their cause or frequency. LOOP and loss of UHS are evaluated at all NPPs currently in operation. Consequently, plants are well protected by a range of redundant and diverse systems. SBO and the loss of UHS combined with SBO are beyond the original design basis for most of the plants. Nevertheless, practically all the plants have (some) means of protection in both of these situations. In some cases the protection is primarily provided by means of physical processes (natural circulation, gravity feed, etc.) while in other cases engineered systems have been added (e. g. completely independent, fully powered and supplied systems located in well-protected bunkers).

It should be noted that in the analysis of the stress tests no credit is claimed for the repair and recovery of electrical power or the UHS, or the use of mobile equipment to provide the necessary safety functions. The outcome of these aspects of the stress tests should be seen in this context.

Based on the evidence of the national stress tests reports, the country presentations, the answers to questions, and the country visits it is apparent that all NPPs are compliant with their current licenses and are well protected against all of the design basis accidents. The plants are, on the whole, protected to some extent against beyond design basis sequences that were assessed within the stress tests.

The review of the national reports and the discussions within the country presentations confirmed that all of the plants have already analysed the need for eventual safety enhancements as a consequence of the lessons learned from the Fukushima accident. The range of improvement measures has been identified and many already implemented. Additional analyses are underway, to support the programme of measures to be implemented in the future, under the supervision of the national regulators. The action plans for further analysis and subsequent implementation of the improvement measures have already been defined, or will shortly be so, in all countries.

The review process determined that in most cases the design is robust, with strong safety features. Nevertheless, the improvement measures to further enhance robustness were identified, and have already been implemented or are underway at many plants. The review process also identified the fact that due to considerable variations in the design concept or features, site specifics but also past approaches to safety upgrades and modifications, not all improvement measures are applicable to all plants. To be the most effective every plant needs to consider a specific range of measures and ensure that it is compatible and well-integrated into the broader safety and operational features, supporting defence in depth and enhancing robustness.

Nevertheless, in terms of added value and the overall safety benefits, several areas were identified as being of broader interest. It is recommended that national regulators consider the following findings:

1) Availability of a variety of mobile devices, with prepared quick connections, procedures on how to connect and use and staff training for deployment of such equipment. It is important that the equipment is to be stored in locations that are safe and secure even in the event of general devastation caused by events (significantly) beyond the design basis. Mobile sources of power would enable the use of existing equipment; mobile pumps would enable direct feeding of the primary or secondary side, even using alternative sources of water. Mobile battery chargers or mobile DC power sources will allow extended use of instrumentation and operation of controls. Fire-fighting equipment, including fire trucks, diesel pumps, generators, emergency lighting, etc., is normally readily available at the plants. Engineered and prepared connections as well as drills on the use of this equipment significantly add to the robustness for BDB events.

2) Using alternative means of cooling including alternate heat sinks. SG gravity feeding, or using other sources of water, supply from stored condenser cooling water, alternate tanks or wells on the site, or water sources in the vicinity (reservoir, lakes, etc) is an additional way of enabling core cooling and prevention of fuel degradation. Some plants identified possible actions, including additional analysis that might be needed.

3) Operational or preparatory actions such as ensuring the supply of fuel and lubrication oil, battery load-shedding to extend battery life are examples of measures that are small (in many cases procedural) but that could make a considerable difference in response to initiators. All in all, most of the plants have already considered these measures and might be adding to them in the future.

4) Within the stress tests evaluation the bunkered system proved its worth in ensuring an additional level of protection, able to cope with a variety of initiators, including those beyond the design basis. The concept is taken even further in the form of the "hardened core" where in addition to equipment, trained staff and procedures designed to cope with a wide variety of extreme events will be available.

5) The stress tests evaluation identified issues and consequently led to improvements in preparedness for the events that could affect multiple units. Previously, the multi-unit site protections were sometimes designed to cope with a serious challenge facing one of the units. During the stress tests, it was identified that robustness could be enhanced if additional equipment and trained staff were to be made available to deal with events affecting all the units on one site. While the process of improvement is not yet completed, it has been initiated on many sites.

The stress tests confirmed that all the units in Europe are well protected for all of the design basis events. It also confirmed that all of the units possess some resistance to the highly unlikely events that are significantly beyond the design basis. In general, the European plants are robust, also thanks to series of PSRs that required the operators to enhance their plants and introduce modifications. Nevertheless, the assessment undertaken during the stress tests identified additional areas for improvement, in particular by adding flexible mobile systems and arranging for connections, sources of power, water, etc. Many of the plants have undertaken the measures to cope with extreme BDB events. Others are to follow in the very near future. Analyses still need to be undertaken and systemic improvement programmes that may be expected to bring all of the EU plants to the highest level of safety are being envisaged.

7 EUROPEAN PLANTS ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

7.1 Description of present situation of plants at the European level

7.1.1 Regulatory basis for safety assessment and regulatory oversight

The status of the legislative basis for accident management (AM) varies across the participating countries: some have relevant national guidelines or legislation already in place since the 1980s or 1990s while others are at different stages of preparation for new legislation. In several countries, licensing requirements are based on the regulations of the country of the reactor vendor. All the countries participating in this review, however, recognise the usefulness of the WENRA RLs applicable to AM for setting legal requirements (these are mainly in areas: F (design extension of existing reactors), LM (emergency operating procedures and severe accident management guidelines) and R (on-site emergency preparedness)). Nevertheless, there are considerable differences, country to country, in how the RLs are incorporated into legislation. Some countries have developed specific regulations to address the RLs. In other countries the RLs are included as conditions within the operator's licence or operating permit. Elsewhere, the RLs are incorporated into the general national legal framework.

All national legal frameworks provide for regulatory oversight of AM, including provision for regulatory assessment and inspections of this topic.

7.1.2 Main requirements applied to this specific area

The main requirements for AM are currently internationally defined in the WENRA RLs and in IAEA safety standards. Most operators' strategies are defined in their EOPs and SAMGs (or equivalent). These are often based on the reactor vendor's suggested strategies, but are suitably amended for the particular plant design. Where the reactor vendor has not yet developed SAMGs, the utilities have developed their own strategies based on international research and knowledge transfer (e.g. through owners' groups). The original source of the SAMGs can have a strong influence on the depth and comprehensiveness of their coverage.

International standards require EOPs and SAMGs to be available in all NPPs. Symptom-based EOPs, focused on prevention of a severe accident, have been implemented in all countries following the Three Mile Island (TMI) accident. SAMGs focused on mitigation of severe accidents, once steps to prevent fuel damage have failed, are still being implemented in some countries.

7.1.3 Technical background for requirement, safety assessment and regulatory oversight

In the absence of any European standards, IAEA safety standards and WENRA RLs are used as guidance when establishing national requirements for NPP safety features. Some countries have adopted requirements from the reactor vendor's country. The depth and detail of these requirements as well as the implementation of the regulations differs between the countries. Whereas some countries are very specific in their requirements, others only define general safety goals.

The majority of participating countries use probabilistic approaches to help determine weaknesses and to focus safety improvements. Level 1 and 2 PSAs form an essential part of these evaluations. However, the scope and depth of these analyses differ and in some cases there is a need for improvement, in order to bring them up to accepted international standards. Common tools to assist with this process include IAEA and World Association of Nuclear Operators (WANO) review missions, the European Framework Programmes, as well as operational experience feedback through international information exchange systems, such as the Institute of Nuclear Power Operations (INPO), WANO, IAEA/NEA International Reporting System, Clearinghouse, etc.

Some of the time schedules appear to delay unnecessarily the correction of known SAM weaknesses that were an issue at Fukushima. Implementation of current SAM requirements in some countries is not well established and this leads to differences in the upgrading of safety functions and the robustness of the operating plants. The stress tests have, however, provided an impetus to accelerate improvements, by highlighting the strengths and weaknesses of the different national approaches to international peer reviews.

7.1.4 Periodic safety reviews

The peer review process has confirmed that PSRs are performed in all participating countries with the usual period of 10 years, in line with international standards. As noted above, PSRs are considered to be a highly effective means of improving SAM in NPPs. That said, the level of detail and depth of the PSRs differs between countries. The Fukushima accident and the related stress tests have triggered a new wave of safety reviews seeking to learn lessons from the accident, particularly with regard to SAM. The peer review concluded that PSRs should be maintained as a key tool for ensuring the continuous enhancement of defence in depth in general, and the provisions of SAM in particular.

7.1.5 Compliance of plants with current requirements

Though operating NPPs comply with their national requirements, not all comply with all aspects of the IAEA safety standards related to SAM. Moreover, some NPPs are behind with their commitments to comply with the WENRA RLs, particularly with regard to the implementation of hardware provisions. In addition, SAMGs are, for the most part, only developed for full-power conditions; only in a few cases are there SAMGs for low-power and shutdown conditions, spent fuel pools or long-duration multi-unit events. When SAMGs do not apply to all plant states, most operators have plans to extend them within a few years. A trend was observed in many countries to increase the scope of SAMG to include all plant power states and accidents in the spent fuel pools. This trend was recognised and was firmly supported. Verification and validation of SAMGs is also essential to ensuring their practicability, robustness and reliability and should therefore form an intrinsic part of their implementation process.

7.2 Assessment of plant robustness beyond the design basis

7.2.1 Approach used for safety margins assessment

In general, when new safety standards are developed, they are expected to be applied not only to new NPPs, but also to existing plants, to the extent possible. This is usually addressed during the PSR.

The approach to SAM used by the countries within the stress tests focused on verification whether necessary components of SAM are in place and they are effective. The required scope of SAM is defined internationally through the IAEA safety standards and WENRA RLs (in particular in areas LM, F and R). In addition, some countries are applying the WENRA safety objectives for new reactors to existing plants. The ENSREG stress tests specifications provided further guidance on the scope of the reviews with regard to SAM.

In some countries, existing regulations include a specific requirement for the implementation of equipment dedicated to severe accidents. Sometimes, compliance with single failure, diversity and independence criteria is also required. In these cases the support systems and power supply sources need to be independent. In other countries, the use of existing equipment is preferred and the SAM requirements are less specific. With regard to the stress tests, these countries indicated the need to implement additional, dedicated SA provisions.

Comprehensive Level 2 PSA is considered to be an important tool for the identification of plant vulnerabilities, quantification of potential releases, determination of candidate high-level actions and their effects and prioritizing the order of proposed safety improvements. Extension of the scope of existing Level 2 PSA to shutdown states, SFPs and consideration of external hazards is, however, still needed in most countries in order to ensure that the PSA can appropriately inform improvements to SAM. Moreover, it is important that PSA be applied in a manner complementing other analyses, e.g. deterministic design basis analysis and analysis of severe accidents, and not be used to exclude scenarios on the basis of their low estimated risk. The PSA should instead inform an appropriate defence in depth approach, so that adequate SAM measures are in place in the unlikely event that design basis provisions fail to prevent the onset of a severe accident.

7.2.2 Main results of peer review and areas for safety improvement identified in the process

The stress tests and their peer review confirmed that AM is recognised and being implemented by all participating countries, although at different levels. During the peer review process, a general commitment and trend towards accelerated implementation of AM measures within regular or extended plant refuelling or maintenance outages was observed.

Generic findings and observations for different components of AM are summarized in the text below for different areas relevant for AM. Potential safety improvements in these areas were also identified during the peer review process; these potential improvements are summarized for consideration by the countries in section 7.2.4 of this report. More detailed descriptions for individual countries can be found in the annexed country review reports.

Procedures and guidelines

Accident management programmes (AMPs) that include EOPs and SAMGs already exist or are being developed in all NPPs.

EOPs, focused on the prevention of core melt, were implemented in all countries following the TMI accident. These procedures are primarily symptom-based in combination with event-based elements. The scope and status of implementation of SAMGs is less advanced, although the extent differs between countries. SAMGs have mostly been developed for full-power conditions. However, in some cases there are also valid SAMGs for shutdown conditions, SFPs and long-duration multi-unit events. Where the SAMGs are incomplete, there are plans to extend them in the near future, or such plans are under consideration.

EOPs and SAMGs use various formats and are typically implemented in line with generic guidance provided by the vendors and/or owners groups. The trend to increase the scope of the SAMGs in order to include all plant states and accidents in the spent fuel pools is being strongly supported. When implementing SAMGs, their validation should also be included, as per the WENRA RLs.

Special equipment for accident management

The prevention of a simultaneous loss of systems due to common-mode failures can be achieved through suitable redundancy, diversity, physical separation and protection against external hazards. Aspects such as flexibility, independence, simplicity and multiple means of connectivity will most likely be important for AM equipment. That said, it is crucial that the equipment functions when needed. There is thus the need for stringent requirements to ensure that the equipment survives the external hazard that can lead to a severe accident (e.g. by means of qualification against extreme external hazards, storage in a safe location) and has the capability for use in the environment in which it will need to operate (e.g. engineering substantiation and/or qualification against high pressures, temperatures, radiation levels, etc). Consideration also needs to be given to aspects such as the functional capacity of the equipment, e.g. whether it will deliver enough flow, power, etc., possibly for several units; how the equipment will be classified (so that it is adequately maintained, tested, inspected, etc.); and how it can be operated within a probably highly degraded infrastructure.

Some countries have already decided to implement special sets of dedicated equipment needed for SAM or to perform design modifications to improve defence in depth.

Reactor coolant system depressurisation

Depressurisation of the reactor coolant system (RCS) after core melt is considered to be a crucial action to avoid high-pressure core melt ejection from the reactor pressure vessel (RPV) (which could potentially challenge containment integrity during the early phase of a SA) as well as to facilitate water injection from low-pressure sources. The prevailing approach uses existing design basis means, such as opening the pressuriser relief or safety valves. Attention in SAM is therefore focused on aspects such as the availability of power supplies and instrument air, and a means of manual action to achieve depressurisation. In some countries dedicated and single failure proof depressurisation lines and valves, designed for severe accident conditions, are used to enhance the robustness of defence in depth.

Hydrogen

Risks from hydrogen and other flammable gases represent a key contributor to potential containment failure and therefore need to be effectively eliminated. Reactor type as well as containment type, size and internal configuration and the selected SA mitigation strategy (in-vessel or ex-vessel molten corium cooling) are determining factors with regard to the severity of this issue.

Several provisions are generally available for mitigation of hydrogen risks, including containment venting, inerting, mixing, use of hydrogen igniters and passive autocatalytic re-combiners (PARs). Rates of hydrogen production need to be determined when sizing the capacity of these systems. Hydrogen risks associated with the use of containment venting have been discussed, as have potential hydrogen leaks to auxiliary buildings in particular for reactors without re-combiners. Risks from hydrogen production in the SFPs have also been discussed during the peer review, but no counter measures have been implemented at NPPS, so far.

Means for mitigation of hydrogen risk inside the containment have already been installed in many plants. Nevertheless, there are still plants with limited PAR capacity (e.g. these are for design basis accidents only), or with limitations in supplying electrical power to igniters (e.g. in the event of a station blackout).

