ENSREG

European Nuclear Safety Regulators Group

EU Peer Review Report of the Taiwanese Stress Tests

November 2013

1 INTRODUCTION

1.1 Background: Implications of Fukushima

On 11/03/2011, a magnitude 9.0 earthquake struck some 80 km off Japan's Tohoku coast. The ensuing tsunami set off by the earthquake devastated communities along the Japanese coast, killing some 16.000 people. The natural disaster also triggered the shutdown and subsequent core melt of three reactors at the Fukushima Dai-ichi Nuclear Power Plant (NPP). Some 100.000 people had to be evacuated because of radioactive contamination, and the total costs of the accident have been estimated as high as several hundred billion Euros.

While Fukushima is not the world's worst nuclear accident, history has shown that each major nuclear accident (Three Mile Island (USA, 1979), Chernobyl (Soviet Union, 1986)) has caused a re-examination of the risks of nuclear power on both national and international levels leading to implementation of additional safety improvement measures.

Although the technical challenges are different with each accident, the analysis of the Fukushima accident reveals already now quite substantial, well-known and recurring technical issues: faulty design, insufficient backup systems, failure to add safety measures to existing reactors, human error, inadequate contingency plans, confusion in the response to a severe accident and poor communications.

Specifically, Fukushima has shown that well-known lessons learned from accidents decades ago have not been fully addressed by the entire nuclear industry and in some cases not sufficiently enforced by regulators, even in a nation that was assumed to have a high standard of safety. In Fukushima's aftermath came a vigorous reassessment of the safe use of nuclear energy worldwide, firstly because it is a severe accident, and secondly because it occurred in a nation that was previously assumed to have a high standard of nuclear safety and technical expertise.

Regarding the European Union (EU), nuclear energy currently generates in over 140 reactors ~1/3 of all its electricity and ~2/3 of its low-carbon electricity. Therefore, ensuring nuclear safety is of the utmost importance to the EU and its citizens. The costs of a nuclear accident, especially when it occurs in densely populated regions, could be so large that they are potentially ruinous to national economies. It is therefore essential for the society and the economy to avoid the occurrence of any nuclear accident in a Member State of the EU, by ensuring the highest possible standards of nuclear safety and quality of regulatory oversight.

The same applies of course to Taiwan which is also a highly developed and very densely populated region of the world.

1.2 EU stress tests process and EU stress tests technical specifications

Against the background of Fukushima and based upon a clear mandate from the European Council at its meeting of 24-25/03/2011, the European Commission (EC) – together with one of its nuclear advisory groups, the so-called European Nuclear Safety Regulators Group (ENSREG) – launched in 2011 EU-wide comprehensive risk & safety assessments of all EU NPPs (hereinafter referred to as **"Stress Tests" (STs)**).

The request of the European Council included STs to be performed first at national level and then to be complemented by a European Peer Review (PR). This was the first time that such a multilateral exercise covering over 140 reactors in all the 15 EU Member States having at that time NPPs with an operating license as well as in 2 EU Neighbouring Countries (Switzerland, Ukraine) was considered.

The European Council invited the EC and its ENSREG advisory group to develop the scope and modalities for the STs with the support of the Western European Nuclear Regulators Association (WENRA); consensus on these specifications, the then so-called "EU-STs specifications", was achieved on 24/05/2011[1].

The EC and ENSREG agreed that the work on the STs should be carried out 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 was carried out by an Ad-hoc Group on Nuclear Security composed of EU Member States experts and was not subject to international PR. The specifications of the PR of the safety track of the STs as well as a working paper on the transparency aspects of the EU-STs were agreed upon at the 11/10/2011 ENSREG meeting.

These European STs lasted from 06/2011 to 04/2012 and – although they have not identified any safety-related weaknesses in NPPs which would require their immediate shutdown – already the ENSREG report[2] and later on the EC Communication[3] identified a significant number of shortcomings in nuclear safety approaches and industry practices in practically all participating countries. The STs also concluded that all these countries have taken significant steps to improve the safety of their NPPs, with quite varying degrees of practical implementation.

In addition to the STs-process, the mandate from the European Council included the request to the EC 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"*. Initial views on potential areas of legislative improvements have already been included in the *Commission Communication on the interim report on the comprehensive risk and safety assessments ('stress tests') of nuclear power plants in the European Union*[4] of 24/11/2011. Any EU legislative proposals that could be put forward should take into account the conclusions of the STs and any lessons learned from the Fukushima accident, as well as the results of the open public consultation and the stakeholders' input. The areas identified for revising the current EU Nuclear Safety Directive are described in more detail in the *Communication from the Commission to the Council and the European Parliament on the*

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[1] http://ec.europa.eu/energy/nuclear/safety/doc/20110525_eu_stress_tests_specifications.pdf
[2] ENSREG peer review report – Stress tests performed on European nuclear power plants of 25/04/2012 (http://www.ensreg.eu/sites/default/files/EU%20Stress%20Test%20Peer%20Review%20Final%20Report_0.pdf)
[3] http://ec.europa.eu/energy/nuclear/safety/doc/com_2012_0571_en.pdf
[4] COM (2011) 784 final

comprehensive risk and safety assessments ("stress-tests") of nuclear power plants in the EU and related activities[5] of 04/10/2012.

1.3 Taiwan – Use of nuclear energy and stress tests in the aftermath of Fukushima

1.3.1 Description of the nuclear power plants

Taiwan started to use nuclear power in 1977, and has developed a considerable experience in the operation of NPPs. According to the *Taiwan Stress Test National Report for Nuclear Power Plants*[6] (NR) and additional information of the Taiwanese nuclear safety regulator, the Atomic Energy Council (AEC), there are currently the following three NPPs on three different coastal sites in operation (two reactors each) and one NPP (two reactors) on one coastal site under construction. All these NPPs are owned and operated by the domestic electricity company Taiwan Power Company (TPC).

NPPs in operation:

- **Chinshan NPP (CSNPP),** located at the North of Taiwan facing the East China Sea about 28 km from Taipei, with two General Electric (GE) (USA) Boiling Water Reactor (BWR)-4 rated 1775 MWt, Mark–I containment, steel drywell and pressure suppression pool. Initial criticality was reached in 1977 and 1978 respectively. The power output was uprated for units 1 and 2 in 2009 and 2008 to 1804 MWt, based on measurement uncertainty recapture. The elevation of the entire NPP is about 5 to 20 m above Mean Sea Level (MSL). The site elevations at the places of the nuclear islands are 11.2 m above MSL. The reactor buildings are situated about 500 m from the shore.

- **Kuosheng NPP (KSNPP),** located close to Keelung city and about 22 km away from Taipei. It is equipped with two GE (USA) BWR-6 reactors rated 2894 MWt, with Mark-III reinforced concrete containments. Unit 1 and unit 2 reached their initial criticality in 1981 and 1982 respectively. KSNPP also completed a power uprate for both units to 2943 MWt based on the measurement uncertainty recapture. The site elevation is about 10 to 20 m above MSL. The site elevations at the places of the nuclear islands are 12 m above MSL. The reactor buildings are situated about 500 m from the shore.

- **Maanshan NPP (MSNPP),** located at the Southern tip of Taiwan Island with two Westinghouse (USA) 3-loop Pressurized Water Reactors (PWRs). The rated power of each reactor is 2775MWt / 951MWe. Unit 1 reached initial criticality in 1984 and unit 2 in 1985. Measurement uncertainty recapture power uprate was conducted at unit 1 in 2009 and at unit 2 in 2008 raising the output to 2822 MWt/960MWe. The reactors and their associated systems are enclosed in a pre-stressed reinforced concrete containment (large dry containment). The site elevation is about 15 m above MSL. The site elevations at the places of the nuclear islands are 15 m above MSL. The reactor buildings are situated about 300 m from the shore.

NPP under construction:

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[5] COM (2012) 571 final (http://ec.europa.eu/energy/nuclear/safety/doc/com_2012_0571_en.pdf)

[6] http://www.ensreg.eu/sites/default/files/Taiwan%20National%20Report%20of%20EU%20Stress%20Test_May%202013_.pdf

- **Lungmen NPP (LMNPP)** is facing the Pacific Ocean and is located at an inward bay area of northeast Taiwan approximately 40 km east of Taipei city. There are two Advanced Boiling Water Reactors (ABWR) with 3926 MWt each, under construction since 1999. These units were due to begin operation in 2006. However, the date for operation has been delayed several times and the exact date of start of operation will be determined later. The ABWR nuclear island was designed and manufactured by GE (USA). The turbine generator was manufactured by Mitsubishi Heavy Industries (Japan). The radwaste system vendor is Hitachi (Japan). The containment vessel is a cylindrical steel-lined reinforced concrete structure integrated with the reactor building. The reactor building provides a secondary containment around the primary containment vessel. Most of the site elevations are about 12 to 30 m above MSL. The eastern part of the site is the reserved NPP area with elevations varying from 8 to 15 m above MSL. The site elevations at the places of the nuclear islands are 12.3 m above MSL. The reactor buildings are situated about 500 m away from the shore.

1.3.2 Nuclear stress tests in the aftermath of Fukushima

Particularly following the series of core melt accidents in Fukushima / Japan, nuclear energy has emerged as a contentious issue among stakeholders also in Taiwan. Like Japan, due to its geophysical position, Taiwan is prone to large scale earthquakes, and although historically rare, Taiwan also faces the danger of tsunamis.

After Fukushima, the responsible regulatory body in Taiwan, AEC, required the licensee. TPC, to re-evaluate each NPP’s capability to cope with extreme natural disasters, including earthquake, tsunami and flooding. This re-assessment comprises *Nuclear Safety* (which is the topic of this report), *Radiation Protection* and *Emergency Preparedness & Response*. According to AEC, these re-assessments have been performed largely based upon the above-mentioned EU-STs specifications, and are thus hereinafter referred to as **"STs for the Taiwanese NPPs"**.

The work on the STs started on 05/08/2011 and was finalised with the publication of the final ST report – *"Taiwan Stress Test National Report for Nuclear Power Plants"* of 28/05/2013 with typo correction by 13/06/2013[7] (hereinafter referred to as **Taiwan "National Report" (NR)**). The NR was published in the Chinese and English languages in 06/2013 (see Sections 2-3).

1.4 NEA peer review

AEC requested already on 01/11/2011 support from the Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD) to perform a PR (hereinafter referred to as **"NEA-PR"**). NEA started its review in 01/2013 and finalised the work with the publication of the NEA-PR Report on 23/04/2013. The report of NEA based on

[7] http://www.ensreg.eu/sites/default/files/Taiwan%20National%20Report%20of%20EU%20Stress%20Test_May%202013_.pdf

a pre-version of the before mentioned NR. According to NEA, the main overall conclusions of the NEA-PR were[8] (citing NEA's exit meeting presentation):

- *"Overall, the Independent Peer Review Team found that the Stress Tests implemented in Chinese Taipei were consistent with the process according to the ENSREG Criteria used in the EU.*
- *Enhancements that have been identified are consistent with those identified in other countries.*
- *Implementation of the enhancements identified by AEC and TPC is seen as strength.*
- *Completion of on-going technical evaluations in the seismic and flooding areas using updated methodologies and assumptions could identify other issues that TPC and AEC may need to address."*

1.5 Mandate given to the European Commission to perform a peer review for the Taiwan stress tests

The EU has solid overall relations with Taiwan. Apart from economic relationships, exchanges also take place in sectors such as research and technology (including nuclear safety), information society, education and culture, fisheries, environment, climate change, intellectual property rights and standards and norms. Consultations between the EU and Taiwan are held every year to discuss issues of concern for both sides.

Against this background, AEC invited the EC by official letter dated 30/04/2013 to set up an independent PR of its STs (hereinafter referred to as **"EU-PR"**). Based upon this request, the EC organised a Peer Review Team (PRT) by selecting volunteering experts from its ENSREG advisory group, from EU Neighbouring Countries participating in the EU-STs as well as from its own Services.

Following months of preparatory organisational and technical activities, the PRT started its in-depth technical work immediately after the submission of the English version of the (first version of the[9]) final NR on 31/05/2013.

1.6 EU peer review objectives

The **objectives of the EU-PR of the Taiwan STs** are:

- to assess the compliance of the Taiwan NR with the EU-STs specifications,
- to check completeness, i.e. that no important problem has been overlooked,
- to verify safety important features within the scope of the EU-STs specifications by direct observation visiting one site with an operating NPP (Maanshan) and the Lungmen site with an NPP under construction,
- to review the Taiwanese action plan, that have been taken in the aftermath of Fukushima to improve safety and their implementation status, and
- to identify strong features and weaknesses, and develop therefrom relevant proposals to further increase plant robustness.

[8] NEA presentation on its PR, Taipei, 15/03/2013
[9] See Section 1.3.2

This work shall be performed in an independent and transparent manner:

- **Independence** is ensured by selecting experts in the PRT
  - being experienced in such type of exercises,
  - having no stake in the industry concerned, and
  - drawing from information sources provided by a variety of different stakeholders (Regulator, Legislator, Non-governmental Organisations (NGOs), Scientific Community, Industry, etc.) supplementing the basic object of the EU-PR, i.e. the final Taiwan NR[10].

- **Transparency** is ensured by quickly publishing key background and communication documents – in agreement with the information provider and also on its direct request – on a dedicated EU-PR project website[11].

1.7 Purpose of this report

The purpose of this report (hereinafter referred to as **"EU-PR Report"**) is to **describe the objectives, methods and results of the EU-PR**, and to present in a concise and transparent manner the process leading to the identification of key strengths and weaknesses of the Taiwanese NPPs and the development of proposals to further increase their robustness.

[10] http://www.ensreg.eu/node/1352
[11] http://www.ensreg.eu/EU%20Stress%20Tests/International%20outreach

2 DESCRIPTION OF THE PEER REVIEW PROCESS

2.1 General approach

<u>Introductory Remark</u>: It was the clear request of the Taiwanese regulator, AEC, to follow as closely as possible the European STs and their follow-up processes up to now.

In Europe, the STs consisted of the following main steps:

<u>A Nuclear STs – June 2011 to April 2012:</u>

1. Reassessments of all NPPs by the licensees on the basis of the EU-STs specifications:
    a. Result: reporting of licensee to regulator.
    b. Outcome: licensee reports.
2. Assessment of the reports of the licensees by the regulator:
    a. Result: reporting of the regulator to ENSREG and public.
    b. Outcome: National report (NR).
3. PR of the NR and visit of the country concerned including a visit to one NPP site:
    a. Result: reporting of PRT to ENSREG, concerned country and public.
    b. Outcome: Country report.
4. The overall conclusions of the whole European STs-exercise have been summarized by ENSREG in a summary *Peer Review Report – Stress tests performed on European nuclear power plants*[12] and as an extract of this report ENSREG published its report *Compilation of Recommendations and suggestions – Peer review of stress tests performed on European nuclear power plants*[13]. Important elements of these technical conclusions have been taken up by the EC and included in its final policy-related *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 EU and related activities*[14] of 04/10/2012.

<u>B Follow-up fact finding site visits - September 2012:</u>

5. Visit of a 2nd site in several countries by PRTs (in countries with a larger number of NPPs or with a variety of different types of reactors). The goal was to gather information about the improvement measures which have been scheduled or implemented in the meantime.
    a. Result: Reporting of PRT to ENSREG, concerned country and public.
    b. Outcome: Fact finding site visit report.

<u>C National Action Plans workshop - April 2013:</u>

6. National actions taken in the aftermath of Fukushima to enhance safety of NPPs. These actions were listed in National Action Plans. Contents and status of implementation was peer reviewed via a common discussion. Main basis of this PR was besides the National Action Plan the above-mentioned report *Recommendations and suggestions – Peer review of stress tests performed on European nuclear power plants*.
    a. Result: reporting of PRT to ENSREG, concerned country and public.

[12] http://www.ensreg.eu/sites/default/files/EU%20Stress%20Test%20Peer%20Review%20Final%20Report_0.pdf
[13] http://www.ensreg.eu/sites/default/files/Compilation%20of%20Recommendationsl.pdf
[14] COM (2012) 571 final (http://ec.europa.eu/energy/nuclear/safety/doc/com_2012_0571_en.pdf)

b. Outcome: rapporteurs reports to each country and an overall summary report *ENSREG National Action Plan - Summary report*[15]

Regarding the Taiwan PR, in order to achieve the goal to follow closely all European procedures and follow-up processes in one PR, AEC had to prepare additional documents and undertake certain activities in order to cover all steps which have been done in Europe separately. For example, in order to cover the step "National Action Plan workshop", AEC had to prepare in addition to the NR a document which described for all NPPs in a comprehensive manner the improvement measures taken in the aftermath of the Fukushima accident and their status of implementation. This document was comparable to the National Action Plans in Europe. The EU-PRT had no time for a special seminar before the visit to Taiwan as was organised by the EC in 02/2012 in Luxembourg in the course of the EU-PRs. Therefore, for the Taiwan EU-PR, the bulk of the review work had to be done during this visit. Also, in order to cover all external hazards relevant for Taiwan, the EU-PRT added the issue of volcanism to the set of external hazards mentioned in the EU-STs specifications. Further, in the course of the visit to Taiwan, two sites were visited by the PRT, i.e. Maanshan and Lungmen. For these and obvious logistical reasons, the PRT's visit to Taiwan lasted longer as compared to PR-visits in Europe (i.e. 1.5 weeks rather than 4 days in Europe).

2.2 Taiwan peer review process

The EU-PR started on 31/05/2013 with a desktop review of the Taiwan NR. Each member of the PRT had access to the NR as well as to the licensee reports and could develop written questions to AEC. In total, 230 written questions were generated by the PRT experts in the first batch and a lot of additional questions after receiving AEC's written answers, and published on the EU-PR project website.

The questions were structured according to the three topical areas of the STs[16]:

- **Topic 1: Impact from extreme natural hazards** (169 questions),
- **Topic 2: Loss of safety systems** (13 questions), and
- **Topic 3: Severe accident management** (48 questions).

After an exchange of questions and answers with AEC on the basis of these written questions, discussions were held in the PRT until consensus was reached. On this basis, a first draft EU-PR Report was developed and sent to AEC prior to the start of the review visit to Taiwan in order to prepare informed discussions during the visit.

From 23/09 to 03/10/2013, the PRT's mission to Taiwan took place.

In the course of this mission, in-depth discussions were held with AEC and – in the context of the NPP site visits – also with TPC in order to obtain appropriate answers to the questions left open after the desktop review as well as clarification on important safety-related issues, not least the ones brought forward by the NGOs (see Section 3). Two NPP sites with altogether

[15] http://www.ursjv.gov.si/fileadmin/ujv.gov.si/pageuploads/si/Porocila/NacionalnaPorocila/NAcP_Workshop_Summary_Report.pdf

[16] Accordingly, the experts were grouped in 3 topical teams.

four reactors were selected by the PRT to be visited in Taiwan: *Maanshan PWR* and *Lungmen ABWR*. On the basis of this input, the report drafted before the review mission to Taiwan was then corrected and completed using additional information obtained during the visit, particularly from the NGOs (see Section 3) and from the scientific community in the form of a topical seminar[17]. The accordingly updated report was discussed within the PRT in order to reach internal consensus and largely finalised before departure from Taiwan. AEC had the opportunity to make remarks but the final decision belonged to the PRT.

The report was then edited by the EC, and handed over by the EC to AEC within 4 weeks after the end of the review mission and published on the Internet.

2.3 Project implementation and schedule

The key milestones of the EU-PR mission to Taiwan were, as follows:

- 30/04/2013 – AEC invited the EC by official letter to set up an independent PR of its STs ("EU-PR").
- 05/2013 – The EC organized a PRT by selecting volunteering experts from its ENSREG advisory group, from EU Neighboring Countries participating in the EU-STs as well as from its own services. Further, contacts with NGOs in Taiwan were established and a continuous communication, including provision of NGO-comments and criticism on the NR, started.
- 31/05/2013 – AEC submitted its NR and the licensee reports for the 4 NPP sites to the PRT – start of the PR desktop review.
- 01/06-10/09/2013 – Desktop review, questions of PRT and answers by AEC.
- 05/06-05/08/2013 – Public consultation by the EC via Internet, placed on a dedicated website under http://www.ensreg.eu/taiwan-stress-test/peer_review.
- 13/06/2013 – AEC submitted the typo corrected NR to the PRT.
- 14/06/2013 – AEC posted the corrected NR and the Chinese version of the 4 utility reports onto its website in response to the request of NGOs.
- 05/07/2013 – In addition to the public consultation webpage, a dedicated EU-PR project webpage has been created by the EC on its ENSREG website to have a comprehensive and publicly accessible coverage of the project development. The link was: http://www.ensreg.eu/EU%20Stress%20Tests/International%20outreach.
- 09/07/2013 – Preparatory one-day meeting in Brussels between AEC and PRT representatives to discuss organization of visit and information needs.
- 23/09-03/10/2013 – PRT's visit to Taiwan.
- 25/09/2013 and 26/09/2013 – Proposed meetings of the PRT in Taipei with NGOs (canceled due to the reasons mentioned in Section 3.4).
- 26/09/2013 – Meeting of the PRT in Taipei with Scientific Community.
- 03/10/2013 – Exit meeting of the PR mission to Taiwan.
- 11/2013 – Final version of the PR-report submitted by the EC to AEC, and published on the EU-PR project website.

[17] The slides presented by the Taiwanese academics in this seminar and discussed with the PRT can be found under: http://www.ensreg.eu/EU%20Stress%20Tests/International%20outreach

3 TRANSPARENCY AND PUBLIC INVOLVEMENT

3.1 Background and framework

The European Council of March 2011 requested that the outcome of the STs and any necessary subsequent measures to be taken should be made public and that corresponding information be provided to the public. Therefore, from the very beginning full transparency was a key issue of the EU-STs.

Being aware that full transparency, combined with the opportunity for public involvement, would significantly contribute to the STs being recognised by all stakeholders, particularly by the public, as a trustworthy reference in order to better understand the status and prospects of nuclear safety, the EC ensured that the EU-PR of the Taiwanese STs was guided from the beginning by the principles of openness and transparency.

The PRT urged all stakeholders, particularly AEC and NGOs, to act as transparent as possible. This was also an important item of discussion during the preparatory meeting on 09/07/2013 in Brussels in order to define the proper conditions from the beginning.

Early after starting the desktop review, the NR and the four licensee reports were published in the English language and soon afterwards also in the Chinese language, and the English versions put on the Internet (see Section 3.2).

Next, on the basis of these reports, a public consultation was launched. While such consultations had lasted during the 2011/12 EU-STs less than one month, the public consultation for Taiwan was extended on the request of the NGOs to two months. By this, the PRT took into account that – in contrast to Europe – the people in Taiwan might be less familiar with the English language and that the Chinese version of the NR was published with some delay.

As mentioned above, in addition to the public consultation webpage, a dedicated Taiwan PR project webpage has been created by the EC on its ENSREG website in order to have a comprehensive and publicly accessible coverage of the project development. On this webpage, which was launched on 05/07/2013, all important documents exchanged among AEC, the NGOs and the PRT were posted in a timely manner during the entire PR.

Last not least, intensive contacts were maintained from the beginning of the PR between the EC (later the entire PRT) and Taiwanese NGOs (assembled on the basis of the kind assistance by Greenpeace). During the visit of the EU-PRT to Taiwan, a dedicated meeting with NGOs was scheduled in Taipei for 25 and later 26/09/2013 (see Section 3.4). This was preceded by receiving sets of questions and comments from NGOs via the dedicated Taiwan EU-PR project website (see Sections 3.2 and 3.3) as well as via direct email communication.

The goal of all these activities was to inform all stakeholders concerned as objective and comprehensive as possible and to collect all views on the key nuclear safety related issues being dealt with in the course of the PR.

Finally, it shall be noted that the transparency actions set in the course of this PR clearly go beyond the ones set for the 2011/12 EU-STs and set a new standard for future PRs. The

fact that both AEC and the NGOs basically agreed to these actions and committed to them throughout the duration of the PR shall explicitly be acknowledged.

3.2 Information on the ENSREG web sites

The EC developed two different websites on its ENSREG website for the Taiwan EU-PR:

- From 05/06-05/08/2013, a web-based tool was offered for the public consultation on the basis of the NR (http://www.ensreg.eu/taiwan-stress-test/peer_review).

- From 05/07/2013 onwards, in addition to the public consultation webpage, a dedicated project website has been created by the EC in order to have a comprehensive and publicly accessible coverage of the entire project development (http://www.ensreg.eu/EU%20Stress%20Tests/International%20outreach). On this website, all important documents provided by AEC, by the NGOs and by the PRT were posted in a timely manner during the entire PR.

    - The information given was structured in *main documents* and *documents for further information*:

        - *Main documents* are the Taiwan-NR, the Licensee Report - CSNPP (Chinshan NPP), Licensee Report - KSNPP (Kuosheng NPP), Licensee Report - LMNPP (Lungmen NPP), Licensee Report - MSNPP (Maanshan NPP) as well as a "Background document on the PR: Q&A".

        - A large variety of *documents for further information* was collected according to the following categories:

            1. EC and ENSREG background documents
            2. Taiwanese legislator documents
            3. Taiwanese regulator documents
            4. Taiwanese scientific community documents
            5. NGO statements and contacts
            6. Preparatory meeting Brussels, 9 July 2013
            7. Other documents

3.3 Suggestions raised by the public on the website, answers and contributions to the peer reviews

As mentioned above, from 05/06 to 05/08/2013, a public consultation was held via Internet. Contributions were accepted during this period both via a dedicated EU-PR website under http://www.ensreg.eu/taiwan-stress-test/peer_review and by email.

