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Written submission from the Canadian Environmental Law Association

Mémoire de l’Association canadienne du droit de l’environnement

In the Matter of the

À l’égard d’

Ontario Power Generation Inc.

Ontario Power Generation Inc.

Application for a licence to construct one BWRX-300 reactor at the Darlington New Nuclear Project Site (DNNP)

Demande visant à construire 1 réacteur BWRX-300 sur le site du projet de nouvelle centrale nucléaire de Darlington (PNCND)

Commission Public Hearing
Part-2

Audience publique de la Commission
Partie-2

January 2025

Janvier 2025

Canada

Canadian Environmental Law Association
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DURHAM NUCLEAR AWARENESS,
SLOVENIAN HOME ASSOCIATION &
THE CANADIAN ENVIRONMENTAL LAW ASSOCIATION

Comments on Ontario Power Generation's Application for a Licence to Construct a Small Modular Reactor for the Darlington New Nuclear Project

Prepared by
Sara Libman, Legal Counsel

Expert Review by:
M.V. Ramana, Professor and Simons Chair in Disarmament, Global and Human Security

November 12, 2024

November 12, 2024

Senior Tribunal Officer, Secretariat
Canadian Nuclear Safety Commission
280 Slater Street, P.O. Box 1046, Station B
Ottawa, Ontario K1P 5S9

Dear Sir or Madam:

Sent by email interventions@cnsc-ccsn.gc.ca

Re: Joint Submission of Durham Nuclear Awareness, Slovenian Home Association, and the Canadian Environmental Law Association, Regarding Ontario Power Generation's Application for a Licence to Construct a Reactor Facility at the Darlington New Nuclear Project Site (Ref. 2024-H-03)

The Canadian Environmental Law Association ("CELA") has enclosed its comments, on behalf of Durham Nuclear Awareness, and Slovenian Home Association, regarding Ontario Power Generation's application for a licence to construct one small modular reactor for the Darlington New Nuclear Project.

Please find below our submission for your review.

By this letter, and pursuant to the CNSC's *Rules of Procedure*, CELA request status to participate as an intervenor in the public hearing and an opportunity to make a 30-minute oral presentation at the January 2025 hearing.

Sincerely,

CANADIAN ENVIRONMENTAL LAW ASSOCIATION

Sara Libman

Sara Libman
Legal Counsel, CELA

I. INTRODUCTION

Durham Nuclear Awareness ("DNA") and Slovenian Home Association ("SHA") together with the Canadian Environmental Law Association ("CELA") and the expert review by Dr. M.V. Ramana,[1] (herein, "the intervenors"), submit this written report in response to the Canadian Nuclear Safety Commission's ("CNSC") Notice of Public Hearing and Participant Funding dated June 27, 2024 to review CNSC staff's and Ontario Power Generation's ("OPG") submissions to the Commission, as well as participate in the hearing process to consider Ontario Power Generation's ("OPG") application for a licence to construct 1 BWRX-300 reactor for its Darlington New Nuclear Project ("DNNP").[2]

In addition to reviewing the documents submitted by CNSC staff and OPG, and the oral submissions made during Part 1 of the Public Hearing process for this licence application, this report considers the CNSC's jurisdiction pursuant to the *Nuclear Safety and Control Act* ("*NSCA*"), which requires that in making a licensing decision, the CNSC ensure the adequate protection of the environment and human health. In meeting this objective, per section 24(4) of the *NSCA*, the intervenors' findings and concerns are itemized below. Our recommendations, including suggested licence and licence condition revisions are summarized in **Appendix A**. Our supporting reference materials are provided in **Appendix B**.

II. INTEREST AND EXPERTISE OF THE INTERVENORS

i. Durham Nuclear Awareness

Durham Nuclear Awareness ("DNA") is a citizens' group with a longstanding interest in the Darlington Nuclear Generating Station. DNA was first organized in 1986 in the wake of the Chernobyl disaster and born out of a need for people in Durham Region to come together, learn & empower themselves.

As a volunteer group of concerned citizens, DNA dedicates themselves to raising public awareness about nuclear issues facing Durham Region, and fostering greater public involvement in the nuclear decision-making process. DNA has appeared on numerous occasions before the CNSC and has a lengthy history arguing for critical public health and safety measures, including improved emergency planning and baseline health studies, and setting standards for tritium in drinking water.

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[1] M.V. Ramana is the Simons Chair in Disarmament, Global and Human Security and Professor at the School of Public Policy and Global Affairs, University of British Columbia, Vancouver, Canada.

[2] Canadian Nuclear Safety Commission, "Notice of Public Hearing and Participant Funding" June 27, 2024, online: https://api.cnsc-ccsn.gc.ca/dms/digital-medias/2024-H-03-Notice-of-public-hearing-for-OPG-application-to-construct-1-BWRX-300-reactor-unit.pdf/object

DNA continues to advocate for upgrades to nuclear emergency plans to ensure the protection of communities in the event of a nuclear accident.

ii. Slovenian Home Association

Slovenian Home Association ("SHA") is a non-profit cultural organization dedicated to the preservation of Slovenian culture language, heritage and identity in Canada. Many Slovenians reside in the vicinity of the Pickering and Darlington nuclear plants and are concerned about the proposed plans to expand nuclear power generation within the region, particularly with OPG proposing novel reactor technology at the Darlington site. Much of these concerns stem from emergency planning for nuclear accidents.

SHA members are not aware of what to do in case of a nuclear alert from the Province of Ontario. Some questions posed to SHA by its members include: *Should they be prepared to evacuate or stay at home? Where is their closest evacuation center? How to protect themselves by staying at home?* Despite emergency planning being a heavy concern for its members, SHA not been made aware of any public information meetings where the details of the actions taken by the citizens, in case of a nuclear alert, were discussed. SHA would welcome an opportunity to distribute emergency preparedness instructions to its members and to organize and host a preparedness workshop on the topic of emergency preparedness.

iii. Canadian Environmental Law Association

CELA is a non-profit, public interest law organization. CELA is funded by Legal Aid Ontario as a speciality legal clinic to provide equitable access to justice to those otherwise unable to afford representation for environmental injustices. For nearly 50 years, CELA has used legal tools to advance the public interest, through advocacy and law reform, in order to increase environmental protection and safeguard communities across Canada.

CELA has been involved in a number of nuclear facility licensing and regulatory matters before the CNSC including federal environmental assessments. CELA also maintains an extensive library of public legal education materials related to Canada's nuclear sector on its website.[3]

iv. Dr. M.V. Ramana

Expert review of this submission was provided by M. V. Ramana, Professor and Simons Chair in Disarmament, Global and Human Security at the School of Public Policy and Global Affairs (SPPGA), University of British Columbia. M. V. Ramana has extensive knowledge of small modular nuclear reactor designs and expertise in analyzing the multiple risks associated with these and accompanying adverse environmental effects. His research interests are in the broad areas of

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[3] Canadian Environmental Law Association, online: www.cela.ca

international security and energy supply, with a particular focus on topics related to nuclear energy and fissile materials that can be used to make nuclear weapons. He combines technical skills and interdisciplinary methods to address policy relevant questions related to security and energy issues.

III. BACKGROUND

In December 2021, OPG announced that GE Hitachi Nuclear Energy was selected as the Small Modular Reactor technology development partner.[4] After OPG submitted an application for a licence to construct one BWRX-300 reactor in October 2022, the CNSC held a multi-stage public consultation process to consider whether the existing Environmental Assessment ("EA") and Plant Parameters Envelope ("PPE") applied to the selected technology. The intervenors participated in the entire process, providing written submissions in March 2023 and November 2023, and oral submissions at the public hearing in January 2024, expressing concerns about applying a decade-old EA decision to such novel technology. Within these submissions intervenors expressed the position that the BWRX-300 reactor design is 'fundamentally different' from the variety of technologies captured within the Environmental Impact Statement ("EIS") and PPE approved under the federal environmental assessment (EA) for this project, and therefore the selected technology does not fit within the parameters of the EIS or PPE.

Despite these concerns, in April 2024, the Commission determined that the EA for the DNNP is applicable to the BWRX-300 reactor technology. As a result of that determination, the CNSC is now assessing OPG's application for the construction of a Class IA nuclear facility.

The scope of this submission's review builds on our previous submissions associated with the entirety of the DNNP's legacy, while focusing on the documents published by OPG and the CNSC for the licence to construct application, as well as various CNSC REGDOCs, international nuclear standards documents, and academic studies regarding nuclear power and small modular reactors.

In reviewing these documents, the intervenors prepare this submission to better assist the CNSC Commission Members in their assessment of whether or not the licence to construct a BWRX-300 reactor at the DNNP site should be granted.

IV. PRELIMINARY MATTERS & PROCEDURAL CONCERNS

Preserving Public Trust and Transparency in Requests for Confidentiality

On September 5, 2024, the CNSC published a Notice of Request for Confidentiality, inviting the public to provide comments on four requests for confidentiality submitted by OPG. Comments on

[4] OPG, "OPG advances clean energy generation project" Media Release, 2 December 2021, online: https://www.opg.com/releases/opg-advances-clean-energy-generation-project/

these requests were due just fifteen days after the notice, on September 20, 2024.[5] Between the four requests for confidentiality, there were over 4000 pages to read through to determine what information OPG was requesting to have either partially or completely redacted from the public record.

The intervenors commend the Commission for opening up the process of assessing requests for confidentiality to allow comments from the public, as opposed to the process occurring in a private manner between the CNSC and the proponent. Allowing members of the public and intervenors to assess what documents are potentially being withheld or redacted adds a layer of transparency in the dissemination of information.

However, the intervenors **submit** there must be increased notice for public review of these requests. As mentioned, the requests submitted by OPG were quite substantial in length, covering numerous documents, assessments, and studies, with many pertaining to safety measures. The requests for confidentiality were submitted by OPG to the CNSC in July 2024, but the public were only invited to provide comments in September 2024, reducing the amount of time that the public could review and comment on these requests.

With the limited timeframe to provide comments, CELA provided a brief submission to the CNSC on the Confidentiality requests. Emphasizing that one of the powers mandated to the CNSC through section 21(1)(e) of the *Nuclear Safety and. Control Act*, the CNSC may, in order to attain its objects, "disseminate objective scientific, technical and regulatory information to the public concerning the activities of the Commission and the effects, on the environment or on the health or safety of persons, of the development, production or use of nuclear energy or the production, possession or use of a nuclear substance, prescribed equipment or prescribed information,"[6] CELA expressed an expectation for transparency and public disclosure to be hallmark in the Commission's regulatory process, and its goal of maintaining public trust.[7]

CELA further submitted that it expected the Commission to stringently scrutinize any requests for confidentiality and limit it to only matters truly prejudicial to security. After reviewing a number of publicly available summaries for the documents OPG sought to have protected under confidentiality, CELA determined that the summaries were not sufficiently transparent for the public to understand the whole picture of what is being proposed for the DNNP site.

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[5] CNSC, Notice of Request for Confidentiality, September 5, 2024, online: https://api.cnsc-ccsn.gc.ca/dms/digital-medias/24-H3-DNNP-Notice-of-Request-for-Confidentiality.pdf/object

[6] *NSCA* at s 21(1)(e)

[7] CELA, "Re: OPG's Request for Confidentiality for OPG's Application for a licence to construct 1 BWRX-300 reactor for its Darlington New Nuclear Project (CMD 24-H3)", Public Comments on the Request for Confidentiality, CMD 24-H3.2, online: https://api.cnsc-ccsn.gc.ca/dms/digital-medias/CMD-24-H3.2.pdf/object at pp 18-20.

On October 30, 2024, the Commission released a partial decision regarding the Request for Confidentiality concerning the Ontario Power Generation Inc. application for a license to construct a BWRX-300 reactor at the Darlington New Nuclear Project Site (DNNP). According to the partial decision, the following documents will all be protected, with only summaries of the respective document being disclosed:

- NK054-REP-00531-10000 – Construction Site Threat and Risk Assessment – New Nuclear at Darlington R003 (e-Doc 6907558, confidential paper record);
- NK054-REP-61400-00001 Preliminary Safety Analysis Report (PSAR) Security Annex: Darlington BWRX-300 Security Assessment R000 (e-Doc 6907558, confidential paper record);
- NK054-REP-01210- 00169, BWRX- 300 Darlington New Nuclear Project (DNNP) Independent Third-Party Review Report of Preliminary Fire Protection Design (e-Doc 6911109 pages 510-580);
- NK054-REP-01210- 00163, BWRX-300 Darlington New Nuclear Project (DNNP) Probabilistic Safety Assessment Summary (e-Doc 6911109 643-802);
- NK054-REP-01210- 00158, BWRX-300 Darlington New Nuclear Project (DNNP) Hazard Analysis Results (e-Doc 6911109 pages 804-834);
- NK054-REP-01210-00191 – BWRX-300 Darlington New Nuclear Project (DNNP) Out of Core Criticality Safety Analysis Demonstration (R000) (e-Doc 7308572 pages 10211-10299).[8]

When reading through the Partial Decision, one of the documents being deemed confidential in its entirety is the "Independent third-Party Review Report of Preliminary Fire Protection Design", on the grounds that "…the document contains information that pertains to nuclear security and confidential information of a commercial and technical nature that is consistently treated as confidential."[9] We acknowledge the importance of protecting nuclear security measures, however with documents pertaining to safety measures for a proposed reactor—especially one that is novel technology never before implemented in Canada (or anywhere in the world for that matter), an entire document should not be withheld from public review. We submit that any elements of a special report such as this one should be redacted when necessary to protect nuclear security, but not withheld in its entirety. This ensures public transparency to assist experts in their assessment of safety measures for proposed nuclear reactors.