Molten corium stabilisation

Stabilisation of molten corium is recognised as essential if a safe and stable state is to be reached following a SA. The strategies being used by the countries for existing reactors include:

- In-vessel retention of molten corium ensured by early flooding of the reactor cavity and heat removal by external cooling of the RPV;
- Early flooding of the reactor cavity or lower drywell prior to any escape of molten corium from the RPV, assuming in-vessel retention is not successful (i.e. so that fragments of the damaged core are quenched in the water pool);
- Keeping the reactor cavity dry until molten corium relocation into the cavity has occurred and then pouring water on top of the corium layer.

Selection of the corium stabilisation strategy has implications for other AM strategies, e.g. for long-term containment heat removal, hydrogen mitigation, filtered venting and the minimisation of radioactive releases. The choice of an appropriate strategy depends on many factors, in particular reactor power; the reactor type (e.g. PWR or BWR); the size and shape of the reactor cavity; and the availability of water and an injection system for flooding. Therefore, even in the same country, different strategies have been selected for different reactors. In a few countries, no final decision has yet been reached on an appropriate strategy, or work is still ongoing to better underpin the existing strategy.

Containment venting

Filtered containment venting has been considered and implemented in many NPPs as a means of preventing containment over-pressurization. It is clear that the efficiency of filtering depends on the design solution. Some countries are considering improvements to increase this efficiency.

The need for containment venting depends on the reactor and containment types, and on the selected strategy for mitigation of SAs. Filtered venting seems to be less important, if ex-vessel severe accident phenomena are effectively prevented; this aspect requires further evaluation. In the majority of other cases, the implementation of filtered venting was identified as the ultimate means for protecting containment integrity, as well as reducing radioactive releases from any containment leaks. The issue of preventing excessive containment under-pressure after venting has also been discussed, but it was not considered a difficult issue.

Re-criticality

Reactor core or SFP re-criticality in severe accidents is considered very unlikely due to inherent safety features such as geometric configurations or the use of fixed neutron-absorbing materials. In many countries, rules to ensure that only borated water is used for fuel cooling are adopted as an additional layer of protection. Nevertheless, based on the discussions held during the peer review, the potential for re-criticality cannot always be ruled out when emergency cooling uses un-borated water and the fuel is no longer in its original configuration. The potential for re-criticality should therefore be considered for analysis when developing relevant SAM strategies.

Accident management for gas cooled reactors

Accident management for gas cooled reactors represents a special case due to their unique design features. On one hand they are not equipped with standard containment and therefore the robust concrete reactor pressure vessel is the ultimate barrier against releases of radioactive materials. On the other hand, very large thermal inertia of the reactors provides for large time margins for performing recovery actions. In addition, many severe accident challenges to confinement integrity such as hydrogen explosion, high pressure melt ejection, steam explosion and direct containment heating are not present due to inherent features of these reactors. Therefore the AM measures are mainly focussed on protection of reactor vessel integrity, or on mitigation of releases in the case of loss of vessel integrity, including repair of possible cracks in the vessel.

Spent fuel pools

Depending on the reactor design, SFPs may be located within the containment, close to the reactor or elsewhere on the plant/site. In all countries, prevention of radioactive releases from the SFPs is to be ensured by maintaining sufficient coolant inventory in the pool and providing for reliable residual heat removal. Design provisions are in place to ensure the structural integrity of the pools, minimising the potential for loss of coolant, and to compensate for reduced coolant inventory from various reasonably accessible resources (e.g. from inside the units or from outside via mobile means). Some countries are verifying the safety margins BDB in this respect. The considerable thermal inertia of the SFPs in most cases offers reasonable time margins for taking recovery steps if cooling is lost. However, it should be remembered that these margins are significantly shortened in the case of complete core offload into the SFP. In the frame of the stress tests, severe accidents involving molten fuel in the SFP have not been considered in any country.

Radiological issues

The expected radiological conditions inside plant buildings and outside during SAs, as well as the limitation of radiological releases, were only partially addressed in the national reports. Similarly, post-accident fixing of contamination and the treatment of potentially large volumes of contaminated water were not covered in detail. Nevertheless the important issues of continued habitability of control locations (e.g. main and emergency control rooms) and the feasibility of SAM measures were recognised and appropriate provisions including radiological monitoring were considered, as demonstrated in the written answers to additional questions and during national presentations within the peer review. Limiting the radiological consequences of severe accidents by prescribed limits in the country regulations is not usually considered, but in some cases was referred to as a safety objective for upgrade projects in terms of frequencies, maximum releases or effective doses.

On-site emergency arrangements

In all countries, initial responsibility following the start of a severe accident remains with control room/plant personnel until technical support is activated. The arrangements include different levels of activation depending on the severity of the situation. It should however be noted that emergency response organisations have generally been developed assuming a single accident on a given site, rather than considering the potential full range of severe accidents that might occur.

In some countries, the availability of an on-site emergency centre, protected against extreme natural hazards and contamination, needs to be ensured, together with the necessary arrangements for rapid intervention by specialized teams, availability of personal protection measures, portable equipment on the site and robust communication means are being ensured.

In some countries, in addition to providing an on-site emergency centre, decisions have been taken to either improve existing external emergency centres, or to build new ones. These will provide assistance to emergency crews and facilitate radiological protection measures (for example concerning equipment, dosimetry, etc). Where such new facilities are being constructed it is recommended that they should be designed to function after extreme external events. In addition, some countries are considering setting up centralised (e.g. national, regional) off-site rescue centres to provide similar functions within less than 24 hours to any affected NPP.

Some countries are considering providing additional means for assisting NPPs in severe accidents by utilising state resources (e.g. civil protection or military transport). The crucial role of communication (such as between plant personnel or between the NPP and the authorities) in the event of an emergency has also been highlighted, leading to improvements in the capacity and robustness of the existing systems. Typically this means installing new communication systems to increase redundancy and diversity, or making improvements to existing systems such as additional or dedicated power supplies.

Off-site emergency arrangements are considered important complementary components to on-site arrangements. However, these were only partially addressed in the stress test process and so remain a potential subject for future consideration.

<u>Further studies and development</u>

The stress tests and the peer review also indicated the need for future studies and development in the following areas:

- Systematic evaluation of the availability of safety functions required for SAM under different circumstances.
- Detailed studies of accident timing, including core melt, RPV failure, basemat melt-through, SFP fuel uncovery, etc.
- Enhancement of PSA analysis, including all plant states and external events for PSA levels 1 and 2.
- Further studies of the radiological conditions on the site and associated provisions necessary to ensure MCR and ECR habitability as well as the feasibility of AM measures in severe accident conditions, multi-unit accidents, containment venting, etc.
- Investigation of core cooling modes prior to RPV failure and of re-criticality issues for partly damaged cores, with un-borated water supply.
- Analysis of phenomena associated with cavity flooding and related steam explosion risks.
- Studies related to engineered solutions regarding molten corium cooling and prevention of basemat melt-through.
- Development of severe accident simulators appropriate for NPP staff training.

7.2.3 Possible measures to increase robustness

Based on the discussions during the peer review process, a number of possible measures to increase AM robustness have been identified. Development of specific post-Fukushima SAM action plans (to be proposed by the plant operators and then assessed by the regulatory bodies) should be considered as an urgent matter. Implementation of these plans should be accelerated and given a degree of priority that reflects the importance of individual provisions for protecting the public.

The discussions resulted in a wide-ranging, although not necessarily exhaustive, list of measures to be considered by the countries, as follows:

- When updating SAM and emergency arrangements, the potential interaction between the reactor and associated SFP has to be considered.
- A decision on a molten corium cooling strategy either in the RPV or in the cavity, appropriate for a given reactor design is to be reached by all countries.
- The feasibility of strategies for molten corium cooling aimed at protecting containment integrity needs to be further assessed, using available knowledge.
- Further attention is to be paid to potential re-criticality in SAM, taking into account potential geometry and material composition changes caused either by external hazards or by the progression of the severe accident.
- Maintained coolant inventory in the SFP needs to be ensured by verification or by upgrading SFP structural integrity, installation of qualified monitoring, and by provisions for redundant and diverse sources of additional coolant resistant to external hazards in order to practically eliminate risk of fuel uncovery.
- Preferable use of dedicated diverse and qualified SAM equipment resistant to extreme external hazards needs to be considered, either passive or powered from reliable sources, including instrumentation required for performing SAM actions.
- The use of mobile equipment could be advantageous due to its flexibility and the feasibility of its protection against loads caused by extreme external hazards. The connecting points and the infrastructure required for their use also needs to be adequately proven and robust.
- Due to the importance of RCS depressurization for the prevention of containment failure and for injection of coolant from low-pressure sources, additional attention needs to be paid to the capacity and reliability of the hardware provisions required for depressurisation.
- Whenever the severe accident assessment indicates a risk of long-term containment over pressurisation, which can not be reliably prevented by other means, containment venting must be considered via the filters designed for severe accident conditions, such as to ensure a sufficiently long venting time.
- High priority must be given to installing means for hydrogen mitigation designed for severe accidents, in order to practically eliminate containment failure due to hydrogen combustion. Installation of passive autocatalytic re-combiners seems to be the preferred option for future upgrading.
- Since hydrogen flammability depends on the composition of the containment atmosphere, which in turn depends on the operation of other systems such as the containment spray system, qualified monitoring of the hydrogen concentration must also be available to avoid such operation when concentrations that allow explosion exist.
- The potential for migration of hydrogen into spaces beyond where it is produced in the primary containment, as well as hydrogen production in SFPs, has to be carefully analyzed and adequate countermeasures adopted if necessary.
- The availability of an on-site emergency centre protected against extreme natural hazards and contamination needs to be enhanced, together with the necessary arrangements for rapid intervention by specialised teams, availability of personal protection measures, portable equipment on the site and robust communication means.
- In some cases, the regional off-site rescue centres established could be shared by several plants.
- The methods and tools for SAM training and exercises are to be further enhanced, utilising lessons learned from the use of all available means (such as desk-top training, use of multi-function or full-scope simulators).

7.2.4 Measures already decided on or implemented by operators and/or required for follow-up by regulators

Immediately after the Fukushima accident, regulators and operators started evaluating the events and possible improvements to the organisation of SAM, related procedures, needed hardware provisions and further studies or research and development needed. In the text below examples of such improvements are provided. Nevertheless the level of implementation varies among countries.

With regard to the organisation of SAM, many countries have decided that the WENRA SAM-related RLs should be reflected in the national regulations. The harmonisation of SAMGs and related training across units, sites, utilities and even across borders is envisaged. The enhancement and improvement of SAM organisation, staffing and logistics for long-duration, multi-unit events is of common concern and has already been addressed in most of the countries reviewed.

Cooperation agreements for emergency support, supplies, equipment, personnel, expertise etc. between countries, utilities, operators and vendors are already in place. Some countries already have or have started to establish national response centres and rapid response forces, as well as preparations for cross border co-operation.

The consequences of the possible adverse effects of external events (earthquakes, floods, heavy weather conditions, etc.) on the SAM infrastructure have been investigated, as well as preparations for emergency personnel supplies, logistics, dosimetry, protective equipment etc. under extreme conditions.

Regular and realistic SAM training exercises, including the use of the necessary equipment, with consideration of multi-unit accidents, long-duration events, etc. are part of the measures expected in almost all countries to improve SAM preparedness. The use of the existing NPP simulators is considered as being a useful tool but needs to be enhanced to cover all possible accident scenarios. Regular inspection and testing of SAM equipment and validation of procedures are being further improved.

The extension of existing SAMGs to all plant states (full and low-power, shutdown), including accidents initiated in SFPs, is under consideration or development in all countries. Their extension to long-duration events, including the need for long-term energy supplies, mobile systems, long-term heat removal, safe release of combustible gases from the containment, ensured prolonged supply of consumables, and so on, is being envisaged.

To ensure the survivability of SAM instrumentation and equipment under severe accident conditions, long-term power savings (including battery load-shedding strategies to prolong battery discharge times) or the use of dedicated power supplies, have been addressed.

Many operators have implemented or plan to implement hardware AM measures. These include dedicated emergency core cooling provisions and related improvements to existing systems and equipment. The use of independent and diverse systems, such as auxiliary turbine-driven or air-cooled diesel-driven pumps and generators is being widely considered. The operation of isolation and depressurisation valves using mobile equipment, such as batteries, nitrogen cylinders, mobile generators, as well as provisions for additional manual operation of valves, are other elements designed to improve the robustness of SAM measures. The upgrading of instrumentation, including containment sampling systems for post-accident conditions and of independent water supplies needed for SAM, is complete or has been started in some units. One country is defining a set of essential equipment able to ensure the basic safety functions, even under external hazards BDB. Alternative, independent control rooms and areas for SAM, including safe shutdown provisions, and the manual control of equipment from sheltered locations, have been installed or are planned for enhanced SAM reliability.

The installation of alternative heat sinks, e.g. alternative cooling towers, sources of water, lakes, are considered to be essential prevention option in many countries.

The habitability of control rooms under severe accident conditions is an issue addressed and being resolved at many NPPs (e.g. by filtered air supply, maintaining over-pressure, use of air cylinders, etc.). In addition, more robust emergency centres for on-site and off-site support of the MCR in SAM, designed for internal and external hazards, are seen as a lesson learned from Fukushima. In that respect, improved communication systems, both internal and external, including transfer of severe accident related plant parameters and radiological data to all emergency and technical support centres, including the regulatory premises, are an essential aspect of the measures ensuring a reliable assessment of the emergency situation. Hydrogen management, monitoring and the re-combination of hydrogen in the containment and related rooms, as well as in the SFPs under SBO conditions, for example using PARs, electrical igniters powered by independent severe accident systems, including dedicated DGs, is seen as an area for improvement in some NPPs.

Filtered containment venting systems, including enhanced filters for retention of organic iodine and the use of dedicated internal or alternatively external containment spray cooling, are widely seen as the ultimate options for preventing containment failure and an uncontrolled release of radioactive materials into the environment.

The use of mobile equipment as alternative means of power and water supply, including prepared connecting points for fast and reliable configuration of these alternatives, has been implemented in many countries as an initial reaction to the Fukushima disaster. Water injection to the reactor pressure vessel, reactor cavity and containment, including primary and secondary feed and bleed operations at PWRs, are part of these provisions.

Improvements to the robustness of emergency facilities, SAM equipment storage (including bunkered buildings), seismic and severe accident qualification, the central storage of specialised equipment such as heavy machinery, mobile diesel driven generators and pumps, remotely controlled equipment, chemicals, personal protection equipment, etc. at a regional, national or even cross-border level, are improvements expected to be implemented in most countries.

The preparation of strategies, procedures and provisions for the post AM period and for handling large quantities of liquid waste, as seen after Fukushima, to avoid contamination of the surroundings and the general environment with radioactive releases, is already being envisaged in some countries.

7.3 Peer review conclusions and recommendations specific to this area

The peer review has confirmed that SAM is recognised by all participating countries as an essential component for defence in depth in NPPs. Moreover, the sharing of SAM experience, together with the current status and plans for improvement as part of the stress tests process, is considered to be making an important and helpful contribution towards improving safety standards across Europe.

Although SAM measures were initially BDB for operating NPPs, all countries are now committed to implementing the needed measures for upgrading safety. Basic components of SAM including organisational, procedural and technical means are already well-established. In spite of this, one of the lessons learned from Fukushima is that the scope of SAM needs to be extended, to take account of plant shutdown states, multi-unit events, long-duration events and accidents initiated in SFPs.