Regarding the online public consultation, merely 8 contributions were received from 06/06 to 05/08/2013, 5 of which were "dummy" entries lacking contents and valid email addresses. The remaining 3 contributions consisted of (1) two repetitions of contributions already sent by email from NGOs and (2) one contribution from a concerned citizen in Taiwan criticizing that the writing of the NR was not well organized, that the Emergency Operating Procedures

(EOP) cannot be carried out timely and properly by TPC and that the Ultimate Response Guidelines (URGs) are not effective enough in case of a severe accident.

In parallel, over a period of several months, contributions from NGOs have been received by the PRT outside the on-line public consultation.

The analysis of these contributions shows that these stakeholders see significant scope for improvements mainly in the scope of the NR, the follow-up in terms of implementation of improvements resulting from the STs and the accident management procedures implemented. Key questions raised are:

- How have impacts from ageing effects been considered in the course of the STs?
- Has AEC introduced timeframes for implementing improvements?
- Scope of NR:
  - Volcanic hazards, including interaction with seismic faults, are missing,
  - Airplane crash impacts are missing,
  - Doubts if sufficient external event combinations have been considered.
- URGs are considered unrealistic.
- Criticism on lack of filters when venting.
- Criticism on lack of separate backup control room in case of severe accident.
- General criticisms on Lungmen project due to alleged unauthorised deviations from original design.

As far as these issues fall within the scope of the STs (see Section 1), they were taken up by the PRT in the information basis for the further evaluations. Most of these issues correspond to the ones received from the NGOs (see description of PRT's treatment of this information in Section 3.4).

Further, the NGOs initially expressed the view that the PR should take place a few months later than scheduled. As an explanation, the NGOs informed the PRT that (1) a postponement of the PR would allow the NGOs to collect more information and that (2) a PR at this time could be misused in the course of preparations for a referendum on the future of the Lungmen NPP scheduled more or less at the time of the PR. The PRT responded that a few months delay would (1) not significantly change the information status of the NGOs and thus of the PRT and that (2) the timing was not decided by the PRT but by the initiator of the PR, i.e. AEC.

3.4 Meeting with the Taiwanese stakeholders during the visit to Taiwan, contribution to the peer reviews

Following months of intensive communication with Taiwanese NGOs and provision of information on their key concerns, a dedicated meeting with NGOs was scheduled to take place at the premises of AEC during the first half of the EU-PRT visit to Taiwan.

The meeting was restricted to participants from the invited NGOs and the PRT in order to learn in an open atmosphere of presentation and discussion about the key nuclear safety related concerns from NGOs. Due to different understanding between AEC and the participating NGOs on the conditions of access to the premises as well as the wish of the PRT to have a bilateral meeting with NGOs without participation of TV and other media, this meeting could in the end unfortunately not take place. An alternative meeting at the "neutral" premises of the European Economic and Trade Office in Taipei was offered by the EC[18], but due to time constraints of some NGOs sufficient participation was not ensured and so also this meeting was canceled by the NGOs. Nevertheless, an informal exchange of views could be organized later between some NGOs and PRT members in order to better understand the background of their concerns. It was not fully clear which of the NGOs present were actually representative for parts of the public opinion or represent more individual interests.

Fortunately, in the months before the visit to Taiwan and again after cancelation by the NGOs of the foreseen meetings, a lot of valuable information has already kindly been provided by Taiwanese NGOs to the PRT. On the basis of this set of documents as well as on the basis of the findings of a recently finalized study by Greenpeace on the Lungmen nuclear new build project[19], a large set of information on the concerns from the viewpoints of NGOs with regard to the use of nuclear power in Taiwan has been collected by the PRT, published on the EU-PR project website[20] and taken into account in this PR.

From these concerns, the following key ones clearly fall within the scope of the STs and have been taken up by the PRT in the following ways:

- **NGOs' doubts concerning earthquake, tsunami, flood and volcanic activity issues** are in consistence with PRT's recommendation to update the corresponding design bases in accordance to 10.000 y recurrence frequency criteria taking into consideration the possible combinations of events, using the newest data and applying state-of-the-art methodologies and applicable to all NPPs in Taiwan (see Section 5). It is understood that these issues are taken up by AEC.

- **NGOs' doubts about sufficient preparedness for Beyond Design Earthquakes:** This is a concern addressed also by the PRT; applicable to both the existing NPPs and the new build project (see Section 5). It is understood that these issues are taken up by AEC.

- **NGOs' doubts concerning climate changes and their impact on the design basis flood:** The corresponding measures are already addressed in AEC order (see Section 5.3.2.5) and during periodic safety reviews performed every ten years (see Sections 5.2.1.4, 5.3.1.5).

[18] The readiness of the colleagues at the European Economic and Trade Office in Taipei to provide efficient support to the PRT throughout its stay in Taiwan shall explicitly be acknowledged.

[19] Oda Becker, Review of the post-Fukushima nuclear stress-tests of the Lungmen nuclear power plant (NPP4), Study commissioned by Greenpeace East Asia, Hannover, Germany, August 2013.

[20] http://www.ensreg.eu/EU%20Stress%20Tests/International%20outreach

- **NGOs' findings on discrepancies in some of the data mentioned in the NR**, e.g. with regard to NPP distances from shores: These discrepancies were essentially clarified by the PRT in the talks with AEC during the visit to Taiwan.

- **NGOs' doubts concerning validity of Ultimate Response Guidelines (URGs)**: The issue is being dealt with by AEC's requirement for further justification of it (see Section 7.2.2.1 and 7.2.3.2).

- **NGOs' criticism that the Lungmen design does not include containment filtered venting despite the fact that these are standard in the ABWR reactors in Japan and those designed for the EU market:** The installation of a filtered venting system is required by AEC order JLD-10114.

- **NGOs' criticism that AEC did not issue a binding requirement to install passive autocatalytic hydrogen recombiners to prevent hydrogen explosions in case of station black-out:** The installation of PARs is required by AEC order JLD-10122.

4 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

4.1 Compliance of the national report with the topics defined in the EU stress tests specifications

Regarding **Topic 1**, the Taiwan NR in general complies with the EU-STs specifications in terms of topics considered: the information provided addresses the seismic, flooding and external hazard issues related to extreme weather conditions. Design Basis (DB) analyses and Beyond Design Basis (BDB) analyses are provided on each of these issues.

Regarding **Topic 2**, the NR in general complies with the EU-STs specifications in terms of topics considered. The aspects related to loss of electrical power supply are described in the Taiwanese NPPs as requested, assuming the subsequent loss of all equipment up to the scenario of total Station Blackout (SBO). Loss of Ultimate Heat Sink (UHS) is covered in the required detail together with the combination of loss of power supply and UHS. For both topics, core cooling as well as Spent Fuel Pool (SFP) cooling are addressed, including measures on how to improve the robustness of the NPPs.

Regarding **Topic 3**, the NR in general complies with the EU-STs specifications in terms of topics considered: the information provided describes existing Accident Management (AM) measures, further measures programmed for implementation, implementation schedules and the assessments performed by AEC. The NR and licensee reports outline the essential provisions required for AM, including the organizational arrangements of AM and on-site emergency planning, the respective hardware measures as well as procedural arrangements (symptom based EOPs, SAMGs, event-based URGs and Extensive Damage Mitigation Guidelines (EDMGs)). The AM topics requested in the EU-STs specifications are generally addressed in the NR to a good quality.

4.2 Adequacy of the information supplied, consistency with the EU stress tests specifications

Regarding **Topic 1**, as NPPs have been constructed at different periods of time, the information with respect to external hazards is not fully consistent among different NPP sites, but still fulfils ENREG requirements. The NR comprises BDB-analyses which are not fully compliant with the EU-STs specifications; for some hazards margins have not been quantified (e.g., storm and some extreme weather phenomena). The seismic margins listed in the NR have been revised during the Taiwan visit.

Regarding **Topic 2**, the Taiwan NR is largely consistent with the guidance provided by ENSREG. It should be noted however that, although the NR provides in general a lot of information, the information is partly sparse and sometimes inaccurate (e.g., flooding protection height given with different rounding accuracy). Nonetheless by the time of closing the present PR report all the figures were checked and confirmed by AEC.

Regarding **Topic 3**, the contents and structure of the NR complies with the EU-STs specifications with sufficient detail for the assessment of Severe Accident Management (SAM). The NR complies well with the guidance provided in the EU-STs specifications. The information supplied in the NR addresses accident management for reactors and SFPs at operating reactors and the one NPP under construction. This has been complemented by more detailed and comprehensive information provided during the PR questions and answer phase, and discussions during the visit to Taiwan.

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

There is no evidence to indicate that the NPPs would not be compliant with their current licensing basis. This is despite the fact that the analysis of the NR with regard to external hazards (**Topic 1**) raises questions about the reliability of the underlying design basis events, in particular for earthquakes and tsunami flooding. For some hazards (e.g., river floods, tornado, extreme temperatures) design basis events have not been defined. Further, the NR mainly focuses on the reactors during operation, the shutdown states do not seem to have been fully considered.

Regarding **Topic 2**, statements about the compliance of the NPPs with their current licensing basis were included in the NR. During the Periodic Safety Reviews (PSRs, also called integrated safety assessments) which are currently performed in Taiwan at the least every 10 years, AEC regularly checks the compliance of the NPPs with their current licensing basis. During the EU-PRT visit to Taiwan, AEC confirmed such compliance.

Regarding **Topic 3**, the NR provides sufficient information with respect to assessment of SAM, the adequacy of the information supplied is generally consistent with the guidance provided. The review of the NR resulted in a number of questions. During the PRT visit to Taiwan, AEC and TPC provided detailed and sufficient answers and clarifications to all the review questions. Some information initially not included in the report was also provided by the Taiwanese experts and clarified during discussions.

NPP compliance with their current licensing bases has been reviewed by AEC during the STs, drawing in part from their normal regulatory oversight processes. Particular attention was paid during the PR process to the PSRs as an important and powerful regulatory tool for regulating improvements.

The NR as well as presentations given during the visit to Taiwan outlined the current licensing basis for EOPs. This includes the fact that the regulatory authorities have issued specific orders, limitations or conditions addressing SAM in the operating licenses. SAM is not part of the current licensing basis. AEC has asked for improvements in the management of BDB-events and severe accidents by developing URGs.

4.4 Adequacy of the assessments of the robustness of the plants: situations taken into account to evaluate margins

Regarding **Topic 1**, the assessment of the robustness is mainly done by the analysis of the safe shut down paths for BDB-conditions. In order to have in addition periodic controls, TPC implemented specific walkdowns including BDB-assessments. For seismic, the criterion to evaluate the failure of safety functions is limited to a medium fragility analysis of SSCs that neither covers SFP safety functions nor outage states. The approach leads to some cliff edge values listed in the NR that seem unreasonably high compared to the technical literature. Explanations to the approach and first results of a more conservative approach for seismic margin assessment were presented during the Taiwan visit.

Regarding **Topics 2 and 3**, all main issues were addressed. Statements about times to cliff edge effects were at least sometimes included. Missing information was provided by AEC during the Taiwan visit. The evaluation of all events analyzed was followed up by the identification of necessary measures that have already been implemented or are in the course of implementation. The robustness of the NPPs is a result of the design features applied and upgrades performed since the beginning of their operation in compliance with US Nuclear Regulatory Commission (USNRC) recommendations. The NR also includes an extensive description of emergency measures and procedures, as part of the measures to address severe accident challenges, including symptom-based Emergency Operating Procedures (EOPs), Ultimate Response Guides (URGs) and Severe Accident Management Guidelines (SAMGs), emergency preparedness arrangements and hardware (e.g. measures to depressurize the primary system, for hydrogen management, in-vessel retention of damaged cores, corium stabilization, containment integrity, overpressure, venting, etc.). Description of SAM includes organizational aspects, emergency operating procedures and AM guidelines, mobile equipment and plans for training. The assessment of the NPPs' robustness as well as the circumstances taken into account to evaluate safety margins are considered adequate. The robustness for SAMs can mainly be thought of in terms of the time available before initiating events escalate the severity of accidents (e.g. battery depletion, core damage, vessel and containment failure) or by the extent of the redundancy, diversity and independence of provisions in place to prevent or limit radioactive releases to the environment.

As proposed in the NR, further analyses needed to improve SAM include further consideration of extreme natural hazards (seismic, tsunami/flooding hazards re-evaluations or volcanic Probabilistic Safety Assessment (PSA)) and simultaneous events at multi-unit sites (to estimate the duration of an independent response capability). Additional requirements have also been issued by AEC, such as installing an alternate Ultimate Heat Sink (UHS) consistent with recommendations of the ENSREG action plan. An area of consideration is related to additional mobile equipment, and how to assure that this equipment will be available and operable during the considered scenarios. The NR describes for each NPP the equipment required and where this equipment should be located.

4.5 Regulatory treatment applied to the actions and conclusions presented in national report (review by experts groups, notification to utilities, additional requirements or follow-up actions by regulators, openness)

4.5.1 General aspects

Taiwanese nuclear requirements and safety assessment practices are based on the applicable USNRC technical standards, guides and regulations. In response to Fukushima, AEC issued a decision requiring TPC to perform for all NPPs a complementary safety assessment. The program of this review was in line with the EU-STs specifications. The NR was prepared on the basis of the reports provided by TPC on each of the nuclear sites. It provides evidence that AEC was actively engaged in the whole process of the STs-realisation.

In 11/2012, AEC established clear requirements based on actions taken by other countries. These requirements were embodied in regulatory orders issued by AEC, while TPC may propose alternatives subject to AEC approval. These orders contained a considerable number of actions to improve the safety of the NPPs and covered all topics of the ST (external hazards, loss of safety functions and SAM). The implementation is on-going and is continuously reviewed by AEC.

The schedule to implement these improvements is from 2012 to 2017, except for the rulemaking process, whose duration is linked to the same process performed by the USNRC. AEC assessed and approved the list of modifications proposed by TPC and the implementation schedule. Additional evaluations were performed by TPC to determine the adequacy of some proposed improvements. For a few items the review of the proposed solutions by the AEC is still ongoing, which results in a scheduling still to be worked out.

The regulatory process applied to the actions and conclusions presented by TPC are not discussed in the NR. However, from the presentations and discussions during the visit to Taiwan, this process has become clearer. The NR did provide information on the various decisions issued by the regulator in response to the demand for a special safety review that was in line with the EU-STs specifications. Initially, the NR did not include an action plan, but a new Section 8 has subsequently been developed by AEC, and the improvements should be implemented before May 2017 as final date.

AEC has played an active role in the Taiwanese STs-process, and in certain cases has already assessed specific new proposals presented by TPC. A significant number of activities are required by AEC based on the USNRC's Near Term Task Force (NTTF) report and others, consistent with recommendations in the ENSREG action plan (like installation of Passive Autocatalytic Recombiners (PARs)). In addition to the orders issued by AEC's Department of Nuclear Regulation, the Department of Nuclear Technology issued three orders related to staffing and communications for emergency, enhancement of the Technical Support Centre (TSC) to address seismic concerns and to building a seismically isolated TSC based on the practice being implemented in Japan in light of the Fukushima accident.

4.5.2 Important regulatory tools for safety assessment: PSA and PSR

Probabilistic Safety Assessment (PSA)

Besides PSR, Taiwan early developed and used PSA as a tool to enhance the safety of its NPPs. AEC stated that it initiated the development of first PSA models for Kuosheng NPP in 1983. An AEC task force conducted the study with technical support from USNRC and consultants. The full power Level 1 and Level 2 PSA models including internal events, earthquakes, typhoons, internal flooding and internal fires events for the first operating BWR-

6 with Mark III containment were completed in 1985.

The same scope Level 1 and 2 PSA models for Maanshan 3-loop PWR with large dry containment and Chinshan BWR-4 with Mark I containment were completed by the task force in 1987 and 1990, respectively. According to these studies, the dominant contribution to Core Damage Frequency (CDF) comes from the seismically induced SBO scenarios. As a result, an additional gas-cooled 5th (or 7th) EDG was installed for each NPP in early 1990. The performance of the 5th (or 7th) EDG has been demonstrated by the SBO event that occurred in 2001 at Maanshan NPP. Some other hardware and procedure modifications for NPPs were also derived from the findings of PSA studies.

TPC started to submit to AEC the PSA results from data updates every 3 years since late 1990. The Level 3 PSA models are updated every 5 years to reassess the adequacy of the Emergency Planning Zone (EPZ). TPC is committed to follow the PSA standards to build-up, update and maintain the PSA models. This includes the peer review process recommended by NEI guidelines and ASME PSA standard. All of the Living PSA models for the 3 operating NPPs in Taiwan were well-developed through PSA peer review processes starting in 2002. From the development of Living PSA models and fast-solving risk tools, some risk-informed applications were reviewed and approved by AEC per USNRC RG 1.174 and related guidance. Since the late 1990s, TPC has expanded the PSA models to analyse the risk for refuelling outages (shutdown PSA). Large Early Release Frequency (LERF) models have also been developed for the NPPs.

In summary, the Living PSA applications for the Taiwanese NPPs include On-Line Maintenance, Maintenance Rule, and Risk-informed In-Service Inspection, Risk Monitor, Fire Protection Program, etc. For AEC, the same PSA models were integrated into the software for significance determination process (SDP) of Reactor Oversight Process (ROP) to determine the significance of the inspection findings during plant operation.

Periodic Safety Review (PSR)

The *Nuclear Reactor Facilities Regulation Act of Taiwan* requires the licensee to conduct Periodic Safety Reviews (PSRs) every 10 y, which is different from US laws and regulations (=country of origin) but in agreement with IAEA safety standards and most countries with operating NPPs. The Nuclear Reactor Facilities Regulation Act states that *"After nuclear reactor facilities have been formally operated, one integrated safety assessment at least shall be implemented every ten years and then be submitted to the competent authorities for review and approval"*. The 10-year integrated safety assessment report includes chapters on safety performance of radiation, radwaste management, major plant modifications, aging management of SSCs, seismic re-evaluation, lessons learned from significant events, and feedback from domestic and foreign experiences and research results. For example, Chapter 6 on seismic re-evaluation will focus on new findings/evidences and new regulatory requirements reflected by technological advancement and recent operating experience.

After Fukushima, AEC required TPC to re-evaluate each site's capability to cope with extreme natural disasters, including earthquake, tsunami and flooding, and to add one specific chapter regarding "Post-Fukushima Comprehensive Safety Assessment and Safety Enhancement" to the most recently submitted or to be submitted 10-year integrated safety assessment reports for all NPPs by 12/2011 to properly reflect the major results of the assessment.

This specific chapter covers all post Fukushima safety re-assessment items, including: to re-examine the capability for loss of all AC power (SBO), to re-evaluate flooding and tsunami protection, to ensure integrity and cooling of spent fuel pool, to assess heat removal and UHS, EOP re-examination and re-training, build-up the URGs, support between different units, considerations for compound accidents, mitigation beyond DBA, preparedness and backup equipment, manpower/organization/safety culture.

TPC has submitted the updated 10-year integrated safety assessment reports with the post Fukushima safety re-assessment chapter in 12/2011. AEC has reviewed it and conducted site inspections. Many actions are taken by TPC and some are still on-going in order to enhance the capability to cope with BDBAs. Besides all the actions TPC has taken, AEC has established clear requirements to further implement enhancements as stated in Section 1.5 of the NR.

In summary, all 3 operating NPPs in Taiwan have so far completed 3 runs of 10-year PSR. During the PSR processes, state-of-the-art methods and equipment were implemented or required to further enhance NPP safety.

4.5.3 Regulatory orders in the aftermath of Fukushima

In general, due to the fact that all its reactors are designed and manufactured by the US, Taiwan's NPPs shall follow all applicable laws and regulations of the country of origin, i.e. the ones of the USNRC. In addition, in light of the lessons learned from Fukushima, AEC also requested TPC to adopt good practices from Japan and Europe to further strengthen the robustness of its NPPs on the basis of the Taiwanese Nuclear Reactor Facilities Regulation Act.

Article 14 of this Act states that *"If there is anything that does not conform to the prescription or if public health/safety or environmental ecology may be endangered, the competent authorities shall order the licensee to improve the situation or take any other necessary measures within a prescribed time period. If the situation is serious, the licensee does not improve it or does not take necessary measures within the prescribed period, the competent authorities may order the licensee to cease the working on the scene, or operation thereof, or may revoke the license or permit the operation only under a limited power."*

Based on the above mentioned legal structure, AEC issued batches of Regulatory Orders:

Regulatory Orders Issued on 5/11/2012 by AEC:

Building on the results of the STs and insights from the actions being taken by other regulators, the AEC has established clear requirements to implement safety enhancements. These requirements were embodied in orders issued by AEC’s Department of Nuclear Regulation to TPC on 5/11/2012. TPC may propose alternatives subject to AEC approval. The orders issued by AEC are, as follows:

1. XX-JLD-10101: Requiring seismic hazard re-evaluations implementing the recommendation from the USNRC NTTF Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.

2. XX-JLD-10102: Requiring flood hazard re-evaluations implementing the USNRC NTTF Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.

3. XX-JLD-10103: Requiring TPC to simulate the mechanism of seismic and tsunami hazards and the resulting risks based on comments from an AEC review meeting.

4. XX-JLD-10104: Requiring the enhancement of the water tightness of buildings (or build seawall, or tidal barrier) to a level of 6 meters above current licensing bases based on the actions being taken at Japanese NPPs and as referred to in the USNRC NTTF Report, to address the uncertainty from the original design basis tsunami height by adding 6 meters of protection.

5. XX-JLD-10105: Requiring seismic, flood and others external events walkdowns consistent with the USNRC NTTF Report Tier 1 recommendation 2.3 to conduct seismic and flood walkdowns.

6. XX-JLD-10106: Requiring TPC to take actions to address Station Blackout (SBO) consistent with the USNRC NTTF Report Tier 1 recommendation 4.1 on SBO regulatory actions.

7. XX-JLD-10107: Requiring at least 2 Emergency Diesel Generators (EDGs) to be in an operable state all the time even when the reactor is shut down so that if one unit is shut down with one EDG under maintenance and the swing EDG is assigned to it according to the new requirement, the capability of the swing EDG to back up the other unit is restricted.

8. XX-JLD-10108: Requiring TPC to enhance emergency DC power supply to secure the batteries storage capacity of at least 8 h without isolating the load and at least 24 h after the unnecessary loads are isolated.

9. XX-JLD-10109: Requiring TPC to extend the SBO coping time to at least 24 h based on specific issues for Taiwan's NPP in that the original requirements of USNRC Regulatory Guide (RG) 1.155 do not include the effects resulting from earthquake and tsunami.

10. XX-JLD-10110: Requiring TPC to install an extra seismic qualified gas-cooled EDG at high elevation for each NPP to address specific defence-in-depth issues with electrical power supplies for Taiwan. AEC accepts the alternatives for this order to provide the water-tightness of the swing EDG building.

11. XX-JLD-10111: Requiring TPC to install an alternate UHS consistent with recommendations from the ENSREG action plan.

12. XX-JLD-10112: Requiring TPC to implement the actions of the USNRC's Post-9/11 action (B.5.b) to stage response equipment on or near site to respond to extreme external events (see USNRC 10 CFR 50.54(hh)(2)).

13. XX-JLD-10113: Requiring TPC to address the USNRC NTTF Report Tier 1 recommendation 4.2 on equipment covered under USNRC regulation 10 CFR 50.54(hh)(2).

14. XX-JLD-10114: Requiring TPC to install reliable hardened vents for Mark I and ABWR containments and request the installation of filtration for all different containment designs consistent with the recommendation of USNRC NTTF Report Tier 1 recommendation 5.1 on reliable hardened vents for BWR Mark I and Mark II containments.

15. XX-JLD-10115: Requiring TPC to install SFP instrumentation consistent with the recommendation of the USNRC NTTF Report Tier 1 recommendation 7.1 on SFP instrumentation.

16. XX-JLD-10116: Requiring TPC to strengthen and integrate the EOPs, SAMGs and

EDMGs with the URGs developed by TPC following the Fukushima accident consistent with the USNRC NTTF Report Tier 1 recommendation 8 on strengthening and integration of EOPs, SAMGs, and EDMGs.

17. XX-JLD-10117: Requiring TPC to perform a volcanic PSA for its NPPs and to study the impacts from ash dispersion based on comments during a high-level review meeting.

18. XX-JLD-10118: Requiring TPC to enhance the water-tightness of the fire doors of essential electrical equipment rooms based on specific concerns with the location of the equipment at Taiwan's NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.

19. XX-JLD-10119: Requiring TPC to enhance the seismic resistance for the fire brigade buildings to cope with BDBE conditions to address specific issues for Taiwan's NPPs and a good practices from EU PRs.

20. XX-JLD-10120: Requiring TPC to improve the reliability of off-site power supplies to address specific issues for Taiwan's NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.

21. XX-JLD-10121: Requiring TPC to improve the seismic resistance of raw water reservoirs at the NPPs and to consider the installation of impermeable liners to address specific issues for Taiwan's NPPs and consistent with the measures being taken by TEPCO in Japan to install impermeable liners.

22. XX-JLD-10122: Requiring TPC to install PARs to prevent hydrogen explosions consistent with recommendations in the ENSREG action plan.

23. CS-JLD-101101: An Order of the Executive Yuan, requiring TPC to conduct an enhancement evaluation of safety related SSCs for the Chinshan NPP followed by the upgrading of the licensing basis SSE from 0.3g to 0.4g for specific SSCs relied upon to respond to an accident.