The intervenors reiterate CELA's **recommendation** that in the interest of effectively disseminating objective scientific, technical, and regulatory information to the public for this application for a licence to construct, the Commission should stringently assess these requests with

[8] CNSC, Partial Record of Decision, Table 1
[9] *Ibid.*

a lens of upholding public transparency. Rather than excluding entire documents, redacting content may be more appropriate, and that technical information, especially information related to safety and emergency planning, should **not** be made confidential.

Recommendation 1: The public should be afforded more time to adequately review and comment on any requests for confidentiality filed by a proponent. This supports judicial fairness and transparency in the public record for matters before the Commission.

Recommendation 2: In the interest of effectively disseminating objective scientific, technical, and regulatory information to the public for this application for a licence to construct, the Commission should stringently assess these requests with a lens of upholding public transparency. Rather than excluding entire documents, redacting content may be more appropriate, and that technical information, especially information related to safety and emergency planning, should **not** be made confidential.

V. ACTION REQUESTED OF THE COMMISSION

After reviewing the publicly available submissions by CNSC staff and OPG ("the CMDs"), the intervenors submit that there is too much uncertainty surrounding the BWRX-300 reactor design for a licence to construct to be granted. Furthermore, there we emphasize there are inadequacies surrounding the siting of the proposed nuclear facility, the emergency planning measures, and climate change mitigation and adaptation strategies.

Aligning with our position from our previous submissions to the CNSC that the selected BWRX-300 reactor technology is 'fundamentally different' from the variety of technologies captured within the original EIS and PPE approved under the federal EA for the Darlington New Nuclear Project, we submit the risks and uncertainties surrounding the BWRX-300 reactor technology are too great for the Commission to issue a licence to OPG to construct one BWRX-300 reactor.

Before any developments can be made in the DNNP, there are issues that must be addressed and resolved by both the CNSC and OPG relating to an absence of discussing proposed nuclear waste storage facilities, incomplete reactor design, emergency planning shortfalls, site location concerns, and climate change and environmental concerns.

The intervenors implore the Commission to take the following concerns into consideration when reviewing OPG's application, and we recommend that the licence to construct be denied in the interest of protecting the health and safety of humans and the environment.

A. Nuclear Waste Storage Facilities

With OPG seeking to construct up to four small modular reactors ("SMRs") beside Lake Ontario at the Darlington site, a primary concern for citizens living in close proximity to this site is the storage of the radioactive waste that would be produced by the reactor(s). In particular, members of the public are concerned about the placement of dry storage containers near Lake Ontario, as well as more details about the dry storage container design. During a invitation-only workshop hosted by OPG on September 18, 2024 to discuss the Licence to Construct application, several attendees sought clarification and details surrounding the dry storage container design and placement at the Darlington site.

Attendees were informed that decisions related to the location of interim storage of used fuel for this project will be made during future licensing phases, i.e., the licence to operate phase, meaning that the final position of the storage containers in relation to Lake Ontario has not been determined, nor has a specific spent fuel storage technology been selected. Some general information leaflets were shared with attendees regarding possible dry storage systems, namely the Orano TN "Horizontal Dry Storage" system, the Holtec International "HI-STORM FW® Vertical Ventilated Storage System", and the NAC International Inc.'s "MAGNASTOR®" system.[10]

During Part 1 of the DNNP public hearing, held on October 2, 2024, the record notes that one of the key concerns of the Mississauga's of Scugog Island First Nation ("MSIFN") is the regulatory process advancing with waste management scoped out of the Licence to Construct application.[11] With MSIFN's objection highlighted at the hearing, Laura DeCoste, an Acting Senior Policy Officer on the Indigenous and Stakeholder Relations Division of CNSC staff, noted that: "the potential waste facility is out of scope for this hearing as construction of a radioactive waste storage facility is not proposed as part of the application. Should OPG propose the construction of a radioactive waste storage facility in the future, a separate application and subsequent licensing decision and consultation activities will be required."[12]

The intervenors also share the objection to the regulatory process advancing with waste management scoped out of the Licence to Construct application. Based on the statement by Officer DeCoste at the hearing, because OPG opted to not include the waste storage facilities in their Licence to Construct application, these facilities are simply not being considered or factored into CNSC staff's application assessment until OPG mentions them at some point in a future application phase.

According to REGDOC-1.1.2, *Licence Application Guide: Licence to Construct a Reactor Facility*, "The description of structures that house nuclear material (such as new and spent fuel or

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[10] See Appendix B for these leaflets.
[11] CNSC, DNNP Hearing Part 1 Transcript, October 2, 2024, at p 91 [**Hearing Transcript**].
[12] *Ibid*, p 91-92.

tritiated light or heavy water) should include the design considerations (for example, applied loads, codes and standards, analytical tools and material properties), the structural stability, the relative displacements, and the means of protection against internal and external events that were considered."[13]

We **submit** the Licence to Construct application should include a discussion of the design considerations for storing spent fuel for the DNNP. Including the nuclear waste storage facilities in the Licence to Construct phase is a logical step to ensure OPG's plans for constructing all of the required facilities associated with the BWRX-300 reactor will not be detrimental to the health and safety of the public and the environment. Because operating the BWRX-300 reactor will necessarily create radioactive wastes of different kinds, details about how these wastes will be managed should be included with details about other site elements being constructed. Only then, can the Commission and members of the public have a holistic view of the risks associated with building more reactors at the Darlington site.

The intervenors emphasize that the waste from the proposed BWRX-300 facility is different from other CANDU waste, and therefore there are additional and different risks associated with these. With this risk in mind, it is crucial that OPG is transparent with the public and the Commission on how it intends to safely store these different forms of waste and prevent any harm to Lake Ontario from the Darlington site. Before OPG applies for a Licence to Operate, essential facilities should be assessed and approved under the Licence to Construct.

We therefore **recommend** that the Commission refrain from issuing a Licence to Construct until OPG provides specifics on the siting and design of the dry waste storage facilities associated with the proposed BWRX-300 technology and these details are shared with the public for their comment.

We further **recommend** that the CNSC amend the regulatory process to ensure that the Licence to Construct phase for Nuclear Facilities encompasses an assessment of the radioactive waste storage facilities and their placement at a site.

Recommendation 3: The Commission must refrain from issuing a Licence to Construct until OPG provides specifics on the siting and design of the dry waste storage facilities associated with the proposed BWRX-300 technology.

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[13] CNSC, REGDOC-1.1.2, *Licence Application Guide: Licence to Construct a Reactor Facility*, version 2 (October 2022), online: https://api.cnsc-ccsn.gc.ca/dms/digital-medias/REGDOC-1_1_2__Licence_Application_Guide__Guide_to_Construct_A_Reactor_Facility__Version_2.pdf/object at section 4.5.5: Structure Design, p 37.

Recommendation 4: The CNSC should amend the regulatory process to ensure that the Licence to Construct phase for Nuclear Facilities encompasses an assessment of the radioactive waste storage facilities and their placement at a site.

B. The BWRX-300 Design is Incomplete

The design of the BWRX-300 reactor as submitted to CNSC is incomplete and various aspects of the design that are relevant to evaluate the safety of the reactor do not appear to be ready. The incompleteness of the design is explicitly acknowledged by both CNSC staff and by OPG in CMD24-H3-1. On page 51 of the document, CNSC staff are reported to have let OPG know that "the PSA submission does not include uncertainty, sensitivity, and importance analyses". In response, OPG reportedly indicated that "the PSAs are iterative in nature and will evolve as the design progresses, and that the final design PSAs will include the uncertainty, sensitivity, and importance analyses".

The first comment by CNSC staff indicates that the OPG submission was incomplete and its probabilistic safety assessment does not take into account the inevitable uncertainties in any project, especially one involving a nuclear reactor design that has never been built or operated anywhere in the world. OPG's response is an admission of not just the incompleteness of the design but also that it had not carried out the full safety assessment of even the tentative design that is under consideration under this submission. CELA submits that without any assessment of uncertainty, the reliability of the initial PSA results is questionable, and that it is not possible to know how these results might change when the design is updated. As a result, CELA submits that any approval to construct would be premature and OPG's proposal should only be considered when the design has been finalized.

Further, on page 51 of CMD24-H3-1, CNSC staff "also note that OPG is using modified importance measures for the identification of risk-significant Safety Class 2 and 3 SSCs. This is an approach that differs from current practice and is currently under review by CNSC staff". In other words, OPG's approach to demonstrating safety is not even a standard one and its reliability was not established as of when the document was prepared.

In addition to questions about the safety of the reactor if and when it is constructed and operated, the incompleteness of the design also raises the possibility of problems during construction. This danger was clearly demonstrated during the construction of the AP1000 reactor in the United States. For background, it may be remembered that Westinghouse submitted the AP1000 design to the U. S. Nuclear Regulatory Commission for review in March 2002, and this design was built on the basis of the earlier experience of the AP600 that was certified in 1999.[14] The 2002

[14] United States Nuclear Regulatory Commission, "NRC Proposed to Certify Westinghouse Electric Company's AP600 Reactor Design" (May 14, 1999), online: https://www.nrc.gov/reading-rm/doc-collections/news/1999/99-100.html

application referred to the experience with the AP600.[15] The initial application from Westinghouse submitted in 2002 was approved in September 2004, but then Westinghouse revised its design, and NRC published a revised safety evaluation in December 2005.[16] Westinghouse revised its design again and this new design was certified in September 2011.[17] Despite the long review process the AP1000 went through before construction started in South Carolina (V. C. Summer plant) and Georgia (Vogtle plant), Westinghouse made "several thousand" technical and design changes during the construction of the plant.[18] This led to major delays in construction and the eventual cancellation of the V.C. Summer project after over 9 billion USD was spent on it.[19]

CELA submits that approving projects, especially ones that start being constructed, is inefficient. Changes to the design will require the regulator to work through the safety implications of these changes and approve, or not, these changes. It is therefore important that an incomplete design not be approved for construction.

Recommendation 5: The CNSC should not approve an application featuring an incomplete design and should require OPG to submit a new application based on a finalized design and a complete probabilistic safety assessment of this design, using standard importance measures.

C. The Reactor's Shutdown Systems Are Not Separate

The BWRX-300 design does not have two separate shutdown systems and this makes it harder to ensure that the reactor will be shut down under all circumstances. CELA has emphasized this concern in earlier submissions too,[20] but OPG has evidently not addressed this problem so far.

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[15] United States Nuclear Regulatory Commission, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design (NUREG-1793)", Introduction and Chapter 1 (September 2004), online: https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1793/initial/chapter1.pdf

[16] United States Nuclear Regulatory Commission, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design (NUREG-1793, Supplement 1)" (December 2005), online: https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1793/sup1/index.html

[17] United States Nuclear Regulatory Commission, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design: Cover through Chapter 8 (NUREG-1793, Supplement 2, Volume 1)" (September 2011), online: https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1793/sup2/v1/index.html

[18] Hals, Tom, and Emily Flitter. "How Two Cutting Edge U.S. Nuclear Projects Bankrupted Westinghouse." *Reuters*, May 2, 2017. https://www.reuters.com/article/us-toshiba-accounting-westinghouse-nucle-idUSKBN17Y0CQ.

[19] Lacy, Akela. "South Carolina Spent $9 Billion to Dig a Hole in the Ground and Then Fill It Back In." *The Intercept*, February 6, 2019. https://theintercept.com/2019/02/06/south-caroline-green-new-deal-south-carolina-nuclear-energy/.