The peer review noted that the level of SAM coverage in national legislations varies from country to country. Nevertheless, suitable regulatory instruments appear to be available in all the countries, for adequate implementation of SAM using standard regulatory tools such as review, approval and inspections. There is an expectation and commitment from the regulatory bodies that the stress tests and their peer review will contribute to accelerated implementation of the necessary measures.

In general, the prevention aspects of SAM are more extensively developed than mitigation aspects. The state of implementation of mitigation features varies among the countries, from initial consideration through to very advanced stages of development.

On-site and off-site emergency arrangements are considered important and complementary components of SAM. While on-site arrangements were addressed by the stress tests, off-site arrangements remain an issue for potential further consideration.

Based on the lessons learned from the stress tests and this peer review exercise, the following recommendations are offered for consideration by the participating countries:

1) PSR should continue to be maintained as a powerful regulatory instrument for the continuous enhancement of defence-in-depth in general, and the provisions of SAM in particular. The lessons learned from the Fukushima accident and from the stress tests should be reflected in the scope of future PSRs.

2) In response to their previous commitments, regulators should incorporate the WENRA reference levels related to SAM into their national legal frameworks, and ensure their implementation as soon as possible.
3) Effective implementation of SAM requires that adequate hardware provisions are in place to perform the selected strategies.
4) The means for maintaining containment integrity should in particular include depressurization of the reactor coolant system, prevention of damaging hydrogen explosions, and means of addressing long-term containment over-pressurization, such as filtered venting.
5) A systematic review of SAM provisions should be performed, focusing on the availability and appropriate operation of plant equipment in the relevant circumstances, taking account of accident initiating events, in particular extreme external hazards and the potential harsh working environment.
6) The assessment of SAM provisions should take account of the need to work with a severely damaged infrastructure (i.e. in which the usual means of communication and access, etc. are disabled), of plant level, corporate-level and national-level aspects, and of long-duration accidents affecting multiple units at the same time (on individual and nearby sites as appropriate).
7) The SAMGs should be comprehensively validated taking due account of the potential long duration of the accident, the degraded plant and the surrounding conditions. Pre-planned SAM actions should be designed to function effectively and robustly for suitably lengthy periods following the initiating event. In most cases, durations of at least several days should be assumed for planning and assessment purposes.
8) Training and exercises aimed at checking the adequacy of SAM procedures and organisational measures should include testing of extended aspects such as the need for corporate and national level coordinated arrangements and long-duration events.
9) When developing SAM action plans, conceptual solutions for post-accident fixing of contamination and the treatment of potentially large volumes of contaminated water should be addressed.
10) Radiation protection of operators and all other staff involved in the SAM and emergency arrangements should be assessed and then ensured by adequate monitoring, guaranteed habitability of the facilities (hardened on-site emergency response facility with radiation protection) needed for accident control, and suitable availability of protective equipment and training.
11) Although PSA is an essential tool for screening and prioritising improvements and for assessing the completeness of SAM implementation, low numerical risk estimates should not be used as the basis for excluding scenarios from consideration of SAM especially if the consequences are very high.

8 CONCLUSION AND RECOMMENDATIONS

8.1 Summary of review process compliance with the ENSREG recommendations and of its quality

The judgement resulting from the peer review of the national reports is that the exercise generally complied with the ENSREG specifications and that the national analyses were done well, with the exception of the margin assessments relative to extreme natural hazards, which raised difficulties. The results were provided on time. The countries proactively sought improvements in safety. It is felt that all participating countries deserve recognition for the serious work that has been done.

With regard to the external hazards topic, overall the design basis events were well addressed in country reports. Most countries have demonstrated an adequate approach to seismic and flooding design bases, although there were significant differences in national approaches. However, the assessment of margins beyond design basis has been quite diverse, and very few countries assessed cliff-edges in the manner requested by ENSREG. This is possibly because of the short timeframe and the lack of a consistently recognised method in this area. Many regulators also indicated that work in this respect is either ongoing or planned in the near future. The situation is even less satisfactory with regard to extreme weather, and especially for combinations of extreme weather phenomena. **The peer review Board recommends that WENRA, involving the best available expertise from Europe, develop guidance on natural hazards assessments, including earthquake, flooding and extreme weather conditions, as well as corresponding guidance on the assessment of margins beyond the design basis and cliff-edge effects.**

For the topic concerning loss of electrical power and loss of ultimate heat sink and the combination thereof, all countries complied with the ENSREG specifications by performing the analysis. For most of the reports the quality was good, with some of them providing analysis in outstanding detail. It should be pointed out that countries having multiple units typically chose to address type-specific rather than plant-specific analysis.

With regard to the accident management topic, the ENSREG specifications were generally addressed with a high level of quality by the national reports, although the level of detail varied among the countries. The national reports outlined the essential technical, procedural and organisational provisions required for accident management and on-site emergency arrangements.

8.2 Summary in relation to the scope of the stress tests of the licensing basis, background of licensing basis and plant compliance

It should be noted that the stress tests reports and the peer review could not provide exhaustive verification of the comprehensiveness and adequacy of the provisions. Consequently, this process cannot replace the more detailed work performed by the national regulatory bodies.

According to the information available to the peer review, national regulators have verified plant compliance with their current licensing/safety case basis before and during the stress tests, in addition to their routine regulatory oversight processes. Dedicated inspections and assessments have been performed and showed that the plants complied with the licensing basis. Minor deviations from regulatory requirements were resolved using standard regulatory procedures.

Regular verification through inspections and walkdowns is recommended to further demonstrate continuing regulatory compliance. Regulators and operators should be encouraged to develop procedures for plant inspections and walkdowns in order to provide a more systematic search for nonconformities.

The stress tests highlighted the importance of the PSRs for continuously improving plant safety and robustness. **The peer review Board recommends that ENSREG underline the importance of periodic safety review. In particular, ENSREG should highlight the necessity to re-evaluate natural hazards and relevant plant provisions as often as appropriate but at least every 10 years.**

Regulators should consider requesting the licensee to re-evaluate the external event design basis whenever new relevant information becomes available and as well as during the PSR.

8.3 Main results for margins, cliff-edge effects and areas for possible further improvements

As has already been stated, the evaluation of seismic and flooding margins was inconsistent. It is therefore difficult to identify general outcomes resulting from these evaluations. The existence of seismic margins, often based on engineering judgement, is a shared view.

Many countries have made a case that beyond design basis flood is an extremely low frequency event and therefore they have not evaluated the condition. It may be accepted that at some sites, due to local geography, any cliff edge effect associated with flooding can be practically eliminated. Only a small number of countries complied with ENSREG specifications relevant to the assessment of flooding margins. ESNREG asked for the evaluation of incremental increases in flood level beyond design basis and a determination of cliff-edges as well as potential improvements to address them. This approach proved to be fruitful. It is recommended that ENSREG encourages the national regulators to consider requesting flooding margin evaluations in accordance with ENSREG specifications, as it can provide a valuable insight into effective and practicable improvements.

As far as loss of electrical power and loss of ultimate heat sink are concerned, all the countries estimated the cliff-edge effects related to various combinations of losses of AC/DC power and/or cooling water. In some cases the methodology for determining the cliff-edge effects was extensively covered by the national reports and in other cases reported during the country presentations. In this regard, margin can be expressed in the time available before safety functions need to be restored. The results varied significantly depending on the type of facility and the cliff-edges considered. For the most severe total losses of cooling with no recovery actions credited typically the time to fuel heat up ranged from 1 to 10 hours. With recovery actions times extended beyond, 72 hours (the ENSREG specifications did not request an evaluation beyond 72 hours). Numerous improvements related to hardware and procedures have been identified; some have been implemented and others are still at the planning stage.

For accident management, it should be noted that although severe accident management measures were initially beyond the design basis for all operating NPPs, all countries are now committed to implementing the necessary measures for safety upgrading, including organisational, procedural and technical means.

In general, the prevention aspects of severe accident management are better developed than mitigation aspects. Implementation of mitigation features varies widely from country to country, ranging from initial consideration to very advanced stages of development. In particular, the provisions required for maintaining containment integrity need to be ensured.

The Fukushima accident highlighted new issues to be handled in accident management, for example the need to perform actions with severely damaged infrastructure and consideration of accidents affecting multiple units at the same time. Other new issues include assignment of responsibilities between the plant level, corporate level and national level.

8.4 Main results on possible means to improve robustness

For external hazards, national reports have identified significant plant-specific improvements, in particular, seismic upgrades and flood protection physical features to improve robustness. For example, the increased height of openings into protected rooms or the provision of additional temporary flood protection dams, are important and should be considered.

Similarly, in the area of loss of power and loss of heat sink, all countries identified improvements that would enhance robustness. The most promising improvements being considered by many countries are additional power and water supplies to be provided by mobile units, for which the connecting arrangements would be established in advance, extending battery capacity, additional sources of water, extended or additional supply of fuel, valve line-up accessibility as well as various operational improvements.

The regulators are overseeing operator improvement plans and should consider the most effective measures to increase robustness.

Within the scope of accident management, all countries are already committed to implementing the safety upgrading of the necessary measures for beyond design basis events. Basic SAM components including organisational, procedural and technical means are already well-established. Hardware provisions for maintaining containment integrity were already known to be important prior to the Fukushima accident and have been implemented in several countries. Where these provisions have not been implemented, they should be. **Urgent implementation of the recognised measures to protect containment integrity is a finding of the peer review that national regulators should consider.**

The measures to be taken can vary depending on the design of the plants. For water cooled reactors, they include equipment, procedures and accident management guidelines to:

- depressurize the primary circuit in order to prevent high-pressure core melt;
- prevent hydrogen explosions;
- prevent containment overpressure.

One of the lessons learned from Fukushima is that the scope of SAM needs to be extended in these areas, in particular multi-unit long-duration accidents, devastated site conditions, harsh environments and contamination. **Necessary implementation of measures allowing prevention of accidents and limitation of their consequences in case of extreme natural hazards is a finding of the peer review that national regulators should consider.**

SAM guidelines are, for the most part, only developed for power operation and only in a few cases are there SAMGs for shutdown conditions, spent fuel pools or multi-unit events. Where SAMGs do not apply to all plant states, operators have plans to extend them within a few years. SAMGs should be developed for all plant conditions, accidents in the spent fuel pools, multi-unit accidents and long-duration events. Validation and verification of SAMGs is also essential for ensuring their practicability, robustness and reliability and so should form an intrinsic part of their implementation process.

The methods and tools for SAM training and exercises are to be further enhanced. SAMGs should be exercised periodically for severe accidents in very harsh conditions, taking account of the extended scope of SAM.

Equipment needed for SAM, including instrumentation and communication means, needs to be resistant to external hazards and sufficient reliability should be ensured under severe accident conditions. Any mobile equipment to be used for Accident Management should also be stored in a location resistant against extreme natural hazards.

On-site emergency centres should be available and designed against extreme natural and radiological hazards.

Finally, necessary additional staff and material resources should be rapidly available to any plant experiencing an accident, taking into account the possible devastation caused by natural disasters.

In addition to the previously mentioned means to improve robustness, the concept of a "hardened core" was also discussed. The "hardened core" is defined as a limited set of material and organisational measures, designed to ensure basic safety functions in extreme situations. The "hardened core" function is to prevent a severe accident or limit its progression, limit large releases and enable operators to perform emergency management. The "hardened core" will be designed to withstand conditions which are significantly more severe than the design basis of the plant. A significant number of European plants have decided to implement the "hardened core." Many reviewers felt that the concept needs further assessment before it can be considered as a European reference.

8.5 Most important assessments, follow-up actions, decisions and measures already made by regulators and operators

There is good evidence that national regulators have been proactive in demanding improvements and further analysis from their operators, although with varying timescales.

Inspections have been performed in areas related to Fukushima in many countries. Further inspections should be undertaken to ensure that equipment is properly installed and maintained and it is recommended that national regulators establish programmes for such inspections, particularly for temporary and mobile equipment used to mitigate beyond design basis external events and subsequent accidents.

Hardware provisions, including mobile equipment, were implemented or were in the process of implementation before Fukushima. After Fukushima, regulators and operators re-evaluated the provisions and proposed improvements. There is a general commitment to implementing these provisions, so in some cases mobile resources have already been acquired. This is also the case for SAM measures.

Although there is common agreement on the scope of most measures, the scale of their implementation is still being approached differently, depending on the pre-existing situation and the regulatory environment. Such is the case, for example, of the on-site emergency centre, the availability of remote support, fixed or mobile equipment, upgrades and additional layers of protection.

8.6 Recommendations to ENSREG for future positions and actions

The action plans for further analysis and subsequent implementation of the improvement measures have already been, or will be shortly defined, in all countries. The general aim is to make improvements as soon as possible, with the initial focus on those measures that can be implemented quickly, thereby providing immediate benefit. However, the completion schedules of all aspects of the action plans vary significantly depending on the scope of the work and the regulatory process. It is recommended that, within the existing arrangements, ENSREG identify an approach to keep this large volume of work under review and to establish the mechanisms for reporting on the implementation of the improvements and for further experience sharing. Such reporting could, for example, be performed as part of the reports which have to be produced by Member States in the frame of the European safety directive.

The peer review identified four main conclusions in addition to many detailed findings and recommendations included in this report.

Overall, the compliance with ENSREG specifications was quite good. However, deviations from the stress tests specifications were highlighted by the peer review in the field of natural hazards, where significant differences exist in the national approaches and where difficulties were encountered for margins and cliff edge effects assessments.

The peer review Board recommends that WENRA, involving the best available expertise from Europe, develops guidance on natural hazards assessments, including earthquake, flooding and extreme weather conditions, as well as corresponding guidance on margins beyond the design basis and cliff-edge effects.

Stress tests showed that periodic safety reviews are well-established in participating countries and form the basis for continuous plant improvements, as well as for regular reassessment of the licensing basis.

The peer review Board recommends that ENSREG underlines the importance of periodic safety review in the field of natural hazards. ENSREG should highlight the necessity to re-evaluate natural hazards as often as appropriate but at least every 10 years.

All the countries participating in this review recognise the benefit of the WENRA reference levels applicable to SAM.

Urgent implementation of the recognised measures to protect containment integrity is a finding of the peer review that national regulators should consider.

The Fukushima event has also shown that defence-in-depth should be strengthened by taking into account severe accidents resulting from extreme natural hazards significantly exceeding the design basis. Such situations can result in devastation and isolation of the site, an event of long duration, unavailability of numerous safety systems, simultaneous accidents of several plants including their spent fuel pools, and the presence of radioactive releases.

Necessary implementation of measures allowing prevention of accidents and limitation of their consequences in case of extreme natural hazards is a finding of the peer review that national regulators should consider.

One of the important results of the public interaction is a strong demand for a European initiative on off-site emergency preparedness. This subject was not part of the mandate of the peer review. However, the Board clearly recognises importance of dealing with off-site emergency preparedness in Europe, as a follow-up of the Fukushima disaster.