24. MS-JLD-101301: Requiring TPC to address the issue with the PWR reactor coolant pump (RCP) seal loss-of-coolant-accident leakage issue for Maanshan NPP consistent with the ENSREG action plan.

In addition to the above orders issued by the AEC's Department of Nuclear Regulation, the following orders are issued by the AEC Department of Nuclear Technology to TPC:

1. HQ-JLD-1013001: Requiring TPC to update "radiation protection measures and planning for the residents within emergency planning zone (EPZ) of nuclear power plant" in response to the expanded EPZ from 5 km to 8 km based on the lessons learned from Fukushima for all NPPs in Taiwan.

2. XX-JLD-1013002 and 1013004: Requiring TPC to address staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions.

3. XX-JLD-10104(AECDNT): Requiring TPC to reinforce the structure of the existing non-seismically qualified Technical Support Centre (TSC) used for emergency response to address specific seismic concerns of the NPPs in Taiwan.

4. XX-JLD-1013003: Requesting TPC to consider building a seismically isolated TSC building based on the practice being implemented in Japan in light of the Fukushima accident and consistent with lessons learned provided by the IAEA.

Regulatory Orders Issued on 5/11/2012 by FCMA:

There are three additional orders issued on 5/11/2012 by the Taiwanese Fuel Cycle and Materials Administration (FMCA):

1. RL-JLD-1012042: Requiring TPC to procure 40 mobile detection equipment with automatic data transmission capability for four NPPs to enhance capability of radiation fallout monitoring in a timely manner.

2. RL-JLD-1012043: Requiring TPC to install 13 radiation monitoring stations within the EPZ of NPPs to set up a radiation monitoring preparedness platform and strengthen radiation monitoring capability.

3. RL-JLD-1012044: Requiring TPC to procure four radiation detection vehicles to enhance mobile radiation monitoring capability.

Regulatory Orders Issued on 6/6/2013 by AEC:

The orders issued on 6/6/2013 by AEC are, as follows:

1. XX-JLD-10201: Requiring TPC to conduct fault displacement analysis for new evidences of Shanchiao and Hengchun Faults near (within a radius of 8 km) the NPPs.

2. XX-JLD-10202: Requiring TPC to provide the interface between existing post-earthquake and post-tsunami operating procedures of NPPs.

3. XX-JLD-10203: Requiring TPC to systematically assess the combinations of events in the areas of flooding and extreme natural events at NPPs.

4. XX-JLD-10204: Requiring TPC to examine the probable maximum precipitation with regional topographical maps of NPPs.

5. HQ-JLD-10201: Requiring TPC headquarters to deploy a local seismic network (one in the north and one in the south) to capture small earthquakes in order to understand whether or not the pattern of the epicentres indicate correlation with postulated tectonic features.

5 PLANT(S) ASSESSMENT RELATIVE TO EARTHQUAKES, FLOODING AND OTHER EXTREME WEATHER CONDITIONS

Introductory Remark: ***The risk to be hit by natural hazards such as earthquakes, flooding including tsunamis, extreme weather conditions and volcanism is much higher in Taiwan than in many other regions of the world and especially much higher than in the European countries which subjected their NPPs to the EU-STs. Therefore, the PRT considers proper treatment of these hazards as being of crucial importance for nuclear safety in Taiwan. The PRT understands that – particularly for this topic – AEC aims at establishing and enforcing a regulatory framework for Taiwan that complies with highest common international state-of-the-art safety requirements and guidelines.***

5.1 Description of present situation of plants in country with respect to earthquake

5.1.1 Design Basis Earthquake (DBE)

5.1.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country)

During the visit to Taiwan, the PRT was informed that all NPPs in Taiwan were designed according to US laws and regulations. In the Final Safety Analysis Report (FSAR) or other licensing documents, TPC is required to follow all the applicable US laws and regulations including orders/ bulletins / generic letters, etc. The approval process by AEC is not explained in the NR but has been explained during the Taiwan visit.

The DBEs are reviewed during NPP licensing.

Complementary information on PSR was provided during the Taiwan visit.

5.1.1.2 Derivation of DBE

Values for DBEs for the 4 NPP sites are derived from a deterministic approach: For each site, two specific DBE values are defined with site-specific Peak Ground Acceleration (PGA) values for the Safe Shutdown Earthquake (SSE) and the Operating Basis Earthquake (OBE). Presently, the following PGA values are valid for SSE and OBE:

- CSNPP: SSE: 0,3g, OBE: 0,15g
- KSNPP: SSE: 0,4g, OBE: 0,2g
- MSNPP: SSE: 0,4g, OBE: 0,2g
- LMNPP: SSE: 0,4g, OBE: 0,2g

Information on seismic design spectra has been provided during the visit to Taiwan.

In the NR, seismic hazard at the design stage was not expressed with a return period.

Up to recently, account for new findings and the advance of science did not lead to the evolution of seismic hazards for the Chinshan, Kuosheng and Maanshan NPPs.

Recent enhancement work is under definition due to new evidences of capable faults in the site vicinity of the Chinshan, Kuosheng and Maanshan NPPs.

The PRT regards the derivation of the updated DBE, the accurate mapping of capable faults in the site vicinity, and the reliable assessment of these faults using paleoseismological methods as an important issue that needs to be clarified and has noticed that AEC has required TPC to re-evaluate the seismic threat due to the Sanchiao and Henchun faults.

5.1.1.3 Main requirements applied to this specific area

Regulatory requirements for seismic safety are not specified in the available documents but are addressed in the FSAR. The assessments of seismic ground motion hazards were subjected to domestic review processes.

Key SSCs are seismically designed, but the original design requirements do not seem to be fully consistent among NPPs and are mostly oriented to cope with the SSE and insofar guarantee the safe shutdown of the reactors. Key SSCs listed in the NR are required to comply with the original design requirements.

Detailed descriptions of SSC seismic design in terms of safety functions addressed are available in the FSAR. TPC is recommended to homogenize requirements between NPPs when relevant (I&C, control room, SFP water level and cooling system, fire protection systems used for safety backup, post-accident monitoring system, etc.).

According to operating requirements, TPC proceeds to regular inspections and periodic tests.

The exceedance of ground shaking level by half of the PGA value triggers detailed inspection of the safety of the NPPs after a seismic event.

Indirect effects of earthquakes, such as seismically induced fire and flooding are addressed; some SSCs upgrades are on-going.

5.1.1.4 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

The deterministic assessment of the DBEs for the 4 NPPs is based on:

- The intensity of the strongest earthquakes that have been observed in a period of a few hundred years, and
- The maximum magnitude derived from the dimensions of near-regional active faults applying some general scaling laws. Ground shaking parameters are calculated for that magnitude and the epicentre distance of the NPP from the DBE using different ground motion prediction equations.

In most cases, the DBE has been selected to be equal to the maximum historical earthquake with adding small safety margins to the historical value. From today`s perspective, this approach is not conservative and not in line with the generally accepted IAEA SSG-9. The approach of determination of DBE complied with the USNRC 10 CFR 100 App. A.

Fault capability and secondary earthquake effects, such as seismically-triggered landslides, ground subsidence/ground heave, and ground settlement that pose potential hazards to the sites are qualitatively addressed in the NR. Information provided by AEC indicates that NPPs are built on soft rock. The PRT was explained that the possible increased ground shaking hazard caused by site amplification due foundation on soft rock have been considered in the design analysis as well as the updated new seismic hazard analysis.

5.1.1.5 Periodic safety reviews (regularly and/or recently reviewed)

The PSR process regarding seismic hazard is not detailed in the NR. Nonetheless, the PRT notes that a process for the update of fault behaviour, in the site vicinity and near region of all NPPs, is on-going and that – irrespective of the result of these studies – the DBE for the Chinshan NPP has been re-assessed.

The currently available information may noticeably impact the presently used values.

It is considered a good practice that seismic hazard is re-assessed as frequent as necessary in order to account for new findings and the advance of science and include regular reviews of the impact on SSCs of the DB and BDB-hazards evolution.

External hazard including earthquake is a large contributor to PSA CDF. Thus, the PRT recommends that a specific focus on this topic is given for the next PSR.

A process to bring the safety goals of existing reactors closer to the ones of most recent reactors, in particular when both will be operated at the same time, may be developed in the course of PSR. In general, when new safety standards are developed, they are expected to apply not only to new NPPs, but also to existing NPPs, to the extent as far as possible.

5.1.1.6 Conclusions on adequacy of design basis

The current DBE does not meet international state-of-the-art requirements; especially it does not meet the requirement that the level to cope with external hazards shall be consistent with a non-exceedance probability of 10^{-4} per year. Further, the current DBE values are challenged by novel geological and geophysical data, in particular by new assessments of capable faults in the near-region and site vicinity of the NPPs. These data are of utmost importance for seismic safety and call for thorough site reassessments.

A new reassessment of the DBE accounting for all geological and geophysical data and the latest USNRC RG 1.208 is currently being developed and will be reviewed by AEC.

The PRT recognizes that the reliable assessment of the seismic capacity of capable faults in the site vicinity and near region of the sites in terms of maximum magnitude, earthquake recurrence intervals, and ground displacement hazard is of crucial importance for the hazard re-evaluation. This requires careful examination of key input parameters such as fault lengths/fault areas, fault geometry, possible fault segmentation, connection of faults to shallow detachment faults extending below the NPPs, slip mechanisms, fault slip rates, and locally validated GMPEs. Constraints for these fault parameters can be obtained by systematic paleoseismological trenching. It will further be important to assess the subduction zones that extend below the NPP sites in terms of maximum magnitude and GMPEs which were derived from the area under consideration.

The PRT stresses the importance of design, classification, qualification and upgrade requirements to be applied in a consistent and timely manner on all NPPs (reactors and SFPs) taking due account of the hazard evolution. DB-analysis as well as BDB-analysis shall include all operating states (operation, outage, refuelling etc.).

5.1.1.7 Compliance of plant(s) with current requirements for design basis

AEC is of the view that TPC fulfils the initial design requirements and has required TPC to update these requirements. Further, AEC has required to clarify the seismic DBs, qualification rules and updated inspection criteria.

The PRT, however, raises questions on the validity of seismic DB-values that were derived by previous deterministic methods.

In response to the evidence of close active faults, TPC has accelerated its enhancement work which shall be verified after the final update of the seismic DB hazard.

The PRT stresses the importance to ensure that all retro-fitting measures that may become necessary due to the possible finding of higher hazard levels are implemented without delay, and to determine consistency in ensuring that all plant review/back-fitting measures achieve this updated level of DBE. The safety re-evaluation of SSCs shall be applied to all seismically qualified SSCs and be consistent with methods recommended by IAEA for seismic re-evaluation of existing NPPs.

5.1.2 Assessment of robustness of plants beyond the design basis

5.1.2.1 Approach used for safety margins assessment

TPC used a methodology based on the identification of safe path to scram and stabilize the reactor and SSC fragility curves to identify weak points.

The criterion considered to evaluate the failure of safety functions is limited to a median fragility analysis of SSCs. Some values provided in the NR seem to be rather high compared to the technical literature. Hence, this criterion should be revisited to ensure that all relevant safety functions have been taken into account. The scope of this analysis does neither cover SFP safety functions nor reactor outage states.

Due to the cliff edge effect caused by a reactor scram failure, AEC should apply in the cliff edge effect analysis significantly higher confidence levels instead of median values. However, the PRT notes that an automatic seismic trip system (ASTS) has been implemented in all 6 currently operating NPP units.

According to the level of acceleration considered, some BDB-induced effects may have some influence in the analysis, as well as the identification of weak points that may occur in some of the reactor operating states. Thus, the margins assessment should not be limited to SSCs performance for reactor stabilization after reactor scram.

In complement to beyond design safe path analysis, the PRT considers that mobile means and their plugging systems should be usable to allow mitigation even for BDBEs.

During the Taiwan visit, AEC explained to the PRT that complementary seismic margin assessment and methods using high confidence low probability of failure (HCLPF) values were on-going.

5.1.2.2 Main results on safety margins and cliff edge effects

Safety margins and cliff edges analysis in the NR are not regarded sufficiently demanding for safety assessment. Due to the cliff edge effect, in the safe path analysis, AEC should apply in the cliff edge effect analysis significantly higher confidence levels instead of median values.

The PRT observed that the seismic PSA is based on long return period shape response spectrum and addresses different return periods.

Currently, a BDBE will potentially require the operators to rely on existing SSCs in a first phase and possibly the implementation of mobile means in a later phase.

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

TPC has performed seismic margin assessment and PSA studies to complete its safety evaluation. Seismic walkdowns that complement the use of these methods to assess the risk of cliff edge effects are implemented. The PRT encourages the continuation and, if possible, the extension of this good practice to identify the potential impact of non-seismically qualified SSC or low seismically qualified SSC on SSC that are required for safe shutdown.

The PRT considers that these walkdowns shall be continued as a regular conformity check. The scope of these walkdowns includes inspection of SSC that may damage other equipment items in the event of an earthquake and SSC that are necessary for crisis management.

Seismic protection has been improved by the implementation of permanent seismic monitoring and alarm systems. Information from such systems enables the licensees to make informed judgement regarding whether or not to continue operation following a seismic event. Such decisions are based on procedures and training already implemented.

In case of NPP site isolation, it is a commendable practice that the licensee has the capability and competences to locally analyse information provided by the monitoring system.

5.1.2.4 Possible measures to increase robustness

Hazard assessments should lead to updated DBEs, and the PRT suggests that the safety demonstration shall be updated accordingly (e.g. by using IAEA safety report n°28 “safety evaluation of existing plants”).

The seismic qualification needs to be clarified, as well as BDBA based on a detailed assessment of the robustness including the consideration of all reactors and SFP operating states.

Clear standards and procedures are required for qualified plant walkdowns with regard to earthquake, flooding and extreme weather to provide a more systematic search for possible non-conformities with the goal to eliminate them. The PRT was explained that seismic walkdown criteria dedicated to post Fukushima follow actions has been implemented by TPC.

Provision of information about the organisation and means to restore outside electrical power in a timely manner after a seismic event is recommended by the PRT.

Clarification of the seismic requirements with respect to the SSCs used for crisis management and the buildings that house the people who may support the NPP in case of seismic events is recommended by the PRT.

5.1.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

AEC established clear requirements to implement enhancements. These requirements were embodied in regulatory orders issued by AEC to TPC on 05/11/2012. TPC may propose alternatives subject to AEC approval. In addition to the 24 orders issued by the AEC’s Department of Nuclear Regulation, there were 5 orders issued by the Department of Nuclear Technology and 3 orders by the Fuel Cycle and Materials Administration. The orders are listed in the NR (orders 10101, 10103, 10104, 10105, 10110, 10112, 10119, 10121, and 101101). Measures include several requirements for seismic safety. The PRT particularly stresses the importance of order no. 10101 (seismic hazard re-evaluation based on USNRC standards).

It is of prime importance to extend the reassessment of earthquake hazards beyond the establishment of updated DBE ground motion values and to include fault capability, ground settlement/ground heave, and mass movements. The geological and climatic conditions in

Taiwan make it necessary to perform hazard assessment for earthquake triggered landslides considering the combined effects of seismic shaking and wet soil due to high precipitation. Such combinations aggravate land sliding hazards.

The PRT noted that the DBE of the Chinshan NPP will be upgraded to 0.4 g, and considers that the seismic justification of SSCs shall be made using methods dedicated to design or used during PSRs for the evaluation of existing NPPs (e.g. by using IAEA safety report n°28 "safety evaluation of existing plants").

After Fukushima, a Review Level Earthquake (RLE) of 1.67 times SSE is required for some systems, which can damage mitigation systems.

5.1.3 Peer review conclusions and recommendations specific to this area

As the plate-tectonic situation of Taiwan is a very specific one, particular emphasis should be put on the seismic issue.

In the past, the value of the DBE was proposed by the licensee, and was reviewed during the plant licensing. In the last years, especially after Fukushima, AEC established clear requirements to re-evaluate the seismic hazards and to enhance the resilience of its NPPs also against BDBEs. The new requirements are mainly based on USNRC standards. The latest requirements were embodied in regulatory orders issued by AEC to TPC on 5/11/2012. As Taiwan and Japan have quite similar geophysical conditions, the current decisions of the Japanese regulator are considered as additional input in the on-going process of further seismic improvements of the NPPs in Taiwan.

To support and promote this comprehensive enhancement process, the PRT recommends considering the following actions and measures:

- It is recommended to define a DBE consistent with an exceedance probability not higher than 10^{-4} per year and an adequate response spectrum in a timely manner[21]. It should be ensured that the re-assessment of the DBE accounts for all geological and geophysical data that are available in the international scientific and technical community and that secondary hazards are adequately addressed. The associated DBE parameters shall be developed by a probabilistic approach on a conservative basis, e.g. following IAEA SSG-9 guidelines. The PRT stresses the importance of adequately assessing the capable faults that have been identified in the near-region and site vicinity of Taiwan's NPPs, such as the Hengchun and Shanchiao faults. PSHA shall implement all capable faults in the hazard model as fault sources applying locally validated Ground Motion Prediction Equations (GMPEs). Particular attention shall be given to extending the data available by paleoseismological trenching. The subduction zones of the Manila and the Ryokyu trenches need to be included in the assessment. – As the seismic issue is a scientifically complex one, a dedicated international participatory peer review on seismic issues is recommended in order to reach a consensus on the adequate input parameters for the PSHA and, finally, the revised DB.

[21] Following ENSREG's PR report, *"Stress tests performed on European nuclear power plants"*, 25/04/2012.

- The PRT assumes that the future hazard assessment to define the updated DBE will lead to increased loads to SSCs. In order to get a quick and significant safety enhancement with regard to seismic hazards, it is recommended to define ground motion values in exceedance of the current DB ground accelerations and to implement intermediate upgrades of SSCs with fundamental safety functions to this newly defined level.

- After an updated DBE has been defined, the seismically qualified SSCs have to be updated accordingly[22].

- The seismic design level for the raw water reservoirs which are located upstream of the Chinshan, Kuosheng and Maanshan NPPs and the connecting pipes should be back fitted in accordance with seismic hazard updates to prevent floods by the failure of these structures.

- As the level of ground acceleration for the OBE is high in absolute values due to Taiwan’s high seismicity and corresponds to the design value of low seismic class SSCs that are not required for safe shutdown but may be required for safe operation, the PRT recommends to pay particular attention to post-seismic inspection of SSC with a low seismic classification.

5.2 Description of present situation of plants in country with respect to flood

5.2.1 Design Basis Flood (DBF)

5.2.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country)

During the Taiwan visit it was explained that the Design Basis Flood (DBF) design is compliant with US NRC App. A of 10 CFR 50 GDC 2 *"Design Bases for Protection Against Natural Phenomena"*, which requires that structures important to safety be designed to withstand the effects of expected natural phenomena when combined with the effects of normal accident conditions without loss of capability to perform their safety function.

DBFs are specified for tsunami and heavy rain including extreme precipitation during typhoons. Flooding from high streams waters (e.g. Chinshan NPP) are qualitatively described.

The initial DBF is described in the safety analysis reports of the NPPs and is mostly composed of flooding due to storm (heavy rain) and tsunami.

Floods caused by failure of water control structures are considered in the drain system design.

[22] In the case of existing NPPs, including LungmenNPP, the updated DBE is the new basis for calculating and upgrading the resilience of SSCs against earthquakes.

5.2.1.2 Derivation of DBF

Flooding due to heavy rain:

The design flood is identified as the probable maximum precipitation for a 10.000 year return period. It is evaluated with the extrapolation from the observation of precipitation levels during a given period of time (mostly about 30 years) at weather stations close to the NPP sites. The methods used to define the 10.000 y rain apply specific design codes.

Tsunami:

The tsunami height values are exclusively based on the evaluation of the run up of a set of historic tsunami records from a limited period of observation (the oldest records date from 1867) added to the local high tide and storm surge. Assessments of pre-historic tsunamis from the geological record are not available.

Some additional margins have been considered on different NPPs: for example season's winds for Kuosheng NPP, typhoon surge and 0.5 m margin for Maanshan NPP, and geographical factors and a 0.5 m margin for Lungmen NPP.

The methodology to determine the tsunami level is not fully consistent between the different sites.

Flooding by streams:

The Chienhwa stream in CSNPP might cause flooding due to high water (it was explained by AEC that some corresponding data are included in the FSAR).

Floods caused by failure of water control structures (dam failure):

Raw water reservoirs are located upstream of Chinshan and Kuosheng NPPs. These NPPs are connected through seismically designed pipes. The seismic design level of these reservoirs and their piping systems complies with the Taiwanese building code for civil engineering structures. The potential flooding hazard due to a failure of these reservoirs are identified and mitigated by the drain system that is also designed according to the building code for civil engineering structures.

5.2.1.3 Main requirements applied to this specific area

Flooding due to heavy rain:

Regarding heavy rain, the main protection measure is the performance of the drain systems.

The safety demonstration is based on the comparison of the probable maximum precipitation with the design of external drain systems. AEC declared that the drain systems have been verified to the 10.000 y return period maximum precipitation.

Periodical reviews of the drain systems are made mainly before the rainy periods and some procedures are provided to prepare the plants before hazard occurs in relation with warning systems, and to mitigate and operate the plants after the hazard occurs.

Tsunami:

The main protection measures against tsunami is the height of the platforms and the water tightness of nuclear safety class SSCs below this level (some of them may need additional verifications).

Systems that are identified as safety class and that are needed for the plants to reach a safe shutdown are verified. Nonetheless, the plant may not be able to restore normal operation without necessary repairs on SSCs that are not seismic class 1.

Based on the plant design, the plant heights of the platforms are all above the design tsunami run-up height, except the water intake structures. The final state of these water intake structures under tsunami attack should be evaluated.

The site accessibility of plants in case of flooding phenomena is not specified in the NR practicability of access route, etc.
During the Taiwan visit, the numerical simulation of tsunami flood inundation analysis to illustrate the access route was presented.

5.2.1.4 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

Information on Flooding Operating Experience Feedbacks (OEFs) was presented during the PRT visit.

Flooding due to heavy rain:

Flooding hazards by heavy rain are assessed by a probabilistic approach using historical data from nearby meteorological stations. The methodology is not fully described in the NR and has been explained during the visit to Taiwan.

Heavy rain phenomena and typhoon generate unequal local precipitation in a given area due to the variability of the phenomenon and the topological specificities. For each site the 10.000 y rain is derived from local weather stations observations which are limited to observation periods of few decades only. A deeper analysis of weather phenomena should be considered as it could provide additional information in complement to the local observations used for an extrapolation to a long period of time.

Tsunami:

The tsunami height value is determined by a deterministic approach by a simple numerical addition of the local historical maximum values for tsunami, storm surge and tide. Further, some (different) small margin values are added.

5.2.1.5 Periodic safety reviews (regularly and/or recently reviewed)

AEC required TPC to re-evaluate each NPP site's capability to cope with extreme natural disasters, including earthquake, tsunami, and flooding and to add one specific chapter regarding *"Post-Fukushima Comprehensive Safety Assessment and Safety Enhancement"* to the most recently submitted or to be submitted 10-year integrated safety assessment reports. This specific chapter covers all the post Fukushima safety re-assessment items, including re-evaluation of flooding and tsunami protection.

TPC regularly conducts specific flooding walk downs dedicated to verify the availability of DB-protection systems. Due to the frequent occurrence of typhoon and other extreme meteorological phenomena, TPC is experienced in implementing such verifications.

TPC conducted some post Fukushima additional walk downs (WANO), and other flooding protection informed walk downs to check the conformity of these SSCs.

AEC has committed to complete its requirements on tsunami induced flooding.

5.2.1.6 Conclusions on adequacy of design basis

The current DBF does not meet international state-of-the-art requirements. Especially it does not meet the ENSREG requirement that the level of external hazards shall be consistent with a 10.000 y return period. It shall, however, be noted that re-assessments are on-going in priority regarding tsunami induced flooding risks.

5.2.1.7 Compliance of plant(s) with current requirements for design basis

AEC identified some deviations from the current licensing basis, which are addressed in the NR. Some remedial actions to resolve these deviations are also described.

5.2.2 Assessment of robustness of plants beyond the design basis

5.2.2.1 Approach used for safety margins assessment

The ENSREG requirements that presume the increase in flood level BDB and determine cliff-edge response and potential improvement to address them was not broadly used (incrementally increase of the flood levels and consider associated potential improvement).

Margins analysis is considered as the ability to monitor and anticipate flooding events through warning systems and to anticipate the implementation of operating measures or the installation of specific protection means or mitigation systems.

These measures that are made for DB-events may positively contribute to BDB management, with regard to the time available to implement them (one can expect a limited time between a tsunami alert and the arrival of the first wave).

In complement, TPC has used the event tree method analysis to identify the level of flooding that would lead to the cold shutdown failure and concludes that the margin from the initiation event level to the cliff edge is of 0.6 m for Chinshan NPP, 0.3 m for Kuosheng NPP, 5.8 m for Maanshan NPP and 0.3 m for Lungmen NPP.

The National Science Council published a complementary report on the *"Influence of Tsunami induced by potential massive scale of earthquakes on the NPP in Taiwan"* on 19/08/ 2011. AEC notes that this study still contains some significant uncertainties in tsunami run up predictions due to the definition of tsunami sources. These preliminary values are found to be lower than the initial design values and the margins between the original design basis tsunami levels and the present levels of the plant platforms is 0.4 m in Chinshan NPP, 1.7 m in Kuosheng NPP, 2.4 m in Maanshan NPP and 3.9 m in Lungmen NPP.

These cliff edges are close to the present level of platforms for 3 NPPs.