[20] Durham Nuclear Awareness, Slovenian Home Association and Canadian Environmental Law Association, "Comments on Ontario Power Generations' Review of the Environmental Impact Statement and Plant Parameter Envelope for the Darlington New Nuclear Project in the Context of the Proposed BWRX-300 Reactor", March 20, 2023 at p. 11; Durham Nuclear Awareness, Slovenian Home Association and the Canadian Environmental Law Association, "Comments on the applicability of the Darlington New Nuclear Project's environmental assessment and plant parameter envelope to Ontario Power Generation's selected BWRX-300 reactor technology", November 17, 2023, CMD 24-H2.8, online: https://api.cnsc-ccsn.gc.ca/dms/digital-medias/CMD24-H2-8.pdf/object at p 10.

The BWRX-300 design uses a hydraulic drive-in system and a fast motor run-in of the control rods as its shutdown systems. But as CNSC staff have observed, on page 51 of CMD24-H3-1, these cannot be "considered as truly independent since they share the only credited negative reactivity insertion devices". Later in the page CNSC staff explain the significance of this lack of independence by referring to the potential for unacceptable consequences in the event of "a complete failure-to-insert of all control rods".

This problem was observed in the case of some VVER reactors, where control rods have failed to get inserted even when there was a shutdown attempt of the reactor. This happened at both the Temelin 1 reactor and even more dramatically in the Kozloduy 5 reactor.[21]

A further concern about the safety of the BWRX-300 design is explained on page 98, and this has to with "the reliability and RIV response times" with RIV referring to Reactor Isolation Valves. This problem exacerbates the concern about lack of truly independent shutdown systems.

CELA submits that these safety lacunae and concerns should be addressed before construction is approved.

Recommendation 6: The CNSC should not approve a design without two truly independent shutdown systems.

D. Site Location

Over the entirety of the Darlington New Nuclear Project's timeline, CELA has expressed concerns surrounding the site location of this project. For instance, in CELA's 2011 submission to the Joint Review Panel discussing the EA and OPG's Application for a Licence to Prepare a Site, CELA cited, *inter alia*, concerns about population growth and emergency planning, proximity to other reactors, and increased accident risks, to argue why siting a new nuclear reactor(s) at the Darlington site would be inappropriate from a safety standpoint.[22] Over a decade later, these concerns persist, with the support of updated population growth and emergency planning information.

For the reasons outlined below, the intervenors submit that OPG's Licence to Construct application fails to show the site's suitability for the construction of a new small modular reactor, as the site location poses a threat to the health and safety of the public and the environment.

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[21] Kastchiev, Georgui, Wolfgang Kromp, Stephan Kurth, David Lochbaum, Ed Lyman, Michael Sailer, and Mycle Schneider. "Residual Risk: An Account of Events in Nuclear Power Plants Since the Chernobyl Accident in 1986." Brussels: The Greens/European Free Alliance, 2007.

[22] CELA, "Final Comments of the Canadian Environmental Law Association", CEAR No.07-05-29525, May 2011, at p 12-21. **[CELA's 2011 JRP and LPS Comments]**

i. Siting is Adjacent to Existing Buildings

The intervenors reiterate that the *NSCA* requires the CNSC to limit risk to Canadian society, and the existence of the aging Darlington Nuclear Generation ("DNGS") reactors on the site make this selected site unsuitable for this project. Any consequences and risks from accidents would be magnified by their proximity to multiple sources of material which can achieve critical chain reactions, both in reactor cores and in used fuel storage.

Our concerns surrounding the approach to storing radioactive waste that would be produced by the BWRX-300 reactor are further compounded by the risks associated with DNGS and its own wet and dry storage facilities for radioactive waste. We note that having a clear understanding of all the facilities required for the DNNP is essential in the safety assessment for this project, as it helps establish what elements of the DNNP would be heavily impacted by any number of risks associated with the aging facilities of DNGS. Serious damage to one facility not only poses a risk for that facility, but also poses a risk to a neighbouring reactor facility simply due to proximity.[23]

We have previously expressed concerns to the Commission about the issue of multi-unit accidents leading to a potential radiological release to the environment. During our assessment of whether the EA and PPE were applicable to the selected technology (which we submit that they are not applicable), we made the recommendation that "for a more fulsome safety analysis, the risk of accidents involving the existing nuclear reactors at the Darlington site should be considered as an external hazard. Without a careful assessment of how the BWRX-300 reactor might interact with the existing reactors at the Darlington site in an emergency situation, the DNNP EA cannot be presumed to apply to the BWRX-300 reactor design."[24]

When reading through OPG's "Application for a Licence to Construct a Reactor Facility", as well as the written submission prepared by OPG for the hearing (CMD 24-H3.1), there does not appear to be a discussion of DNGS being considered as external hazards. As a result, our previous recommendation that would ensure there is a more fulsome safety analysis remains unresolved by OPG and CNSC staff. With numerous documents being deemed as confidential, the public are not given the opportunity to scrutinize the degree in which OPG weighed the risk of severe accidents and multi-unit/multi-facility accidents involving the existing reactors at the Darlington site. The intervenors seek clarification on how DNGS fits within the safety analysis for this project.

According to the CNSC staff written submission (CMD 24-H3), "OPG stated that the hazard analysis screening process, and the associated PSAs, will continue to evolve as the BWRX-300

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[23] *Ibid* at p.16.

[24] Durham Nuclear Awareness, Slovenian Home Association and the Canadian Environmental Law Association, "Comments on the applicability of the Darlington New Nuclear Project's environmental assessment and plant parameter envelope to Ontario Power Generation's selected BWRX-300 reactor technology", November 17, 2023, CMD 24-H2.8, online: https://api.cnsc-ccsn.gc.ca/dms/digital-medias/CMD24-H2-8.pdf/object at p 14.

design progresses and procedures continue to be developed. Any consequential changes to the safety analyses will be provided to CNSC staff on a routine basis for review and compiled into the facility's Safety Analysis Report."[25] The intervenors **submit** that the hazard analysis for the BWRX-300 needs to be updated to fully consider and address the severe risk of a multi-unit or multi-facility accident involving the DNGS. Without a consideration of the existing, aging nuclear reactors on the site, the safety analysis for this project is incomplete.

ii. <u>IAEA Guidance on Siting</u>

According to the International Atomic Energy Agency ("IAEA"), population density and population characteristics should be important considerations in decisions about siting nuclear power plants and emergency planning. In 2016, CELA, DNA, and Greenpeace Canada jointly submitted an application for review to the Ministry of Municipal Affairs and Housing under the *Environmental Bill of Rights* to review their current acts, regulations and policies, and create new acts, regulations and policies, to restrict land use and population growth around nuclear power plants.[26]

In the application, we determined that Ontario was not complying with IAEA standards and instead encouraged population growth in locations near nuclear power plants. Nearly a decade later, the intervenors emphasize that this is still the case, and that continuing to use the Darlington site as the prospective location to construct up to four BWRX-300 reactors is not in compliance with the IAEA guidelines for siting nuclear facilities.

The IAEA's safety standard for *Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants* states:

> The presence of large populations in the region or the proximity of a city to the nuclear power plant site may diminish the effectiveness and viability of an emergency plan.[27]

The IAEA standard requires study of the regional population near the site of a nuclear power plant to evaluate the potential radiological impacts of normal radioactive discharges and accidental releases, and to assist in the demonstration of the feasibility of emergency response plans.[28]

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[25] CNSC, " A New Licence: Ontario Power Generation, Inc. (OPG) Application for a Licence to Construct a BWRX-300 Reactor at the Darlington New Nuclear Project Site (DNNP)", June 28, 2024 (CMD 24-H3) at p 47.

[26] CELA, DNA, Greenpeace Canada, "Application for Review to the Ministry of Municipal Affairs and Housing", September 26, 2016.

[27] International Atomic Energy Association, Safety Standard for Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants, Safety Guide No. NS-G-3.2, March 2002, s 6.4, p 28 ["IAEA Safety Standard for Dispersion of Radioactive Material"]

[28] *Ibid*, s 5.1, p 25

Section 5.3 provides that emergency plans must account for the characteristics of the population around the site:

> The external zone includes an area immediately surrounding the site of a nuclear power plant in which population distribution, population density, population growth rate, industrial activity, and land and water uses are considered in relation to the feasibility of implementing emergency measures.[29]

There should be no adverse site conditions which could hinder sheltering or evacuation of the population.[30] The Safety Guide identified factors that may diminish the effectiveness and viability of emergency plans, including population density and distribution in the region, distance of the site from population centres and special groups of the population who are difficult to evacuate or shelter.[31] Site related factors must be reviewed periodically.[32]

Section 4.6 of the IAEA's safety standard for *Site Evaluation for Nuclear Installations* sets out the following aspects that shall be addressed at an early stage of the site evaluation when assessing the suitability of a site:

> (a) The effects of natural and human induced external events occurring in the region that might affect the site;
>
> (b) The characteristics of the site and its environment that could influence the transfer of radioactive material released from the nuclear installation to people and to the environment;
>
> (c) The population density, population distribution and other characteristics of the external zone, in so far as these could affect the feasibility of planning effective emergency response actions [9], and the need to evaluate the risk to individuals and to the population.[33]

If one or more of these considerations indicate that the site is unacceptable and the deficiencies cannot be compensated for by a means of a combination of measures for site protection, design features of the nuclear installation and administrative procedures, then the site shall be deemed unsuitable for nuclear installation.[34]

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[29] *Ibid*, s 5.3 p 25
[30] *Ibid*, s 6.1, p 27
[31] *Ibid*, ss 6.3 and 6.4, pp 27-28
[32] *Ibid*, s 6.7, p 28
[33] International Atomic Energy Agency, *Site Evaluation for Nuclear Installations*, IAEA Safety Standards Series No. SSR-1, IAEA, Vienna (2019), 4.6, p 9 ("*IAEA Safety Standard for Site Evaluation*")
[34] *Ibid*, s 4.7, p 8

Requirement 26 within the *Site Evaluation for Nuclear Installations* safety standard is concerned with population distribution and public exposure. This requirement highlights Ontario's responsibility to monitor demographic conditions around a nuclear installation over its lifetime.[35] Population density near the nuclear plant is to be closely monitored, with particular attention to densely populated areas and residential centres in the region, and to residential institutions such as schools, hospitals and prisons.[36]

The intervenors submit that there has been considerable population growth and urban development in the region surrounding the selected site, and the population density would negatively affect the feasibility of planning effective emergency response actions, indicating that this site is not suitable for the construction of a new nuclear facility. The intervenors **submit** there must be a reassessment of the suitability of this site in accordance with the safety standards set out by the IAEA.

iii. Accident Planning Zones are Insufficient

The intervenors reiterate their concerns expressed in previous submissions before the Commission that accident planning zones are insufficient for such a concentration of nuclear facilities in such a high population area. In March 2023, we expressed the need to revisit and expand the emergency planning zone around the site, explaining that as the aftermath of Fukushima revealed, planning to evacuate people based on concentric circles ranging from a radii of 5-30 km is too rigid and inadequate for protecting the public during a serious nuclear disaster.[37] The intervenors submitted that OPG must provide more information on how emergency planning for BWRX-300 deployment will encompass a larger range of the population in the event of a severe nuclear incident.[38]

When reviewing the most recent OPG's submissions for this application, there is very little mention of expanding the emergency planning zone to accommodate the population growth and urban development. In the contrary, OPG's Application for aa Licence to Construct briefly states: "As a result of that increased safety as well as simplicity of design, the BWRX- 300 can have a much smaller emergency planning zone (EPZ),"[39] completely disregarding the increased risk of siting multiple nuclear reactors in the same area, surrounded by rapid population growth and increasingly dense urban development.

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[35] *Ibid*, ss 6.8-6.10, p 27

[36] *Ibid*, s 4.11, pp 19-20

[37] *Lessons from Fukushima*, by Greenpeace (February 2012), online (pdf): https://www.greenpeace.org/usa/research/lessons-from-fukushima/, at 18 [Greenpeace].

[38] Durham Nuclear Awareness, Slovenian Home Association and Canadian Environmental Law Association, "Comments on Ontario Power Generations' Review of the Environmental Impact Statement and Plant Parameter Envelope for the Darlington New Nuclear Project in the Context of the Proposed BWRX-300 Reactor", March 20, 2023, at p 24 ["**March 2023 intervenor submission"**]

[39] OPG, *Darlington New Nuclear Project: Application for a Licence to Construct a Reactor* Facility, October 2022, p 4

As a result, the intervenor once again recommend that the Commission require OPG to provide more information on how emergency planning for BWRX-300 deployment will encompass a larger range of the population in the event of a severe nuclear incident.

Recommendation 7: The intervenors seek clarification on how the DNGS fits within the safety analysis for this project.

Recommendation 8: The hazard analysis for the BWRX-300 needs to be updated to consider and address the severe risk of a multi-unit or multi-facility accident involving the DNGS. Without a consideration of the existing, aging nuclear reactors on the site, the safety analysis for this project is incomplete.