Finally, it should be mentioned that performing such a peer review was a challenge and required very significant resources from the participating countries. In that sense, it should be considered as an exceptional exercise, which cannot be reproduced frequently. Notwithstanding, it was judged very positively by most of the participants and is expected to contribute to enhancing safety in Europe and in each European country.

9 ANNEXES

List of acronyms

AC	Alternating Current
AGR	Advanced Gas-cooled Reactor
AM(P)	Accident Management (Programme)
BDB	Beyond Design Basis
BWR	Boiling Water Reactor
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DC	Direct Current
DG	Diesel Generator
EC	European Commission
ECC	Emergency Control Centre
ECR	Emergency Control Room
ENSREG	European Nuclear Safety Regulators Group
EOP	Emergency Operating Procedures
EU	European Union
EU Council	European Council
IAEA	International Atomic Energy Agency
JRC	EC Joint Research Centre
LOOP	Loss of Off-site Power
MCR	Main Control Room
NPP	Nuclear Power Plant
PAR	Passive Autocatalytic Recombiner
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Review
PWR	Pressurized Water Reactor
RCIC	Reactor Core Isolation Cooling
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RLs	Reference Levels
SA(M)(G)	Severe Accident (Management) (Guidelines)
SBO	Station Blackout
SG	Steam Generator
SL1 / SL2	Seismic Level 1 / Seismic Level 2
SFP	Spent Fuel Pool/Spent Fuel Pond
SFSF	Spent Fuel Storage Facility
SSC	Structure, System and Component
TMI	Three Mile Island (accident)
UHS	Ultimate Heat Sink
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators' Association

Country reports

Statistics about questions received on national reports

Number of questions put per country of reviewers:

Austria - AT	147
Belgium - BE	118
Bulgaria - BG	37
Croatia - HR	16
Czech Republic - CZ	60
Denmark - DK	8
Finland - FI	27
France - FR	108
Germany - DE	148
Greece - GR	18
Hungary - HU	28
Ireland - IE	21
Italy - IT	50
Lithuania - LT	27
Luxembourg - LU	34
Netherlands - NL	128
Poland - PL	44
Romania - RO	44
Slovakia - SK	47
Slovenia - SI	50
Spain - ES	126
Sweden - SE	7
Switzerland - CH	102
Ukraine - UA	175
United Kingdom - UK	45
European Commission - EC	399

Number of questions received per country:

Belgium – BE	174
Bulgaria – BG	128
Czech Republic – CZ	137
Finland – FI	122
France – FR	144
Germany – DE	101
Hungary – HU	98
Lithuania – LT	62
Netherlands – NL	90
Romania – RO	96
Slovakia – SK	83
Slovenia – SI	139
Spain – ES	175
Sweden – SE	120
Switzerland – CH	123
Ukraine – UA	88
United Kingdom – UK	120
Generic to all countries - CG	14

The following numbers of questions were received concerning the following topical areas:

General quality of national reports and assessments	74
Assessment with regard to earthquakes, flooding and extreme weather conditions	422
Assessment with regard to loss of electrical power supply and loss of ultimate heat sink	587
Assessment with regard to severe accident management	931

List of Participants

Board Members

Name	Country	Role
Garribba M.	EC	European Commission representative
Gurgui A.	ES	Vice-Chair
Jamet P.	FR	Chair
Krs P.	CZ	Project Manager
Liszka E.	SE	Team Leader, Loss of Safety Systems
Misak J.	SK	Team Leader, Severe Accidents
Molin A.	AT	Non-nuclear country representative
Shepherd D.	UK	Team Leader, External Events

Reviewers

Name	Country		Name	Country
Adorján F.	HU		Martin-Ramos M.	EC
Alm-Lytz K.	FI		Matteocci L.	IT
Aszódi A.	HU		Mattila R.	FI
Avdijev K	BG		Misak J.	SK
Bai J.	FR		Munuera A.	ES
Bennemo L.	SE		Noel M.	EC
Bogdan D.	RO		Nystrup P. E.	DK
Boichuk V.	UA		Pascal G.	EC
Bucalossi A.	EC		Patasius Z.	LT
Canadell- Bofarull V.	EC		Perez A.	ES
Ciurea-Ercau C.	RO		Podjavoršek M.	SI
Decker K.	AT		Raimond E.	FR
Delfini G.	NL		Ranieri R.	IT
Dinca E.	RO		Ratajova M.	CZ
Duchac A.	EC		Rebleanu I.	RO
Elsing B.	EC		Reer B.	CH
Filipov O.	UA		Rovny J.	SK
Foucher L.	FR		Rühl E.	DE
Frid W.	SE		Sairanen R.	FI
Gadó J.	HU		Shepherd D.	UK
Ganchev T.	BG		Sholomitsky S.	UA
Glockler O.	EC		Smith K.	IE
Grözinger O. ll	DE		Staron E.	PL
Harrison S.	UK		Tchien Minh Tang	BE
Hart A.	UK		Thiry J.C.	LU
Hirsch H.	AT		Tipek Z.	CZ
Hulsmans M.	EC		Tombuyses B.	BE

Name	Country		Name	Country
Jansen R.	NL		Tomic B.	AT
Jimenez A.	ES		Tronea M.	RO
Jirsa P.	EC		Tsvetanov V.	EC
Kiełbasa W.	PL		Tsvetanova E.	BG
Kimtys E.	LT		Uhrik P.	SK
Kirchsteiger C.	EC		Van Rompuy T.	BE
Koehne W.	EC		Vesely J.	CZ
Legenis V.	LT		Vrankar L.	SI
Liszka E.	SE		Vuorio U.	FI
Louis T.	NL		Weidenbrück K.	DE
Loy D.	CH		Yadigaroglu G.	GR
Majdański M.	PL		Zerger B.	EC
Maresca G.	IT		Zwicky P.	CH

Observers

Name	Country/ Organisation
Bajs T.	HR
Bannai T.	JP
Basic I.	HR
Drake P.	FANR,UAE
El-Shanawany M.	IAEA
Fukushima Y.	IAEA
Hirano M.	JP
Hopkins J.	US-NRC
Kuzmina I.	IAEA
Lecann G.	FANR,UAE
Lyubarskiy A.	IAEA
Mahmood H.	IAEA
Norton C.	US-NRC
Ogura K.	JP
Schwarz G.R.	CNSC
Šimić Z.	HR
Uchiyama Y.	JP
Yllera J.	IAEA

Communications Task Force Members

Name	Country
Besenyei E.	HU
Clipet N.	FR
Forster A.	AT
Jackson C.	FR
Kravos M.	EC
Leblancdemolines J.-M.	FR
Lyons C.	UK
Muner R.	AT
Petit E.	FR

26 April 2012

Stress tests and Peer Review Process

Joint statement of ENSREG and the European Commission

The national European regulators and the European Commission as European Nuclear Safety Regulators Group (ENSREG) have endorsed today the peer review board report prepared as an answer to the mandate delivered by the European Council of 25 March 2011, asking for the launch of stress tests on the European NPPs;

ENSREG and the European Commission share the view that the work achieved since the Fukushima accident has been of exceptional nature from a quantitative and qualitative point of view. The seventeen national reports[1] covering all nuclear power plants of the EU and of participating countries have been assessed by 80 reviewers from 24 nations in Europe and the European Commission;

ENSREG and the European Commission underline that the stress tests and peer review have been a rigorous review of the safety of NPPs in the light of three main areas of the Fukushima accident. This review was carried out through three different steps:

1) *The first step required the operators to perform an assessment and make proposals for safety improvements, following the ENSREG specifications;*
2) *The second step was for the national regulators to perform an independent review of the operators' assessments and issue requirements, whenever appropriate;*
3) *The third step was a European peer review of the national reports submitted by regulators, subdivided in 2 phases:*

    - *Peer review on the basis of the national reports, from January to March 2012.* This review was conducted through a topical review structured around the 3 topics of the stress tests (natural hazards, loss of safety systems and severe accident management). Each national regulator was heard and questioned on its report;

    - *"Country peer reviews", from March to April,* on which occasion each country subjected to the peer review was visited by a team of eight peer reviewers for several days (including sites visits, in order to provide complementary information of some aspects of the implementation and results of the stress tests).

According to the principle of continuous improvement, ENSREG and the European Commission consider that the stress tests have identified tangible improvements. Both the overall peer review report and the country reports issued contain very practical recommendations aiming at achieving these concrete improvements:

- the overall report highlights four main areas for improvement to be explored across Europe:

[1] Fifteen EU countries, Switzerland and the Ukraine.

1) *Issuing WENRA guidance with the contribution of the best available EU expertise on assessment of natural hazards and margins taking account of the existing IAEA guidelines*
2) *Underlining the importance of Periodic Safety Review*
3) *Implementing the recognised measures to protect containment integrity*
4) *Minimising accidents resulting from natural hazards and limiting their consequences*

- national actions plans have already been or will be shortly defined in all countries;

ENSREG and the European Commission recognise that the results of the stress tests related to loss of safety systems and severe accident management provide valuable insight also in all indirect initiating events like aircraft crashes.

ENSREG and the European Commission have made their best efforts to make the stress tests process as transparent as possible, and to ensure the best possible accessibility to all interested stakeholders and the citizens. Transparency and public accessibility have been acknowledged as key objectives from the beginning of the process. National reports as well as all EU documents were made public in the English version on the ENSREG website. A European public meeting was held in January 2012 to inform the stakeholders about the ongoing process and trigger a constructive dialogue. A new European public event is scheduled next 8 May in Brussels to present the results of the stress tests; ENSREG and the European Commission encourage the staging of national events to further inform the public;

ENSREG and the European Commission welcome the fact that this unprecedented exercise was rapidly echoed internationally. For instance, several third states demonstrated great interest in the ongoing process and subsequently decided to get involved in it. The stress tests thus contributed in strengthening the EU's commitment to actively promote nuclear safety at world level.

ENSREG and the European Commission realise that the full implementation of the measures identified in the reports to improve safety will be a long-term process.

ENSREG and the European Commission agreed to propose an action plan in the national, the European and the global context. This action plan should comprise:

- *Implementation of the recommendations of the peer review report;*
- *Implementation of the IAEA action plan on nuclear safety;*
- *The outcomes of the extraordinary meeting of the Convention of Nuclear Safety;*
- *Additional site visits as agreed.*

ENSREG and the European Commission will ensure that all the stress test relevant information received from licensees, national authorities, including plant specific information, will be available via its web site with the exception of confidential information.

ENSREG and the European Commission share the understanding that work may be required in other areas than nuclear safety – such as off-site emergency preparedness and response.

The endorsed peer review board report will be sent to the June European Council for information. ENSREG and the European Commission understand that, on the basis of the peer review report and the additional elements above, the European Commission will present its Communication to the European Council.

EUROPEAN
COMMISSION

Brussels, 4.10.2012
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COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT

on the comprehensive risk and safety assessments ("stress tests") of nuclear power plants in the European Union and related activities

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1. INTRODUCTION

There are currently 132 nuclear reactors in operation in the EU, grouped on 58 sites. Their safety record is such that although incidents have occurred and continue to occur, no major accidents have ever taken place. While the overall safety record is therefore good, EU citizens' confidence in Europe's nuclear industry hinges on continuous improvements of the EU nuclear safety and security framework, so as to ensure that it remains the most effective in the world, based on the highest safety standards.

The challenges which nuclear safety and its governance face were highlighted in the accident at the Fukushima reactors in Japan following the earthquake and the tsunami in March 2011. This event demonstrated that nuclear reactors must be protected even against accidents which have been assessed as highly improbable. Events at Fukushima revealed well-known and recurring issues: *faulty design, insufficient backup systems, human error, inadequate contingency plans*, and *poor communications*. The EU must learn the lessons of Fukushima to further reduce the risk of nuclear incidents in Europe.

The Fukushima accident resulted in unprecedented efforts to review the safety of nuclear installations in Europe and worldwide. Initiatives were taken at national, regional and international level.

In the EU, the European Council, in March 2011[1] concluded that “the safety of all EU nuclear plants should be reviewed, on the basis of a comprehensive and transparent risk and safety assessment ("stress tests"); the European Nuclear Safety Regulatory Group (ENSREG) and the Commission are invited to develop as soon as possible the scope and modalities of these tests in a coordinated framework in the light of lessons learned from the accident in Japan and with the full involvement of Member States, making full use of available expertise (notably from the Western European Nuclear Regulators Association); the assessments will be conducted by independent national authorities and through peer review; their outcome and any necessary subsequent measures that will be taken should be shared with the Commission and within the ENSREG and should be made public.” In addition, the European Council asked the Commission to invite EU neighbouring countries to take part in the stress test process, to "review the existing legal and regulatory framework for the safety of nuclear installations" and to "propose by the end of 2011 any improvements that may be necessary".

[1] EUCO 10/11 (paragraph 31).

Close cooperation between plant operators, nuclear regulators and the Commission made it possible to carry out stress tests in 2011 and 2012. The Commission can now give a response to the European Council's mandate with the present report which identifies the Commission's conclusions and recommendations based on the stress tests and related activities. It also considers the international dimension of nuclear safety and security and outlines how the nuclear safety framework in the EU can be improved, underlining the dynamic nature of nuclear safety: enhancing nuclear safety is not a one off exercise, it must be continually reviewed and updated. Above all, it brings together all the strands of the review exercise with a view to developing legislative, non-legislative and project proposals. All these measures seek to improve the safety of the plants and related governance at EU and national level, and to promote EU values for nuclear safety and security in the international context.

Details on the technical findings and the stress test methodology are presented in the accompanying Commission Staff Working Document.

2. THE PROCESS, KEY FINDINGS AND IMMEDIATE FOLLOW-UP TO THE RISK AND SAFETY ASSESSMENTS

2.1. An unprecedented review of nuclear safety and security

In response to the Fukushima accident and the subsequent mandate given by the European Council to the Commission, many layers of activities ran in parallel. These are presented briefly below.

While ENSREG and the Commission developed the scope and modalities of the tests, the assessment of the safety of nuclear power plants falls under the responsibility of nuclear operators and national regulators who participated in the stress tests on a voluntary basis. The Commission cannot guarantee the nuclear safety and security of nuclear installations, since the legal responsibility remains at national level. All the conclusions in the present Communication need to be read against this background.

The safety assessments lead by ENSREG

The stress tests were defined as a targeted reassessment of the safety margins of NPPs in the light of the lessons drawn from the events in Fukushima related to extreme natural events challenging the plants safety functions. They were organised taking due account of the distribution of competences among the various stakeholders in the area of nuclear safety[2]. All fourteen EU Member States that operate nuclear power plants[3] plus Lithuania[4] participated in these assessments on a

[2] According to article 6 of the Nuclear Safety Directive, the prime responsibility for nuclear safety lies with the "licence holder" (i.e. the plant operator) under the supervision of the national competent regulatory authority. Member States are responsible for establishing and maintaining a national legislative, regulatory and organisational framework for nuclear safety. Under the Euratom Treaty, the Commission can make legislative proposals to create an EU legislative framework for nuclear safety, without however being able to substitute its responsibility for that of the Member States. A change to this situation would require an amendment of existing legislation.