5.2.2.2 Main results on safety margins and cliff edge effects

TPC has inspected installations and reviewed procedures to identify non conformities or possible improvements.

Some of the improvements consist in the providing and implementation of mobile means for which the implementation delays could be an issue after a hazard warning provided by the alert system.

The main issue consists in the intention of building an additional tsunami protection for which the technical requirements are not known.

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

Tsunami flooding has appropriately been identified as an important issue due to the necessary improvement of its design basis definition and its possible source of cliff edge effects on ultimate safety functions.

For the CSNPP, KSNPP and MSNPP NPPs, tsunami walls of 17, 17 and 19 m heights above mean sea level are scheduled to be completed before the end of 2016. This is seen as a good practice.

A set of procedures is available to safely shut down a flooded plant. These operating procedures deal as well with flooding mitigation. The PRT recommends that they should be completed according to possible dependences between flooding and other external hazards, mainly earthquake. These procedures should be consistent between all plants.

TPC conducts periodic walk downs to verify the capacity of equipment and material needed to mitigate external and internal flooding, including mobile means. The storage conditions of these mobile means are not detailed in the NR but AEC declared that they are appropriately protected against external hazards.

A strong feature is the great number of mobile means available.

The PRT notes the importance of human factor analysis for the implementation of a large quantity of mobiles means, mainly in case of combined hazards such as an earthquake and a tsunami or potential accidental conditions.

5.2.2.4 Possible measures to increase robustness

Regarding the expectable delay to have adequate studies and investigations available in order to reduce the uncertainties of – in particular – seismic or undersea land sliding induced tsunami flooding levels, the implementation of complementary mitigation means for BDB-flooding to prevent cliff edge effects should be considered, mainly with fixed SSCs to prevent safety failure due to implementation delay. These additional means shall be designed to withstand combined hazards which may be related to tsunami phenomena (earthquake and protection against internal and external SSC failure due to earthquake).

Concerning the combination of an accident with an internal flooding of the NPP, the implementation of mobile pumping facilities for contaminated water in some buildings should be clarified.

5.2.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

Based on lessons learned from Fukushima, some complementary measures have been decided on NPPs: automatic closing gates, prevent large debris inlet clogging, install flood barriers, install water pipes above ground, install water tight doors, etc.

AEC established clear requirements to implement enhancements. These requirements were embodied in regulatory orders issued by AEC to TPC on 5/11/2012. TPC may propose alternatives subject to AEC approval. The orders issued are listed in the NR (orders 10102, 1010, 10104, 10105, and 10118).

In complement, AEC considers that TPC shall appropriately define DB-tsunamis in the light of the experience from other NPP licensees worldwide and take appropriate measures to review DB-flooding during PSR to identify specific improvements for Chinshan NPP whose platform is lower than expected.

For CSNPP, KSNPP and MSNPP, tsunami walls of 17, 17 and 19 m heights above MSL are scheduled to be completed before the end of 2016.

All these actions are relevant to improve robustness and defence-in-depth.

5.2.3 Peer review conclusions and recommendations specific to this area

In the past, the value of the DBF was proposed by the licensee, and was reviewed during the plant licensing. In the last years, and especially after Fukushima, AEC established clear requirements to re-evaluate especially the tsunami hazards and to enhance the resilience of the NPPs also against BDB-flooding. The new requirements are mainly based on USNRC standards. The latest requirements were embodied in regulatory orders issued by AEC to TPC on 5/11/2012. As Taiwan and Japan have similar geophysical conditions, decisions of the Japanese regulator are currently considered as additional input to the on-going process of further flooding improvement of the NPPs in Taiwan.

To support and promote this comprehensive enhancement process the PRT recommends AEC to consider the following actions and measures:

- The different types of flooding hazards shall be assessed for an exceedance probability not higher than 10^{-4} per year. The effects of dependencies between different hazards should be considered (e.g. earthquake/tsunami). For tsunamis, all possible initiators such as earthquake, undersea land sliding, and volcanic eruption are to be considered. The run up evaluation for tsunami should use the latest state-of-the-art methods and tools; uncertainties should appropriately be considered in the models. A significant effort is needed to increase the tsunami database by geological records as the exclusive reliance on historical data covering only short periods of time is not considered sufficient. The indirect effects of tsunamis should also be assessed (shore stability, risk of intake and outlet clogging, sedimentation of material transported, etc.). – The evaluation of the tsunami heights may require international PRs or benchmarks before reaching a consensus on the updated DB.
- A timely construction of tsunami walls for all NPP sites is considered a noticeable step forward to improve safety. In addition, all openings of safety-relevant buildings should be back fitted to withstand in case of a tsunami disaster the pressure of water and be watertight up to the height of the tsunami walls.

5.3 Description of present situation of plants in country with respect to extreme weather

5.3.1 Design Basis Extreme Weather

5.3.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country)

During the Taiwan visit, it was explained that USNRC GDC 2 in 10CFR 50 Appendix A, is the applicable regulatory requirement regarding extreme weather.

Though the previous flooding issue considers storms as potential source of flooding, "storm" is considered by TPC as DB for extreme weather. In the NR, hazards induced by typhoons, heavy rains, mudslides and strong wind are detailed. A combination of these effects is considered at the design stage for NPPs.

Maximum precipitation:

The following values for Probable Maximum Precipitation (PMP) are listed in the NR:

- Chinshan NPP: 297 mm/h
- Kuosheng NPP: 241 mm/h
- Maanshan NPP: 228 mm/h
- Lungmen NPP: 310 mm/h.

Strong wind:

The NR lists different wind speeds for civil structures, switchyards and off-gas stacks. It has been clarified during the Taiwan visit that the listed values refer to the speeds of design basis storms derived from site-specific hazard assessments. The design wind speed has been defined as the 100 years maximum plus an additional margin. For several plants design wind pressures are also listed for some plants and structures.

The design wind speeds for buildings are given, as follows:

- Chinshan NPP: height 0-50 feet: 148 mph; 50-150 feet: 168 mph.
- Kuosheng NPP: height 0-30 feet: 157 mph, for seismic category 1 structures 206 mph (FSAR); windblown debris (external missiles) is considered.
- Maanshan NPP: no values are specified in the NR. Data has been provided during the Taiwan visit.
- Lungmen NPP: for seismic category 1 structures the NR lists two values, 121 mph and 157 mph (elevation 9 m above ground).

For the Chinshan, Maanshan and Lungmen NPPs no information is available about the consideration of windblown debris (external missiles). During Taiwan visit, it was confirmed that the windblown debris was considered in the FSAR per US NRC SRP requirement.

Mud slides:

No information on the DBs or requirements for mud slides is provided in the NR, the PRT was explained that this issue is qualitatively evaluated.

Mass movements:

Mass movements (dip slope sliding) are considered in the safety assessment of the sites. The PRT considers that dip slope sliding is a realistic threat to the Chinshan NPP.

Other meteorological phenomena:

The NR provides no information about other meteorological effects such as lightning, saltspray/saltstorm, waterspouts, and extreme temperatures. For salt spray, procedures have been implemented to reduce the effects of this phenomenon. AEC/TPC consider that the lightning issue and waterspouts are not relevant for Taiwan. The PRT considers that this position shall be documented.

5.3.1.2 Derivation of extreme weather loads

Maximum precipitation:

The derivation of heavy rain flooding is consistent with the approach described in Section 5.2.1.2. The maximum precipitation values (in mm/h) are derived from statistical analyses of meteorological data recorded at stations close to the sites. Values are given for a 10.000-year return period. The protection against flooding is justified by the performance of the external drainage system and in some cases by the implementation of the water tightness of safety relevant buildings.

Some measures to ensure water tightness of safety relevant buildings are implemented in the Chinshan and Lungmen NPPs (although limited to design basis flood level at Lungmen).

Strong wind:

The derivation of the design basis for wind speeds is not explained in the NR. The strong wind hazard definition may in some cases depend on the safety class of SSC. During the Taiwan visit, it is confirmed from the FSAR that the design wind speeds were derived based on 100 year return period of maximum wind speed plus some safety margins.

Mud slides:

Mud slides hazards rely on a classification of streams by the Taiwanese Soil and Water Conservation Bureau (SWCB). Systematic site-specific assessment of streams in the site vicinity has not been performed; nonetheless some assessments based on geological survey were procured. AEC considers that due to local topography and local geology, mud slides would not likely occur or may not induce risk.

Mass movements:

Dip slope is identified as a limited issue but taken into account in the safety assessment. The issue is relevant for the Chinshan and Lungmen NPPs. No details about the geological and geotechnical assessment of possibly instable slopes are provided in the NR. Safety assessment relies on the fact that no mass movements have been recorded so far. The PRT concludes that this evidence is insufficient as the specific geological (subsoil composed of young soft sediments, high seismic hazard) and climatic situation of Taiwan (high and long-lasting precipitation events) aggravate landslide hazards.

5.3.1.3 Main requirements applied to this specific area

Maximum precipitation:

Safety of the plants with respect to flooding by heavy rain is demonstrated by comparing maximum hourly precipitation values and drainage capacities.

Strong wind:

Warning systems for extreme meteorological events are available, emergency procedures are implemented on a regular base according to regular external weather alerts.

5.3.1.4 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

Maximum precipitation:

External hazards (heavy rain) have been conservatively defined using mostly deterministic codified rules extrapolating a given observation period of time. These codified methods embedded a state-of-the-art probabilistic part. These methods are mostly dependant on the period and the quality of observations. This can lead in some cases to inconsistencies (e.g. regarding heavy rain: Chinshan and Kuosheng NPPs 10.000 yearly rain are slightly different, though the plants are relatively close). The analysis of these small differences could be used to slightly improve the use of such methods.

Strong wind:

The approach for assessing strong wind has been clarified during the visit to Taiwan.

Mud slides:

The mudslide model used to assess this risk is not detailed.

Mass movements:

The assessment of dip slope sliding is not detailed but is assessed qualitatively. It is unclear whether a systematic approach was made to identify and assess instable slopes by geological, geomorphological, and geodetic methods.

Experience feedback processes are not presented and could be valuable to improve design requirements for all phenomena.

5.3.1.5 Periodic safety reviews (regularly and/or recently reviewed)

The PSR process regarding meteorological hazards is not detailed in the NR. But AEC required updates for storm and extreme precipitation that account for climate changes. PSRs are an opportunity to consolidate and harmonize the DB-requirements of "storm" phenomena and their combination to consider in the safety demonstration and to complete the additional phenomena that shall be taken into account.

Extreme weather hazards and their impact on the NPPs should be regularly assessed within a periodic review process at least every 10 years using latest meteorological and other relevant input data. The good practice of regular walk downs shall be perpetuated and extended in light of beyond design hazards.

According to the importance of external hazards in PSA studies and operational feedback, the PRT recommends that TPC completes its analysis on relevant external hazards and their relevant combination and identifies potential design improvements.

5.3.1.6 Conclusions on adequacy of design basis

Maximum precipitation:

AEC considers that the approach adopted by TPC to derive DB-extreme precipitation complies with approved methodologies.

Strong wind:

AEC considers the design base is appropriately defined.

Mud slides, mass movements:

Landslide (dip slope sliding) and mudslide effects are qualitatively addressed in the NR and the FSAR and would deserve a more detailed analysis. Specific safety requirements have not been defined for these phenomena.

Other meteorological phenomena:

As assessed by AEC, extreme weather is a contributor to the flooding issue that has been presented previously. No DBs have been defined for other meteorological phenomena.

5.3.1.7 Compliance of plant(s) with current requirements for design basis

AEC states in the NR that the approach adopted by TPC to re-evaluate risks associated with extreme weather complies with the methodology approved by AEC. It is further stated that *"most of the considered hazards were taken into account in the design basis of the facilities".*

The PRT recommends that AEC clarifies its requirements for the definition of the effects of extreme weather phenomena, their combinations, and the duration of phenomena to consider in the safety demonstration. These requirements (methodologies and criteria) shall be consistent for all NPPs.

AEC has not defined clear safety requirements with respect to landslides (dip slope sliding) and mudslides; the applicable SRP requirement applied and stated in the FSAR shall be further documented.

The PRT notes that the adequacy of the safety demonstration relies on the conformity of SSCs and that the normal local operating conditions are demanding (sub-tropical sea shore atmosphere). The PRT notes that TPC proceeds to periodic walkdowns and implements specific maintenance programs.

5.3.2 Assessment of robustness of plants beyond the design basis

5.3.2.1 Approach used for safety margins assessment

Regarding the safety margins for flooding and maximum wind speeds, the NR has only identified safety margins for design flooding in MSNPP. The differences between the DB-events maximum hourly precipitation (wind speed) and drainage capacities are not defined. Design principles have been presented during the Taiwan visit.

The NR, however, clearly identifies a number of plant-specific cliff edge effects. This includes the identification of civil structures and SSCs that are expected to be flooded first in BDB-events, effects of clogging of drainage systems by mudflows, and clogging of cooling water intakes. Safety margins analysis is basically assessed by the conventional identification of cliff edge effects due to mudslides, internal flooding of some safety class buildings and in some cases the loss of UHS due to inlets clogging.

5.3.2.2 Main results on safety margins and cliff edge effects

Quantitative safety margins for extreme precipitation (PMP) versus drainage capacity, and wind speeds versus building robustness are not presented in the NR. During the Taiwan visit, safety margins were presented for the Maanshan NPP. The NR identifies some potential cliff edges due to extreme precipitation and clogging of the drainage systems by mudflows. The NPPs have weather alert information that allows the implementation of specific existing procedures aimed at preparing the plants against potential impacts against weather phenomena (mudslide monitoring procedure, drain performance restoration, internal flooding mitigation).

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

Due to the frequency of external hazard phenomena, weather warning systems, plant preparation (walk downs) and preventive mitigation means are regularly implemented. TPC staff seems to be well aware of and trained in handling challenges of severe weather conditions due to the frequent occurrence of such conditions (high precipitation, typhoon). Chinshan NPP slope stability assessments under OBE conditions have been procured, and are supplemented by on-site controls, which is a good practice that could be completed by on-site monitoring instrumentation. The implementation of site-specific monitoring systems for mudflows upstream of the NPPs and the installation of permanent geodetic systems to monitor slope movements is commonly regarded as good practice.

5.3.2.4 Possible measures to increase robustness

TPC has identified enhancement measures that consist in dedicated walk downs, verifying trench performance, implementing mobile means (pumps, diesels) to support systems (internal drainage, electrical systems, etc.), implementing flood barriers, etc. The implementation of such means and procedures could be harmonized between NPP sites.

5.3.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

AEC established clear requirements to implement enhancements. These requirements were embodied in regulatory orders issued by AEC to TPC on 5/11/2012. The orders issued require flood, others external events and walk downs and are consistent with the USNRC NTTF Report Tier 1 recommendation 2.3 (order 10105).

In addition, AEC identified the following requirements to improve the resilience of the NPPs:

- Confirm the protection of the buildings containing safety related equipment against projectiles of beyond design typhoons with wind speeds exceeding 70.2 m/s.
- Review the appropriateness of the DB PMP in the context of climate change and envisage associated improvements of the drainage systems. These should be reviewed through the process of periodic safety assessment.
- Clarify the watertight capability of fire-fighting doors and pipeline penetrations seals.
- Perform a systematic evaluation of combinations of extreme natural events.
- TPC should evaluate to install a second UHS.

5.3.3 Peer review conclusions and recommendations specific to this area

Taiwan has a lot of experience with extreme weather conditions. Therefore, from the beginning of the use of nuclear power, great efforts have been made to have high resilience against most of the extreme weather impacts happening in Taiwan. The impact of climate change should be taken into account during the regular PSR.

To support and promote this enhancement process the PRT recommends AEC to consider the following actions and measures:

- Definition of the design external hazard consistent for all NPPs and for DB-events with an exceedance probability not higher than 10^{-4} per year taking into account all relevant additional phenomena[23], and their combinations and durations, consistent for all sites.

- On the basis of a thorough geological and geomorphological assessment, mud flows and mass movements should be assessed on a site-specific basis. This assessment shall account for possible triggering by earthquakes, rain, and the combination of both. Slopes that pose threats to facilities shall be continuously monitored.

- Procedures to prevent and mitigate external hazards shall be updated to take into account all relevant external hazard phenomena and their realistic combinations, and be consistent among the NPP sites.

5.4 Volcanism

5.4.1 Assessment of hazards and design basis

5.4.1.1 Derivation of the design basis

No DBs have been established for volcanic hazards (except for tsunamis triggered by submarine eruptions). Volcanic hazards are, however, considered in BDB-considerations. The DB for tsunami triggered by submarine volcanic eruptions is given by a flood height of 7.5 m derived from the largest observed historical event, which occurred in 1867.

5.4.1.2 Main requirements applied to this specific area

The NR and the additional information provided by AEC do not include information on the legal or regulatory basis for the assessment of volcanic hazards. During the Taiwan visit, it

[23] E.g., typhoon, tornadoes, missiles that could be associated with tornadoes, lightning, extreme temperature of air or heat sink cooling water, salt spray waterspouts, heat sink clogging etc.

has been clarified that AEC requested TPC to follow the guidelines IAEA SSG-21 for identification, screening and assessment of potential hazards.

5.4.1.3 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

The potential volcanic hazards in the site vicinity of the NPPs are described in the FSAR which follows the US NRC Standard Review Plan (SRP), which is provided by TPC. AEC states that any potential volcanic hazard should be included and updated in that report.

Hazard assessment screened out all volcanic hazards for all NPP sites except tsunami triggered by submarine volcanic eruptions. The out-screening is apparently justified by the absence of historical volcanic activity. Consequently a DB is only defined for tsunami. The DB-tsunami equals the largest observed historical event (tsunami caused by a submarine volcanic eruption 1867 with additional margins).

The arguments used to screening out all volcanic hazards except tsunami are not fully described in the NR and it remains unclear whether the process followed accepted formal guidelines or not. The issue is particularly relevant for the Chinshan and Kuosheng NPPs. Both NPPs are located close to the Quaternary Tatun and Keelung volcanic areas. AEC's statement that the youngest recorded volcanic activity in this area occurred about 0.8 million years ago is challenged by scientific evidence for significantly younger volcanic rocks.

The approach to volcanic hazard assessment outlined in the supplement to the NR is not regarded state-of-the-art. The absence of historical eruptions does not support the current conclusion that volcanic hazards can be screened out for all NPP sites.

5.4.1.4 Periodic safety reviews (regularly and/or recently reviewed)

AEC established requirements to implement enhancements to cope with volcanic hazards. These requirements for a probabilistic volcanic risk assessment are embodied in regulatory orders issued by AEC to TPC on 5/11/2012.

5.4.1.5 Conclusions on adequacy of design basis

The DB for tsunami triggered by submarine volcanic eruption is not regarded adequate (see Section 5.2.1 of the report). DBs for other volcanic hazards have not been defined.

5.4.1.6 Compliance of plant(s) with current requirements for design basis

There is no indication that NPPs do not comply with the current DB-tsunami. DBs for other volcanic hazards have not been defined.

5.4.2 Assessment of robustness of plants beyond the design basis

AEC provided information about measures and procedures for BDB-volcanic events. Measures and procedures are defined for a list of volcanic phenomena that closely follows IAEA SSG-21 (list of hazardous volcanic phenomena that could affect nuclear installations). As DBs have not been established for these volcanic hazards, the PRT understands that all volcanic events that may affect the NPP sites are considered as BDB-events.

5.4.3 Peer review conclusions and recommendations specific to this area

The assessment and screening of volcanic hazards seems to fully rely on historical evidence. The consideration of such short historical time intervals for hazard assessment is not fully in line with current state-of-the-art.

The PRT recommends considering a re-assessment of the volcanic hazard by a state-of-the-art analysis addressing all potentially threatening phenomena. For this, it is necessary to update the volcanic hazard assessment by a probabilistic study and perform a new screening of volcanic phenomena in accordance with IAEA SSG-21. The new assessment needs to be based on a comprehensive volcanological database that covers much longer time periods than considered so far (i.e. up to several millions of years).

The PRT stresses that AEC has already established clear requirements to implement corresponding enhancements. These requirements were embodied in regulatory orders issued by AEC to TPC on 5/11/2012 (order JLD-10117).

6 PLANT(S) ASSESSMENT RELATIVE TO LOSS OF ELECTRICAL POWER AND LOSS OF ULTIMATE HEAT SINK

6.1 Description of present situation of plants in country

6.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country)

All NPPs in Taiwan are of US design; AEC applies the principle of country of origin and hence USNRC regulations are followed by the Taiwanese NPPs. In the FSAR, the applicable rules and reference guidelines (including applicable 10 CFR 50, Regulatory Guides, etc.) are indicated. The FSAR of each NPP unit contains all regulatory requirements and is legally binding. Every 3-4 years, TPC is required to submit an update about the actual state of applicability of the USNRC 10 CFR 50 and Regulatory Guides. Deviations from the 10 CFR 50.55a need to be approved by AEC.

6.1.2 Main requirements applied to this specific area

The approach of the US Federal Code 10 CFR 50.63 is followed concerning SBO (Loss of all AC power). Accordingly, a minimum coping time of 8 h is required by design. USNRC Regulatory Guide 1.155 (SBO) describes methods which can be used to provide the required demonstration. With regard to loss of UHS, the requirements of the USNRC Regulatory Guide 1.27 (Rev. 1) are applied. In the orders issued by AEC after Fukushima the requirements have been updated (see Section 6.2.5).

6.1.3 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

A deterministic approach complemented with PSA studies and models is adopted. The PSA database is regularly updated every 3 years according to TPC's procedure. OEF is systematically analysed and results are used as one of the inputs for improvements of the regulatory requirements/guidance. For example, at the Maanshan NPP a diesel engine driven auxiliary feed-water pump was installed reacting to the specific SBO event in 2001; another example is that AEC required TPC to improve outage procedures for EDGs in accordance with lessons learnt from the 2011 SBO event at the Higashidori NPP / Japan.

6.1.4 Periodic safety reviews (regularly and/or recently reviewed)

PSR has been performed at Taiwan's NPPs at 10 years intervals (see Section 4.5.2 above). With reference to the evaluation of past operating experience and Fukushima, the scope of a PSR includes also the safety analyses and design considerations related to SBO and loss of UHS.

6.1.5 Compliance of plants with current requirements

Based on the assessment of the reports of TPC and supporting documents, subsequent technical meetings and on-site inspections, AEC considers that the provisions currently adopted are adequate. However, as a consequence of Fukushima, AEC has developed additional demands and recommendations to further improve the robustness of all NPPs, as described in detail in the NR. During the PRT's visit to Taiwan, AEC clearly concluded that the statutory requirements on safety provisions needed to fulfil the fundamental safety functions are met. On this basis, there is no indication that NPPs in Taiwan would not be compliant with current requirements.

6.2 Assessment of robustness of plants

6.2.1 Approach used for safety margins assessment

The general approach adopted in assessing safety margins with respect to loss of electrical power and loss of heat sink aspects is to describe the relevant systems available together with the associated levels of redundancy and diversity of equipment. Next, the timescales by which various safety functions need to be established by this equipment in order to prevent significant fuel damage are presented. Finally, the level of autonomy with respect to fuel or coolant supplies is quantified. The times to fuel damage indicated in the present PR report conservatively refer to water level reaching the top of the fuel. The analyses performed by TPC and AEC consider other criteria as well, such as boiling temperature, cladding temperature, etc.

6.2.2 Main results on safety margins and cliff edge effects

<u>Power Supply features</u>:

Main power supply features can be summarized, as follows: the Taiwanese NPPs are connected to two external grids (345 kV and 69 kV grids or 345 kV and 161 kV grids) with several transmission lines each. On-site AC power supply is primarily provided by redundant and qualified EDGs. The operating sites also possess an air-cooled swing diesel generator that can backup both units and two air-cooled gas turbines located on a higher elevation to provide power to the safety buses. Should all fix installed AC power be unavailable, the Taiwanese NPPs can resort to batteries and various mobile diesel generators.

Loss of off-site power (LOOP):

In case of loss of the main and reserve grid, there are several lines of defence available: EDGs - seismic category I, water cooled – are installed at all sites. In case of failure of the EDGs, the on-site swing EDG can be aligned manually and provide AC power to each of the units (each site in Taiwan hosts a twin unit). Beyond that, in all operating NPPs, AC power supply can be taken over by two gas turbines. Installation of gas turbines is also planned for the Lungmen new nuclear build site.

Chinshan (CS):

The CSNPP is equipped with 2x 3600 kW EDGs of seismic category I per unit situated in the combined building at 11.2 m (NPP ground elevation). The EDGs are water-cooled via the Combined Structure Cooling Water system (CSCW) to the ultimate heat sink (ESW). Operation of the EDGs without ESW can be assured via CSCW to the SFP and subsequently from the SFP to the atmosphere via cooling tower. On-site fuel stocks are sufficient to last for 17 days considering that fuel moving equipment from the main tank to the daily tanks is also seismically qualified. Additional fuel is situated in the auxiliary boiler fuel tank and gas turbine fuel tanks. The seismic category I swing EDG is a 4000 kW air-cooled generator situated in a separate building at NPP ground elevation. Fuel stocks are available for 8 days. Lastly, the non-seismically qualified 2x 50 MW gas turbines at an elevation of 22.4 m can feed the safety buses and can count on fuel sufficient for 30 days.