Recommendation 9: There must be a reassessment of the suitability of this site in accordance with the safety standards set out by the IAEA.

Recommendation 10: The Commission should require OPG to provide more information on how emergency planning for BWRX-300 deployment will encompass a larger range of the population in the event of a severe nuclear incident.

E. Emergency Planning

With this reactor being proposed for an unsuitable site for the aforementioned reasons, there are further details surrounding emergency planning that need to be resolved before this project can be granted a licence to construct. The members of DNA and SHA generally reside within close range of the Darlington site, and as a result, adequate emergency planning, and transparency with the public on nuclear safety are paramount issues.

i. Expanding KI pill Distribution

The intervenors submit that the distribution of potassium iodide pills ("KI pills") are an important element of emergency preparedness for all nuclear power generating sites, and that while most of the focus of this licensing application revolves around the design and construction plans for this project, it is crucial that the Commission ensures there are adequate emergency planning measures linked with this project.

As an active member of the advisory group to the KI Pill Working Group, CELA submits that the distribution of KI pills is currently inadequate. While operators and regulators have spent years working on understanding the current framework for storing and distributing potassium iodide, the critical work has not begun to further distribute KI pills to residents living beyond the current 10 km pre-distribution area.

The DNNP is proposing to add up to four nuclear reactors to a site that has aging nuclear generating units already in operation. With the growth in population within the GTA, robust emergency preparedness is key as Ontario seeks to expand nuclear power generation in the most densely populated region in the province. The intervenors **recommend** expanding the delivery of KI pills to a pre-distribution area of 50 km, rather than the current 10 km pre-distribution area. This measure is especially critical for vulnerable populations, such as children.

ii. The Need for Expanding Detailed Evacuation Planning

In addition to KI pill distribution, an essential element of effective emergency preparedness is implementing a robust, detailed evacuation plan. The issues of land use planning and site suitability mentioned above have a direct correlation with effective emergency preparedness—a central factor in the CNSC fulfilling its obligations to limit harm to Canadian society. The intervenors have repeatedly expressed concerns about the emergency planning measures for this project.

Effective emergency planning needs to factor in population growth—including in the Ingestion Planning Zone and not just the 10-km radius of a nuclear power site. In the intervenor's March 2023 submission, the intervenors noted that the Darlington Evacuation Time Estimate relies on the 2016 National Census Data with per-decade population projections out to 2088. OPG was to issue an updated Darlington Site Evacuation Time Estimate in the first quarter of 2023, that was to be based on 2021 national census data; the estimate was also to subsequently be shared with stakeholders.[40]

This updated information was not available during the commenting period that ended in March 2023, and nor was this information discussed in either CMD submitted by OPG and CNSC staff in September 2023 for the intervenor's submission assessing the applicability of the EA and PPE to the selected technology. The intervenors reiterate that with the proposed BWRX-300 reactors projected to in operations in 2025, updated population projections are essential in determining whether OPG's emergency plans are adequate and Site Evacuation Time Estimates are accurate.

According to the CNSC staff CMD for the application for a Licence to Construct:

> OPG also has a memorandum of understanding with the Province of Ontario's Emergency Management Ontario (EMO) to revise the *Provincial Nuclear Emergency Response Plan* (PNERP) [R2.9-3] prior to 'fuel-in' commissioning activities. This will include a revised Darlington Implementing Plan, or a separate Implementing Plan specific for the DNNP. This Implementing Plan is intended to specify the emergency planning zones for the DNNP, and

[40] Ontario Power Generation Inc. Darlington New Nuclear Project: BWRX-300 Preliminary Safety Analysis Report, by Ontario Power Generation, Revision 0 (2022) at page 2-172.

> OPG will be required to perform a revised evacuation time estimate study. OPG will be required to have this information available should this project proceed to the LTO stage.[41]

The intervenors are disappointed that this project is undergoing yet another phase without having an updated evacuation time estimate study available for the public to review. Having the PNERP updated is important for emergency planning, and it is needed to produce accurate emergency plans for the DNNP. The intervenors submit that waiting until OPG decides to proceed to the Licence to Operate stage before a revised evacuation time estimate study is required not acceptable. We further **submit** that before a Licence to Construct can be issued for this project, at minimum, the updated Darlington Site Evacuation Time Estimate and emergency planning models based on the 2021 Census data must be made available to the Commissioners and the Intervenors, and explicitly considered during the hearing in January 2025.

We **recommend** that any decision about the Licence to Construct is delayed until after the PNERP is updated, as to ensure the most current information is available to develop accurate and detailed evacuation planning measures.

iii. More Comprehensive Public Education on Emergency Response is Required

As the intervenors have highlighted during various stages of this project, public awareness is a key factor in effective emergency planning, yet most citizens in the Greater Toronto Area are not aware that they live within the Ingestion Planning Zone—extending 50 km from nuclear facilities—of not one but two very large nuclear generating stations each with multiple existing large units. Even fewer are aware of the SMRs developments proposed in Durham Region.

With the lack of public awareness surrounding nuclear safety and emergency preparedness, groups such as CELA, DNA, and SHA find themselves trying to fill the gaps in public education on the subject matter: "according to a poll conducted in 2018, 54 percent of respondents were unaware of any emergency response plans in case of a nuclear accident, a clear indication of the need for stronger awareness efforts."[42] In an attempt to inform citizens living in a nuclear host community, CELA organized a one-hour information webinar with DNA, Northwatch, and Safecast on April 23, 2024, informing attendees about ways they can become more engaged in nuclear issues impacting their families and communities.[43]

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[41] CMD 24-H3, pp 137-138, *emphasis added.*

[42] Masahda Lochan-Aristide, "Blog: Neighbour of a Nuclear Plant – What Residents of Durham Region Should Know About Nuclear Energy" CELA (April 17, 2024), online: https://cela.ca/blog-neighbours-of-a-nuclear-plant-what-residents-of-durham-region-should-know-about-nuclear-energy/

[43] CELA, "Neighbours of a Nuclear Plant: An Information Session for Durham Residents" (April 23, 2024), webinar, online: https://cela.ca/webinar-neighbours-of-a-nuclear-plant-an-information-session-for-durham-residents/

The intervenors **submit** that to ensure there is effective nuclear safety awareness and emergency preparedness in the region surrounding the DNNP, more comprehensive public education on emergency response is required. The intervenors **recommend** that the CNSC and OPG collaborate with community groups and intervenors to develop a strategy to better inform the public on what to do in case of emergency.

Recommendation 11: The CNSC should consider expanding the delivery of KI pills to a pre-distribution area of 50 km, rather than the current 10 km pre-distribution area.

Recommendation 12: Before a Licence to Construct can be issued for this project, at minimum, the updated Darlington Site Evacuation Time Estimate and emergency planning models based on the 2021 Census data must be made available to the Commissioners and the Intervenors, and explicitly considered during the hearing in January, 2025.

Recommendation 13: Any decision to issue a Licence to Construct for this project should be delayed until after the PNERP is updated, as to ensure the most current information is available to develop accurate and detailed evacuation planning measures.

Recommendation 14: To ensure there is effective nuclear safety awareness and emergency preparedness in the region surrounding the DNNP, more comprehensive public education on emergency response is required. The CNSC and OPG should collaborate with community groups and intervenors to develop a strategy to better inform the public on what to do in case of emergency.

F. "Beyond Design Basis" Accidents

With the design of the BWRX-300 reactor not being finalized, and CNSC staff making note throughout their CMD that more details or information is required to support OPG's determinations on various safety measures, the intervenors are skeptical as to whether the assessment of "beyond design basis" accidents is sufficiently robust and note that the likelihood of severe offsite accidents may well be much higher than their stated "one in a million operating years."

Recommendation 15: The intervenors would like clarification and in depth evidence as to whether OPG's assessment of "beyond design basis" accidents is sufficiently robust and note that the likelihood of severe offsite accidents may well be much higher than their stated "one in a million operating years."

G. Climate Change Mitigation and Adaptation

During Part 1 of this public hearing, David Tyndall, the Vice President of New Nuclear Engineering of OPG, discussed OPG's assessments of extreme weather events for climate change adaptation, making the bold statement that OPG "concluded that there are no nuclear safety impacts as a result of climate change, given the way that the plant has been designed."[44]

As the intervenors have pointed out in previous submissions, the impact of climate change and extreme weather events need not be just through any "influence" on "physical structures or systems of the DNNP". Such events could also affect the institutional response to any unusual events at the nuclear plant during such an extreme event for a variety of reasons. For example, it might be difficult for plant personnel to reach the site because roads around the plant are flooded or because trees might have fallen and blocked roads. This might prevent specialists or even replacement workers from reaching the site. Lake levels may vary widely in various climate scenarios, and the risk to safe operations from seiches must be evaluated.

Therefore, we disagree with the statement that there are no nuclear safety impacts as a result of climate change, as extreme weather events and other impacts of climate change may not necessarily touch the reactor's operations directly. We **submit** that it is necessary to carefully study how severe weather events and other climate change related physical impacts will affect the capacity of OPG and plant operators to respond to unusual events or accident precursors and to evaluate climate risks on the proposed plant in this specific location and with the current context of other facilities on the site, before concluding that the proposed project fits within the PPE of the prior EA.

Recommendation 16: The application from OPG should not be approved until it is accompanied by a carefully conducted study on how severe weather events and other climate change related physical impacts will affect the capacity of OPG and plant operators to respond to unusual events or accident precursors and to evaluate climate risks on the proposed plant in this specific location and with the current context of other facilities on the site.

VI. CONCLUSION

For the foregoing reasons provided in this intervention, DNA, SHA, and CELA submit the uncertainties in the technology's design and the inappropriate siting of this project bring cause for concern that allowing this project to proceed would bring unreasonable risk to the health and safety of the public and the environment, and therefore recommend the CNSC issue an order:

(1) Granting Durham Nuclear Awareness, Slovenian Home Association, and the Canadian Environmental Law Association the status of intervenor;

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[44] Hearing Transcript, p 181

(2) Granting Durham Nuclear Awareness, Slovenian Home Association, and the Canadian Environmental Law Association the opportunity to make an oral presentation at the January 2024 public hearing;

(3) Making a determination that a licence to construct should not be granted to OPG on the grounds that allowing OPG to commence construction of a BWRX-300 reactor while there are many uncertainties surrounding the reactor design, issues with the siting of this reactor, and emergency planning shortfalls would pose aa risk to the health and safety of the public and the environment;

(4) In the alternative, before a licence to construct can be granted, OPG must provide specifics on the siting and design of the dry waste storage facilities associated with the proposed BWRX-300 technology.

Sincerely,

On behalf of
CANADIAN ENVIRONMENTAL LAW ASSOCIATION
DURHAM NUCLEAR AWARENESS
SLOVENIAN HOME ASSOCIATION

Sara Libman

Sara Libman, Legal Counsel

APPENDIX A - SUMMARY OF RECOMMENDATIONS

Recommendation 1: The public should be afforded more time to adequately review and comment on any requests for confidentiality filed by a proponent. This supports judicial fairness and transparency in the public record for matters before the Commission.

Recommendation 2: In the interest of effectively disseminating objective scientific, technical, and regulatory information to the public for this application for a licence to construct, the Commission should stringently assess these requests with a lens of upholding public transparency. Rather than excluding entire documents, redacting content may be more appropriate, and that technical information, especially information related to safety and emergency planning, should **not** be made confidential.

Recommendation 3: The Commission must refrain from issuing a Licence to Construct until OPG provides specifics on the siting and design of the dry waste storage facilities associated with the proposed BWRX-300 technology.

Recommendation 4: The CNSC should amend the regulatory process to ensure that the Licence to Construct phase for Nuclear Facilities encompasses an assessment of the radioactive waste storage facilities and their placement at a site.

Recommendation 5: The CNSC should not approve an application featuring an incomplete design and should require OPG to submit a new application based on a finalized design and a complete probabilistic safety assessment of this design, using standard importance measures.

Recommendation 6: The CNSC should not approve a design without two truly independent shutdown systems.

Recommendation 7: The intervenors seek clarification on how the DNGS fits within the safety analysis for this project.

Recommendation 8: The hazard analysis for the BWRX-300 needs to be updated to consider and address the severe risk of a multi-unit or multi-facility accident involving the DNGS. Without a consideration of the existing, aging nuclear reactors on the site, the safety analysis for this project is incomplete.

Recommendation 9: There must be a reassessment of the suitability of this site in accordance with the safety standards set out by the IAEA.

Recommendation 10: The Commission should require OPG to provide more information on how emergency planning for BWRX-300 deployment will encompass a larger range of the population in the event of a severe nuclear incident.