[3] Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom.

voluntary basis. The 132 nuclear reactors[5] in operation in the EU, are based on different technologies and types, but are mainly Pressurised Water Reactors (PWR), Boiling Water Reactors (BWR) or gas cooled reactors. Stress tests were started by self-assessments carried out by nuclear operators and the preparation of national reports by national regulators in line with the responsibilities for the safety of NPPs. Peer review teams mainly composed of experts from the Member States, with support from the European Commission, visited 23 sites, taking into account the type of reactor as well as the geographical location. Team visits to selected sites in each country were organized in order to firm up the implementation of the stress tests, without encroaching on the responsibilities of national authorities in the area of nuclear safety inspections, which organised inspections of each operating nuclear power plant (NPP) in the EU after the Fukushima accident. Information on each NPP can be found in the accompanying Commission Staff Working Document as well as its references to information made available by plant operators, the national regulators or ENSREG as a whole.

Following the presentation of the Commission Interim Report[6], an extensive EU wide peer review process was carried out from January to April 2012. It produced an overview report by the ENSREG Peer Review Board, endorsed by ENSREG, and seventeen individual national reports[7] with detailed recommendations. In July, ENSREG agreed on an Action Plan to follow up the implementation of the peer review recommendations. It is on this basis that safety findings and recommendations described in this Communication are formulated.

<u>Work on nuclear security by the Council (Ad Hoc Group on Nuclear Security, AHGNS)</u>

In order to deal with matters related to the security of nuclear power plants, a new *ad hoc* group was set up in the Council. The group met regularly as of September 2011, chaired by the Polish and Danish Presidencies. It comprised security experts from the Member States with the Commission closely associated. In contrast to the ENSREG safety assessments, the AHGNS did not look at individual installations but assessed the state of nuclear security in the EU as a whole, by looking at methodology for the evaluation and protection of nuclear power plants including preventive measures.

The AHGNS encouraged the exchange of existing practices and identified possible methodological improvements, making mainly use of good practices in the existing International Atomic Energy Agency (IAEA) guidance. It concluded its work in May 2012.

4 Where the Ignalina NPP is being decommissioned.

5 Altogether, the stress tests were performed on the 132 reactors in operation in the EU, 13 EU reactors that were phased out since the stress tests were initiated, 15 reactors in Ukraine, and 5 reactors in the Swiss Confederation.

6 COM 784 final, 24.11.2011.

7 14 Member States operating nuclear power plants (Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom), Lithuania (where the Ignalina units are being decommissioned under operating licenses) and Switzerland and Ukraine as EU neighbouring countries.

Involvement of EU neighbouring countries in the process

Switzerland, Ukraine and Croatia participated fully in the EU stress tests and the peer review process, while other neighbouring countries (e.g. Turkey[8], Belarus and Armenia[9]) that agreed to work on the basis of the same methodology, are working within different timetables. The Russian Federation also carried out re-assessments and identified improvement measures at its NPPs, using its own methodology. Switzerland is fully committed to follow up the recommendations of the stress tests, while Ukraine has included the stress tests finding in the modernisation programme of its nuclear power plants. The Commission appreciates these efforts to converge with the EU's approach in this field.

Commission assessment of the institutional and legal framework

Beyond the review of the safety of the plants, the Commission has assessed the institutional architecture and legal framework for nuclear safety in Europe, taking into account the IAEA Action Plan[10] and the outcome of international discussions on the Convention on Nuclear Safety. It has identified gaps and best practices that can be addressed or included within EU legislation on the basis of the existing balance of competences, extended collaboration among Member States or in the implementation of existing EU programmes.

Effects of aircraft crashes

Events that could affect both the safety and the security of nuclear power plants, like aircraft crashes, have been considered within this review exercise. The effects of aircraft crashes on the safety of nuclear power plants are covered in the ENSREG stress tests specification. On security, the AHGNS report identifies good practices to be followed by Member States on the prevention of malevolent aircraft crashes.

The Commission has organised a seminar *"Safety of Nuclear Power Plants against Aircraft Impacts"* on 25 September 2012 aimed at upgrading plant safety and exploring alternative protection methods. Participation included Member States safety regulatory authorities as well as contributions from USA and Japanese experts. Invited experts considered the characteristics of existing plants and new designs separately.

Off-site emergency preparedness

During the peer review phase of the safety stress tests some NGOs requested to extend the scope of the stress tests to off-site emergency preparedness. In the EU, 47 nuclear power plants with 111 reactors have more than 100 000 inhabitants living within a circle of 30 km. This demonstrates that off-site preventive measures are of

[8] Stress test report submitted to the Commission in May 2012.
[9] Financial and technical assistance from the EU Instrument for Nuclear Safety Cooperation. A report is expected by early 2013.
[10] http://www.iaea.org/newscenter/focus/actionplan/reports/actionplanns130911.pdf

primary importance. The responsibility for such measures is shared by several national, regional and local authorities. The Commission, with ENSREG support, is launching a study aiming at drawing a picture of current arrangements, focussing on cross border regions in the EU and at making recommendations as necessary. Results are expected by the end of 2013.

Cooperation in the framework of international organisations

The Contracting Parties to the Convention on Nuclear Safety held an Extraordinary Meeting in August 2012 to review its effectiveness and continued suitability. The Commission prepared a report on behalf of the Euratom Community[11] and has been mandated by the Member States in the Council to negotiate improvements to the implementation of the Convention as well as amendment proposals tabled by other Contracting Parties.

2.2. Findings from the safety assessments and from the institutional and legal review

The findings are described in detail in the Commission Staff Working Document accompanying this Communication. Key considerations for each topic are summarised in the following paragraphs.

2.2.1. Findings on safety measures in existing NPPs

Based on the stress tests, national regulators concluded that there are no technical reasons requiring the shutdown of any NPP in Europe, and identified a series of good practices. The Commission is not empowered to make assessments of this nature. However, practically all NPPs need to undergo safety improvements, as hundreds of technical upgrade measures have been identified. Following the accidents at Three Mile Island and Chernobyl, measures to protect nuclear plants were globally agreed. The stress tests demonstrated however that in many instances the implementation of those measures is still pending.

The Annex highlights the main recommendations identified in the stress test exercise. Further detail on required improvements and on good practices detailed by NPP is provided in the Staff Working Document.

Examples of significant findings:

In 4 reactors (located in two different countries), there is less than 1 hour available to operators to restore the safety functions in case of loss of all electrical power and/or ultimate heat sink.

In 10 reactors, on-site seismic instrumentation is not installed yet.

4 countries currently operate additional safety systems fully independent from the normal safety systems, located in areas well protected against external events (e.g. bunkered systems or hardened core of safety systems). A fifth country is considering this option.

11 C(2012) 3196 final, 10.5.2012.

Mobile equipment, especially diesel generators needed in case of total loss of power, external events or severe accident situations, are already available in 7 countries, and will be installed in most of the others.

The seminar on aircraft crashes showed the existence of significant differences in the national approaches to deal with the assessment of the safety implications with regard to existing and new NPPs:

Design requirements for new NPPs require that – following impact of a large aircraft, no releases to outside of the containment take place. For historical reasons, the situation is different for existing NPPs, and the methodologies applied and implications developed are not necessarily coherent and consistent across Member States.

Participants stressed the need to keep a clear separation with security issues because of the different level of institutional responsibility and transparency vis-à-vis the public.

2.2.2. *Findings on safety procedures and frameworks*

The stress tests highlighted best practices as well as shortcomings in Member States. These are detailed in the Staff Working Document. The following key issues have emerged from the stress tests and from other reports on the Fukushima investigations[12]:

- **There is a lack of consistency with respect to assessing and managing external hazards to plant safety.** For example, the International Atomic Energy Agency guidance for seismic loads or the guidelines for flooding are not implemented by all Member States (first ENSREG peer review Board recommendation, see 2.3.2.).

- **The scope and depth of the Probabilistic Safety Assessment** (PSA) used to characterise the safety of nuclear reactors differ significantly and in some Member States there is an urgent need to bring them up to accepted international standards.

- **Severe Accident Management Guidelines** (SAMG's) covering all types of situations have to be available in all NPPs. The stress tests have shown that SAMG's need to be updated and fully implemented as soon as possible in a number of Member States.

- **Improvements in safety culture are needed**. There are **gaps in ensuring comprehensive and transparent identification and management of key safety issues.** A glaring lesson from Fukushima is that the tsunami hazard was underestimated, mostly due to human, systemic and organisational factors.

[12] "Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company", final report July 2012 (http://icanps. go.jp/) and "The Fukushima Nuclear Accident Independent Investigation Commission", final report July 2012 (http://www.naiic.jp/en/2012/)

2.2.3. Findings on the legal framework for safety and its implementation

A number of weaknesses in the existing nuclear safety framework at the European and the Member States level have been identified.

- The key finding relates to **continuing differences between Member States resulting in the absence of a consistent approach to nuclear safety regulation.** There are no codified EU mechanisms to agree on technical standards and ways to conduct safety reviews. The Nuclear Safety Directive does not have any provisions to this end.

- The provisions covering **the independence of the national regulatory authorities and the means to ensure their effectiveness** are minimal and not necessarily sufficient for preventing situations where the regulatory responsibility is split between several entities or is included directly in Ministries (Economy, Environment, etc.). Moreover, the existing catalogue of regulatory competencies is not sufficiently explicit.

- **Transparency** is essential in ensuring that the best possible safety practices are used, as shown by the stress tests. However, the Nuclear Safety Directive contains only generic requirements on public information.

- The **monitoring and verification mechanisms at EU level** are limited to the peer review of the national nuclear safety framework.

2.3. Key recommendations from the stress tests on safety

2.3.1. Recommendations on safety measures in existing NPPs

The Staff Working Document provides an overview of the number of safety measures required in individual nuclear power plants.

<u>Follow-up:</u>

All participating countries have begun to take operational steps to improve the safety of their plants. These measures include additional mobile equipment to prevent or mitigate severe accidents, the installation of hardened fixed equipment, and the improvement of severe accident management, together with appropriate staff training measures. The costs of additional safety improvements are estimated to be in the range of €30 million to €200 million per reactor unit. Thus, the total costs for the 132 reactors operating in the EU could be in the order of €10–25 billion for all NPP units in the EU over the coming years. These figures are based on the estimates published by the French nuclear safety authority (covering more than one third of the reactors in the EU) and are subject to confirmation in the national actions plans.

In line with a Joint Declaration issued by the Commission and ENSREG on 25 April 2012[13], ENSREG agreed an Action Plan in July, which aims at ensuring that the

[13] http://www.ensreg.eu/sites/default/files/EC%20ENSREG%20Joint%20Statement%2026%20April%202012%20-Final%20to%20publish.pdf

recommendations from the peer review process are implemented in a consistent and transparent manner. This must be a priority for all affected Member States. In view of the high number of recommended improvements, methods and criteria need to be developed and applied to judge the importance of different measures, to prioritise and allocate funding to those areas which bring the greatest safety benefits.

At the same time, the assessment carried out on plants being constructed considered the likelihood for new reactor designs to be strongly affected by all of these safety upgrading measures as low. Therefore, large increases in the investment costs for new nuclear generation capacity in Europe are unlikely if the best available technologies are chosen.

The responsibility for implementing monitoring and verification mechanisms belongs to the Member States.

2.3.2. Recommendations on procedures and frameworks

Regarding safety, the ENSREG peer review Board report identified four main areas for further improvement across Europe:

- **European guidance should be developed on the assessment of natural hazards, including earthquake, flooding and extreme weather conditions, and safety margins, in order to increase consistency between Member States**. The Western European Nuclear Regulators' Association (WENRA), involving the best available expertise from Europe (linked with the first finding under 2.2.2.) would be well placed to carry out this task.

- **Periodic Safety Review (PSR) of each NPP should be carried out at least every 10 years**, to maintain and improve the safety and robustness of plants and revaluate the natural hazards to which plants may be subject to.

- **Recognised measures** to protect containment integrity as the last barrier to protect people and the environment against radioactive releases must be implemented.

- **Accidents resulting from natural hazards should be prevented and/or mitigated so as to limit their consequences.** Measures to be considered include bunkered equipment to prevent and manage a severe accident, mobile equipment protected against extreme natural hazards, emergency response centres protected against extreme natural hazards and contamination, rescue teams and equipment rapidly available to support local operators in long duration events.

Follow-up:

The Commission and national regulators have agreed that national action plans with timetables for implementation will be prepared and made available by the end of 2012. The peer review methodology will be applied to them in early 2013 in order to verify that the “stress tests” recommendations are consistently implemented in a transparent way throughout Europe. In areas where additional technical analysis and guidance are needed national regulators will closely collaborate in the WENRA framework.

The occurrence of incidents in nuclear plants, even in Member States with otherwise good safety records, confirms the need for thorough safety reviews on a regular basis and for the assessment of operational experience, and highlights the need for close cooperation and information sharing between operators, vendors, regulators and European institutions, such as the European Clearinghouse of Operating Experience, maintained by the Commission Joint Research Centre (JRC). In addition, ENSREG can play a key role in ensuring that experience and conclusions from any nuclear incident are shared promptly and applied consistently in other Member States. For example, the results of recent investigations into the Doel 3 reactor in Belgium have demonstrated the need to continuously check plant status with state of the art techniques and share information as widely as possible.

Furthermore, the Commission recommends that national regulators include in their future safety reviews more detailed analysis with respect to the effects of multi-unit accidents, considering also ageing on equipment and materials, protection of spent fuel storage ponds and possibilities to reduce the amount of spent fuel stored in ponds, in order to reduce risks due to loss of cooling.

The Commission considers that extending the safety assessment to off-site emergency preparedness and response arrangements is an important additional activity to improve citizens' safety. Therefore, as a first step, the Commission is launching a study on the "Review of Current Off-Site Nuclear Emergency Preparedness and Response Arrangements in EU Member States and Neighbouring Countries". The objective is to review the off-site nuclear emergency preparedness and response capabilities in EU Member States and neighbouring countries, to identify inconsistencies and gaps, and to develop proposals (legislative or non-legislative) for possible improvements.

Regarding the safety implications of aircraft crashes on nuclear power plants, the Commission recommends to ENSREG to work urgently on a European safety approach in order to develop a coherent methodology and to arrive at comparable high-level standards across the European Union.

2.4. Key findings and recommendations from the security assessments[14]

The final report of the Ad Hoc Group on Nuclear Security[15] presents conclusions on the five themes discussed, namely physical protection, malevolent aircraft crashes, cyber-attacks, nuclear emergency planning, and exercises and training. As national security remains a Member States responsibility and the sensitivity of the subjects and confidentiality obviously implies strict constraints, the report contains several recommendations to the Member States in order to strengthen nuclear security in the EU. It highlights in particular:

- the urgent need for the Member States which have not yet done so to **complete ratification of the amended Convention on Physical Protection of Nuclear Materials**;

[14] This section is based on the Final Report of the Council Ad-hoc Group on Nuclear Security (AHGNS).
[15] http://register.consilium.europa.eu/pdf/en/12/st10/st10616.en12.pdf, 31.5.2012.

- the added value of **IAEA's guidance and services**, including IPPAS[16] missions on a regular basis in all Member States having nuclear power plants;

- the importance of **regular and close cooperation** between Member States and with neighbouring countries and

- the necessity to define modalities and fora for the **continuation of EU work on nuclear security**.