Kuosheng (KS):

The KSNPP is equipped with 2x 3600 kW (Division 1, 2) and 1x 2200kW (Division 3 only for HPCS) water-cooled EDGs of seismic category I per unit situated in separate compartments of the diesel generator building at 12 m (NPP ground elevation). On-site fuel stocks are sufficient to last for 7 days considering that fuel moving equipment from the main tank to the daily tanks is also seismically qualified. Additional fuel is situated in the auxiliary boiler fuel tank and gas turbine fuel tanks. The seismic category I swing EDG is a 3910 kW air-cooled generator which can provide power to division 1 or 2 of each unit or one division of unit 1 and one division of unit 2. It is situated in a separate building at NPP ground elevation. Fuel stocks are available for 7 days. Lastly, the non-seismically qualified 2x 50 MW gas turbines at an elevation of 22 m can feed the safety buses and can count on fuel sufficient for 72 days.

Maanshan (MS):

The MSNPP is equipped with 2x 7000 kW water-cooled (via the Nuclear Service Cooling Water system) EDGs of seismic category I per unit situated in a separate building at 15 m (NPP ground elevation). On-site fuel stocks are sufficient to last for 7 days considering that fuel moving equipment from the main tank to the daily tanks is also seismically qualified. Additional fuel is situated in the auxiliary boiler fuel tank and gas turbine fuel tanks. The seismic category I swing EDG is a 7000 kW air-cooled generator situated in a separate building at NPP ground elevation. Fuel stocks are available for 7 days. Lastly, the non-seismically qualified 2x 50 MW gas turbines at an elevation of 35 m can feed the safety buses and can count on fuel sufficient for 14 days.

Lungmen (LM):

The LMNPP is equipped with 3x 7500 kW EDGs of seismic category I per unit situated in the reactor building in separate compartments at 12.3 m (NPP ground elevation). The EDGs are water-cooled via the cooling chain of the Reactor Building Cooling Water (RBCW) and Reactor Building Service Water (RBSW) systems. On-site fuel stocks dedicated to the EDGs are sufficient to last for at least 7 days. Equipment used to transfer fuel from the main tank to the daily tanks is also seismically qualified. Additional fuel is situated in the auxiliary boiler fuel tank and gas turbine fuel tanks. The seismic category I swing EDG is a 7800 kW air-cooled generator, situated in the auxiliary fuel building at NPP ground elevation. Fuel stocks are available for 7 days.

Based on the information provided above, AEC confirmed during the visit to Taiwan that in case of loss of off-site power all NPPs have autonomy for at least 72 h without external help as per EU-STs specifications.

<u>Station Blackout (SBO):</u>

In case of loss of all permanently installed AC power sources the NPPs have provisions of DC power and mobile on-site AC diesel generators. External help with equipment and manpower from neighbouring NPPs or local fire brigades and/or the army can support the on-site efforts depending on road and general accident conditions.

Chinshan (CS):

For coping with a SBO scenario the NPP relies on the Reactor Core Isolation Cooling (RCIC) system or High Pressure Core Injection (HPCI), both steam driven, and the operation of the Reactor Pressure Vessel (RPV) Safety Relief Valves (SRV) including related instrumentation. DC power to operate the RCIC is designed to last 8 h and with appropriate load shedding can last up to 24 h. The corresponding time for HPCI is at least 8 h. Air supply for the SRVs is sufficient for 43.2 h (after a design change has been completed with N_2 bottles connected to fix air supply pipes). Manual operation of RCIC has been successfully tested and included in the procedure as an accident management measure. In the extreme case that all devised measures are not successful, core uncovery may occur within 25.7 h.

Kuosheng (KS):

The coping strategy for SBO is operation of the RCIC system (steam driven) and actuation of the SRVs. The batteries for RCIC and SRV actuation are designed to last 8 h and can reach 24 h with appropriate load shedding. According to the Taiwan NR, the batteries are the limiting factor, all other support systems reaching 24 h autonomy. As accident management measure the RCIC can be operated manually without any DC power. In addition, a dedicated mobile diesel generator with its associated rectifier can supply DC to RCIC and SRVs. A mobile air compressor can supply service air to SRVs. In the extreme case that all devised measures are not successful, core uncovery may occur within 20.1 h.

Maanshan (MS):

In case of SBO the NPP relies on heat removal via secondary side, i.e., the Power Operated Relief Valves (PORVs) on the Steam Generators (SG) are actuated and the auxiliary feedwater system (steam-driven or diesel-driven pump) must inject water on the SG secondary side. The first step is load shedding in order to preserve battery capacity for essential loads. This has to be performed according to procedures within 30 min after SBO. Subsequently, considering the availability of water, compressed instrumentation air and DC power, it has been shown that the NPP has autonomy for 8 h in case of SBO. This analysis includes explicit consideration of Reactor Coolant Pump (RCP) seal leakages with leakage rate based on NUMARC-87-00. Should all DC power be unavailable, the steam-driven pump of the auxiliary feedwater system, together with the SG PORVs, can be operated manually as an accident management measure. In the extreme case that secondary side heat removal is not successful, core uncovery may occur within 2 h. In response to AEC order JLD-10109, further analyses and measures to extend grace time to core uncovery are being performed and evaluated. With reference to the ENSREG action plan (item 3.2.7) AEC has asked the operator to address the issue of RCP seal leakage in further detail in the order JLD-101301.

Lungmen (LM):

As is the case for the already operating BWRs in Taiwan, the RCIC system and SRVs/ADS (safety and automatic depressurisation valves) including necessary instrumentation are used to cope with SBO scenarios at the LMNPP new build. DC power, which is needed for operation of RCIC and SRVs/ADS is available 21 h without shedding, and at least 24 h with load shedding. Operation of the RCIC can be pursued also manually as accident management measure. In the extreme case that all devised measures are not successful, core uncovery may occur within 23.1 h.

In summary, besides the installed power supply all NPPs in Taiwan have a variety of on-site mobile DGs available which need to be transported to the foreseen connection points and/or only connected to the loads. These DGs can be used to power essential equipment and the battery chargers to extend battery life. The NPPs have diverse sources of treated water on-site which can be aligned to provide water injection for decay heat removal. Beyond that, raw water hill reservoirs with volumes of water ranging from 37’000 m^3 to 107’000 m^3 are available at higher elevations (with the possibility of gravity-driven injection) on all sites which can be used as extreme measure. The seismic resistance of such reservoirs should undergo further analysis and improvement (see Section 6.2.5).

<u>Loss of Ultimate Heat Sink (UHS):</u>

Chinshan (CS) and Kuosheng (KS):

UHS is the sea water through the Circulating Water system (CW, for normal operation, seismic category II) and the Essential Service Water system (ESW, for accident conditions, seismic category I) for CS resp. Emergency Circulating Water system (ECW, for accidental conditions, seismic category I) for KS. The ESW building at the CS site is located at 11.2 m, i.e. NPP ground elevation. The ESW has two pumps with 100% capability each and backup power through the EDGs or swing EDG. The ECW building at the KS site has been back-fitted to be water-tight up to an elevation of 12 m, i.e. NPP ground elevation. In case of loss of

UHS the alternative is to depressurize the reactor and inject water from available raw water sources. In such cases venting of the containment becomes necessary using the atmosphere as UHS.

Maanshan (MS):

UHS is the sea water through the Nuclear Service Cooling Water system (NSCW, seismic category I). Back-fitting in the pump house has brought protection against flooding up to 12.9 m (15 m being NPP ground elevation). In case of loss of UHS heat removal via secondary side can be maintained through the use of the turbine-driven or motor-driven Auxiliary Feedwater Pump (AFP) to inject water into the SGs. Steam is then released via the PORVs, the atmosphere serving then as UHS. Water reserves are the Condensate Storage Tank (CST), the Demineralized Water Storage Tank (DST) or raw water reservoir.

Lungmen (LM):

UHS is the sea water through the CW system (normal operation) and the reactor Building Service Water system (RBSW, for accident conditions, seismic category I). The RBSW system has three trains with 50% capacity each. Each train is equipped with two pumps. Backup power supply is provided by the EDGs or swing EDG. Water-tightness is demonstrated up to an elevation of 12.3 m (12.3 m being NPP ground elevation). As is the case for the already operating BWRs in Taiwan, also for the LMNPP new build the strategy to cope with loss of UHS is based on depressurizing the reactor and injecting water from all available sources. Venting the containment is then necessary, the atmosphere serving as UHS. Apart from the active venting path, there is a passive venting possibility (Containment Overpressure Protection System, COPS) for the wetwell via a rupture disk set to open at 6.52 bar.

Loss of UHS with SBO:

According to the information provided in the Taiwan NR for the Taiwanese NPPs, the combination of SBO and loss of UHS is covered by the SBO sequences. Essentially, in case of SBO, loss of UHS is a direct consequence of the initiating event and hence does not represent an aggravation of the SBO sequences.

Spent fuel pools:

The NR analyses SFPs cooling issues for all NPPs. The cooling possibilities and times to cope with loss of cooling are determined. Each NPP has redundant possibilities to cool the SFPs under design basis conditions. The possibilities to cool the SFP under SBO conditions are comprehensively analysed within accident management procedures.

Chinshan (CS):

During LOOP scenarios the EDGs and swing EDG will supply the SFP Cooling System (SFPCS, water-cooled) and the SFP Additional Cooling System (SFPACS, air-cooled through cooling towers) to ensure the cooling function, but not that of water makeup. In case of SBO, all the cooling and makeup systems to the pool are lost; the NPP has to resort to accident management measures identified to this purpose (e.g. fire water system using raw water provisions, or mobile DG directly connected to the Motor Control Center (MCC) to provide power to the SFPACS). Should all measures fail, if the core is entirely in the SFP, it will take ca. 9.4 h for the pool water to boil and 76.8 h to reach top of the active fuel .

Kuosheng (KS):

The SFP emergency cooling system is powered by the safety-related power system with backup via EDGs and swing EDG. In case of SBO, all the cooling and makeup systems to the pool are lost; the NPP has to resort to accident management measures identified to this purpose. In the most penalising conditions, if the core is entirely in the SFP in the 10th day of a typical outage, it will take 8 h for the pool water to boil and 69 h to reach top of the active fuel .

Maanshan (MS):

During LOOP scenarios the EDGs and swing EDG will supply the SFPCS (two trains with each 100% capability per unit). In case of SBO, all the cooling and makeup systems to the pool are lost; the NPP has to resort to accident management measures identified to this purpose. In the most penalising conditions identified in the Taiwan NR, it will take 10.3 h for the pool water to boil and 83 h to reach top of the active fuel.

Lungmen (LM):

During LOOP scenarios the Fuel Pool Cooling and Cleanup system (FPCU, mostly seismic category I), which is not on safety-related buses, cannot be powered, hence pool cooling and water makeup need to be provided through residual heat removal Fuel Pool Cooling mode with EDGs and swing EDG serving as backup power. In case of SBO, all the cooling and makeup systems to the pool are lost; the NPP has to resort to accident management measures identified to this purpose. In the most penalising conditions identified in the Taiwan NR, it will take 9.5 h for the pool water to boil and 91 h to reach top of the active fuel.

In summary, based on the recommendation of NEI 06-12, all operating NPPs have additionally installed equipment (including sprays) that allows water injection into the SFPs from outside without entering the SFP building. The sprays can provide a flow rate of 200 gpm and injection for SFP makeup amounts to 500 gpm according to the requirements of B.5.b (NEI 06-12). The LMNPP has procured the required equipment which will be installed before fuel loading. Temperature and water level measurements for the SFPs are powered for CS and LM by safety related batteries, for KS and MS by non-safety related batteries.

In case of loss of UHS, as well SBO combined with loss UHS, the cliff edge times for all NPPs in Taiwan are confirmed to be essentially the same as in the SBO case. Time until boiling depends on the NPP and operational mode and varies from 8 to 10.3 h under the most penalising conditions when the full core is moved to the SFP. Correspondingly, the time until fuel is uncovered varies from 69 up to 91 h.

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

Regarding strong features of the Taiwanese NPPs, the manifold and diverse equipment available on-site for coping with loss of power supply and in particular with SBO should be mentioned. Additional mobile equipment has been procured by the NPPs and included in the procedures. Considerations of time available and personnel needed to perform the different measures have also been made.

The availability of large amounts of raw water which can possibly be injected by gravity is also a plus provided that sufficient seismic resistance of such equipment can successfully be demonstrated and/or improved.

Flooding protection of equipment vital for core and containment cooling is an issue which TPC and AEC are following up and where targeted improvements have already been identified.

6.2.4 Possible measures to increase robustness

TPC put down a list of measures that are envisaged in order to increase the robustness of the NPPs. Among them, the following ones are highlighted here that are expected to contribute to improving safety at the NPPs:

- Enhance emergency DC power supply.
- Enhance water-tight capabilities for the fire doors of essential electrical equipment rooms.
- Improve seismic capacity of raw water hill reservoirs.
- Install gas turbines for the Lungmen site in a seismically isolated building.
- Water-tighten the existing air-cooled swing EDG for CS, KS and MS NPPs.
- Upgrade SFPACS cooling tower and related piping to seismic category I at Chinshan.

AEC has evaluated all the proposed measures in relation to their coherence and opportunity, and has finally issued the relevant orders with a complete set of binding requests to TPC (see also Section 6.2.5). AEC's oversight follows up on the adopted measures; an overview of the actual status of implementation was provided to the PRT (see Section 8).

6.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

Several measures have been decided and in part already implemented at the Taiwanese NPPs as consequence of Fukushima. In particular, AEC has asked TPC to implement the NTTF report's recommendations prioritized in Tier 1 by the USNRC in 10/2011. These measures are built on the B.5.b program (SBO and Advanced Accident Mitigation) launched by the USNRC in the aftermath of the events of 11/09/2001 and also adopted by the AEC. In particular, AEC has requested TPC to extend the SBO coping time to at least 24 h based on specific issues for the Taiwanese NPPs with reference to recommendation 4.1 of the NTTF report.

Regarding specifically SBO and loss of UHS, several measures are identified by AEC. The following issues must be addressed by TPC:

- TPC is required to analyse the consequences of accidents involving several units on one site in more detail.
- TPC is required to analyse shutdown conditions in more detail, in particular mid-loop operation for PWRs.
- TPC is required to evaluate in more detail the impact on the SPF of extreme external hazards resulting in SBO and complete loss of UHS.
- Currently, there are 2 EDGs per unit in the operating NPPs. If one unit is in normal operation and the other unit is shut down with one EDG under inspection, the swing EDG will be assigned to the latter unit according to a new requirement issued as OEF after the SBO event of the Higashidori NPP in Japan on 7/04/2011. Therefore, the capability of the swing EDG to back up the unit in normal operation is restricted. Envisaged measures to resolve this issue are required.
- With respect to the SBO, TPC is required to establish the equipment, procedures, and training necessary to implement an "extended loss of all AC" time of 72 h for core and SFP cooling and for reactor coolant system and primary containment integrity as needed. The design of the systems supporting the 72 h extended coping time should cover the same scope of functions as the 8 h minimum coping time, but it can be based on realistic analysis with reasonable operator action using portable or permanently installed equipment governed by established procedures and training.
- TPC is required to perform an evaluation regarding to the installation of an additional air-cooled DG at the NPPs.
- TPC is required to perform an evaluation regarding to the establishment of an additional alternate heat sink such as the water fed by groundwater wells.
- TPC is required to increase robustness of the NPPs in dealing with the primary coolant pump seal LOCA issue (MSNPP) during SBO.
- Referring to the emergency management and requirements in Japan, TPC is required to enhance the off-site power system and increase its reliability.
- TPC is required to strengthen SBO mitigation capability at all operating and new reactors for DB- and BDB-external events as recommended in item 4 of the USNRC NTTF report.
- TPC is required to conduct a systematic review of non-conventional means, focusing on the availability and appropriate operation of NPP equipment in the relevant circumstances. The operability of the non-conventional means should be justified on the basis of technical data. The facilities where the mobile equipment is stored should be evaluated and reinforced if necessary so that they are secure even in the event of general devastation caused by events (significantly) BDB.
- URG is required to be justified on the basis of rigorous systematic review and thorough accident analysis.
- The hydrogen and containment pressure control strategies in the URG shall take into account various accident scenarios.
- TPC is required to study the feasibility of adding a mobile heat exchanger to remove the heat from the containment and/or the reactor.

6.3 Peer review conclusions and recommendations specific to this area

The NR indicates that extensive analyses and evaluations were performed by TPC concerning the topics of loss of power supply and loss of UHS, including combinations thereof. As a reaction to Fukushima, TPC performed several walkdowns and inspections for all operating NPPs as foreseen in the relevant procedures and also following WANO 2011-2 SOER's recommendations. Based on the assessment of TPC's reports and supporting documents, technical meetings and on-site inspections and audits, AEC confirmed that the resulting action plan is adequate.

The Taiwanese NPPs have several lines of defence against a loss of power supply (EDGs, swing EDG, batteries, mobile generators for battery recharging and supply of critical equipment, gas turbines).

Provisions against loss of UHS are based on resorting to accident management measures with the atmosphere serving as UHS. It is noted that, following Fukushima, some European countries have pursued the back-fitting of a seismically qualified and flood resistant alternative UHS, and this option is recommended to be considered also for the Taiwanese NPPs. In fact, AEC has already requested TPC to investigate an alternate UHS, e.g. in the form of groundwater wells.

According to the NR and the TPC reports, the cliff edge effect for flooding is close to the NPP DBF. Since the probabilistic flooding hazard evaluation is still on-going and in view of the inherent uncertainties in the analyses, provisions should be envisaged to improve the margin to the cliff edge. For this purpose, the assumption should be made that NPP sites are flooded beyond current DB. In order to improve the margin over the mentioned cliff edge (CS 11.2 m; KS 12.3 m; LM 12.3 m; MS 15 m) it is hence suggested to consider ensuring operability of necessary equipment for a higher flooding elevation (beyond current DB). The issue has been addressed in part in the orders JLD-10104 and JLD-10118 where AEC has already requested TPC to enhance the water tightness of buildings (or build seawall or tidal barrier) to a level of 6 m above the current licensing bases and of the fire doors of essential electrical equipment rooms (see also the corresponding recommendation in Section 5.2.3).

Alternatively, it is recommended for each NPP to consider additional emergency equipment. This equipment should meet all requirements with respect to external hazards and be able to endure tsunamis and their run-up heights far beyond the present design basis and supply the respective NPP also after an extreme tsunami disaster with the necessary electrical power and cooling water to keep the NPP in a long-term safe condition[24].

TPC has additionally procured mobile air compressors for all the operating sites. Further improvements of the availability of RPV depressurization for BWRs are proposed for consideration, e.g. back-fitting of diverse means to ensure that the RPV remains depressurized.

It is recognized that the time to recover SFP cooling and water makeup under e.g. SBO conditions is already in the order of days (time until fuel is uncovered, assuming that the pool's structural integrity is maintained). Nevertheless, it is suggested to consider whether the provisions for assuring availability of temperature and level measurements in the pool are adequate in case of total loss of AC power under the new hazard assumptions. In fact, AEC

[24] A reference model for such considerations could, in principle, be the French post-Fukushima hardened safety core concept or the comprehensive approaches with bunkered special emergency safety systems implemented since a long time in several other European countries (Germany, Netherlands, etc.).

has already requested TPC to follow-up this issue considering the related NTTF report's recommendation.

7 PLANT(S) ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

7.1 Description of present situation of nuclear power plants in Taiwan

In Taiwan there are currently four different sites with two units each. Whereas the Chinshan, Kuosheng and Maanshan NPPs are in operation, the Lungmen NPP is still under construction and a governmental decision on whether or not to proceed with the project is pending. Details of their location, power rating, initial criticality and basic design features can be found in Section 1.3. During almost 30 years of operation, the operating units have benefitted from various safety reviews and improvements, upgrades and modernizations, including the requirement for TPC to submit and review the 10-year PSR report of the 3 operating NPPs.

7.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country)

On a general level, the regulatory basis of Taiwan (and thus also the regulatory basis relative to SAM) relies almost entirely on the applicable USNRC technical standards and regulations, as the US companies GE and Westinghouse are the main NPP vendors. Due to historical reasons and the deeper nature of these requirements, those USNRC standards and regulations still apply in Taiwan. The USNRC requirements for life time extensions have been applied (NRC license renewal rule 10 CFR 54 and NUREG 1800 for the review of application). TPC submitted a license renewal application (LRA) for Chinshan NPP in July 2009. AEC started the technical review in Sep. 2009 after an acceptance review and scheduled to complete the review process within 2 years. The review activity was temporarily suspended in 12/2010 due to TPC submitting a Stretch Power Uprate (SPU), which could change current licensing basis. After the Fukushima accident, the government announced a new energy policy in 10/2011 that all operating NPPs will not extend their operating licenses, unless new developments require a review of the present energy policy. Therefore, the review effort has been suspended.

The Taiwanese legislation on nuclear safety is relatively compact and is mainly based on USNRC 10 CFR regulation together with subordinate decrees and regulations. In response to Fukushima, AEC issued a decision building on the results of the STs and insights from the actions being taken in other regions of the world. AEC established clear requirements to implement safety enhancements for all NPPs in Taiwan. These requirements were embodied in regulatory orders issued by AEC to TPC on 5/11/2012. Meanwhile TPC may propose alternatives subject to AEC approval.

In addition to the 24 orders issued by the AEC's Department of Nuclear Regulation, there were 5 orders issued by the Department of Nuclear Technology (see Section 4.5.2). Among them were the requirements to install a seismically qualified extra gas-cooled EDG at each NPP to address specific issues with electrical power supplies defense-in-depth for Taiwan, to install an alternate UHS consistent with recommendations from the ENSREG action plan and to implement the actions of the USNRC's Post-9/11 action ("B.5.b") to stage response equipment on or near site to respond to extreme external events. Furthermore, TPC is required to finish the integrated PSA analytical model based on the ASME PSA standard.

7.1.2 Main requirements applied to this specific area

Regarding SAM, AEC issued the following main requirements to TPC:

- To combine the additional equipment and operations into procedures or guidelines;
- To re-evaluate the feasibility of EOPs and SAMGs with the involvement of new procedures/guidelines;
- To ensure that the SAMGs are appropriate for multi-unit events and to promote them from guidelines to procedures if required;
- To strengthen SBO mitigation at operating reactors for DB and BDB external events;
- To improve emergency preparedness staffing and communications according to the USNRC NTTF report;
- To identify URG and its implementation timing, the subsequent measures and monitoring strategy after implementing URG, including the monitoring of radioactive releases, backup ability of present systems and equipment;
- To estimate the duration of independent response capability for various severe accidents, BDBAs, and multi-event accidents;
- To ensure the capability of DC power for instrumentation and control systems of MCR, TSC, backup TSC, etc. for monitoring unit conditions during SBO accidents. The duties, associations and implementations of staff under these conditions should also be identified;
- To improve the seismic level of TSC and enhance the robustness of the equipment inside MCR, TSC and backup TSC;
- To assess the adequacy of MCR human arrangements in case of multi-unit events.
- To integrate the URG into EOPs, SAMGs, and EDMGs;
- To enhance the SFP instrumentation as per USNRC NTTF report;
- To install an alternate UHS consistent with recommendations from the ENSREG action plan;
- To implement the actions of the USNRC's Post-9/11 action (B.5.b);
- To store response equipment on or near site to respond to extreme external events;
- To install reliable hardened vents for Mark I and ABWR containments and requested the installation of filtration for all different containment designs consistent with the recommendation;
- To strengthen and integrate the EOPs, SAMGs and EDMGs with the URGs being developed by TPC;
- To install PARs to prevent hydrogen explosions consistent with recommendations in the ENSREG action plan;
- To address staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report;
- To provide appropriate training and qualification to the decision makers, like shift managers, plant managers, etc.

In reference to recommendation 5.1 in USNRC's NTTF report, AEC recommended TPC:

- To add a filtration in the originally designed robust and reliable containment venting system in Chinshan NPP (Mark-I), and to install a filtered containment venting system for all different containment designs;

- To integrate EOPs, SAMGs, and EDMGs and identify the commands and control strategies of implementations.

As mentioned above, in addition to the orders issued by the AEC's Department of Nuclear Regulation, there were 5 orders issued by the AEC's Department of Nuclear Technology requiring to address staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions, to enhance the structure of the existing non-seismically qualified TSC used for emergency response to address specific seismic concerns with the NPPs in Taiwan and to consider building a seismically isolated TSC building based on the practice being implemented in Japan in light of Fukushima and consistent with guidance provided by the IAEA.

Furthermore, USNRC B.5.b requirements on EDMGs covering SFP strategies and reactor and containment strategies apply.

7.1.3 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

As mentioned before, the nuclear requirements of Taiwan and safety assessments are based on the applicable USNRC technical standards, regulations and guides. SAMGs have been adopted based on the generic guidelines provided by the vendors (GE/Westinghouse). During the PR-discussions it was confirmed that SAM is in line with BWR Owner's Group EPG-SAG and PWR Owner's Group SAM Guidelines plus additional AEC orders after Fukushima.

Furthermore, the NR mentions that TPC should finish the integrated PSA analytical model based on the ASME PSA standard. The PSA model has been developed including Levels 1–3 and the evaluation of Large Early Release Frequencies (LERFs). A number of modifications have been evaluated with respect to their impact on the PSA model (and thus also on the frequencies of large early releases).

7.1.4 Periodic safety reviews (regularly and/or recently reviewed)

NPPs in Taiwan are following in general the applicable USNRC standards and regulations. However, a 10-year PSR is included in Taiwan's regulation, which is different from US laws and regulation. All operating NPPs have so far completed 3 reviews.