Recommendation 11: The CNSC should consider expanding the delivery of KI pills to a pre-distribution area of 50 km, rather than the current 10 km pre-distribution area.

Recommendation 12: Before a Licence to Construct can be issued for this project, at minimum, the updated Darlington Site Evacuation Time Estimate and emergency planning models based on the 2021 Census data must be made available to the Commissioners and the Intervenors, and explicitly considered during the hearing in January, 2025.

Recommendation 13: Any decision to issue a Licence to Construct for this project should be delayed until after the PNERP is updated, as to ensure the most current information is available to develop accurate and detailed evacuation planning measures.

Recommendation 14: To ensure there is effective nuclear safety awareness and emergency preparedness in the region surrounding the DNNP, more comprehensive public education on emergency response is required. The CNSC and OPG should collaborate with community groups and intervenors to develop a strategy to better inform the public on what to do in case of emergency.

Recommendation 15: The intervenors would like clarification and in depth evidence as to whether OPG's assessment of "beyond design basis" accidents is sufficiently robust and note that the likelihood of severe offsite accidents may well be much higher than their stated "one in a million operating years."

Recommendation 16: The application from OPG should not be approved until it is accompanied by a carefully conducted study on how severe weather events and other climate change related physical impacts will affect the capacity of OPG and plant operators to respond to unusual events or accident precursors and to evaluate climate risks on the proposed plant in this specific location and with the current context of other facilities on the site.

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APPENDIX B – SUPPORTING DOCUMENTS AND MATERIALS

1. Orano TN “Horizontal Dry Storage” system leaflet **(pages 3-4)**
2. Holtec International “HI-STORM FW® Vertical Ventilated Storage System” leaflet **(pages 5-6)**
3. NAC International Inc.’s “MAGNASTOR®” system leaflet **(page 7)**
4. United States Nuclear Regulatory Commission, “NRC Proposed to Certify Westinghouse Electric Company’s AP600 Reactor Design” (May 14, 1999), online: https://www.nrc.gov/reading-rm/doc-collections/news/1999/99-100.html **(pages 8-9)**
5. United States Nuclear Regulatory Commission, “Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design (NUREG-1793)”, Introduction and Chapter 1 (September 2004), online: https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1793/initial/chapter1.pdf **(pages 10-33)**
6. Hals, Tom, and Emily Flitter. “How Two Cutting Edge U.S. Nuclear Projects Bankrupted Westinghouse.” Reuters, May 2, 2017. https://www.reuters.com/article/us-toshiba-accounting-westinghouse-nucle-idUSKBN17Y0CQ. **(pages 34-36)**
7. Lacy, Akela. “South Carolina Spent $9 Billion to Dig a Hole in the Ground and Then Fill It Back In.” *The Intercept*, February 6, 2019. https://theintercept.com/2019/02/06/south-caroline-green-new-deal-south-carolina-nuclear-energy/ **(pages 37-44)**
8. Kastchiev, Georgui, Wolfgang Kromp, Stephan Kurth, David Lochbaum, Ed Lyman, Michael Sailer, and Mycle Schneider. “Residual Risk: An Account of Events in Nuclear Power Plants Since the Chernobyl Accident in 1986.” Brussels: The Greens/European Free Alliance, 2007. **(45-160)**
9. CELA, “Final Comments of the Canadian Environmental Law Association”, CEAR No.07-05-29525, May 2011 [CELA’s 2011 JRP and LPS Comments] **(pages 161-189)**
10. CELA, DNA, Greenpeace Canada, “Application for Review to the Ministry of Municipal Affairs and Housing”, September 26, 2016. **(pages 190-205)**

11. International Atomic Energy Association, Safety Standard for Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants, Safety Guide No. NS-G-3.2, (March 2002) **(pages 206-247)**

12. International Atomic Energy Agency, *Site Evaluation for Nuclear Installations*, IAEA Safety Standards Series No. SSR-1, IAEA, Vienna (2019) (**pages 248-303**)

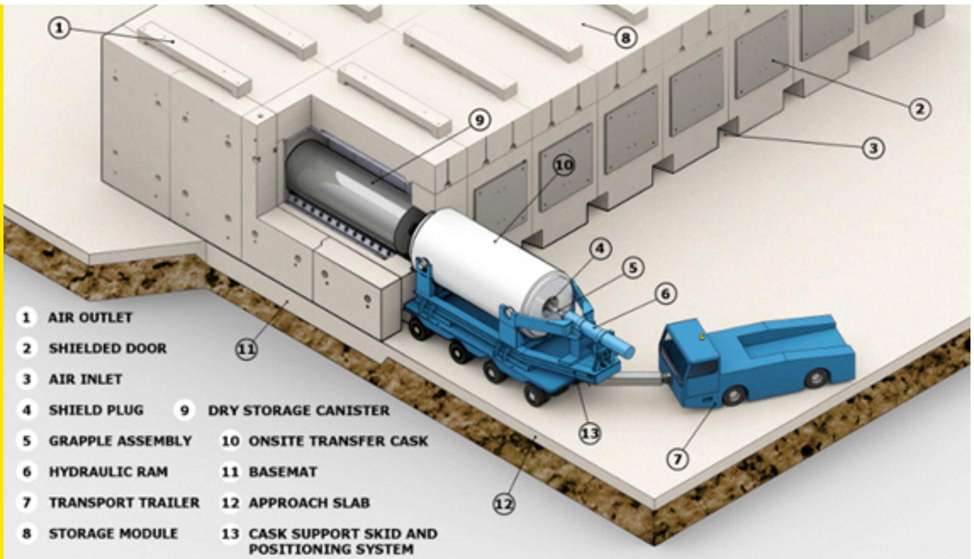
13. Lessons from Fukushima, by Greenpeace (February 2012), online (pdf): https://www.greenpeace.org/usa/research/lessons-from-fukushima/ **(pages 304-355)**

14. Durham Nuclear Awareness, Slovenian Home Association and Canadian Environmental Law Association, "Comments on Ontario Power Generations' Review of the Environmental Impact Statement and Plant Parameter Envelope for the Darlington New Nuclear Project in the Context of the Proposed BWRX-300 Reactor", March 20, 2023 **(pages 356-386)**

15. Masahda Lochan-Aristide, "Blog: Neighbour of a Nuclear Plant – What Residents of Durham Region Should Know About Nuclear Energy" CELA (April 17, 2024), online: https://cela.ca/blog-neighbours-of-a-nuclear-plant-what-residents-of-durham-region-should-know-about-nuclear-energy/ **(pages 387-393)**

Orano TN
Horizontal Dry Storage
Modules

More than 1,500 of our dry fuel storage (DFS) systems have been successfully loaded at 32 sites in the U.S.



Cutaway of canister inside Horizontal Storage Module (HSM) after placement

Options for your specific needs:

HSM-H - Enhanced shielding performance, increased heat rejection capabilities (40.8 kW), and enhanced ruggedness for resisting acts of sabotage.

HSM-HS - A high seismic version of HSM-H, designed for sites with 1.0 g horizontal and 1.0 g vertical seismic accelerations.

BENEFITS

Experienced at different sites and configurations

Earthquake Resistant - up to 1.0 g horizontal and vertical acceleration

Highest shielding performance of any dry storage system in the U.S.

Reduced risk by using horizontal-to-horizontal transfer process

Easy accessibility allows for 100% inspection of stored canister surface and module

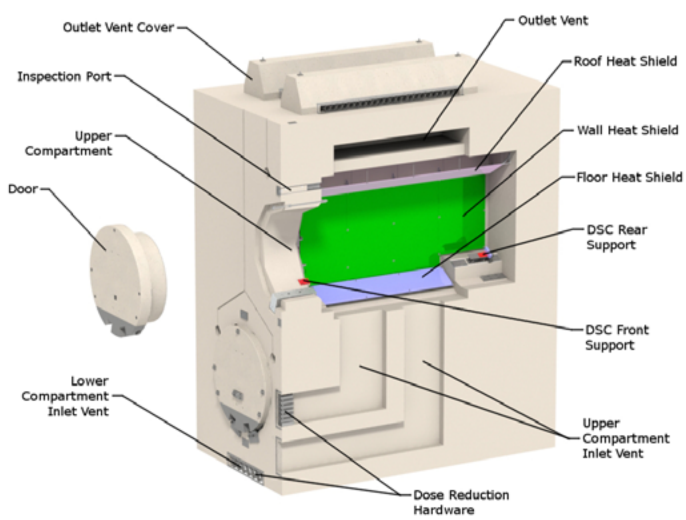
EOS® HSM - Higher heat rejection capabilities (50kW) than the HSM-H or HS, and designed for seismic accelerations of 0.45 g horizontal and 0.33 g vertical.

Matrix® HSM (HSM-MX)
- A dual-level system that addresses space constraints, aging management concerns, dose rates, site excavation costs, and Beyond Design Basis events.

Loading of(HSM-MX, which reduces your ISFSI footprint as much as 45 percent

IDEAL FOR...

...any facility requiring a safe, stable, simple Independent Spent Fuel Storage Installation



The configuration of the NUHOMS Matrix module

Highest Shielding

The self-shielding features of the HSM array results in dose rates that are lower by a factor of 5 or more compared to competing vertical systems. For example, to meet the NRC site boundary annual dose limit of 25 mrem, the EOS system estimates 1,150 ft, whereas the competing systems require 1,560 ft, or greater.

Dry Shielded Canisters

NUHOMS® canisters are constructed using alloy steel, aluminum, and metal matrix composite (MMC) plates. Geometric spacing, fixed neutron absorbers, and soluble boron (for PWR) are used to maintain criticality control for enrichments up to 5.0% ^{235}U. The canister shells can be fabricated from three different types of stainless steel to account for varying corrosive environments.

Earthquake Resistant

Orano's NUHOMS system has successfully withstood significant earthquakes. Its low profile, array structure, and horizontal position ensure stability. The NUHOMS system is the highest seismically qualified dry fuel storage system in the world.

Flooding and Tornado Risks

Orano's NUHOMS system has safely operated through tornado events. Our impact design analysis criteria examples include withstanding the impacts of a 275 lb steel pipe traveling more than 105 mph, a 275 lb armor-piercing artillery shell at 125 mph, and a 4,000 lb. automobile traveling more than 133 mph (equivalent to a full-size pickup truck).

Even when submerged, Orano's robust NUHOMS dry storage system is designed to maintain its secure storage, stability, and cooling. Watch video simulation.

Accessible and Retrievable

NUHOMS canisters are easy to retrieve and move due to their stable horizontal orientation. This allows for lower doses during the fuel loading process, as it takes less time to move the canister, and makes it easy to retrieve to transport off site.

Watch a complete inspection of the NUHOMS module and canister.

Orano TN offers a variety of Dry Shielded Canisters for the storage of high-capacity, high-burnup, and high-heat load systems, and are compatible with the HSM systems.

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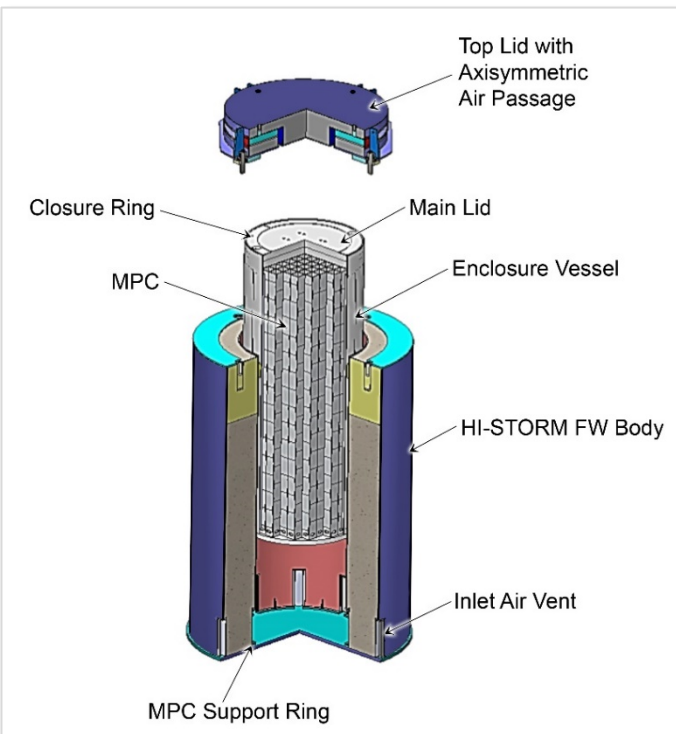
HI-STORM FW® Vertical Ventilated Storage System

HOLTEC INTERNATIONAL

The **H**oltec **I**nternational **Stor**age **M**odule **F**lood and **W**ind (HI-STORM FW) system is Holtec International's USNRC-licensed, highest capacity canister-based system for storage of spent nuclear fuel (NRC Docket No. 72-1032). The design details of the HI-STORM FW System have been guided by two decades of research and technology development by Holtec International. The canister, known as the multi-purpose canister (MPC), is licensed by the USNRC for transportation in the HI-STAR 190 transportation overpack (NRC Docket No. 71-9373). Holtec's dry cask storage technology is predicated on providing our clients with an integrated solution for all stages of spent fuel management in a safe and secure manner that limits the dose to the public and employees. In use at over 60% of the operating nuclear units in the United States, there are more than 1,200 Holtec dry storage systems loaded.