2.5. Recommendations on linking work between safety and security issues

Sustained efforts are required to link up work on nuclear safety and security and address possible gaps. For example, neither the safety stress tests nor the report on nuclear security answer all relevant questions on issues like aircraft crashes or the resistance of nuclear power plants to external events. However, the stress tests have to a considerable extent covered the effects of aircraft crashes through the thorough work undertaken on station blackout and loss of plant cooling. While this is an area where competence is shared among different authorities, the Commission intends to further study this area through dedicated expert hearings. On other areas of nuclear security, specific projects under the EU CBRN Action Plan and actions on cyber security will need to be considered in close collaboration with Member States ENSREG has agreed in its action plan to further collaborate on the issue of aircraft crashes as far as the legal competencies of national regulators permit.

3. STRENGTHENING THE EU NUCLEAR SAFETY FRAMEWORK

3.1. Implementing the existing nuclear safety legislative framework

The deadline for the EU Member States to complete the transposition of the *Nuclear Safety Directive*[17] at national level was 22 July 2011. The European Commission started infringement proceedings against twelve Member States that did not comply with this deadline[18]. To date, two Member States[19] have still not completed their transposing measures. The Commission will now start an in depth analysis of the quality of the transposing measures by the Member States.

3.2. Improving the legislative framework for nuclear safety

3.2.1. Revision of the nuclear safety directive

It is crucial to ensure that the lessons learned from the Fukushima accident and the conclusions of the stress tests are properly and consistently implemented in the EU and reflected in the legislative framework. The stress tests, the reports from Japan and the work of the international community in the IAEA have confirmed that there

16 International Physical Protection Advisory Service.

17 Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations.

18 Austria, Belgium, Cyprus, Denmark, Estonia, Greece, Italy, Latvia, Poland, Portugal, Slovakia and the United Kingdom.

19 Poland and Portugal.

are not only significant differences between Member States, but also gaps in ensuring comprehensive and transparent identification and management of key safety issues.

Moreover a number of weaknesses with the existing EU nuclear safety framework have been identified (see section 2.2.3). In order to address these, the Nuclear Safety Directive requires revision in the following area:

(1) Safety procedures and frameworks. The scope of the existing Nuclear Safety Directive is limited to overall principles mainly fixing the distribution of competencies among nuclear operators, national regulators and other national instances, hence it cannot address the technical safety issues identified in the Fukushima nuclear accident and the stress tests. The main framework recommendations arising from the stress tests (e.g. the periodic revaluation of external hazards, the implementation of recognised techniques to minimise the impact of accidents, etc.) need to be translated into agreed mechanisms anchored in the revised directive on which the national regulatory authorities can base their independent decisions. Improvements are needed in preparing and responding to a serious nuclear or radiological emergency. The revised directive should include provisions that require Member States to have in place appropriate on-site emergency preparedness and response measures. Specific attention needs to be paid to the safety of new nuclear installations. While the revised directive can define basic parameters and safety objectives, the role of ENSREG in providing guidance for their implementation needs to be defined, as shown by recent developments in the reactor in Doel. Those events have once more highlighted the need for dialogue between operators and safety authorities in order to share and implement best practices and state of the art technology. For new reactors, WENRA safety objectives should be considered in the directive.

(2) Role and means of nuclear regulatory authorities. The current provisions on regulatory separation and the effectiveness of nuclear regulatory authorities need to be strengthened to ensure the effective independence of these authorities and guarantee that they have the appropriate means of action.

(3) Openness and transparency. Transparency of regulatory decisions and regular provision of information to the public by nuclear operators should be extended and specified, for example by putting obligations on the licence holders, or by specifying the type of information that should be provided, as a minimum, to the public by the competent regulatory authority.

(4) Monitoring and verification. The provisions on monitoring and verification, for example through the extended use of peer reviews, should be extended to other areas than the review of the national regulatory framework.

3.2.2. Nuclear Insurance and Liability

The analysis of provisions for the compensation of victims in case of nuclear incidents or accidents is not covered at all by the current EU legislative framework. As such, this was not part of the stress test process. However, Euratom Treaty article 98 provides for Council Directives establishing binding measures on this issue. Therefore, based on an impact assessment, the Commission will analyse to what extent the situation of potential victims of a nuclear accident in Europe should be improved, within the limits of EU competence. The Commission intends to propose binding legislation in the area of nuclear insurance and liability. In this context, compensation for damage to the natural environment should also be addressed.

3.2.3. Revising the legislation on food and feedstuff

The management of food and feedstuff that is contaminated as a result of a nuclear emergency is covered both by the Basic Safety Standards Directive (96/29/Euratom), and it is subject to specific provisions with regard to their placing on the market in Council Regulation (Euratom) No 3954/87 laying down maximum permitted levels of radioactive contamination. The latter legislation has become the subject of a recast procedure[20]. However, the Commission now intends to withdraw the proposal for a recast and to bring this Regulation in line with the new Comitology Regulation[21] which entered into force in March 2011.

The experience gained from the events in Fukushima and Chernobyl demonstrated a need to differentiate between instruments regulating the import of food from third counties and those for the placing on the market of food in case of an accident within the EU. On the basis of this experience, the Regulation needs to be revised in order to provide more flexible tools which will allow specific, targeted reactions to any nuclear accident or radiological emergency (in the EU, in the vicinity of the EU or in a remote country).

3.3. Strengthening human resources and training

Whether a country has chosen to continue the use of nuclear energy, to phase out the use or to start using this energy source for the first time, ensuring the availability of an experienced workforce should be a top priority.

At European level the EC Joint Research Centre, in cooperation with EU nuclear safety regulators and TSOs, manages the Operating Experience Feedback initiative. The Joint Research Centre will open these activities to all national nuclear regulatory authorities, who want to participate, in order to establish a permanent European Nuclear Safety Laboratory for the continuous improvement of safety. This laboratory will provide scientific and technical support for effective work for the continuous improvement of nuclear safety in particular through incident analyses and assessments, which may be identified by the Commission or ENSREG.

In Euratom research and innovation actions (Horizon-2020), special attention should be dedicated to the lessons from Fukushima, and better coordination between national, European and international actions in this area is needed. Further exchanges of best practices should be encouraged as a way of continuously improving and harmonising nuclear safety culture.

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20 COM(2010)184 final, 27.4.2010.

21 Regulation EU 182/2011.

3.4. Building up international cooperation

The Commission will continue to encourage all EU neighbouring countries through appropriate incentives and instruments to share the results of their stress tests, participate in peer reviews and ensure that experiences in the implementation of recommendations are shared to improve nuclear safety both inside the EU and at its borders. A Euratom loan is currently being considered for Ukraine, in order to speed up the implementation of its comprehensive safety upgrade programme.

Contacts are also under way to develop bilateral cooperation on stress tests and regulatory issues with Japan. A draft Memorandum of Understanding for better cooperation on nuclear safety has already been submitted to the IAEA. More generally, the Commission will work with the European External Action Service (EEAS) in order to make the best use of existing external cooperation instruments in the field, in particular the Instrument for Nuclear Safety Cooperation, the Instrument for Stability in its Chemical, Biological, Radiological and Nuclear risk mitigation component and the Instrument for Pre-Accession.

3.5. Improving the global legal framework for nuclear safety

Through the IAEA, the main instruments governing nuclear safety are internationally agreed safety standards and conventions, in particular the Convention on Nuclear Safety (CNS), and the Convention on the Early Notification of a Nuclear Emergency, to which the Euratom Community is a Contracting Party. The extraordinary meeting of the Convention on Nuclear Safety in August 2012 agreed to set up a working group tasked with reporting in 2014 on a list of actions to strengthen the Convention and on proposals to amend it, if necessary. A majority of nations participating to this working group highlighted the need to take into account the IAEA safety standards, regulatory independence and effectiveness, extended use of peer reviews as well as improved openness and transparency. The Commission will take full account of these principles and objectives. The continued commitment of Member States and EU institutions is needed to ensure that the EU legislation is reflected to the extent possible in future revisions of the international nuclear safety framework. The Commission will continue its efforts to make this possible.

4. REINFORCING NUCLEAR SECURITY

The Commission supports the findings and recommendations highlighted in the final report of the AHGNS. In order to contribute to the work on nuclear security matters, the Commission will use the existing competencies and programmes to encourage Member States in progressing further on the implementation of specific measures. In particular, the Commission will continue to work with Member States on:

– the reduction of the threat of Chemical, Biological, Radiological, Nuclear (CBRN) incidents of intentional origin, including acts of terrorism and detection of radioactive and nuclear materials, through the implementation of the EU CBRN Action Plan and the management of programmes on CBRN security;

– the revision of Directive 2008/114/EC on the identification and designation of European critical infrastructures[22], foreseen in 2013;

– the Commission will table a legislative proposal on network and information security by the end of the year. Under the proposal operators in certain critical sectors relying heavily on ICT will be required to ensure the security of their information systems and report serious security breaches to public authorities. Electricity utilities with nuclear operations will be subject to these requirements;

– adoption of the proposal for the revision of the Union Civil Protection Mechanism[23] that facilitates co-operation between the Member States in civil protection assistance interventions in the event of major emergencies, including radiological and nuclear accidents as well as prevention and preparedness actions (e.g. risk assessments and risk management plans, CBRN modules, training and exercises for large-scale disasters, scenario development and contingency planning);

– the speedy ratification of the amended Convention on Physical Protection of Nuclear Materials by all Member States. The Commission will complete the ratification process by Euratom as agreed by the Council in 2006 once Member States have finalised their internal procedures.

The Commission also considers that there remains a need to tackle more explicitly aspects located at the interface between nuclear safety and security.

Outside the EU, the Instrument for Stability – the EU CBRN Centres of Excellence programme – will enhance institutional capacities of selected countries and regions against chemical, biological, radiological and nuclear risks.

5. CONCLUSIONS AND WAY FORWARD

The EU nuclear stress tests were an unprecedented exercise in terms of extent, collaboration and commitment of all parties involved. They have been used internationally either as basis or as a benchmark for the safety assessment of nuclear power plants[24]. The public availability of all safety-related reports and the participation of non-nuclear countries have made the exercise an example of transparency.

The stress tests are now completed. However, their impact should not be considered as a one-off exercise, but as an on-going process to improve nuclear safety, in close collaboration with national regulatory authorities in the context of ENSREG and the IAEA. The EU must seek to develop a comprehensive European approach to safety,

[22] Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection, OJ L 345, 23.12.2008, p. 75–82.

[23] Proposal COM/2011/0934 under negotiation in the Parliament and the Council to repeal Council Decision 2007/779/EC, Euratom establishing a Community Civil Protection Mechanism (recast).

[24] For example the Latin American forum of nuclear regulators (FORO), the Russian Federation and Japan have followed closely the EU stress tests and made use of part of the specifications.

which includes a revision of nuclear safety specific Euratom legislation, complemented by legislative or non-legislative instruments on nuclear liability, on emergency preparedness and response, and by pursuing actions in the area of nuclear security. In this way, citizens in the whole EU can be confident that nuclear power produced in the EU is subject to the most stringent safety conditions in the world.

The stress tests and related activities are a major achievement for the EU and the regulatory authorities in the Member States and have led to tangible results:

- Significant and tangible plant improvements have been identified in all participating countries, and are being implemented or planned.

- Weaknesses in frameworks and procedures, as well as gaps in the legal arrangements, have been identified and proposals to improve these are on the drawing board.

- First bridges have been built between authorities dealing with safety and those dealing with security. Improving the dialogue between them on topics that reside at the safety/security interface is essential to respond to citizens' concerns.

With a view to ensuring proper follow-up to the stress tests, the Commission:

- invites the European Council to commit Member States and to call upon participating third countries to implement swiftly the recommendations of the stress tests. The Commission will ensure openness and transparency during the follow-up of the stress test process but will, under the current legislation, not be legally responsible for the operational assessment of the safety of NPPs. It proposes that the European Council examine the status of the implementation of the recommendations by June 2014, on the basis of a consolidated report by the Commission, to be drafted in close cooperation with ENSREG. It invites Member States to take action without delay to implement all stress test recommendations, in accordance with the timetable of the ENSREG action plan and with the aim of implementing the vast majority of the required safety improvements by 2015;

- will present an **ambitious revision of the EU nuclear safety directive,** which it will submit to the European Parlament and Council by early 2013 at the latest, after consulting Member States scientific and technical experts as foreseen by article 31 of the Euratom Treaty. Presentation of a further proposal on nuclear insurance and liability is under consideration and will follow in 2013, just as the proposal on maximum permitted levels of radioactive contamination of foodstuffs and feeding stuffs;

- will explore proposals in the the Horizon 2020 Euratom programme aiming to faciliate the exchange between Member States of staff working in the nuclear field;

- will propose to the Council a mandate to participate actively in the working group on effectiveness and transparency in the framework of IAEA seeking improvements of the Convention on Nuclear Safety and preparing a European joint proposal for the next review meeting in March 2014; the Commission will also maintain the ongoing dialogue with other countries to ensure the maximum convergence on the European proposals;

- will continue to encourage scientific activities aiming at further harmonization of nuclear safety assessments and practices in EU;

- will continue to contribute to the reinforcement of nuclear security building as appropriate on existing work on CBRN, by using reinforced cooperation of Member States and EU insitutions as needed as well as external cooperation instruments in close collaboration with the EEAS.

LIST OF ABBREVIATIONS:

AHGNS	Ad-hoc Group on Nuclear Security
BWR	Boiling Water Reactor
CBRN	Chemical, Biological, Radiological, Nuclear
CNS	Convention on Nuclear Safety
EEAS	European External Action Service
ENSREG	European Nuclear Safety Regulators' Group
IAEA	International Atomic Energy Agency
ICT	Information and Communication Technologies
INSC	Instrument for Nuclear Safety Cooperation
IPPAS	International Physical Protection Advisory Service
JRC	Joint Research Centre of the European Commission
NPP	Nuclear Power Plant
SAM	Severe Accident Management
SAMG	Severe Accident Management Guidelines
TSO	Technical Safety Organisation
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Reviews
WENRA	Western European Nuclear Regulators' Association

Annex[25]

Summary of the Main Recommendations for Improvement during the Stress Tests in EU Member State Nuclear Power Plants

External hazard safety cases corresponding to an exceedance probability of less than once in 10 000 years should be used for earthquakes.

> *(The suitability of a NPP construction site should be assessed based on an seismic analysis that takes into account the most severe earthquake over the last 10 000 years)*

External hazard safety cases corresponding to an exceedance probability of less than once in 10 000 years should be used for flooding.

> *(The suitability of a NPP construction site should be assessed based on an analysis that takes into account the most severe flood over the last 10 000 years)*

A Design Basis Earthquake corresponding to a minimum peak ground acceleration of 0.1 g should be used.

NPP design must be able to withstand an earthquake producing at least a peak ground acceleration 0.1 g.

Means needed to fight accidents should be stored in places adequately protected against external events.

On-site seismic instrumentation should be installed or improved.

Time available to the operator for restoration of the safety functions in case of loss of all electrical power and/or ultimate heat sink should be more than 1 hour (without human intervention).