According to AEC, all operating NPPs have completed Level 2 PSA models since the 1990s LMNPP PSA Level 2 in 2007. Furthermore, TPC should finish the integrated PSA analytical model based on ASME PSA standards. Risk-informed applications adopt the measures of CDF and LERF from PSA models. TPC will submit the results of data updated every 3 years. TPC will follow the PSA standards to build-up, update and maintain the PSA models.

All NPPs have MAAP model to simulate severe accident phenomena. Continuous efforts to update the SAMGs are made to meet revisions of the owner-groups guidelines.

7.1.5 Compliance of plants with current requirements (national requirements)

The regulator confirmed that the SAMGs have been initially validated and periodically updated according the generic guidelines of the main supplier.

7.2 Assessment of robustness of plants

7.2.1 Adequacy of present organizations, operational and design provisions

7.2.1.1 Organization and arrangements of the licensee to manage accidents

An organizational structure, including support from the Taiwanese nuclear emergency organization at the level of the whole territory and from the emergency organization at the TPC headquarters office at the company level, is implemented to manage a severe accident.

In case of an emergency, the accident response organization structure includes Accident Management Teams, on-site and an off-site TSC, the Main Control Room (MCR), Emergency Public Information Center (EPIC), and Health Physics Center (HPC) staff. In case of a severe nuclear accident, when the transition from EOP to SAMG is in place, responsibility of decisions is transferred from MCR to TSC. The OSC is organized to deploy the intervention teams on the site and carry out intervention measures determined in the TSC.

For a multi-event and multi-unit severe accident like Fukushima, each NPP has duplicated the teams in the TSC and the AMT.

The off-site structure of the Emergency Response Organization (ERO) activated in case of a site or general emergency, consists of the Emergency Operations Facility (EOF). The Nuclear Emergency Planning Executive Committee (NEPEC) of TPC is responsible for off-site technical support. The governmental Central Disaster Response Center (CDRC) is responsible for coordinating rescue supporting resources outside of the plant.

In the case of a severe accident, the on-site Emergency Control Team (ECT) will immediately identify the accident type and the level of severity, and deploy technical groups to carry out the corresponding processes. At the same time, the ECT shall report to the NEPEC about the evolution of the accident according to the regulation. NEPEC will support the plant in accident management as soon as possible. If the requirements for off-site supports are upgraded, all external resources assembled will be allotted to CDRC and its Forward Command Post (FCP) under NEPEC. All resources and materials will be dispatched and utilized via CDRC. The supports from the Interior Ministry’s Fire Department, Police Department, the Military Command Units, other government departments, and those received from abroad are under the command or coordination of the CDRC.

The emergency preparedness and response in case of an accident is conducted on various levels: the whole Taiwanese territory, regional, local and at the plant. After Fukushima, each

NPP has collaboration agreements with military, local hospitals and local police stations for supports in case of nuclear accidents.

Under accident conditions, the MCR is automatically isolated and a cleanup system is started to keep the area habitable. MCR systems are redundant, safety related, seismically qualified and energized from independent safety power buses. Breathing apparatus with compressed air tanks are also available. In case of evacuation of the MCR, remote shutdown panels are available in the plants with sufficient control and monitoring capabilities for a safe shutdown of the plant to a cold shutdown state using a special set of operating procedures. Also TSC and OSC are structured, equipped and organized to enable long-term habitability.

There are various and redundant communication means inside the plants and between the plants, Emergency Operations Facility and other external organizations involved in the emergency response (satellite phone, internal and external phones, plant paging, etc.). They are powered with different uninterruptible power supplies. For the extreme case when all communication links are broken, satellite phones are available.

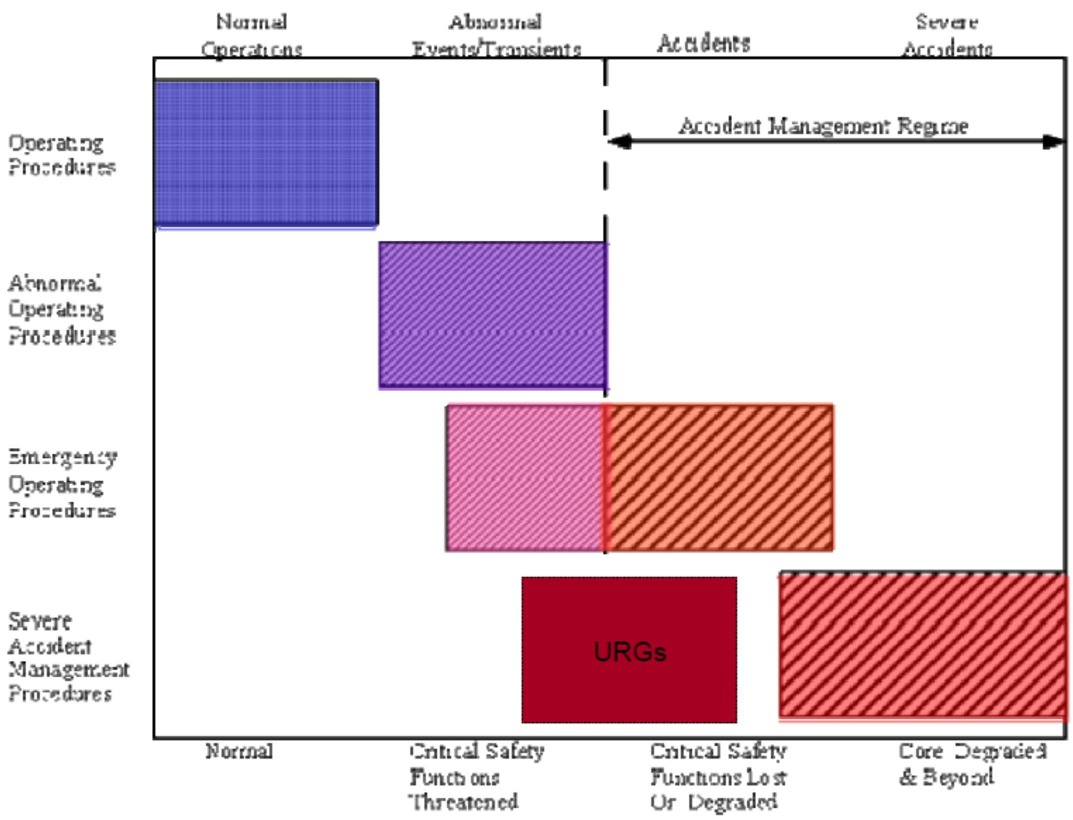
7.2.1.2 Procedures and guidelines for accident management (Full power states, Low power and shutdown states)

SAM programs have been implemented at the NPPs in Taiwan and symptom-oriented EOPs have been developed as well. If core damage is observed, the transition from EOP to SAMG is made. The SAMGs focus on preserving the containment fission product barriers and on halting the progression of core damage. SAMGs have been developed according to the Nuclear Steam Suppliers System’s generic guidelines using the existing equipment. After Fukushima, however, several improvements were or are being implemented, such as building the tsunami wall at Chinshan NPP, Kuosheng NPP's purchase of more fire water tanker, strengthening the prevention capability against flooding or strengthening the capability of back-up injection water into steam generator at Maanshan NPP, or storage of existing mobile disaster rescue equipment in a place not susceptible to disaster harm at Lungmen NPP. SAMGs are plant-specific and validated with emergency exercises.

In general, all procedures and guidelines, such as SOPs, AOPs, EOPs and URGs are applied for all plant states (full power, low power, shutdown, refuelling) at Taiwan's NPPs. But there are some procedures used in specific plant states. For example, the 200-series procedures are applied to the scopes between reactor start-up and full power operation. They also address loss of coolant events during shutdown modes in EOP 570.15 of Maanshan NPP. Actually, US SAMGs were originally developed for full power. Now, the owner's group may develop SAMGs also for low power or shutdown.

There are four operating states, including normal operations, abnormal events/transients, accidents and severe accidents. During the plant visit to Maanshan NPP, TPC the underlying concept was explained and some examples of the URG were shown to the PRT.

After Fukushima, TPC has developed plant-specific URGs. The interfaces between EOPs/SAMGs and URGs are shown in the following Figure:



7.2.1.3 Hardware provisions for severe accident management

A detailed overview on all hardware provisions already installed or foreseen can be found in Section 4.5.2.

The *Maanshan* and *Kuosheng NPPs* have relatively large containments and associated systems on which the containment functions depend: the containment isolation system, the containment spray system, the containment air recirculation and cooling system and combustible gas control system. Meanwhile nitrogen is injected to the atmosphere of the Mark I containments for *Chinshan NPP* during operations as precaution against hydrogen deflagration.

Chinshan NPP:

The existing equipment at the Chinshan NPP considered available to be used in case of a severe accident is divided into two categories: the already established one (fixed, used in normal and emergency conditions) and the other one used for supporting emergency situations (usually used for handling emergencies with fixed, movable and partially movable).

There is important equipment included in the design, used in normal and emergency conditions, available to inject water into RPV/Primary containment, venting the primary containment, reactivity control (Automatic Seismic Trip System, Alternate Rod Insertion (ARI), Control Rod and Standby Liquids Control System (SBLC), pressure control of the RPV (Safety Relief Valve/Automatic depressurization system SRV/ADS), hydrogen control in the primary containment (Hydrogen detection system, suppression pool ventilation system; drywell ventilation; primary containment Air/Nitrogen Purge System; Hydrogen recombiner; drywell spray; suppression pool spray) or Secondary containment control & radioactive materials release control (standby gas treatment system and HVAC system). Supporting systems include emergency power sources, emergency Diesel Generators, Air-cooled 5th Diesel Generator; Gas Turbine Generators, heat removal (heat sink), cooling water system, essential service water system and pool water cooling systems, etc. The above equipment is included in the Chinshan plant's quality assurance system for regular test, maintenance, and controlled by MMCS (Maintenance Management Computerization System).

Additional other equipment for supporting emergency situations (used in response to emergencies, with fixed, movable and part of them are movable), including software on the working stations for AMT, the parameters indicating instruments (including ERF and board instruments panel) needed in accident situations; inject raw water into reactor core (including raw water reservoir, corresponding conduits and caps); EOP interlocks needed to be crossed over or disconnected, verify the numbers of cross-over lines and positions; mobile air compressor (EDG start-up air for backup); TSC/OSC diesel generator; Firefighting (including water sources, CO_2 storage quantity, generators, fire hydrant water pump, water pumps, fire engines, etc.). This equipment has been verified through tests, inspections and/or walkdown to confirm their availability and functionalities according to their (active or passive) characteristics.

Chinshan has completed the verification of important equipment for mitigating consequences about the locations, grades of seismic-proof, utilized power sources and current maintenance measures, including equipment for reactor water injection, reactivity control, hydrogen control, containment venting, reactor venting and pressure control, emergency water supply system of the SFP, emergency service water system and firefighting equipment, etc.

Chinshan has already a significant number of mobile equipment (12 480V mobile diesel generators, 1 diesel generator vehicle 4.16kV, 2 mobile diesel air compressors, 3 small mobile air compressors, and 8 mobile large type fire-fighting pumps, etc.). If a beyond design basis accident would happen and the units would lose on-site and off-site AC power, or the water injection into reactor, the plant has already implemented URGs, including all kinds of responding measures (like reserve power, water sources, gas sources, water injection routes, containment pressure control, hydrogen control, etc.), maneuvering all possible manpower and materials, arranging all available water sources in the shortest periods. In that case injection and cooling functions of the design base will not be restored in a short time, the available reserve water sources will be injected into reactor immediately to assure fuel coverage by water and to avoid damage of the fuel and release of radioactivity.

Kuosheng NPP:

After Fukushima, the Kuosheng NPP quickly followed the recommendations in WANO SOER 2011-2 to perform the recommended verifications and countermeasures. Kuosheng NPP checked the availability and function of equipment and instrumentation designed for present procedures for severe accident mitigation, including the SAMG, the EOPs and SFP cooling. The functions of the reactor water makeup, the RPV vent and pressure control, the reactivity control, the hydrogen control, the containment vent, the emergency water makeup system of SFP, the emergency power supply, the emergency circulating water (ECW) system, the necessary instrumentation and indication for post-accident management (including ERF and the panel instrument meters) and others were confirmed. The availability of systems required in the Technical Specifications was verified through tests or inspections. Active components of other equipment, which were not scheduled in periodic inspections, were tested. Passive items of other equipment, which were not listed in a periodic inspection scheme were inspected and walked down.

After Fukushima a comprehensive inspection was completed by 30/04/2011. The availability and function of equipment and instrumentation designed for present procedures of severe accident mitigation were verified. The results indicated that the service life of the "fire water tanker" had expired, but the function was normal. Kuosheng NPP has purchased more fire water tankers after this checkup. The verified equipment has been integrated into Kuosheng's routine test and maintenance program per Quality Assurance Program to assure their availability and function.

The Kuosheng NPP has developed a plant-specific URG to establish alternative core injection paths by lining up all available alternative injection paths, power supplies and water sources within the shortest time possible. If the recovery of the original cooling functions in a short term cannot be expected, the plant will implement water injection into the RPV via the established alternative paths to ensure that the nuclear fuel is covered to prevent fuel damage.

Maanshan NPP:

Should a severe nuclear accident happen in the Maanshan NPP, EOPs and SAMG will be initiated. For incidents related to the SFPs, the "treatment and recovery of SFP from loss of cooling capability and loss of pool water" procedure is to be followed to assure that spent fuel remains submerged under water. The Maanshan NPP has scrutinized the corresponding equipment and procedures for mitigating severe accidents. The first type of equipment categorized as safety-level equipment/systems (fixed, used for normal or emergency operation). The other type is categorized as emergency-level equipment (fixed and mobile, generally used for emergency operation).

Safety-level equipment/systems include RCS/Containment water injection, steam generator make-up and steam discharge, containment cooling system, containment hydrogen analyzer, hydrogen recombiner system and containment low volume purging system. Supporting systems include EDGs (train A, train B and the 5th diesel generator) and gas turbine generators, residual heat removal, service water system, SFP cooling systems and SFP make-up water system. All these equipment/systems are periodically tested and maintained according to the procedures under the quality assurance program in Maanshan NPP.

Other equipment used for supporting emergency situations includes, among others, the hardware for the Accident Management Team, parameters showing facilities (including Emergency Response Facilities and panels), spare boric acids, systems/components for supplying raw water into reactor core at urgent condition (including raw water reservoirs, corresponding piping and caps).

However, if a compound disaster of earthquakes/tsunami/flood occurs and causes a long period of a loss of AC/DC power and the ultimate heat sink, the above systems/equipment could be unable to sustain their intended function of mitigating accidental consequences.

After Fukushima, the Maanshan NPP implemented several improvement measures. Some of them were already completed in 2011, such as the URG, implementation of tsunami resistance of service water pump room, addition of grills and covers above the service water intake pool to prevent garbage from getting into the pool during tsunamis, water-tight doors and water retaining walls for the service water pump rooms of the individual unit and loop, strengthening of the prevention capability against flooding, installation of flooding protection plates, increasing the water draining capability of buildings in cases of flooding, installation of 20 submerged pumps for draining, or additional 30 diesel driven draining pumps.

Also, Maanshan has already procedures to monitor important plant parameters during loss of DC power or to operate TDAFWP and open the PORVs without DC power supply.

The existing mobile equipment at the Maanshan NPP designed for accident mitigation are the mobile emergency diesel generators for the power supply of the TSC and the fire engines. For accidents like Fukushima, the Maanshan NPP established the URG, in which the strategies of using mobile power, gas and water for mitigation measures are developed. The execution steps of every strategy, location of required equipment installed or stored, involved manpower, and schedule arrangements are all detailed in the URG. All rescue operations are foreseen to be prepared under tight time limits.

In the Maanshan URG, there are several strategies foreseen using the existing mobile equipment to inject water to the steam generators from fire-fighting water (raw water), sump pumps drainage operation; connect the mobile 480V diesel generator; supply power sources to containment ventilation valves by mobile air compressors and nitrogen bottles; supply/spray water to SFP; supply water into CST from mobile water source, supply water into RWST from mobile water source; connect 4.16kV power vehicles and removal of garbage at the entrance of Essential Service Water System.

Flooding of the reactor cavity is identified as a means to avoid MCCI if the RPV fails. In order to protect the cavity floor against the corium before the reactor vessel fails, a modification was made allowing the flooding of the cavity by connecting it with the containment sump. Water can also be injected into the containment through other systems such as the containment spray system, the Refueling Water Storage Tank (RWST) with gravity drain and the fire protection pipes for the reactor coolant pumps. To avoid potential re-criticality, the use of borated water is preferred and is sourced from the RWST and two boric acid tanks for both units.

Lungmen NPP:

The major safety systems are designed as seismic category 1 and are all built at an altitude of more than 12 meters above sea level. In view of the Fukushima accident, the station had carried out a “Comprehensive Safety Assessment”. The NPPs existing mobile disaster rescue equipment to be used for accidental conditions as well as the further expanded planned mobile equipment foreseen after the Fukushima accident was proposed according to the review results of the “Comprehensive Safety Assessments” under AEC supervision. The above-mentioned relevant facilities and equipment had been planned to be stored in places where they are not susceptible to disaster damage if a beyond design basis accident would happen, so that plant personnel could rapidly allocate them for emergency rescue.

In case of a loss of on-site and off-site AC power supplies or reactor water makeup during beyond design-basis accidents, the Lungmen NPP has established URGs, including alternative flooding-paths, power supply and water sources. The station will also mobilize all possible manpower, materials and physical resources to complete available water source arrangement in the shortest time possible. If operators judge that the design basis reactor coolant injection and cooling functions cannot be recovered in short time, the available backup water sources will be injected into the reactor immediately to insure that the nuclear fuel is covered by water and to prevent nuclear fuel damage.

In case the station experiences beyond design-basis accidents, the unit may lose reactor building seawater (RBSW) or reactor building cooling water (RBCW) and all off-site (on-site) AC power sources. Due to the failure of the above-mentioned equipment, the reactor water makeup will be lost and the water level of the SFP could drop if the decay heat couldn't be removed.

Each emergency diesel engine has sufficient fuel to run continuously at full load for a period of 5 h (provided by each EDG's daily tank; with additional dedicated underground (DBE) tanks). The three EDGs have enough fuel for 7 days of continuous operation if refilled using the on-site storage tank. For the mobile diesel generators, the plant maintains an on-site fuel supply for SAM operations at least for a period of 3 days. A set of mobile equipment essential for managing a severe accident (SAME) according to EOPs and SAMGs strategies is stored on-site. The SAME is located to avoid impairments due to severe conditions (earthquake, floods, fire etc.).

The combustible gas control systems to reduce the hydrogen concentration in the containment consist of two redundant electric re-combiners and inerted containment atmosphere in severe accident conditions.

Flooding of the reactor cavity is identified as a means to cool the corium and to avoid further MCCI if the RPV fails. In order to protect the cavity floor against the corium if the reactor vessel fails, the design includes valves that open at higher temperatures connecting the suppression pool with the drywell. Water can also be injected into the containment through other systems such as the containment spray system.

7.2.1.4 Accident management for events in the spent fuel pools

Prevention of radioactive releases from the SFPs is ensured in all NPPs by maintaining a sufficient coolant inventory in the pool and provisions for a reliable residual heat removal

In case of a loss of the spent fuel cooling function it is considered that a 10 ft. water level coverage above the Top of the Active Fuel (TAF) provides adequate shielding against radiation. A new SFP cooling system with a 480V mobile generator could be used in some NPPs (like at Chinshan) to recover the SFP cooling function or make-up water can be added from different sources. In case of an inaccessibility of the SFP floor with the power supply available, the SFP cooling or water makeup in accordance with the Ultimate Response Guideline should be carried out. Otherwise, the SFP cooling or water makeup by adding injection or spray piping located in fuel building could be performed. Adding water can be from a relatively large number of systems even fire hydrants to maintain the safe state of the SFP.

The high diversity of cooling methods guarantee with sufficient confidence, that level in the SFP would not drop below the top of the fuel elements leading to fuel cladding degradation and fuel defragmentation causing severe radiological releases. On-line monitoring of the hydrogen concentration at the SFP is therefore not envisaged.

After the serious damage of SFP in this circumstance, all means must be taken to reduce the fuel temperature and restrain the release of the radioactivity. At the same time, the hydrogen concentration in the SFP building must be monitored, and the hydrogen control strategy must be adopted to avoid a critical accumulation of hydrogen.

AEC has required TPC to implement the actions of the USNRC's Post-9/11 action (B.5.b) to stage response equipment on or near site to respond to extreme external events (see USNRC 10 CFR 50.54(hh)(2)).

7.2.1.5 Evaluation of factors that may impede accident management and capability to severe accident management in case of multiple units

In the case of severe external events it is expected that the normal access path to the NPP could be restricted. If the surrounding plant area (including the outside road) is widely damaged, the plant must rely on the staff, manpower, equipment and other resources in the vicinity. If the accident occurs during office hours and the operators on duty are not able to access the plant, the standby support shift staff, the maintenance personnel of each department could help or assist the unit operation. If the event occurs during off-duty hours, as most of the plant workers live in the plant vicinity, it is estimated that a sufficient number of personnel will be able to reach the site. If roads outside the plant are obstructed support of the central government' authority to recover the damaged roads will be requested. Helicopters could be used to carry personnel, materials and equipment for repair as well as for emergency transport of personnel for medical care. The emergency response plans clearly specify the responsibilities and maneuvering ways for those organizations of the ECT, including the staff on duty, and emergency operation backup team.

7.2.2 Margins, cliff edge effects and areas for improvements

The evaluation of margins within the area of SAM is not systematically and explicitly treated in the report. On the other hand, cliff edge effects and times are considered and analyzed for each NPP in case of SBO. Sufficient reactor water levels can be maintained by RCIC system (for Chinshan, Kuosheng and Lungmen NPP) or by the TDAFWP (for Maanshan) to feed the steam generators. Those systems are designed with 8 h DC power (24 h DC power supply in case of unnecessary loads isolated). During this period of time, the stations normal power supplies and alternative power supplies including the swing Diesel Generators, Gas Turbine Generators, and mobile power can be set up. The risks of cliff edge effects and timing have been assessed with MAAPs. As a conservative assumption, it is supposed that RCIC fails (or TDAFW respectively) after 8 h & 24 h resulting in a loss of core water makeup and cooling.

The RPV failure (or steam generator's dry-out followed by core uncovery for Maanshan) is determined using the MAAP code.

7.2.2.1 Strong points, good practices

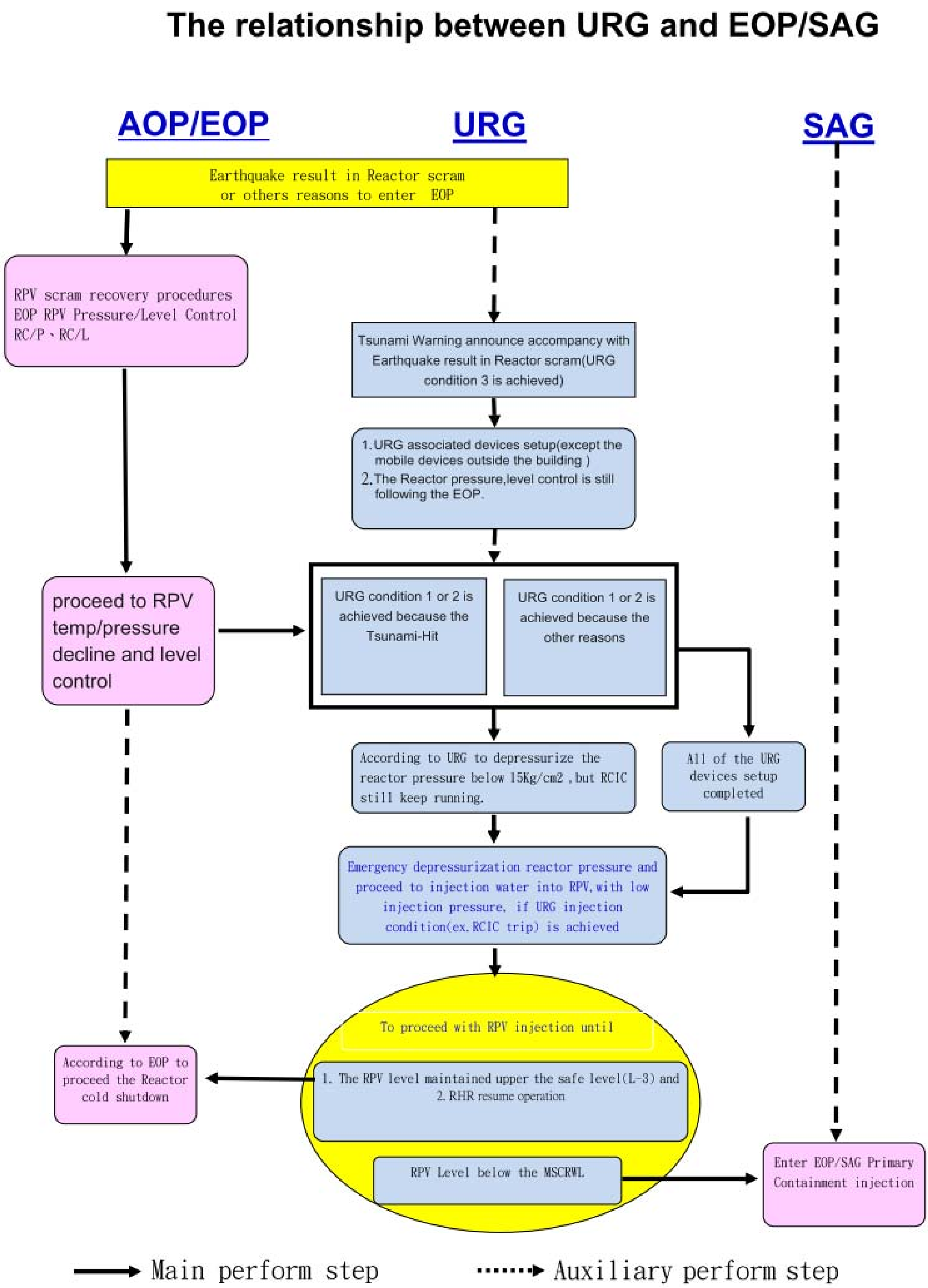
The NPPs in Taiwan implemented prevention and mitigation strategies for severe accidents including the extensive use of alternative mobile equipment (diesel generators, mobile generators, fire trucks or mobile pumps for cooling water supplies, providing alternative water sources including sea water, air supplies for safety relief valves (SRVs)) among other safety improvement measures.