HI-STORM FW on VCT at a U.S. Nuclear Plant



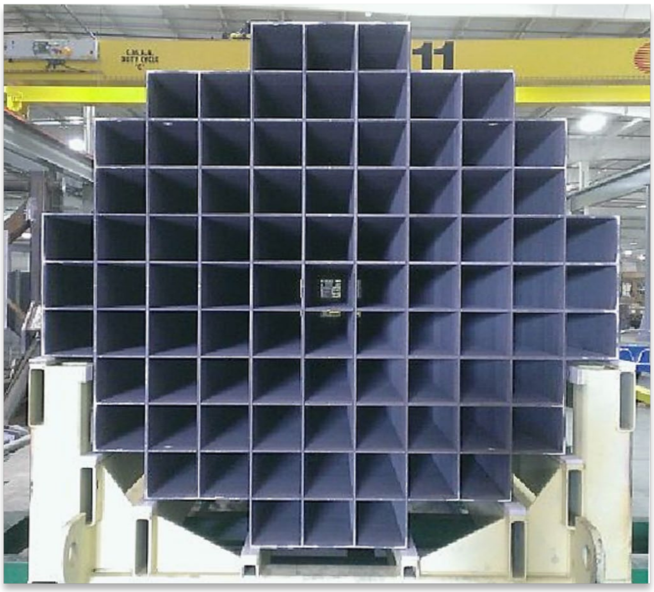
HI-STORM FW Overpack and MPC Shown in Partial Cutaway View

The HI-STORM FW system consists of interchangeable sealed MPCs, which contain the fuel, a vertically ventilated storage overpack constructed from a combination of steel and concrete which protects the MPC during storage, and a variable weight transfer cask (HI-TRAC VW) which contains the MPC during loading, unloading, and transfer operations. The variable weight allows for maximum shielding for any given crane lifting capacity (up to 130 tons). The surveillance and maintenance required by the plant's staff is minimized since the system is completely passive and is composed of proven materials.

The HI-STORM FW system can safely store up to 37 PWR or 89 BWR fuel assemblies in the MPC-37 or MPC-89, respectively, including damaged fuel, fuel debris, BWR fuel with and without channels, and other non-fuel hardware. The MPC external diameters are identical to allow the use of a single overpack, transfer, and transportation cask design.

The steel exterior of the HI-STORM FW overpack protects the stored contents from natural and manmade projectiles including an F-16 plane impact. The steel exterior of the overpack ensures no spalling of concrete is possible as there is with dry storage systems employing exposed concrete. No rebar is used in the plain concrete; this feature eliminates the development of cracks which cause radiation streaming paths and also makes on-site assembly a simple process.

The entire basket is manufactured from the neutron absorber material, Metamic®-HT, that serves the dual function of structural integrity and criticality control. Manufactured by laser-cut slotted plates of extruded Metamic-HT panels, there are no bends or radii at the cell corners, no internal welds, and large cell openings to ensure ease of fuel assembly insertion, even severely deformed fuel. Since Metamic-HT is the sole material of the basket, concerns regarding interaction of coated carbon steel materials and various MPC operating environments are not applicable; there is no risk of corrosion or hydrogen generation from the fuel basket material.



Metamic®-HT Basket (MPC-89)

The use of Metamic®-HT and its vertical orientation allow HI-STORM FW to accommodate total high heat load, high heat load per assembly, and short cooling time, making it ideal for the defueling of Part 50 facilities as promptly as possible and assisting with long term spent fuel management. "One MPC fits all," meaning that there is one basket design regardless of fuel type, initial enrichment, or burnup. All locations of the MPC basket are usable regardless of fuel type, initial enrichment, or burnup.

The height of the MPC cavity can be customized for each fuel type to be stored in it. Accordingly, the height of the HI-STORM FW overpack and the height and weight of the HI-TRAC VW transfer cask are optimized for the fuel length. The weight savings afforded by the reduced equipment height is directly translated into additional shielding in the HI-TRAC VW. Benefits include minimized dose to loading personnel and the prevention of expensive plant modifications.

HI-STORM FW System – General Information

	MPC-37	MPC-89
Number of Assemblies	37	89
Maximum Heat-Load (System)	45 kW	46.36 kW
Maximum Heat-Load Per Assembly	3.20 kW (pending approval)	1.45 kW (pending approval)
Maximum Initial Enrichment	5 w% U-235	4.8 w% U-235 (Planar-Avg.)
Maximum Acceptable Fuel Burnup	68,200 MWd/MTU	65,000 MWd/MTU
Minimum Fuel Cooling Time	1 year (pending approval)	1 year (pending approval)
Non-Fuel Hardware Approved Contents	Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Devices (TPD), Control Rod Assemblies (CRAs), Axial Power Shaping Rods (APSRs), Wet Annular Burnable Absorbers (WABAs), Rod Cluster Control Assemblies (RCCAs), Control Element Assemblies (CEAs), Instrument Tube Tie Rods (ITTRs), Water Displacement Guide Tube Plugs, and Orifice Rod Assemblies.	With or Without Fuel Channels
No. of Damaged Fuel Assemblies	Up to 12 damaged fuel assemblies per system	Up to 16 damaged fuel assemblies per system

NAC Solutions:

MAGNASTOR® — Proven, High Capacity Spent Fuel Management

NAC INTERNATIONAL

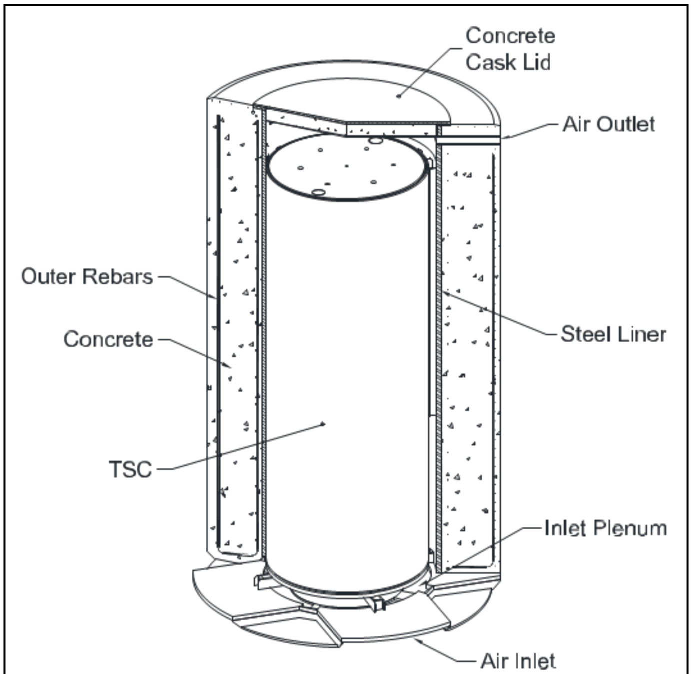
Features

MAGNASTOR incorporates unique design, fabrication, and operations features. Among these are:

- a developed-cell basket design that increases spent fuel capacities and simplifies fabrication, while providing high strength and excellent heat removal
- a unique canister closure design that improves welding time, reduces personnel dose,a nd enhances drying performance
- a low-profile vertical concrete cask design to improve on-site handling and site dose rates, with proven, simple construction and operations features; also maintains robustness against beyond-design-basis threats
- a simple, proven transfer system that facilitates transfer without excessive dose or handling
- a new, effective and efficient approach to water removal and canister drying

MAGNASTOR System Key Design Parameters	
Fuel-Specific Data	**PWR / BWR**
Maximum Assembly Capacity:	37 / 87
Thermal Capacity:	Storage: 35.5 kW / 33 kW (design 40 kW) Transport: 24 kW nitial license
Fuel Cool Time:	Storage: Three years minimum* Transport: To meet maximum heat loads
Fuel Initial Enrichment:	5.0 wt % / 4.5% wt % U-235 maximum
Fuel Burnup (Assembly Avg.):	60 GWD/MTU maximum
Key System Dimensions	**PWR / BWR**
VCC Length:	Standard: 225 inches Segmented Body: 204 inches
VCC Outer Diameter:	136 inches
Canister Cavity Length:	Type 1/3—173 inches Type 2/4—180 inches
Internal Cavity Diameter:	71 inches
Overall Canister Length:	Type 1/3—173 inches Type 2/4—180 inches
Canister Shell Thickness:	0.5 inches
Max. Weight on Crane Hook:	114.25 tons / 114.75 tons
Max. Weight on ISFSI Pad:	160 tons / 161 tons

*MAGNASTOR CoC Amendment 5 includes a unique regionalized loading zone for spent fuel with three years cool time.



Vertical Concrete Cask Components

Cost Savings

MAGNASTOR design enhancements drive the following dry storage cost savings:

- capital and operational costs per assembly substantially reduced for the long terms
- greater savings in life cycle costs for dry storage when considering turnkey fleet implementation program
- system fabricability and construction have been fine-tuned to reduce costs as compared to earlier designs
- mechanical assembly assures low risk, high quality and predictable fabrication and construction

Improved Operations

Other MAGNASTOR improved operational features include:

- simple, easy-to-install lid system—final closure operations and personnel exposures can be greatly reduced
- the transfer cask has improved operations and maintenance features
- concrete cask design increases ingress and egress capabilities, while simplifying site handling and operations

NRC Proposes to Certify Westinghouse Electric Company's AP600 Reactor Design

	NRC NEWS U. S. NUCLEAR REGULATORY COMMISSION	
	Office of Public Affairs	Telephone: 301/415-8200
	Washington, DC 20555-001	E-mail: opa@nrc.gov

No. 99-100
May 14, 1999

NRC PROPOSES TO CERTIFY WESTINGHOUSE ELECTRIC COMPANY'S AP600 REACTOR DESIGN

The Nuclear Regulatory Commission is proposing to amend its regulations to certify the AP600 standard plant design developed by the Westinghouse

Electric Company. The certification would be the third to be issued under the NRC's new licensing process for standard design certification and would be valid for 15 years.

The public is invited to submit comments on the proposed design certification rule, the AP600 design control document submitted by Westinghouse which has been incorporated into the NRC rule, and the environmental assessment of the AP600 design. Interested parties also may request an informal hearing. Both comments and hearing requests on the proposed rule change should be filed within 75 days of publication of a notice on the AP600 which will be published shortly in the Federal Register.

Last fall, the NRC issued a final design approval for the Westinghouse AP600 plant, completing the staff's technical review of the application for design certification received in 1992. This step permitted the staff to begin the administrative, or rulemaking, phase.

The AP600 design is for a nuclear power plant that would be capable of producing 600 megawatts of electricity. The plant, which can be assembled from modular components, features enhanced safety systems that rely on gravity and pressure differentials to safely shut the reactor down or mitigate the effects of an accident. It is designed for a 60-year operating life.

If certified by the Commission, a utility that wishes to build and operate a new nuclear power plant could choose to use the design and reference it in an application for a license. Safety issues within the scope of the certified design would not be subject to litigation, although site-specific environmental impacts associated with building and operating the plant at a particular location would be.

Future applicants for a license could make plant-specific changes to portions of the AP600 standard design by following the procedures set out in the design certification rule. The applicant would be required to maintain records of all such changes until the license is terminated.

No application for a license using the AP600 standard design has been filed with the NRC.

Written comments as well as hearing requests on the proposed amendment to 10 CFR Part 52 should be addressed to the Secretary, U.S. Nuclear Regulatory Commission, Washington, D.C., 20555-0001, ATTN: Rulemakings and Adjudications staff. Comments may also be submitted via the NRC's electronic rulemaking website at http://www.nrc.gov. Select "rulemaking" from the tool bar and then "rulemaking forum." In addition to NRC, a copy of each hearing request must be sent by overnight mail to Brian A. McIntyre, Manager, Advanced Plant Safety and Licensing, Westinghouse Electric Co., P.O.B. 355, Pittsburgh, PA 15230-0355.