Emergency Operating Procedures should cover all plant states (full power to shutdown states).

Severe Accident Management Guidelines should be implemented and should cover all plant operating states (from "full power" to "shutdown" states).

Passive measures to prevent hydrogen explosions (or other combustible gasses) in case of severe accident should be in place (such as Passive Autocatalytic Recombiners or other relevant alternatives).

Containment Filtered Venting Systems should be in place, so as to limit the amount of radioactivity released outside the containment in case of accident.

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[25] The issues listed should be read together with the accompanying Commission Staff Working Document where they are explained in more detail and linked to nuclear power plants where they were observed.

A backup Emergency Control Room should be available in case the Main Control Room becomes inhabitable as a consequence of the radiological releases of a severe accident, of fire in the Main Control Room or due to extreme external hazards.

歐核電廠補強 需砸數百億美元

法新社 – 2012 年 10 月 3 日 上午 2:05

相關內容

放大顯示

歐核電廠補強 需砸數百億美元

（法新社布魯塞爾 2 日電） 歐洲聯盟（EU）核電廠壓力測試報告顯示，歐洲核電廠存在缺乏地震裝置、緊急備用系統等數百項問題，需投入上百億美元加以補強。

法新社取得的這份報告指出，歐盟執行委員會（European Commission）估計，改善歐洲 134 座反應爐的安全，「必須投入 100 億至 250 億歐元（130 億至 320 億美元）經費」，並希望核電廠更新計畫 2015 年前在監督下完工。歐盟執委會並無要求任何核電廠關閉。

這份報告 4 日將由能源執委歐汀納（Gunther Oettinger）正式公布。

建議要點是根據日本去年 311 強震導致福島（Fukushima）核災後所做的壓力測試而得出，歐盟領袖將於 18 至 19 日舉行的高峰會，針對這些建議展開審議。

報告提到，由於歐洲有 111 座反應爐位於建物密集地區，距離反應爐 30 公里內有超過 10 萬人居住，「歐盟必須記取福島核災教訓，進一步降低歐洲發生核子事故的風險」。

（譯者：中央社蔡佳伶）

NucNet

The Communications Network for Nuclear Energy and Ionising Radiation

News No. 234 / 4 October 2012

04.10.2012_No234 / **News**

Stress Tests Show 'Urgent Measures' Are Needed On Nuclear Safety

4 Oct (NucNet): Hundreds of technical upgrade measures are needed at nuclear power plants in Europe with many "urgent measures" identified after Three Mile Island and Chernobyl still not implemented in some European countries, the European Commission has said.

In a formal communication today on the final results of stress tests carried out on Europe's 134 nuclear reactors at 68 sites following the March 2011 Fukushima-Daiichi accident, the EC said "practically all" nuclear plants covered by the tests need to undergo particular safety improvements.

The commission called for a safety review of every nuclear plant to be carried out at least every 10 years.

It said there is "no consistent approach" to nuclear safety regulation among European Union member states and "improvements in safety culture are needed".

The commission said in a statement that standards of safety of nuclear power plants in Europe are "generally high but further improvements in the safety features of almost all European nuclear power plants are recommended".

It said the main message of today's communication on results of the nuclear stress tests is that national safety authorities came to the conclusion that no closure of nuclear power plants was warranted.

Energy commissioner Günther Oettinger said the stress tests revealed "where we are good at and where we need to improve".

He said the tests were serious, and they were a success. "Generally, the situation is satisfactory but there is no room for complacency. All authorities involved must work to ensure that the highest safety standards are in force in every single nuclear power plant in Europe."

The EC said that in addition to recommending numerous specific technical improvements, the stress tests have shown that international standards and practices have not been applied everywhere. In addition, lessons from Fukushima-Daiichi need to be drawn. In particular, these include:

- Earthquake and flooding risk. Current standards for risk calculation are not applied in 54 reactors (for earthquake risk) and respectively 62 reactors (for flooding risk) out of the 145 checked. The risk calculation should be based on a 10,000 year time frame, instead of the much shorter time periods sometimes used.

- Onsite seismic instruments to measure and alert of possible earthquakes should be available at every nuclear power plant. These instruments should be installed or improved in 121 reactors.

- Containment filtered venting systems to allow safe depressurising of the reactor containment in case of an accident, should be in place. 32 reactors are not yet equipped with these systems.

- Equipment to fight severe accidents should be stored in places protected even in the event of general devastation and from where it can be quickly obtained. This is not the case for 81 reactors in the EU.

- A backup emergency control room should be available in case the main control room becomes inhabitable in case of an accident. These are not yet available in 24 reactors.

The EC said the next step in the process will be for national action plans with timetables for implementation to be prepared by national regulators and made available by the end of 2012.

The action plans will go through peer reviews in early 2013, in order to verify that the stress tests recommendations are consistently implemented in a transparent way throughout Europe. The commission intends to report on the implementation of the stress test recommendations in June 2014, in partnership with national regulators.

In addition to the specific technical findings and recommendations, the EC has reviewed the existing European legal framework for nuclear safety and will present a revision of the current Nuclear Safety Directive in early 2013. The proposed amendments will focus on safety requirements, the role and powers of nuclear regulatory authorities, transparency, as well as monitoring.

This will be followed by further proposals on nuclear insurance and liability and on maximum permitted levels of radioactive contamination in food and feedstuff. The stress test process has also highlighted the need for further work on nuclear security (prevention of malevolent acts), where the main responsibility lies with the member states.

The cost of additional safety improvements recommended as a result of the stress tests will be between 30 million euro (EUR) (38 million US dollars) and EUR 200 million per reactor unit, the EC estimates. Total costs for the 134 reactor units operating in the EU will therefore be from EUR 10 billion to EUR 25 billion in the coming years.

Giving examples of significant findings, the EC said at four reactors in two different countries there is less than one hour available to operators to restore safety functions if electrical power and/or ultimate heat sink are lost. At 10 reactors, onsite seismic instrumentation is not yet installed, the EC said.

However, four countries already operate additional safety systems fully independent from the normal ones and located in well-protected areas, the EC said. Mobile equipment such as diesel generators is already available in seven countries.

The EC statement included a number of key findings on the safety of nuclear plants site-by-site.

Summarising, it said there is a “lack of consistency” when assessing and managing external threats to plant safety. International Atomic Energy Agency guidelines for seismic loads and flooding were not implemented in all member states.

The scope and depth of the probabilistic safety assessment used to characterise the safety of reactors “differ significantly” and in some member states there is an urgent need to bring them up to accepted international standards.

Severe accident management guidelines must be available to all nuclear plants. The stress tests have shown that these guidelines are still lacking implementation or even basic development “in a large number of member states”.

The statement underlined the dynamic nature of nuclear safety and said “enhancing nuclear safety is not a one-off exercise; it must be continually reviewed and updated”.

The statement also said improvements in safety culture are needed. A “glaring” lesson from Fukushima-Daiichi is that the tsunami hazard was underestimated, mostly due to human, systemic and organisational factors.

On the legal framework for safety, a key finding is that there are “continuing differences” between member states resulting in “the absence of a consistent approach to nuclear safety regulation”. There are “no codified EU mechanisms to agree on technical standards and ways to conduct safety reviews. The European Nuclear Safety Directive has no such provisions, the EC noted.

The EC also said provisions covering the independence of regulators are minimal.

On procedures and frameworks, the stress tests identified four main areas for improvement across Europe:

- European guidance should be developed on the assessment of natural hazards;

- A safety review of every nuclear plant should be carried out at least every 10 years;

- Accidents resulting from natural hazards should be prevented. Measures include bunkered equipment, mobile equipment and emergency response centres;

- “Recognised measures” – such as filtered venting and systems to prevent hydrogen explosions – must be taken to protect containment integrity as the last barrier to protect people and the environment from radioactive releases.

The statement said that in July 2012, the EC and the European Nuclear Regulators Group (Ensreg) agreed an action plan aimed at making sure recommendations from the peer reviews are implemented. This must be a priority for all member states, the EC said. In view of the high number of recommended improvements, methods and criteria need to be developed to judge the importance of different recommendations and to “prioritise and allocate funding to those areas which bring greatest safety benefits”.

The stress tests were carried out using different steps including an assessment of nuclear facilities by operators and an independent review of those assessments by national regulators.

Country peer reviews were carried out from March to April 2011, with each country visited by a team of eight peer reviewers for several days.

The 15 European Union countries with nuclear power plants as well as Switzerland and Ukraine performed the stress tests and were subjected to the peer review.

The operators submitted their final assessments on 31 October 2011 and the regulators submitted their final national reports on 31 December 2011. The peer review started on 1 January 2012.

Today's communication is online:

http://ec.europa.eu/energy/nuclear/safety/stress_tests_en.htm

An EC backgrounder on the stress tests is online:

http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/12/731&format=HTML&aged=0&language=EN&guiLanguage=en

Related reports in the NucNet database (available to subscribers): MEPs Call For ‘Ambitious But Reasonable’ EU Safety Directive (News No.233, 03 October 2012)

Editor David Dalton

NucNet

The Communications Network for Nuclear Energy and Ionising Radiation

News No. 233 / 3 October 2012

03.10.2012_No233 / **News**

MEPs Call For ‘Ambitious But Reasonable’ EU Safety Directive

Security & Safety

3 Oct (NucNet): In response to a final report on stress tests carried out on European nuclear plants Europe should launch a revised Nuclear Safety Directive with "ambitious but reasonable" minimum standards, the European People's Party (EPP Group) said in a statement today.

The group, which is the largest in the European Parliament with 271 members and three observer members, was responding to leaked excerpts from the final stress test report, due to be made public tomorrow. Those excerpts indicate hundreds of technical upgrade measures are needed at nuclear power plants in Europe with many "urgent measures" identified after Three Mile Island and Chernobyl still not implemented in some European countries.

The EPP Group said the European Commission's report on stress tests does not indicate any severe safety risk requiring the closure of reactors, but does identify safety gaps in the face of extreme external events such as earthquakes and floods.

"There is a lack of preparedness and response capacity in a number of installations. This is a problem we have to address," said Pilar del Castillo Vera, EPP Group coordinator on the European Parliament's industry, research and energy (ITRE) committee.

Based on the results of the stress tests, Europe's Nuclear Safety Directive should be revised to include ambitious but reasonable minimum standards, the EPP Group said. "This should include provisions such as onsite emergency preparedness and response, strong and independent regulatory bodies, as well as policies to ensure the availability of a skilled and experienced workforce."

A revised Nuclear Safety Directive is already being negotiated in the European Council as part of a revision of safety standards based on earlier recommendations that emerged from the stress tests.

Romana Jordan, EPP Group vice-coordinator on the ITRE committee, said in light of the EC's report, the legal framework has to be reinforced, as well as the "self-organisation" of the EU's nuclear energy sector.

"We should particularly focus on transparency, the cooperation between regulators and with the European Nuclear Safety Regulators Group [Ensreg]," she said. "A proper safety framework and culture should aim to be the most ambitious worldwide so as to ensure that nuclear energy can play its future role in a competitive low-carbon EU economy."

Related reports in the NucNet database (available to subscribers): EU Details Safety Progress In Europe Since Fukushima-Daiichi (News No.52, 14 March 2012)

Source NucNet
Editor David Dalton

News No. 134 / 21 June 2012

21.06.2012_No134 / **News**

Europe Continues Work On Revised Nuclear Safety Directive

Policies & Politics

21 Jun (NucNet): A nuclear safety directive is being negotiated in the European Council as part of a revision of safety standards based on recommendations that emerged from stress tests carried out on European nuclear plants following the Fukushima-Daiichi accident, a conference heard.

During a Brussels conference on nuclear safety organised by industry group Foratom and the European Nuclear Society, the European Commission's deputy director-general at the Directorate-General for Energy, Peter Faross, said the Commission is focusing on revising nuclear safety legislation by updating and simplifying it into one single directive.

He said there will be three main areas for legislative improvement: nuclear safety governance, technical safety requirements and increased transparency.

He also said the harmonisation of independence among national regulators will be "a key issue" to tackle in the directive.

Mr Faross also said the Commission is in the process of verifying whether member states are applying at national level the existing nuclear safety directive from 2009.

After its entry into force in July 2009, the content of the directive had to be transposed into the national laws of member states by 22 July 2011.

This directive was supplemented by a directive on radioactive waste and spent fuel management which was adopted by the European Council in July 2011 and should be transposed into the national laws of member states by July 2013.

Mr Faross said it was vital that as many neighbouring countries as possible became involved in the revision of safety standards.

The European Commission's final report containing proposals on the revision of safety standards will be issued in October 2012.

Related reports in the NucNet database (available to subscribers): Ensreg Forms Task Force To Study Peer Review Proposals (News No.19, 11 May 2012)

Source NucNet
Editor Eva Donelli

ENSREG
European Nuclear Safety Regulators Group

European stress tests

The European 'stress tests' exercise arose out of European Council conclusions on 24 and 25 March that, two weeks after the Fukushima accident was triggered, wanted to submit European nuclear power plants to a complementary safety assessment.

In accordance with the mandate given by the European Council, the final agreement dated 25 May 2011 between the Safety Authorities and the Commission on the specifications for 'stress tests' of these power plants sets the major steps of the process:

- 1 June 2011 at the latest: formal launch of stress tests for European nuclear power reactors in European countries;
- 15 September 2011: each Member State sends ENSREG and the Commission an interim 'national report';
- 31 December 2011: each Member State sends its final national report.

Besides these time-line items, the ENSREG (European Nuclear Safety Regulators' Group) specifications also state that the final national reports will be subject to peer review, from January 2012.

It is added that the European Commission will send an 'interim report' for the European Council meeting on 9 December 2011, and a final report for the European Council meeting in June 2012.

The Communications Network for Nuclear Energy and Ionising Radiation

News No. 144 / 29 June 2012

29.06.2012_No144 / **News**

France's Regulator Calls For 'Rapid Increase' In Plant Robustness

Security & Safety

29 Jun (NucNet): France's nuclear regulator says the country's nuclear facilities are safe, but their "robustness" to extreme situations must be increased beyond existing safety margins "as rapidly as possible" including new emergency bunkers and a rapid intervention force for nuclear plants.

The Autorité de Sûreté Nucléaire (ASN) says in a report released on 26 June 2012 that nuclear facilities in France show a level of safety that is sufficient to warrant "no immediate closure of any of them".

But ASN said it is asking licensees to adopt a range of measures designed to protect plants against a combination of natural phenomena "of an exceptional scale". The measures are also designed to protect facilities against "severe accident situations" following the prolonged loss of electrical power or heat sinks.

One of the measures is for all nuclear facilities in France to create what ASN called a "hard core of material and organisational arrangements" that would help prevent a severe accident and limit large-scale radioactive releases.

The report says this will, for example, involve setting up a "bunkerised" emergency management centre with diesel electricity generator and a diverse backup water supply. The equipment at this centre must be designed to withstand major events of a scale "far in excess of those used to determine the strength of the facilities", ASN said.

ASN has asked licensees to notify it by tomorrow (30 June 2012) of the content and the specifications of the emergency centre for each facility.