The existence of a large variety and number of mobile equipment for responding to a severe accident can be considered as a strong point.

The storage of mobile equipment should be done in separated places to avoid common mode damage and close to their places of possible deployment to minimize transport and deployment time required. These storage locations should be hardened against external and internal events to ensure the functioning of the equipment when needed. In this respect AEC requires TPC to follow the NEI 12-06 per NTTF recommendation 4.2.

The use of mobile equipment under accident conditions can require significant manpower resources that might not be always readily available under disaster conditions. However, TPC URGs first stage strategies are implemented by plant on-duty personnel to line up equipment for reactor/SG depressurization and alternate makeup to secure fuel integrity within one hour.
Training is conducted yearly for SAM strategies. Large scale exercises are carried out on a three yearly basis rotating between the NPPs which included practical drills under simulated extreme conditions. Although the URGs are event-based guidelines, some strategies have been developed on how they are to be used in conjunction with EOPs and SAMGs which are described in the below Figure. The relationship between these procedures and guidelines is, as follows:

- Before the NPP reaches the entry condition of the URGs, EOPs are usually followed to manage the event. However, once the plant reaches the entry condition of the URGs, the URG is followed to manage the event instead of the EOPs.
- The URGs have several kinds of procedures to prepare ultimate responses such as depressurization of the RPV, reactor core injection, early primary containment venting and SFP makeup or spray among others.
- In the case that URG procedures fail to secure the core cooling function or other functions, the EOPs/SAMGs will be re-introduced to manage the event.


The relationship between URG and EOP/SAG
AOP/EOP
URG
SAG
Earthquake result in Reactor scram or others reasons to enter EOP
RPV scram recovery procedures EOP RPV Pressure/Level Control RC/P、RC/L
Tsunami Warning announce accompany with Earthquake result in Reactor scram(URG condition 3 is achieved)
1. URG associated devices setup(except the mobile devices outside the building)
2. The Reactor pressure,level control is still following the EOP.
proceed to RPV temp/pressure decline and level control
URG condition 1 or 2 is achieved because the Tsunami-Hit
URG condition 1 or 2 is achieved because the other reasons
According to URG to depressurize the reactor pressure below 15Kg/cm2 , but RCIC still keep running.
All of the URG devices setup completed
Emergency depressurization reactor pressure and proceed to injection water into RPV, with low injection pressure, if URG injection condition(ex. RCIC trip) is achieved
To proceed with RPV injection until
According to EOP to proceed the Reactor cold shutdown
1. The RPV level maintained upper the safe level(L-3) and 2. RHR resume operation
RPV Level below the MSCRWL
Enter EOP/SAG Primary Containment injection
Main perform step
Auxiliary perform step

As necessary, SAMGs will be introduced to manage a severe accident should they be required. The most positive aspect noted in the SAM area is the ongoing development of URGs to deal with emergency situations such as a loss of all of reactor water supply systems, SBO and BDBEs and tsunamis. This activity is clearly based on lessons learned from Fukushima.

The Fukushima accident highlighted also the significant potential for accidents to occur in the SFPs at the same time as an accident in the reactor. As such, it is important that SAM strategies are developed and implemented for the loss of cooling of the SFPs. The SAM strategies that TPC has in place for SFP loss of cooling implies the use of mobile equipment to supply water to the SFP. It is assumed that there is enough time for TPC to manage such an event because the water temperature of the SFP will increase slowly. It is considered that there should be enough time (more than 10 h before boiling and several days to reach the TAF. Using this information, TPC has developed and implemented URGs to deal with severe accident situations for the SFPs using the strategy to supply water from any of the large variety of systems available.

During the visit to the MSNPP, TPC explained and walked the PRT through the alternative coolant injection measures for the SFP using fire hoses, newly installed piping and the use of the SFP spray line. Moreover, at the KSNPP it is also possible to inject water into the SFP using fire trucks through the entrance gate of the SFP building.

It was noted that there are several alternative SFP cooling backups sufficient to manage a severe situation in the SFP. In addition, the use of the spray header system provides for mitigating the release of radioactive materials in addition to the spent fuel cooling if the water level of the SFP has fallen below the TAF. This can be considered a strength in TPC's SAM strategies for the loss of SFP cooling.

During the PR process, the following strong points were identified:

- The use of turbine- and diesel-driven AFW pumps to supply water to SGs (PWR) or turbine-driven RCIC for BWR.
- Potential failure of the containment would be prevented by over pressure by venting and containment spray activation (Chinshan, Kuosheng and Maanshan).
- URGs are in place for the reactors as well as for SFP and are independent of the reactor operating state.
- Availability of several alternative SFP cooling backups and installed spray headers for mitigating radioactivity release.

7.2.2.2 Weak points, deficiencies (areas for improvements)

During the PR, the following possible areas for improvement have been identified:

- Hydrogen control has not been designed for severe accident conditions, but AEC required the installation of PARs.
- The minimal battery capacity is only 8 h, but AEC requires in order XX-JLD-10108 to extend the battery capacity from 8 h to 24 h).
- For Chinshan NPP (Mark I containment), a hardened venting system without filtration has been installed. AEC order XX-JLD-10114 requires the installation of filtration venting for all different containment designs.

- Apart from local operating consoles and remote shutdown panels, no alternative ECRs exist that would represent an additional hardened alternative to the Main Control Room.
- There are no seismically qualified Nuclear Accident Emergency Support Centers available outside the evacuation zones. However, AEC is requiring the construction of a new, seismically isolated Technical Support Center on every site in order XX-JLD1013003.
- Hydrogen detectors: Hydrogen detectors were originally installed at the CSNPP in the drywell and added in the reactor building. KSNPP had originally hydrogen detectors in the Drywell and reactor building, has added some in the Auxiliary Building (DCR-4177/4178), and plans to add additional ones in the Fuel Building (DCR-4281/4282). MSNPP has 2 hydrogen detectors inside the containment for each unit. The other possible hydrogen accumulation area is the fuel building. A venting path will be established before start of boiling of the SFP water as part of the URG. AEC has requested TPC to consider the installation of detectors in order 10122 which is related to the installation of PARs.

7.2.3 Possible measures to increase robustness

The NPPs in Taiwan have upgraded EOPs and SAMGs in place which provide adequate instructions for the staff under such conditions. TPC developed also URGs. Extensive usage of mobile equipment in case of a severe accident has been implemented in all NPPs. It was mentioned before that AEC established clear requirements to implement enhancements. These requirements have been embodied in regulatory orders issued by AEC to TPC on 5/11/2012. TPC may propose alternatives subject to AEC approval.

7.2.3.1 Upgrading of the plants since the original design

In the 1960s, GE developed the Mark-I containment design with the advantages of easy construction, small volume and low costs. BWR3 and BWR4 NPPs were built with Mark-I containments. At the same time, the mitigation capability of the Mark-I containment was challenged because of its small volume feature. Thus, GE proposed several modifications on improving the containment venting system to prevent containment failure in case of core overheating. With the recommendations in NUREG-0061 set forth in 1982, TPC implemented improvements in Chinshan NPP (Mark-I containment), including the strengthening of the downcomers, the addition of containment hardened vent pipes, the inertisation with nitrogen during normal operations, etc., which were completed at the end of 1990.

7.2.3.2 On-going upgrading programmes in the area of accident management

The NR includes several activities required by AEC to improve or upgrade the procedures and guides, such as:

- Integration of the additional equipment and operations into the procedures or guidelines;

- Re-evaluation of the feasibility of EOPs and SAMGs taking into account the new procedures/guidelines;
- Ensuring that the SAMGs are appropriate for multi-unit events and promoting them from guidelines to procedures if required;
- Strengthening SBO mitigation at operating reactors for DB and BDB external events;
- Improving emergency preparedness staffing and communications according to the USNRC NTTF report;
- Identification of the URG and their implementation timing, the subsequent measures and monitoring strategy after implementing URG, including the monitoring of radioactive releases, backup ability of present systems and equipment;
- Estimation of the duration of independent response capability for various severe accident scenarios, BDBAs and multi-event accidents. The required materials and equipment in contracting the off-site supports should also be identified.
- The improvement of MCR in case of a BDBA in order to:
    - ensure the capability of DC power for instrumentation and control systems of MCR, TSC, backup TSC, etc. in case of monitoring unit conditions during SBO accidents, identifying duties, associations, and implementation of these staff should also be identified;
    - improve the seismic level of MCR, TSC, backup TSC, and their equipment;
    - assess the adequacy of MCR human arrangement in case of multi-unit events.
- Design and reliability of containment hardened vent with filters (only for Chinshan Mark I and Lungmen ABWR NPPs): Following recommendation 5.1 of the USNRC NTTF report AEC recommended to add a robust and reliable hardened vent and filtered containment system in Chinshan NPP (Mark-I) and Lungmen (ABWR). The drywell or wetwell hardened vent system should not be shared with the other units, and be able to be operated either with electrical power or manual operation.
- Improvements and integration of EOPs, SAMGs and EDMGs, and URGs; identify the commands and control strategies of implementation; and to finish the current procedures to cover conditions of low power, shutdown and refueling. Each NPP should prepare the response action before revising the current SAMG. Appropriate training and qualification should also be applicable to the decision-maker personnel.
- Enhancement of the SFP instrumentation per USNRC NTTF report.

7.2.4 New initiatives from operators and others, and requirements or follow up actions (including further studies) from Regulatory Authorities: modifications, further studies, decisions regarding operation of plants

In addition to the improvements mentioned above, AEC issued the order listed in Section 4.5.2 requiring the following measures:

- Installation of PARs to prevent hydrogen explosions.
- Requiring TPC to address staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions.
- Requiring TPC to enhance the structure of the existing non-seismically qualified TSC used for emergency response to address specific seismic concerns with the NPPs.

- Requesting TPC to consider building a seismically isolated TSC building based on the practice being implemented in Japan in light of Fukushima and consistent with guidance provided by the IAEA.
- Furthermore, TPC should finish the integrated PSA model based on ASME PSA.

7.2.4.1 Upgrading programmes initiated/accelerated after Fukushima

After Fukushima, TPC has performed its first and quick review trying to identify possible short-term improvements. Following the AEC requirements, TPC did a reassessment in the following areas related to SAM:

- Capability for Loss of AC power (SBO);
- Cooling of SFP;
- Capability of heat removal and UHS;
- Re-evaluation of EOPs;
- Implementing URGs;
- Support between different units;
- Mitigation beyond DBAs;
- Preparedness and backup equipment.

In each of these areas, TPC implemented measures to address both prevention and mitigation of severe accidents including measures such as alternative mobile diesel generators, procurement of portable generators, the use of fire trucks or portable pumps for cooling water supplies, providing alternative water sources including sea water, providing alternative air supplies for safety relief valves (SRVs), among other measures to enhance safety.

AEC requires in order XX-JLD-10203 TPC to systematically assess the combination of events in the areas of flooding and extreme natural events. On the basis of the outcome, TPC is requested to re-evaluate their systems and procedures for potential cliff edge effects and identify safety enhancements to address any new weakness found.

7.2.4.2 Further studies envisaged

Studies show that continuous supply of NPP subsystems with electrical power is of the utmost importance for nuclear safety. Accordingly, the NPPs in Taiwan have implemented or are implementing additional corresponding upgrades.

7.2.4.3 Decisions regarding future operation of plants

No information has been provided on this issue in the NR, but AEC is of the opinion that the NPPs offer a sufficient safety level to require no immediate shutdown of any of them. At the same time, however, AEC required that their continued operation requires an increase in their robustness to extreme situations beyond their existing safety margins as soon as possible. These include the upgrading programs mentioned, mainly the implementation of an extensive number of mobile equipment as well as the implementation of several other improvements, such as URGs. A set of requirements regarding the Fukushima experience feedback were issued by 11/2012.

AEC required also the completion of improvements regarding the emergency response organization mobilization aspects to ensure that it is able to manage a "multi-facility" event.

Following recommendations and foreign experience, AEC required also the implementation of several improvements like PARs, or to consider building a seismically isolated TSC building based on the practice being implemented in Japan in light of the Fukushima accident and consistent with guidance provided by the IAEA. TPC may also propose alternatives subject to AEC approval.

7.3 Peer review conclusions and recommendations specific to this area

After Fukushima, AEC has made an in depth review of the organisation, procedures, and provisions regarding AM.

According to the information provided in the NR, the present accident management organization appears to be well structured and adequate to cope with different levels of severity in case of accidents, including severe core damage. However, it should be checked if the hydrogen control systems have sufficient capacity to cope with BDBA scenarios (in addition to DBAs), including other rooms outside containment.

It is recommended to consider a systematic assessment of combinations of events, including multi-unit and multi-site accidents, since some of the NPPs are located in relatively close vicinity. As far as necessary, the potential for cliff-edge effects should be re-evaluated.

The accident management provisions rely to a large extent on the use of an extensive amount of mobile equipment. Therefore, adequately trained personnel has always to be available in sufficient numbers on the sites. Alternatively, the fixed installation of some of the mobile equipment should be considered.

It should be considered to improve the habitability in the local shutdown panel areas under accident conditions.

With order XX-JLD-1013003 AEC requested TPC to consider establishing a seismically isolated TSC building based on the practice being implemented in Japan in the light of Fukushima and consistent with lessons learned provided by the IAEA. The PRT considers this a good practice which is recommended for urgent implementation. However, the seismic design target of these TSCs should be at least the updated DBE (see Section 5.1.3).

The storing of mobile equipment and spare parts in separated places on different elevations (to avoid common mode damage) and close to their places of possible deployment (to minimize transport and time required) is considered as a good practice. However, storage of mobile equipment (e.g. protection against falling) should be able to resist the considered earthquakes.

It is proposed to consider the SAM review within the scope of the PSR as it is currently not required by the regulatory process in Taiwan.

In the case of an extensive external event, some aggravating circumstances could be expected regarding the plant emergency staff arrival to the site. Since some of the plant personnel is living close to the NPPs, this should not be a major issue. However, roads/bridges represent possible weak points regarding access to the facility in case of a strong earthquake and corresponding infrastructure improvements could thus be considered. In this respect, the availability of heavy road-clearing equipment should be considered.

The aftermath of Fukushima has shown that the treatment of large volumes of contaminated water can be challenging under post-accident conditions. The PRT suggests developing strategies to minimize the quantities of contaminated water produced under accident conditions and to evaluate possible options to create closed cooling circuits.

8 IMPLEMENTATION OF NATIONAL ACTIONS TO BE TAKEN IN THE AFTERMATH OF FUKUSHIMA TO ENHANCE SAFETY OF NPPs

On request of the PRT, AEC prepared the following 3 additional documents to demonstrate the present implementation status of post-Fukushima improvements:

- *"Implementation status of Post-Fukushima improvements in Taiwan's nuclear power plants"*, issued by AEC on 30/08/2013. This checklist was compiled out of the items of the ENSREG document *"Compilation of Recommendations and suggestions – Peer review of stress tests performed on European nuclear power plants"* and the CNS Final Summary Report of the 2nd Extraordinary Meeting 2012 para. 21 "significant activities and action". This checklist comprises all important areas of safety improvements of NPPs which were recognized during the European STs and as a result of the 2nd Extraordinary CNS Meeting 2012, giving indication of whether each topic is addressed in a regulatory order (i.e. still open at the time of the order's issuing), or covered by another activity (e.g. current regulatory oversight) or possibly already closed. The document contains also an overview of the regulatory orders issued by AEC to the licensees. The orders cover the exact topics still to be addressed by the licensees and were issued in two batches, the first one on 5/11/2012 and the second one on 6/6/2013.
- *"Implementation status of envisaged measures of the National Report"*, issued by AEC on 03/09/2013. This list gives the present implementation status of the envisaged measures mentioned in the NR.
- *"Implementation status of Post-Fukushima orders in Taiwan's nuclear power plants"*, issued by AEC on 01/10/2013. This list shows the present implementation status of the regulatory orders issued by AEC and FCMA (see chapter 4.5.3).

These 3 documents give a comprehensive overview in respect to the implementation status and the scheduled completion dates of all listed items.

8.1 Assessment of the actions

8.1.1 Adequacy of the information supplied

Contents and structure of the NR complies well with the guidance provided in the EU-STs specifications. In addition, AEC submitted the ST-reports for the six Taiwanese reactors in operation and the two reactors under construction. Taiwan informed comprehensively and in an understandable manner how its NPPs were improved in the aftermath of Fukushima according to domestic assessments, the recommendations and findings of the European STs, the recommendations of the USNRC and the conclusions of the CNS process.

8.1.2 Bases of the actions recommendations (EU-STs, USNRC, National assessments)

Topic 1:

After Fukushima, AEC established requirements to re-evaluate external hazards and to enhance the resilience of the Taiwanese NPPs. These new requirements are based on the Nuclear Reactor Facilities Regulation Act promulgated by Presidential Decree on 15/01/2003 and a number of Enforcement Rules for the Implementation of Nuclear Reactor Facilities Regulation Act, particularly the rules issued on 27/08/2003. Accordingly, the design, construction and operation of nuclear reactor facilities shall be complied with the quality assurance criteria of nuclear reactor facilities prescribed by the competent authorities. The competent authorities are entitled to enforce these criteria.

AEC's requirements are mainly based on USNRC standards. AEC has also required TPC to perform an updated and thorough seismic evaluation and to take every measure needed to fulfil the EU-STs requirements. For flooding and tsunami AEC requests TPC to follow the Tier 1 recommendations of the USNRC NTTF report (recommendations 2.1 and 2.2). For extreme weather conditions AEC requests TPC to follow the Tier 1 recommendations of the USNRC NTTF report (Section 2.3).

Topic 2:

AEC has worked along the lines of the USNRC NTTF report adopting Tier 1 recommendations 4.1 and 4.2 for SBO. In particular, AEC requirements to TPC regarding SBO coping time go beyond those of recommendations 4.1 in order to take into account the specific situation of the NPPs in Taiwan. Additionally, AEC has requested TPC to complete the implementation of the US Post 9/11 B.5.b actions and of the lessons learned from previous SBO events. Protection of electric equipment against flooding is also to be increased according to AEC regulatory orders. Regarding loss of UHS, AEC has adopted the ENSREG recommendation and asked TPC to investigate an alternative UHS, e.g., water from groundwater wells. In parallel, AEC requested TPC to improve the seismic resistance of the raw water reservoirs, which could also be used as an additional water source.

Topic 3:

Actions and recommendations are mainly based on the results of the STs and insights from the actions taken by other regulators, particularly in the form of the USNRC NTTF recommendations. AEC established clear requirements to implement enhancements issuing regulatory orders to TPC on 5/11/2012. TPC may propose alternatives subject to AEC approval. Consistent with the recommendations from the ENSREG action plan, AEC required TPC to install an alternative UHS, to install a seismically qualified extra gas-cooled EDG at each NPP, to enhance the seismic resistance for the fire brigade buildings BDBE, to install PARs to prevent hydrogen explosions, and to address the issue with the PWR reactor coolant pumps (RCP) seal loss-of-coolant-accident leakage issue (for Maanshan NPP). Several actions are also based on recommendations from the Japanese regulatory body for NPPs in Japan (i.e. to improve the reliability of off-site power supplies, to improve the seismic resistance of raw water reservoirs at the NPPs, and to enhance the water-tightness of the fire doors of essential electrical equipment rooms).

8.1.3 How have the actions been enforced

AEC established clear requirements in the regulatory orders issued by AEC to TPC on 5/11/2012. The requirements are detailed in 24 orders issued by the AEC's Department of Nuclear Regulation whereas 5 additional orders were issued by the Department of Nuclear Technology. The Fuel Cycle and Materials Administration also issued 3 orders covering radiation monitoring in the surrounding of the NPPs. The orders are addressed in the NR and listed as a whole set in the document *"Implementation status of Post-Fukushima improvements in Taiwan's nuclear power plants"*.

8.1.4 How have the recommendations of the ENSREG Action Plan been addressed?

According to the 4 general recommendations in the ENSREG Action Plan:

Natural hazards: assessment, prevention and mitigation of consequences:

See Section 5 of this report.

Periodic Safety Review:

See Section 4.5.2 of this report.

Containment integrity:

Fukushima highlighted once again the critical importance of the containment function as the last barrier to protect the people and the environment against radioactive releases resulting from a nuclear accident. For water cooled reactors, the measures to protect containment integrity include equipment, procedures and accident management guidelines.

AEC did start immediately after the Fukushima accident with a detailed review of design and operational provisions to improve the capability of the Taiwanese NPPs to maintain the integrity of the containment under accident conditions.

A first measure is the detection of the hydrogen in the containment. Whereas most of the NPPs had already installed some hydrogen detectors, additional ones were ordered to be installed to avoid a possible undetected build-up in the containment and adjacent rooms. The installation of PARs was requested to be able to limit the hydrogen build-up below critical concentrations. Whereas only one NPP had a hardened venting system installed, now all plants are ordered to install a filtered venting system, thus allowing the operators to limit the pressure build-up of the containments below critical levels and to limit radioactive releases in case of containment venting being necessary.

The above provisions are important elements in the accident management strategy of the NPPs and their expeditious implementation is considered crucial by the RT.

Transparency:

See Section 3 of this report.

According to the 3 topics of the STs:

Topic 1:

The 9 ENSREG recommendations for natural hazards have been addressed, as follows:

- **The implementation of a strong PSR process that includes the re-evaluation of natural hazards and relevant plant provisions at least every 10 years:** AEC requested that TPC should review the appropriateness of the DBF and the hazard levels of extreme meteorological events every 10 years considering effects of climate change. A re-comprehensive assessment of seismic and tsunami hazards has been ordered by AEC and is currently ongoing.

- **Driving all plant reviews/back-fitting with respect to external hazards safety cases to the 10^{-4} per year:** AEC's requirement to TPC to re-assess natural hazards makes reference to USNRC standards and ENSREG recommendations. In the current report the PRT strongly supports AEC's activities to define design basis events for all natural hazards according to this ENSREG recommendation.

- **The consideration of secondary earthquake effects:** The new hazard assessments have to account for the whole range of secondary earthquake effects (see Section 5.1.3).

- **The use of a protected volume approach to demonstrate flood protection for identified rooms or spaces:** In AEC order JLD-10118, TPC is required to enhance water tightness of the fire doors of essential electrical rooms. In addition, the PRT recommends all openings in safety relevant buildings to be upgraded (see recommendation in Section 5.2.3).

- **Early warning notifications:** A warning system is available for extreme weather and emergency procedures are implemented to respond to regular external weather alerts. Similar procedures are available for flooding and tsunami alerts. However, warnings and procedures are not consistent between the NPPs. In the current report the PRT suggests the establishment of early warning systems for mud slides and mass movements.

- **Seismic monitoring:** According to AEC, three seismic instrumentation systems are installed at each plant: (1) seismic monitoring system (SMS), deployed according to US NRC RG 1.12 to record PGA and spectral acceleration; SMS triggers earthquake alarm and determines whether OBE/SSE is exceeded and hence to orderly shutdown the reactor. (2) Automatic Seismic Trip System (ASTS), deployed following Japanese practice to initiate auto scram command immediately when OBE is exceeded by real time peak accelerations comparison. (3) System Identification System composed by accelerometers deployed at different floors and locations for the purpose of structure health diagnosis.

- **Qualified walkdowns:** the requirement of seismic, flooding and other external events walkdowns has been issued by AEC (5/11/2012, order 10105).

- **Flooding margin assessment:** the NR provides information on safety margins and cliff edges for all NPPs. Detailed PRT comments are included in Section 5.2.

- **External hazard margins:** Assessments of safety margins are included in the NR. Detailed PRT comments are included in Sections 5.1 to 5.4.

Topic 2:

Regarding Topic 2, the ENSREG action plan lists a total of 19 recommendations which have been addressed by Taiwan, as follows:

- **Enhance safety systems to withstand an unexpected natural event:** AEC requested the implementation of Tier 1 recommendation 4.2 from the USNRC NTTF report, adapting the request so as to tackle Taiwan specific issues (combination of earthquake and tsunami). Other backfits are being considered for improving the ability of the NPPs to cope with flooding events beyond the current DB (e.g. water-tightness of doors and buildings, additional air-cooled EDG).

- **Alternate Cooling and Heat Sink:** AEC requested the corresponding ENSREG recommendation to be implemented by TPC.

- **AC Power Supplies** and **DC Power Supplies:** AEC requirements are in line with the Tier 1 recommendations from the USNRC NTTF report and the previously initiated B.5.b actions. In addition, AEC has adapted those recommendations to the characteristics of the Taiwanese NPP sites (combination of earthquake and tsunami). Lessons learned from previous domestic and international SBO events have been integrated in the AEC demands to TPC. Also an improvement of the off-site power supplies has been addressed by AEC in a specific regulatory order (JLD-10120).