Page Last Reviewed/Updated Thursday, March 25, 2021

1. INTRODUCTION AND GENERAL DISCUSSION

1.1 Introduction

On March 28, 2002, Westinghouse Electric Company (hereinafter referred to as Westinghouse or the applicant) tendered its application for certification of the AP1000 standard nuclear reactor design with the U.S. Nuclear Regulatory Commission (the NRC or Commission). The applicant submitted this application in accordance with Title 10 of the Code of Federal Regulations (10 CFR) Part 52, Subpart B, “Standard Design Certifications,” and 10 CFR Part 52, Appendix O, “Standardization of Design: Staff Review of Standard Designs.” The application included the AP1000 Design Control Document (DCD) and the AP1000 Probabilistic Risk Assessment (PRA). The NRC formally accepted the application as a docketed application for design certification (Docket No. 52-006) on June 25, 2002. Information submitted before that date is associated with Project No. 711.

The applicant originally submitted the AP1000 DCD on March 28, 2002. The DCD information is divided into two categories, denoted as Tier 1 and Tier 2. Tier 1 means the portion of the generic design-related information that is proposed for approval and certification, including, among other things, the inspections, tests, analyses and acceptance criteria (ITAAC). Tier 2 means the portion of the generic design-related information proposed for approval but not certification. Tier 2 information includes, among other things, a description of the design of the facility required for a final safety analysis report by 10 CFR 50.34. Subsequently, the applicant supplemented the information in the DCD by providing revisions to that document. The applicant submitted the most recent version, DCD Revision 14, to the Commission on September 7, 2004. Similarly, the applicant originally submitted the PRA on March 28, 2002. The most recent revision of this report, Revision 8, was submitted by letter dated August 2, 2004. In addition, throughout the course of the review, the NRC staff (staff) requested that the applicant submit additional information to clarify the description of the AP1000 design. Some of the applicant’s responses to these requests for additional information (RAIs) are discussed throughout this report. Appendix E to this report provides a listing of the issuance and response dates for each RAI the staff submitted to the applicant. The DCD, PRA, Tier 1 information, and all other pertinent information and materials are available for public inspection at the NRC Public Document Room and the Agencywide Documents Access and Management System Public Electronic Reading Room (ADAMS).

This final safety evaluation report (FSER) summarizes the staff’s safety review of the AP1000 design against the requirements of 10 CFR Part 52, Subpart B, and delineates the scope of the technical details considered in evaluating the proposed design. In addition, this FSER documents the resolution of the open and confirmatory items identified in the draft safety evaluation report (DSER) for the AP1000 design, issued on June 16, 2003. Appendix G to this report includes a copy of the report by the Advisory Committee on Reactor Safeguards (ACRS) required by 10 CFR 52.53, “Referral to the ACRS.”

As described above, the applicant supplemented the information in the DCD by providing revisions to the document. The staff’s review of these revisions to determined their impact on the conclusions in this FSER was Open Item 1.1-1 in the DSER. The staff has completed its review of the most recent version of the DCD, as documented throughout this report, and for the reasons set forth herein, finds it to be acceptable. Therefore, Open Item 1.1-1 is resolved.

Sections 1.2 and 1.3 of this report summarize the AP1000 design. Section 1.4 of this report identifies the agents and contractors who provided design services to the applicant or other support for the design. Section 1.5 of this report provides a discussion of the principal matters that the staff reviewed.

1.1.1 Metrication

This report conforms to the Commission's policy statement on metrication published in the Federal Register on June 19, 1996. Therefore, all measures are expressed as metric units, followed by English units in parentheses. The unit of air volume flow was converted from standard cubic feet per minute at 14.7 psia and 68 °F to standard cubic meters per hour at 760 mmHg and 0 °C.

1.1.2 Proprietary Information

This report references several Westinghouse reports. Some of these reports contain information that the applicant requested be held exempt from public disclosure, as provided by 10 CFR 2.790, "Public Inspections, Exemptions, Requests for Withholding." For each such report, the applicant provided a nonproprietary version, similar in content except for the omission of the proprietary information. The staff predicated its findings on the proprietary versions of these documents, which are primarily referenced throughout this report.

1.1.3 Combined License Applicants Referencing the AP1000 Design

Applicants who reference the AP1000 standard design in the future for specific facilities will retain architect-engineers, constructors, and consultants, as needed. As part of its review of an application for a combined license (COL) referencing the AP1000 design, the staff will evaluate, for each plant-specific application, the technical competence of the COL applicant and its contractors to manage, design, construct, and operate a nuclear power plant. COL applicants will also be subject to the requirements of 10 CFR Part 52, Subpart C, "Combined Licenses," and any requirements resulting from the staff's review of this standard design. Throughout the DCD, the applicant identified matters to be addressed by plant-specific applicants as "Combined License Information." This report refers to such matters as "COL Action Items" throughout. Appendix F to this report provides a cross-reference between the COL action items identified in this report and the COL information referred to in the DCD.

1.1.4 Additional Information

Appendix A to this report provides a chronology of the principal actions, submittals, and amendments related to the processing of the AP1000 application. Appendix B of this report provides a list of references identified in this report. Appendix C of this report provides a list containing definitions of the acronyms and abbreviations used throughout this report. Appendix D of this report lists the principal technical reviewers who evaluated the AP1000 design. Appendix E of this report provides an index of the staff's RAIs and the applicant's responses. Appendix F of this report provides a cross-reference of the COL information in the DCD, FSER, and COL action items. Appendix G of this report includes a copy of the letter received from the ACRS providing the results of its review of the AP1000 design.

The NRC licensing project managers assigned to the AP1000 standard design review are Mr. John P. Segala, Mr. Joseph Colaccino, Mr. Steven D. Bloom, and Ms. Lauren M. Quinones-Navarro. They may be reached by calling (301) 415-7000, or by writing to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, DC 20555-0001.

1.2 General Design Description

1.2.1 Scope of the AP1000 Design

The requirement that governs the scope of the AP1000 design can be found in 10 CFR 52.47(b)(2)(i)(A)(4), which requires that an applicant for certification provide a complete design scope, except for site-specific elements. Therefore, the scope of the AP1000 design must include all of the plant structures, systems, and components that can affect the safe operation of the plant, except for its site-specific elements. The applicant described the AP1000 standard design scope in DCD Tier 2, Section 1.8, "Interfaces for Standard Design," including the site-specific elements that are either partially or wholly outside of the standard design scope. The applicant also described interface requirements (see DCD Tier 2, Table 1.8-1, "Summary of AP1000 Plant Interfaces with Remainder of Plant") and representative conceptual designs, as required by 10 CFR 52.47(a)(1)(vii) and 10 CFR 52.47(a)(1)(ix), respectively.

1.2.2 Summary of the AP1000 Design

The AP1000 design has a nuclear steam supply system (NSSS) power rating of 3415 megawatt thermal (MWt), with an electrical output of at least 1000 megawatt electric (MWe). The plant is designated for rated performance with up to 10 percent of the steam generator (SG) tubes plugged and with a maximum hot-leg temperature of 321.1 °C (610 °F). The plant is designed to accept a step-load increase or decrease of 10 percent between 25- and 100-percent power without reactor trip or steam dump system actuation, provided that the rated power level is not exceeded. In DCD Tier 2, Section 1.2, "General Plant Description," the applicant also indicated that the plant is designed to accept a 100-percent load rejection from full power to house loads without a reactor trip or operation of the pressurizer or SG safety valves. The goal for the overall plant availability is projected to be greater than 90 percent, considering all forced and planned outages, with a rate of less than one unplanned reactor trip per year. The applicant stated that the plant has a design objective of 60 years without a planned replacement of the reactor vessel. However, the design does provide for replaceability of other major components, including the SG. The following is a general description of the AP1000 design. Subsequent sections of this report provide detailed descriptions of the individual systems that make up the AP1000 design.

1.2.2.1 Reactor Coolant System Design

The AP1000 reactor coolant system (RCS) is designed to effectively remove or enable removal of heat from the reactor during all modes of operation, including shutdown and accident conditions.

The system consists of two heat transfer circuits, each with the following components:

- an SG
- two reactor coolant pumps (RCPs)
- a single hot-leg
- two cold-legs

In addition, the system includes a pressurizer, interconnecting piping, valves, and the instrumentation necessary for operational control and safeguards actuation. All of the system equipment is located within the reactor containment. Figure 1.2-1 of this report shows a diagram of the AP1000 RCS.

Operation of the pressurizer controls the reactor system pressure. The spring-loaded safety valves installed on the pressurizer provide overpressure protection for the RCS. These safety valves discharge to the containment atmosphere. The valves for the first three stages of automatic depressurization are also mounted on the pressurizer. These valves discharge steam through spargers to the in-containment refueling water storage tank (IRWST) of the passive core cooling system (PXS). The discharged steam is condensed and cooled by mixing with water in the tank.

The following auxiliary systems interface with the RCS:

- chemical and volume control system (CVS)
- component cooling water system
- liquid radwaste system
- primary sampling system
- PXS
- spent fuel pit cooling system
- SG system

1.2.2.2 Reactor Design

An AP1000 fuel assembly consists of 264 fuel rods in a 17x17 square array. The fuel grids consist of an eggcrate arrangement of interlocked straps that maintains lateral spacing between the rods. The fuel rods consist of enriched uranium, in the form of cylindrical pellets of uranium dioxide, contained in ZIRLO tubing. The tubing is plugged with seals welded at the ends to encapsulate the fuel. An axial blanket comprised of fuel pellets with reduced enrichment may be placed at each end of the enriched fuel pellet stack to reduce the neutron leakage and improve fuel utilization. Other types of fuel rods may be used to varying degrees within some fuel assemblies. One type uses an integral fuel burnable absorber containing a thin boride coating on the surface of the fuel pellets. Another type uses fuel pellets containing gadolinium oxide mixed with uranium oxide. The boride-coated fuel pellets and gadolinium oxide/uranium oxide fuel pellets provide burnable absorber integral to the fuel.

The applicant stated that the reactor core is designed for an 18-month fuel cycle. A core design is maintained for projected fuel cycles. The reactor core is located low in the vessel to minimize core temperature during a postulated loss-of-coolant accident (LOCA). The core is designed to have a moderator temperature coefficient that is nonpositive over the entire fuel cycle and at any power level, with the reactor coolant at the normal operating temperature. The core design provides an adequate margin so that departure from nucleate boiling will not occur with a 95 percent probability and 95 percent confidence basis for all Condition I and II events. No vessel penetrations exist below the top of the core because the AP1000 does not use bottom-mounted in-core instrumentation. In addition, the design employs an integrated head package that consists of the following components:

- control rod drive mechanisms
- integrated head cooling fans
- instrument columns
- insulation
- seismic support
- package lift rig

A permanent, welded-seal ring provides the seal between the vessel flange and the refueling cavity floor.

1.2.2.3 Steam Generator Design

The AP1000 design uses the Model Delta 125 SG, which employs thermally treated, nickel-chromium-iron Alloy 690 tubes and a steam separator area sludge trap with clean-out provisions. The channel head is designed to directly attach the two RCPs, and to allow both manual and robotic access for inspection, plugging, sleeving, and nozzle dam placement operations.

1.2.2.4 Reactor Coolant Pump Design

The four AP1000 RCPs are hermetically sealed canned pumps. Two RCPs are attached directly to the SG channel head with the motor located below the channel head to simplify the loop piping and eliminate fuel uncovery during postulated small-break LOCA scenarios. Each RCP includes sufficient internal rotating inertia to permit coastdown to avoid departure from nucleate boiling following a postulated loss-of-coolant flow accident. Each pump impeller and diffuser vane is ground and polished to minimize radioactive crud deposition and maximize pump efficiency. The RCPs are designed such that they are not damaged due to a loss of all cooling water for the period up to and including a safety-related pump trip on high-bearing water temperature. This automatic protection is provided to protect the RCPs from an extended loss of coolant water.

1.2.2.5 Pressurizer and Loop Arrangement

The pressurizer is a vertical, cylindrical vessel with hemispherical top and bottom heads. One spray nozzle and two nozzles for connecting the safety and depressurization valve inlet headers are located in the top head. Electrical heaters are installed through the bottom head. The piping layouts for the AP1000 are designed to provide adequate thermal expansion flexibility, assuming a fixed vessel and a free-floating SG/RCP support system. The reactor coolant loop and surge line piping are designed to leak-before-break criteria. The pressurizer itself is designed such that the power-operated relief valve function is neither required nor provided, given the AP1000 design spray flow rates.

1.2.2.6 Steam and Power Conversion System Design

Turbine Generator

The AP1000 turbine generator design consists of a double-flow, high-pressure cylinder (high-pressure turbine) and three double-flow, low-pressure cylinders (low-pressure turbines) that exhaust to the condenser. It is a six-flow, tandem-compound, 1800-rpm machine. The turbine system includes the following components:

- stop, control, and intercept valves directly attached to the turbine and in the steam-flow path

- crossover and cross under piping between the turbine cylinders and the moisture separator reheaters

The high-pressure turbine has extraction connections for one stage of feedwater heating, and its exhaust provides steam for one stage of feedwater heating in the deaerator. The low-pressure turbines have extraction connections for four stages of feedwater heating.