The report also confirms the gradual deployment, as of 2012, of the Nuclear Rapid Intervention Force (FARN) for nuclear plants proposed by Electricité de France (EDF). This is a national intervention force comprising specialised teams and equipment able to take over from personnel at any site affected by an accident. FARN will be able to deploy "additional emergency response means" within 24 hours. The system will be fully operational by the end of 2014, ASN said.

The report also says France will introduce "reinforcement measures" for fuel storage pools. For the spent fuel storage and recycling plant at La Hague, feasibility studies will be carried out concerning the use of technical measures to protect ground and surface waters in the event of a severe accident.

Areva said yesterday it would be submitting its technical and organisational proposals to ASN for reinforcing the safety of its sites.

The company said for the facilities concerned (La Hague, Tricastin, the Melox MOX fuel plant and the FBFC Romans fuel assembly plant) its safety experts have been working on "the systems and functions of last resort intended to prevent a very serious accident or limit its consequences".

Areva said it is also going to strengthen the "global crisis management system" on its sites by installing new emergency response and communications equipment such as pumps, measurement equipment and satellite telephones.

The ASN report summarises the steps taken by France in the wake of the Fukushima-Daiichi accident and was prepared for a forthcoming review meeting of signatories to the International Atomic Energy Agency's Convention on Nuclear Safety. All signatories have been asked to produce a similar report.

It is based primarily on stress tests carried out in France and covers six topics: external events, design studies, severe accident management and recovery (on-site), national organisation, emergency and post-accident situation organisation (off-site), and international cooperation.

The English version of the report is online:

www.french-nuclear-safety.fr/index.php/English-version/News-releases/2012/Convention-on-Nuclear-Safety-french-report-is-published-on-ASN-website

Related reports in the NucNet database (available to subscribers): ASN Urges Areva To Improve La Hague Fire Protection (News No.15, 13 April 2012)

Source NucNet
Editor David Dalton

法國將對 “不可思議的 ” 意外事故做好準備

譯自: *Inside* **NRC** - Platts: 9 May 2011

日本福島(Fukushima)事故後，法國必須爲應付“不可思議的”核意外事故情況做好準備，法國輻射防護與核能安全研究所 (Institute of Radiation Protection and Nuclear Safety, IRSN) 的所長 Mr. Jacques REPUSSARD 於5月5日如此表示。

“此等威脅我們的並不是一般所謂的 '標準' 事故，”Mr. REPUSSARD 說。依據 IRSN 所做的分析顯示，法國電力公司 (EDF) 的所有核電廠將可以 “非常令人滿意地” 承受 “一般的” 事故情況，他說。目前這起發生在日本福島第一核電廠且仍在持續演化的事故，在受到地震和海嘯雙重蹂躪的環境下，它集合了喪失所有的電源和所有的冷卻功能，顯示法國社會必須 “接受 — 我們必須爲那些完全不可思議的情況做好準備，”他表示。

法國核能安全委員會(Nuclear Safety Authority, ASN) 的主任委員 Mr. Andre-Claude LACOSTE 表示，法國過去均採用 “基本確定性“ 方法佐以概率評估以便 “洞察” 核能安全問題。但是，福島發生的事實已經顯示，Mr. LACOSTE 說，是有需要 “進一步超越，與其只是說 '這種情況是完全不可能的'，並採取一種以癥狀爲基礎的方法”，來假設某些核設施存在的退化狀態，並在該情況下來獲得保持電廠與環境的安全。

Mr. REPUSSARD 表示，IRSN 曾被批評說其所建議的一些核事故情況“不切實際“，但發生在福島的事故”在過去並未曾被考量會是事實”—電廠被爲抵擋海嘯而建設的海嘯牆，其兩倍高度的海嘯所吞沒。

法國國會技術評估辦公室(Opecst) 的官員在其所辦理的聽證會上說，Opecst 已開闢了一個爲期兩天的後核事故(post-nuclear-accident)規劃研討會。該研討會 —這已是第二個同類型的研討會，是爲了審查有關中程和長程階段管理之準備進度而舉行的，期程從核事故後的幾年間或甚至到數十年之後。

Codirpa 委員會議是由 ASN 來進行安排，率領國家指導委員會進行規劃核事故後的準備工作。該委員會(Codirpa) —係由法文縮寫而來 — 其工作乃是致力於研擬過渡階段的指導方針，從事故發生的階段到緊接著的事故後階段，並從那時段起到以後更長的時間。

“沒有人能保證在法國永遠不會發生核意外事故，“ Mr. LACOSTE 表示。他說，必須盡一切努力來避免發生這樣的意外事故，唯一旦事故發生發生則須減輕其後果，而且 “我們必須具備足夠的能力來管理它們。“

一個位在 Normandy 地區的非政府組織 — ACRO (l'ACROnique du nucleaire)裡的科學家小組成員 Mr. Pierre BERBEY 表示，福島第一核電廠發生的核災難顯示，對核事故之研究必須加以修訂，並應考量到“非常複雜“的事故情況，這對核能發電是至關重要的，譬如: Flamanville 核電廠場址附近的一座油槽發生意外。他說: 一個以概率爲基準的做法是不再會被接受了。

Mr. BERBEY 又說，在面對核電廠發生事故的潛在後果，社會必須能夠參與辯論並決定在道德上是否可以接受“繼續使用只以風險爲基礎進行考量的隨機方法“，亦即，後果乘以概率。

一個核能發展計畫是一個“國家的決定，”Mr. BERBEY 表示，但它必須針對潛在 “難以容忍的後果“做出正當且合理的考慮，包括爲後代子孫做考量。

差異性（*Discrepancies*）

在歐洲議會負責輻射防護工作的 Mr. Augustin JANSSENS 在聽證會上說，法國是歐洲唯一正式推動國家層級研究來針對”如何處理核事故所有階段”的國家。

經濟合作開發組織核能機構(OECD Nuclear Energy Agency) 的輻射防護組長 Mr. Ted LAZO 表示，該機構自 3 月 11 日福島核事故發生後就一直在蒐集個別國家對保護其公民所做的決定與處置措施之相關資料。這些決定與處置措施大多數是一致的，但 Mr. LAZO 強調—並不是所有的國家都一樣，而這些差異性有可能會造成大問題。

正當日本當局下令疏散居住在福島第一核電廠方圓 20 公里的居民，以及要求那些在核電廠周圍 20 至 30 公里的人口進行室內庇護時，美國當局則建議居住在日本的美國藉公民撤離至距離核電廠半徑 50 英里(80 公里)以外的地方，Mr. LAZO 指出說 “一些其他國家亦跟隨“ 美國的做法。

美國的建議不僅對日本當局製造出問題，但同時也引發了對美國核電廠週遭民眾的保護是否足夠之疑問，譬如 Indian Point 核電廠附近的城市—紐約。所有美國的核電廠都必須依據的核能管理委員會(NRC)之規定採用 10 英里(16 公里)的緊急計畫範圍制定緊急應變計畫，但核能機構和核產業的官員表示，如果是因應嚴重事故的情況下需要較大的疏散範圍是可以被規劃辦理的。

Mr. LAZO 說，各個國家的主管部門要對他們自己的公民負責。但他亦表示，NEA 負責緊急計畫的工作團隊正向各國提出要求，希望在”消息向公眾發布”之前能相互協調有關因應決策與信息。

國際核緊急事件管理工作團隊(Working Party on Nuclear Emergency Management, WPNEM) 上週初在巴黎開會，對福島核事故學到之初步的經驗教訓進行審查，並表示在 “必須在同一時間裡處理數個緊急事件“的情況下，有關疏散和就地掩護的準備作爲應該再予以審查。

該工作團隊亦表示，在核事故發生後各國政府必須對即時提供大量“翻譯成英語“信息的需求做好準備，如此，這些信息才可以被國際充分理解，Mr. LAZO 說。

對於重要議題必須提前與利益相關者舉行討論會議，例如：協調當疏散命令下達後，如果兒童和他們的父母在不同的地方時，如何撤離他們? Mr. LAZO 說。

市長（*Mayors*）

在法國核設施周圍地區之信息委員會全國協會(National Association of Local Information Commissions around French nuclear facilities)的主席 Mr. Jean-Claude DELALONDE，在會議場邊說，福島核事故終於引起法國國家主管當局對地方官員的重視。

在日本發生核意外事故之前，他說，省長 — 一個代表國家的地方首長 — 在他們的事故處理計劃中經常繞過市長。

"自從福島核事故之後我們接獲了很多的電話，" Mr. DELALONDE 說，作爲省長者應該意識到在法國他們需要得到市長和其他地方官員的幫助來管理意外事故。

許多在核設施附近的社區還沒有城鎮的(社區的)緊急應變計畫，特別是小型社區他們需要協助來規劃制定其緊急應變計畫，Mr. DELALONDE 說。

豁免基準 (*Exemption levels*)

在開幕式上，法國內政部公共安全部門負責重大風險之辦公室主管 Mr. Guillaume DEDEREN 呼籲，爲處理核事故工作後可能受到污染的儀器與設備建立豁免基準。

Mr. DEDEREN 後來補充說明，公共安全部門派出一隊專家到日本受災最嚴重的縣市，俾拯救生命和幫助清理瓦礫工作，然而至今卻未能遣返一些儀器設備回法國，因爲法國的相關條文仍認定，任何曾經處於受污染地區的物件將被視爲放射性廢棄物。

他說，這些儀器設備的成本有些價值數十萬歐元，而且公共安全部門還需要利用這些儀器設備，俾能夠對爾後發生的災害提供援助。

法國是那些僅僅少數拒絕設定通用豁免基準的國家之一，包括除役之廢棄物，理由是這種豁免基準將會鼓勵大量的稀釋含有放射性元素的物質，使他們的濃度下降到豁免基準。

但是 Mr. LACOSTE 在研討會場邊說，有關遣返公共安全部門之儀器設備的問題不需立即制定豁免基準，就可以獲得解決。然而，ASN 和政府有關部門正著手制定相關之法規，俾於未來可根據暫時的豁免基準規定，在核事故後方便管理受污染的車輛和儀器設備。

Codirpa 研討會的議程裡廣泛地討論了核事故後管理的議題，包括: 環境輻射量測之策略，如何處理大量的放射性廢物，如何降低早期事故後階段的污染，如何管理受影響地區的農產品，以及受害者賠償等。

Mr. LAZO 說， ASN 已經要求 NEA 對 Codirpa 提出的方案進行同行審查，而且各方已同意於 5 月 6 日討論如何對此方案進行審查。

France to debate 'energy transition'

world nuclear news 21 September 2012

A national debate will be launched later this year to discuss France's 'energy transition'. The results of the debate will be used in formulating a new energy policy bill in mid-2013. Meanwhile, the directors of the country's nuclear power plant fleet have voiced their support for their colleagues at Fessenheim, ordered to shut down in 2016.

Plans for the debate were presented by minister for environment, sustainable development and energy, Delphine Batho. It is being organized "in a concern for environmental effectiveness, economic efficiency and social justice. Particular attention will be paid to social issues and economic transitions as well as industrial and professional retraining authorities."

The debate will take place in three phases. An 'information phase' will be held between November and December 2012, followed by a phase of public participation between January and April 2013. This phase - which will be supported by a dedicated website and regional conferences - will lead to recommendations being made in May 2013. The results of the debate will be used to formulate an energy policy bill in June 2013.

The debate will be moderated by several bodies: a national organizing committee; a committee of scientific experts; a citizens' committee; and a national commission representing state and local authorities, employers, workers, associations and parliamentarians.

A conference on France's 'ecological transition' was held on 14-15 September in Paris to conduct a consultation on the government's work program on environmental issues. The government will hold a seminar soon to consider a road map for implementing conclusions from the conference. Batho said that the environmental conference helped to clarify the terms of the national debate on energy transition.

Socialist Francois Hollande was elected as the president of France in May, narrowly defeating the former Republican president Nicolas Sarkozy. Hollande's campaign manifesto proposed a reduction in nuclear's share of the country's energy mix and pledging to order the closure of the two-unit Fessenheim plant - France's oldest nuclear power plant - before the end of his first term in 2017.

Speaking at the ecological transition conference, Hollande confirmed that Fessenheim - in the Alsace region of north-eastern France - will close "at the end of 2016", provided that provisions are in place to ensure a secure electricity supply for the region and to safeguard employment. The president pledged that the site would become an "example" to the world of French decommissioning expertise.

Fessenheim support

The site directors of all of EDF's French nuclear powers plants have written an open letter expressing their "incomprehension" of the closure of Fessenheim plant and showing their support for the workers there.

Calling the shut down a "profound injustice," the letter said, "We recognize your work and investment and we all know very well what this encompasses. We understand the bitterness felt today, all the more as you have always fulfilled your mission ... to provide France with safe, available, affordable and low-carbon electricity."

It added, "This decision creates considerable uncertainty about EDF's plans for its nuclear power plant fleet. It also casts doubt on employment and economic development for our territories, starting with the territory of Alsace. Our plants do not relocate, we live with them with our families integrated into areas that are dear to us."

The site directors said that a transition to low-carbon, sustainable energy production "will have to take into account, while protecting the competitiveness of our economy, the purchasing power of households and the confidence we have in our future." France currently has some of the cheapest electricity prices and lowest carbon dioxide emissions in Europe.

Researched and written
by World Nuclear News

Four years left for Fessenheim

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France's oldest operating nuclear power plant will be forced to close in 2016, as president Francois Hollande sets the country on a path to reduce nuclear's share of generation from 75% to 50% by 2025.

Francois Hollande opens the conference (Image: Presidence de la Republique)

Socialist Hollande was elected as the president of France in May, narrowly defeating the former Republican president Nicolas Sarkozy. Hollande had campaigned from a platform proposing a reduction in nuclear's share of the country's energy mix and pledging to order the closure of the two-unit Fessenheim plant before the end of his first term in 2017.

Speaking at a two-day environmental conference in Paris, Hollande confirmed that Fessenheim will close "at the end of 2016", provided that provisions are in place to ensure a secure electricity supply for the region and to safeguard employment. The president pledged that the site would become an "example" to the world of French decommissioning expertise.

Fessenheim is located in the Alsace region of north-eastern France, close to the borders with both Germany (less than 2km away) and Switzerland. The first of the plant's two 880 MWe pressurized water reactors entered commercial service in 1977, followed several months later by the second unit in early 1978. A review by French nuclear regulators in 2011 approved its suitability to operate for a further ten years subject to the completion of several measures including strengthening the unit's concrete basemat.

France currently relies on nuclear energy for 75% of its electricity, under a long-standing policy to ensure the country's energy security drawn up following the first oil crisis in the early 1970s. In his speech, Hollande reiterated his election promise to cap nuclear's share at 50% by 2025, and said he "regretted" the delay in French diversification into renewable energy, promising a strategy based on energy efficiency and renewable energy to effect an energy transition in France.

As the 1760 MWe of capacity at Fessenheim reaches its closure date in 2016 France's newest nuclear unit, the 1750 MWe EPR currently under construction at Flamanville, will be due to enter service. Prior to his election Hollande agreed to the completion of the Flamanville 3 EPR and indicated that he would not prevent the construction of another 1750 MWe EPR at Penly.

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