- **Operational and Preparatory Actions:** AEC reports completion of this action on all four sites where supply of consumables has been checked and has confirmed to comply with requirements. Annual exercise and drills are performed to train personnel in the use of mobile equipment.

- **Instrumentation and Monitoring:** AEC has requested TPC to extend SBO coping times in line with Tier 1 recommendations 4.1 and 4.2 from the USNRC NTTF report. As regards SFPs, a specific order (JLD-10115) requests the installation of reliable SFP instrumentation.

- **Shutdown Improvements:** In the NR, AEC has requested additional investigations for mid-loop operation. Specific improvements related to the availability of the EDG during shutdown have been requested based on the lesson learned from previous SBO events.

- **Reactor Coolant Pump Seals:** In the regulatory order JLD-101301 AEC has requested the MSNPP to perform additional investigations on the issue of RCP seal LOCAs.

- **Ventilation:** The issue is covered by Tier 1 recommendations 4.1 and 4.2 from the USNRC NTTF report and required by AEC order JLD-10109.

- **Main and Emergency Control Rooms:** The MCR habitability is addressed in chapter 6.1.3.2 of the NR. (see Section 7.2.1.1). As regards the emergency control room, it should be noted that the Taiwanese NPPs do not have such ECR but rely on remote shutdown panels (see also Section 7.3).

- **SFP** and **Ensure cooling of SFPs:** Beyond the installation of safety-related SFP instrumentation, AEC has requested the B.5.b actions to be completely implemented, including among others additional equipment (including sprays) that allows water injection in the pools from the outside without entering the SFP building. AEC reports completion of the B.5.b actions for the operating NPPs.

- **Separation and Independence:** AEC has requested the implementation of an additional UHS which should reduce dependence on the existing service water systems.

- **Flow Path and Access Availability:** See DC power supply and mobile devices.

- **Mobile Devices:** All Taiwanese NPPs have procured mobile equipment as further line of defence, if the installed AC and DC power capabilities should not be available. Smaller DGs are to be used to directly recharge the batteries or to supply power to pumps. Mobile air accumulators are available as well. AEC confirmed during the PR visit to Taiwan that the mobile equipment is included in the procedures and regular training and drills are performed.

- **Bunkered/Hardened Systems:** AEC has asked on one side to improve the seismic resistance of the fire brigade building for beyond design-basis earthquakes and on the other hand to enhance AC power supply by installing an additional seismically qualified, air-cooled EDG placed at higher elevation (or improve water tightness of the building with the 5th EDG). These are targeted improvements, whereas a global approach of an additional line of defence with all the required equipment for core cooling, completely separated from the existing equipment, was not chosen as an option.

- **Multiple Accidents:** Multi-unit accidents are addressed in Tier 1 recommendation 4.2 from the USNRC NTTF report. Beyond that, the AEC orders JLD-1013002 and JLD-1013004 require TPC to address staffing and communication issues in line with Tier 1 recommendation 9.3 from the USNRC NTTF report as well as to consider building a seismically isolated technical support centre.

- **Equipment Inspection and Training Programs:** Addressed with the implementation of Tier 1 recommendation 4.2 from the USNRC NTTF report.

- **Further Studies to Address Uncertainties:** Further analyses, if to be performed, are addressed under the specific issues listed above.

<u>Topic 3:</u>

The ENSREG recommendations for SAM have been addressed, as follows:

- **Periodic Safety Review:** Under the Nuclear Reactor Facilities Regulation Act, AEC requests that *“After nuclear reactor facilities have been formally operated, one integrated safety assessment at least shall be implemented every ten years and then be submitted to the competent authorities for review and approval”*. The 10-year PSR report includes chapters on “Overall Safety Performance” of Radiation, Radwaste Management, Major Plant Modifications, Aging Management of SSCs, Seismic Re-evaluation, Lessons Learned from Significant Events, and Feedback from Domestic and Foreign Experiences and Research Results, but no information was included in the NR about the PSR results regarding SAM.

- **Containment integrity:** Under severe accident conditions, there are some guidelines addressed in SAMGs, including containment venting, containment spraying and injection based on various parameters in the containment. AEC requires Chinshan and Lungmen NPPs to conform to the requirements from Recommendation 5.1 in the NTTF report of USNRC (consideration of the filtration function in Mark I and II containments).

- **WENRA Reference Levels:** Not applicable.

- **SAM Hardware Provisions:** Safety related instrumentation is seismic category 1 designed and adequate hardware provisions are in place to survive external hazards (e.g. by means of qualification against extreme external hazards, storage in a safe location) and the severe accident environment (e.g. engineering substantiation and/or qualification against high pressures, temperatures, radiation levels, etc.), to perform the selected strategies. The NR describes the USNRC rulemaking (NTTF Tier 1 R4.2: Mitigation strategies to implement and maintain guidance and strategies intended to maintain or restore core cooling, containment, and SFP cooling capabilities under the circumstances associated with BDB external hazards resulting in an extended loss of all AC power or a loss of the UHS capability).

- **Review of SAM Provisions Following Severe External Events:** The URG established from the various evaluations of Taiwanese NPPs has the concept of defense-in-depth in the corresponding strategies and plans. It also sets up various and multiple strategies (like various water resources, power, etc.) to ensure the effectiveness of rescue operations responding to compound disasters.

- **Enhancement of Severe Accident Management Guidelines (SAMG):** AEC required TPC to strengthen and integrate EOPs, SAMGs and EDMGs within the URGs developed by TPC following the Fukushima accident consistent with the USNRC NTTF Report Tier 1 recommendation 8 on strengthening and integration of EOPs, SAMGs and EDMGs. Further information on the evaluation of the guidance to manage emergency situations resulting from severe accidents was received during the visit to Taiwan.

- **SAMG Validation:** According to the NR, the EOPs and SAMGs are reviewed and updated if new technologies and research results become available. TPC will update their SAMGs according to future revisions of the BWROG and PWROG.

- **SAM Exercises:** Since many years, TPC carries out regular exercises of EOPs and SAMGs for operators in all operating NPPs.

- **SAM Training:** AEC required TPC to ensure that the SAMGs are appropriate for multi-unit events. The existing CSNPP simulator can be used for this purpose. However, for the other NPPs only desktop exercises are performed. These training sessions are carried out on a regular basis (2-3 times / year) and the duration is in the order of about half a day.

- **Extension of SAMGs to All Plant States**: The extension of existing SAMGs to all plant states (full and low-power, shutdown) is not clearly described in the NR. However, during the PRT visit to Taiwan, AEC explained that the US SAMG was developed originally only for full power. The owner's group is developing guidance for low power and shutdown. For low power conditions, the system requires the same as for full power operation; therefore, the same SAMG can be used as developed for full power operation. For shutdown conditions, TPC has prioritized the importance of equipment and procedures via the PSA model and established a risk management plan for different maintenance configurations. For high risk periods, TPC has developed procedures to cope with possible events during shut down periods. These strategies may help the SAMGs to be successfully implemented. Under the order XX-JLD-10116, TPC is requested to integrate the URG, EOP and SAMG. TPC will revise or modify the entry conditions to integrate all possible plant states, such as low power, shutdown, etc.

- **Improved Communications:** AEC required TPC to improve the emergency preparedness staffing and communications as per USNRC NTTF report.

- **Improving radiation monitoring and communications capabilities:** The Taiwanese Fuel Cycle and Materials Administration (FMCA) has required TPC to procure 40 mobile detection equipment with automatic data transmission capability for all 4 NPPs to enhance the capability of radiation fallout monitoring in a timely manner, to install 13 radiation monitoring stations within the EPZ of the NPPs, to set up a radiation monitoring preparedness platform and strengthen radiation monitoring capability and to procure four radiation detection vehicles to enhance mobile radiation monitoring capability. Regarding the communication infrastructure, AEC has required TPC to address staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions.

- **Presence of Hydrogen in Unexpected Places:** AEC requires TPC in order XX-JLD-10122 to install PARs to prevent hydrogen explosions consistent with recommendations in the ENSREG action plan. In addition, in the same order, TPC is also required to consider the accumulation of hydrogen in the adjacent buildings. Details can be found in Section 7.

- **Large Volumes of Contaminated Water:** According to the NR, AEC required TPC to improve the seismic resistance of the raw water reservoirs at the NPPs. Regarding the management of contaminated water, AEC explains in the NR that at all NPPs have additional storage capacity in other buildings by flooding lower level floors. However, TPC has mobile systems, including charcoal and resin beds to treat limited amounts of contaminated water thus reducing releases into the sea. Provisions to establish re-circulating cooling circuits could be a possible alternative option.

- **Radiation Protection:** The measures considered for the radiation protection of operators and for all other staff involved in the SAM are described in the NR.

- **On-site Emergency Centre:** AEC requires TPC to enhance the structure of the existing non-seismically qualified TSC used for emergency response to address specific seismic concerns.

- **Regional, off-site and on-site emergency response centres. Upgrading regional, off-site and on-site emergency response centres:** The emergency response organization does not include a regional response center. However, close to each site there are dedicated facilities available as near-site emergency response centers.

- **Support to Local Operators:** AEC requires TPC to address staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions in orders XX-JLD-1013002 and XX-JLD-1013004. However, all NPPs have already either dormitories or staff housing for essential emergency personnel in the vicinity of the plant.

- **Level 2 PSAs:** According to the NR, a complete full power operation mode and shutdown mode PSA is available for each NPP. During the PRT visit to Taiwan, AEC explained that TPC periodically uses PSA models to prioritize the improvement measures and to decide which hardware modifications or procedural changes are required to enhance plant safety. After Fukushima, with insights from PSA, the importance of alternate heat removal strategies became apparent. TPC established alternate mitigation strategies, such as the local operation of the TDAFWP or the lineup of the Diesel Driven AFWP. The plant MAAP models were used to determine how much time would be available to implement these alternate heat removal strategies. These strategies were then transferred into procedures and periodic training is scheduled. In addition, the PSA showed the importance of backup AC power and water sources and strategies to establish them were developed.

8.1.5 Schedule of the implementation of the actions

The above mentioned documents - *“Implementation status of Post-Fukushima improvements in Taiwan’s nuclear power plants”* - issued by AEC: 30/08/2013 - and *“Implementation status of envisaged measures of the National Report”* - issued by AEC: 03/09/2013 -, which are seen as amendment of the NR give clear information on the time schedule of the implementation of the actions which have been taken in the aftermath of Fukushima.

Regarding **Topic 1**, several actions are completed and most will be completed until 2016 or in some cases until 2017. A few issues are in consideration and thus not yet scheduled.

Regarding **Topic 2**, most the actions have a clear deadline for completion. Currently few issues have already been closed, other have completion dates ranging from 2013 up to 2017. If these latter issues keep up with the foreseen schedule, it would result in reaching a rather ambitious goal. The actions related to the rulemaking process are to follow the same schedule as applied by the USNRC (plus 6 months for transferring to the Taiwan’s case). During the Taiwan visit AEC has provided additional insights indicating that some actions, for which the review by the AEC of the solutions proposed by TPC is still ongoing, have the deadline of implementation still to be decided. This results in a scheduling still to be worked out.

Regarding **Topic 3**, many of the issues identified have already been addressed and improvement measures are in place. The remaining AEC orders regarding the area of topic 3 have completion dates up to May 2017.

8.1.6 Transparency of the regulatory decisions and of the process of the implementation of the tasks identified within it

The NR does not include information on that issue. However, the information needed was clarified in discussions with AEC during the visit to Taiwan, e.g. dates of orders issued, information put on the AEC website, public meetings held by AEC, etc.

8.1.7 Commendable aspects (good practices, experiences, interesting approaches) and challenges

The PRT acknowledges the clear requirements included in the regulatory orders issued by AEC to TPC on 5/11/2012.

Topic 1:

The PRT considers the performance of full-scope hazard assessments for all natural hazards (seismic, secondary seismic effects, flooding, extreme weather and volcanic hazards), and subsequent implementation of protection measures do represent a very challenging task.

Topic 2:

The choice of adopting the relevant requirements of the country of origin of the Taiwanese NPPs, i.e. those of the USNRC for US NPPs, is coherent with the philosophy of profiting from the operating experience of a big NPP fleet. Also the practice of adapting US requirements to the specific situation and sites in Taiwan should be mentioned positively. Further, AEC has followed the STs-process in Europe, adopting the requirement concerning the alternate UHS from the ENSREG compilation of recommendations. In the opinion of the PRT, the implementation of this last requirement may prove to be a challenge in view of site-specific constraints. Besides, embedding the newly acquired (or planned) copious equipment in the existing coping strategies is quite a delicate task, which requires an in-depth evaluation of possible side effects and trade-off decisions between benefits and drawbacks.

Topic 3:

The NPPs in Taiwan implemented prevention and mitigation strategies for severe accidents including extensive use of alternative mobile equipment (diesel generators, mobile generators, fire trucks or mobile pumps for cooling water supplies, providing alternative water sources including sea water, air supplies for safety relief valves (SRVs), etc.) among other measures to enhance safety. The existence of a large variety and number of mobile equipment for responding to a severe accident can be considered as a strong point.

Training is conducted for SAM strategies. Practical drills under simulated extreme conditions are carried out on a rotating basis for all operating plants on a yearly basis meaning every 3 years at each plant.

As necessary, SAMGs will be introduced to manage a severe accident should they be required. The most positive aspect noted in the SAM area is the ongoing development of URGs to deal with emergency situations such as a loss of all of reactor water supply systems, station blackout and beyond design base earthquakes and tsunamis. This activity is clearly based on lessons learned from the Fukushima accident.

Fukushima highlighted the significant potential for accidents to occur in the SFPs at the same time as an accident in the reactor. Thus, it is important that SAM strategies are developed and implemented for the loss of cooling of the SFPs. The SAM strategies that TPC has in place for SFP loss of cooling imply the use of mobile equipment to supply water to the SFP. It is assumed that there is sufficient time for TPC to manage such an event because the water temperature of the SFP will increase only slowly (more than 10 h before boiling and several days to reach the TAF). Using these figures, TPC has developed and implemented URGs to deal with severe accident situations for the SFPs using the strategy to supply water from any of the large variety of systems available.

8.2 Peer review conclusions and recommendations specific to this area

Topic 1:

Performing full-scope hazard assessments for all natural hazards and subsequent implementation of protection measures is a challenging and time consuming task. AEC should consider prioritizing the actions on seismic and tsunami hazards as the results of the PSAs listed in the NR show that the contribution of these hazards to the CDFs dominates over all other hazards.

Topic 2:

It is recommended that AEC considers to follow-up consistently on the measures implemented or planned at the Taiwanese NPPs keeping an overview of coping strategies at the NPPs. A prioritization of actions could be envisaged. Most importantly, for those actions which are not yet scheduled, an indication of the process and dates to reach a decision should necessarily be given (e.g., analyses to be performed by date X, regulatory decision to be taken by date Y, implementation time frame year Z).

Topic 3:

According to the information provided in the NR, the present accident management organization appears to be well structured and adequate to cope with different levels of severity in case of accidents, including severe core damage. However, it should be checked whether the containment hydrogen control systems have sufficient capacity to cope with BDBA-scenarios (in addition to DBAs).

Overall, AEC is well aware of the special geophysical situation of Taiwan and has ordered in the aftermath of Fukushima already different measures to further improve the safety of the Taiwanese NPPs. Extent and schedule of these measures were explained to the PRT in detail;

the PRT acknowledges the great efforts which are being taken. The tight schedule seems very ambitious. The PRT underlines that the improvement measures identified so far should be implemented by TPC within the foreseen schedule and followed-up by AEC with the adequate emphasis.

9. MAIN CONCLUSIONS OF THE PEER REVIEW TEAM

The PRT acknowledges the open and constructive atmosphere in which the discussions between PRT and AEC took place. Additional important input could be collected in the course of the two NPP site visits, the scientific seminar with Taiwanese distinguished academics and the parallel public consultation. All important documents were timely provided and uploaded on the EU-PR project website for public access.

According to the structure of the ST-specifications, the following main conclusions are proposed by the PRT within the 3 topical areas:

Topic 1 – Extreme natural hazards

Due to its specific plate tectonic and climatic setting, the exposure of Taiwan to natural hazards such as earthquakes, tsunamis, flooding and typhoons is much higher than that of those European countries that subjected their NPPs to the 2011/12 EU-STs. The reliable assessment of the severity of these hazards and the implementation of suitable measures to protect against them is of crucial importance for nuclear safety in Taiwan. Against this background, the PRT recommends to update the design basis events for all natural hazards and all NPPs for exceedance probabilities not higher than 10^{-4} per year.

Among the natural hazards, the PRT considers earthquakes and tsunamis of prime importance given the fact that Taiwan is situated on top of two active subduction zones, the Manila and Ryukyu trench.

For earthquakes, the close vicinity of the NPP sites to active faults, such as the Shanchiao- and Hengchun-faults, poses a severe challenge to the safety of the plants. An adequate assessment of seismic hazards shall therefore use the most advanced geological, paleoseismological and seismological techniques to update the design basis events in terms of vibratory ground motion, and identify other earthquake-related hazards such as fault capability and seismically triggered landslides. The PRT assumes that the new design basis events will lead to increased demands on the robustness of the plants. It is therefore recommended to define ground motion values in exceedance of the licensing base ground accelerations and to implement intermediate upgrades of SSCs with fundamental safety functions to these newly defined levels. After the completion of the seismic hazard re-assessment and the definition of the new design bases, the seismically classified SSCs have to be updated accordingly.

The assessment of tsunami design basis flood levels should be extended to use geological records of past events and the latest state-of-the-art techniques. Uncertainties should appropriately be considered in the models as well as secondary effects of tsunamis. The effects of dependencies between different hazards should be considered (e.g. earthquake/tsunami). The timely construction of tsunami walls for all NPP sites is considered a good practice to improve safety. In addition, all openings of safety-relevant buildings should be back fitted to withstand in case of a tsunami flooding the pressure of water and be watertight up to the height of the tsunami walls.

Topic 2 – Loss of safety systems

The power supply and ultimate heat sink systems in the Taiwanese NPPs were designed in accordance with USNRC safety requirements and, as confirmed during the visit to Taiwan, are in compliance with them.

The Taiwanese NPPs have several lines of defence against a loss of power supply (e.g. multiple electric grid transmission lines, EDGs, air-cooled swing EDGs, batteries, mobile generators for power supply to critical systems and for battery recharging, gas turbines). Accident management measures to bring and keep the reactor in a safe shutdown mode and cool the SFPs are available which resort to manual operation of systems without power supply using various alternative water sources. The sea is the ultimate heat sink for all NPPs in Taiwan. Feed and bleed using the atmosphere as heat sink is already implemented within severe accident management in the plants.

Extensive analyses and evaluations were performed on the topics of station black-out and loss of ultimate heat sink resulting in a series of orders issued by AEC to TPC. System improvements as approved by AEC are planned following the USNRC requirements, ENSREG recommendations, and practices in Japan and other countries. Implementation of these improvements has already started.

The PRT provided recommendations concerning the power supply and ultimate heat sink. In particular, the improvements of the flooding protection of essential equipment and seismic resistance of the raw water reservoirs which were initiated by AEC are important to enhance the safety of the NPPs.

Topic 3 – Severe accident management

After Fukushima, AEC has made an in-depth review of the organisation, procedures, and provisions regarding accident management which appear to be well structured and adequate to cope with different levels of severity in case of accidents, including severe core damage. However, a certain number of recommendations seem to be necessary to further improve the preparedness of NPPs` beyond design situations.

It is recommended to consider a systematic assessment of combinations of events, including multi-unit and multi-site accidents, since some of the NPPs are located in relatively close vicinity.

The accident management provisions rely to a large extent on external support and on the use of mobile equipment. Therefore, adequately trained personnel has to be available in sufficient numbers always on the sites, or, alternatively, the fixed installation of some of the mobile equipment should be considered. The storage of this equipment should be in separated places on higher elevations to avoid common mode damage and as close as possible to the foreseen places of deployment to save manpower.

The foreseen construction of seismically isolated Technical Support Centers (TSCs) is considered as a significant improvement based on lessons learned from Fukushima. However, the seismic design target of these TSCs should correspond at least to an earthquake level beyond the present design basis.

In the case of an extensive external event, some aggravating circumstances could be expected regarding the plant emergency staff`s arrival to the site. Since some of the plant personnel are living close to the NPPs, this should not be a major issue. However, roads/bridges represent probably the weak point regarding access to the facility in case of a strong earthquake and corresponding infrastructure improvements could thus be considered. In this respect, the availability of heavy road-clearing equipment should be taken into account.

The aftermath of Fukushima has shown that the treatment of large volumes of contaminated water can be challenging under post-accident conditions. The PRT recommends developing strategies to minimize the quantities of contaminated water produced under accident conditions and evaluating options to create closed cooling circuits.

List of acronyms

ABWR	Advanced Boiling Water Reactor
AC	Alternating Current
ADS	Automatic Depressurization System
AEC	(Taiwan) Atomic Energy Council
AFP	Auxiliary Feedwater Pump
AFWP	Auxiliary FeedWater Pump
AM	Accident Management
AMT	Accident Management Team
ARI	Alternate Rod Insertion
ASME	American Society of Mechanical Engineers
ASTS	Automatic Seismic Trip System
BDB	Beyond Design Basis
BDBA	Beyond Design Basis Accident
BDBE	Beyond Design Basis Earthquake
BWR	Boiling Water Reactor
CDF	Core Damage Frequency
CDRC	Central Disaster Response Center
CFR	Code of Federal Regulations (USNRC)
CNS	Convention on Nuclear Safety
COPS	Containment Overpressure Protection System
CS	Chinshan (NPP)
CSCW	Combined Structure Cooling Water system
CST	Condensate Storage Tank
CW	Circulating Water system
DB	Design Basis
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DC	Direct Current
DG	Diesel Generator
DST	Demineralized Water Storage Tank
EC	European Commission
ECR	Emergency Control Room
ECT	Emergency Control Team
ECW	Emergency Circulating Water system
EDG	Emergency Diesel Generator
EDMG	Extensive Damage Mitigation Guidelines
ENSREG	European Nuclear Safety Regulators Group
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedure
EPG	Emergency Procedure Guideline

EPIC	Emergency Public Information Center
EPZ	Emergency Protection Zone
ERF	Emergency Response Facility
ERO	Emergency Response Organization
ESW	Essential Service Water system
EU	European Union
FCP	Forward Command Post
FMCA	Fuel Cycle and Materials Administration (of Taiwan)
FPCU	Fuel Pool Cooling and cleanUp system
FSAR	Final Safety Analysis Report
g	standard value of the gravitational acceleration (9,81 m/s^2)
GE	General Electric company
GMPE	Ground Motion Prediction Equation
HPC	Health Physics Center
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
KS	Kuosheng (NPP)
LERF	Large Early Release Frequency
LM	Lungmen (NPP)
LOOP	Loss Of Off-site Power
LRA	license renewal application
MAAP	Modular Accident Analysis Program
MCC	Motor Control Centre
MCCI	Molten Core Concrete Interaction
MCR	Main Control Room
MMCS	Maintenance Management Computerization System
MS	Maanshan (NPP)
MSL	Mean Sea Level
NAcP	National Action Plan
NEA	Nuclear Energy Agency (of the OECD)
NEI	Nuclear Energy Institute (formerly NUMARC and USCEA)
NEPEC	Nuclear Emergency Planning Executive Committee
NGO	Non-Governmental Organisation
NPP	Nuclear Power Plant
NR	(Stress Test) National Report
NSC	(Taiwan) National Science Council
NSCW	Nuclear Service Cooling Water system
NTTF	Near Term Task Force (of the USNRC)
NUMARC	Nuclear Management and Resources Council (now NEI)
OBE	Operating Basis Earthquake
OECD	Organisation for Economic Cooperation and Development
OEF	Operating Experience Feedback
OSC	Operation Support Centre

PAR	Passive Autocatalytic Recombiner
PGA	Peak Ground Acceleration
PMP	Probable Maximum Precipitation
PORV	Power Operated Relief Valve
PR	Peer Review
PRT	Peer Review Team
PSA	Probabilistic Safety Assessment (also known as PRA)
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor
Q&A	Questions and Answers
RBCW	Reactor Building Cooling Water
RBSW	Reactor Building Service Water
RCIC	Reactor Core Isolation Cooling
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RLE	Review Level Earthquake
RPV	Reactor Pressure Vessel
RWST	Refuelling Water Storage Tank
SAG	Severe Accident Guideline
SAM	Severe Accident Management
SAME	Severe Accident Management Equipment
SAMG	Severe Accident Management Guideline
SBGT	StandBy Gas Treatment system
SBLC	control rod and StandBy Liquids Control system
SBO	Station Blackout
SFP	Spent Fuel Pool
SFPACS	Spent Fuel Pool Additional Cooling System
SFPCS	Spent Fuel Pool Cooling System
SG	Steam Generator
SMA	Seismic Margin Assessment
SOER	Significant Operating Experience Report
SPRA	Seismic Probabilistic Risk Assessment
SRV	Safety Relief Valves
SSC	Structures, Systems and Components
SSE	Safe Shutdown Earthquake
ST	Stress Test
SWCB	Soil and Water Conservation Bureau
TAF	Top of Active Fuel
TDAFWP	Turbine Driven Auxiliary FeedWater Pump
TPC	Taiwan Power Company
TSC	Technical Support Centre
UHS	Ultimate Heat Sink
URG	Ultimate Response Guidelines
US	United States
USCEA	U.S. Council for Energy Awareness (now NEI)
USNRC	United States Nuclear Regulatory Commission

WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association