Two moisture separator reheaters are located between the high-pressure turbine exhaust and the low-pressure turbine inlet. The moisture separator reheater, an integral component of the turbine system, extracts moisture from the steam and then reheats the steam to improve turbine system performance. The reheater has two stages of reheat.

The turbine is oriented in a manner that minimizes potential interactions between turbine missiles and safety-related structures and components.

Main Steam System

The main steam system is designed to supply steam from the SG to the high-pressure turbine over a range of flows and pressures for the entire plant operating range. The main steam system is also designed to dissipate the heat generated by the NSSS to the condenser through the steam dump valves, or to the atmosphere through power-operated atmospheric relief valves or spring-loaded main steam safety valves, when either the turbine generator or the condenser is not available. There are two steam headers, with each one utilizing six SG safety valves.

Main Feedwater and Condensate System

The main feedwater system is designed to supply the SGs with adequate feedwater during all modes of plant operation, including transient conditions. The condensate system is designed to condense and collect steam from the low-pressure turbines and turbine bypass systems, and then to transfer this condensate from the main condenser to the deaerator. The applicant stated that the main feedwater and condensate systems are designed for increased availability and improved dissolved oxygen control.

1.2.2.7 Engineered Safeguards Systems Design

The engineered safeguards systems include the following systems and components. Figure 1.2-2 of this report shows some of the passive safety features, including the containment, the passive containment cooling system (PCS), and the PXS.

- The containment vessel is a free-standing, cylindrical steel vessel. Its engineered safety feature (ESF) function is to contain the release of radioactivity following a postulated design-basis accident (DBA). The containment vessel provides shielding for the reactor core and the RCS during normal operation. It also functions as the safety-related ultimate heat sink for the removal of the RCS sensible heat, core decay heat, and stored energy.

- The PCS consists of the following components:

    - a passive containment cooling water storage tank that is incorporated in the shield building structure above the containment

    - an air baffle that is located between the steel containment vessel and the concrete shield building

    - air inlet and exhaust paths that are incorporated in the shield building structure

    - a water distribution system

    - an ancillary water storage tank and two recirculation pumps for onsite storage of additional PCS cooling water

    Upon actuation, the PCS delivers water to the top, external surface of the steel containment shell, which forms a film of water over the dome and side walls of the containment structure. Air is induced to flow over the containment as it is heated, causing a chimney effect. This air flow and cooling water evaporation removes the heat generated within the containment and expels it to the outside air. The applicant stated that the PCS maintains the containment pressure and temperature within the appropriate design limits for both DBA and severe accident scenarios. Figure 1.2-3 of this report shows the PCS.

- The major function of the containment isolation system is to provide containment isolation to allow the normal or emergency passage of fluids through the containment boundary while preserving the integrity of the containment boundary. This function prevents or limits the escape of fission products that may result from postulated accidents. In the event of an accident, the containment isolation provisions are designed so that fluid lines penetrating the primary containment boundary are isolated. The containment isolation system consists of the piping, valves, and actuators that isolate the containment.

- The containment hydrogen control system controls the hydrogen concentration in the containment so that containment integrity is not endangered. It consists of the hydrogen monitoring system, passive autocatalytic hydrogen recombiners, and hydrogen ignitors.

- The PXS provides emergency core cooling following postulated design-basis events. The PXS is comprised of the following components:
  - two core makeup tanks
  - two accumulators
  - the IRWST
  - a passive residual heat removal (PRHR) heat exchanger
  - pH adjustment baskets
  - associated piping and valves

- The automatic depressurization system (ADS), which is part of the RCS, provides important passive core cooling functions by depressurizing the RCS. The PXS system provides emergency core cooling following a postulated DBA by providing (1) RCS makeup water and boration when the normal makeup supply is lost or insufficient, (2) safety injection to the RCS to ensure adequate core cooling during a postulated DBA, and (3) core decay heat removal during transients and accidents. Figure 1.2-4 of this report shows the safety injection systems.

- The main control room (MCR) emergency habitability system is comprised of a set of storage tanks connected to a main and an alternate air delivery line. Components common to both lines include a manual isolation valve, a pressure-regulating valve, and a flow metering orifice. This system is designed to provide the ventilation and pressurization needed to maintain a habitable environment in the MCR for 72 hours following any DBA.

In DCD Tier 2, Section 1.2.1.4.1, "Engineered Safeguards Systems Design," the applicant stated that the engineered safeguards systems are designed to mitigate the consequences of DBAs with a single failure. With the exception of the MCR emergency habitability system, the passive safety systems are designed to cool the RCS from normal operating temperatures to safe-shutdown conditions. In addition, all of these systems are designed to maximize the use of natural driving forces, such as pressurized nitrogen, gravity flow, and natural circulation flow. They do not rely on active components such as pumps, fans, or diesel generators to function. These systems do, however, use valves to initially align the safety systems when activated. In addition, the safety systems are designed to function without safety-related support systems, such as alternating current; component cooling water; service water; or heating, ventilation, and air conditioning (HVAC).

The design of the AP1000 minimizes the number and complexity of operator actions needed to control the safety systems. To meet this objective, the approach was to eliminate the action, rather than automating it.

The automatic RCS depressurization feature included in the design meets the following criteria:

- The reliability (redundancy and diversity) of the ADS valves and controls satisfies the single-failure criterion as well as the failure tolerance called for by the low core melt frequency goals.

- The design provides for both real demands (i.e., RCS leaks and failure of the CVS makeup pumps) and spurious instrumentation signals. The probability of significant flooding of the containment due to the use of the ADS is less than once in 600 years.

The design is such that, for small-break LOCA up to 20.32 cm (8 in.) in diameter, the core remains covered.

Non-Safety-Related Systems Designs

The applicant stated that the non-safety-related systems used in the AP1000 are not relied on to provide safety functions needed to mitigate DBAs. The AP1000 includes active systems that provide defense-in-depth (DID) (or investment protection) capabilities for RCS makeup and decay heat removal. These active systems are the first line of defense to reduce challenges to the passive systems in the event of transients or plant upsets. Most active systems in the AP1000 are designated as non-safety-related.

Examples of non-safety-related systems that provide DID capabilities for the AP1000 design include the CVS, normal residual heat removal system, and the startup (backup) feedwater system. For these DID systems to operate, the associated systems and structures to support these functions must also be operable, including the non-safety-related standby diesel generators, the component cooling water system, and the service water system. The AP1000 also includes other active systems, designated as non-safety-related, such as the HVAC system which removes heat from the instrumentation and control (I&C) cabinet rooms and the MCR to limit challenges to the passive safety capabilities for these functions.

In existing plants, as well as in the evolutionary advanced light-water reactor (ALWR) designs, many of these active systems are designated as safety-related. However, by virtue of their designation in the AP1000 design as non-safety-related, credit is generally not taken for the active systems in DCD Tier 2, Chapter 15, “Accident Analyses,” licensing DBA analyses, except in certain cases in which operation of a non-safety-related system could make an accident worse.

The residual uncertainties associated with passive safety system performance increase the importance of active non-safety-related systems in providing DID functions to the passive systems. These active systems are not required to meet all of the criteria imposed on safety-related systems, but the staff does expects a high level of confidence that active systems which have a significant safety role will be available when challenged. As discussed in SECY-94-084, “Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Design,” issued March 28, 1994, a process was developed for maintaining appropriate regulatory oversight of these active systems in passive ALWR designs. In a staff requirements memorandum (SRM) dated June 30, 1994, the Commission approved the recommendations made in SECY-94-084 concerning the issue of regulatory treatment of non-safety-related systems (RTNSS). Chapter 22 of this report summarizes the staff’s evaluation of RTNSS.

1.2.2.8 Instrumentation and Control System and Electrical System Designs

Control and Protection Systems Designs

The AP1000 control and protection systems are significantly different from I&C systems in operating reactor designs. In particular, the AP1000 employs digital, microprocessor-based I&C systems, instead of the analog electronics, relay logic, and hard-wired systems currently used in most operating plants. In DCD Tier 2, Section 1.2.1.5.1, “Control and Protection Systems Design,” the applicant stated that the design of the control and protection systems ensures that a single failure in the I&C system will not result in a reactor trip or ESF actuation during normal operation. As compared to currently operating plants, the design is intended to reduce the potential for a reactor trip and a safeguards actuation because of failures in the reactor control or protection systems.

The AP1000 design minimizes the number of measured plant variables used for reactor trip and for safeguards actuation relative to currently operating plants. The margin between the normal operating condition and the protection system setpoints is increased relative to currently operating plants. The potential for interaction between the protection and safety monitoring system (PMS) and the plant control system is reduced, relative to currently operating plants by incorporating a signal selector function that selects signals for control and for protection.

The AP1000 I&C systems are comprised of the following major systems:

- PMS
- special monitoring system (SMS)
- plant control system (PLS)
- diverse actuation system (DAS)
- operation and control centers system (OCS)
- data and display processing system (DDS)
- incore instrumentation system (IIS)

The PMS monitors plant processes using a variety of sensors; performs calculations, comparisons, and logic functions based on those sensor inputs; and actuates a variety of equipment. The PMS provides the safety-related functions necessary to control the plant during normal operation, to shut down the plant, and to maintain the plant in a safe-shutdown condition. The PMS is also used to operate safety-related systems and components.

The SMS consists of specialized subsystems that interface with the I&C architecture to provide diagnostic and long-term monitoring functions.

The PLS (1) controls and coordinates the plant during start-up, ascent to power, power operation, and shutdown conditions, (2) integrates the automatic and manual control of the reactor, reactor coolant, and various reactor support processes for specified normal and off-normal conditions, (3) controls the non-safety-related decay heat removal systems during shutdown, and (4) permits the operator to control plant components from the MCR or remote shutdown workstation.

The DAS provides a backup to the PMS for some specific diverse automatic actuation and provides diverse indications and controls to assist in operator manual actions. The DAS is a

DID system that is also designed to provide essential protection functions in the event of a postulated common-mode failure of the PMS.

The OCS includes the complete operational scope of the MCR, remote shutdown workstation, technical support center, local control stations, and the emergency operations facility.

The DDS comprises the equipment used for processing data that result in non-safety-related alarms and displays for both normal and emergency plant operations.

The IIS provides a three-dimensional flux map of the reactor core. It also provides the PMS with in-core thermocouple signals to monitor the adequacy of postaccident core cooling.

Alternating and Direct Current Power Designs

All safety-related electrical power is provided from the Class 1E direct current (dc) power system. The AP1000 does not include a separate safety-related alternating current (ac) power system. Safety-related dc power is provided to support reactor trip and engineered safeguards actuation. Batteries are sized to provide the necessary dc power and uninterruptable ac power for items such as PMS system actuation; control room functions including habitability; actuation of dc-powered valves in the passive safety systems; and containment isolation.

Main Control Room Design

The MCR controls the plant during normal and anticipated transients, as well as DBAs. It includes indications and controls that are capable of monitoring and controlling the plant safety systems and the non-safety-related control systems. The MCR contains the safety-related I&C to allow the operator to achieve and maintain safe shutdown following any DBA.

During normal operation, the MCR is serviced by redundant, non-safety-related power sources and HVAC systems. In the event that either the normal power source or the HVAC system becomes unavailable, the applicant has stated that passive systems (batteries and compressed air) will be available to support MCR operation for up to three days. The safety-related power sources and passive cooling system are designed to provide a habitable environment for the operating staff, assuming that no ac power is available. By using a passive cooling system, the safety-related instrumentation (equipment racks) is maintained at acceptable ambient conditions for three days following a loss of all ac power. After three days, it will be possible to continue operation with the control room cooled and ventilated by the natural circulation of outside air.

The operators can transfer control from the MCR to the remote shutdown workstation should the MCR become uninhabitable. The remote shutdown workstation contains the safety-related indications and controls that allow an operator to achieve and maintain safe shutdown of the plant following an event when the MCR is unavailable.

1.2.2.9 Plant Arrangement

The AP1000 plant is arranged with the following principal building structures:

- the nuclear island
- the turbine building
- the annex building
- the diesel generator building
- the radwaste building

The nuclear island is structurally designed to meet seismic Category I requirements in accordance with the guidance in Regulatory Guide 1.29, “Seismic Design Classification.” The nuclear island consists of the following buildings:

- a free-standing steel containment building
- a concrete shield building
- an auxiliary building

The nuclear island is designed to withstand the effects of postulated internal events such as fires and flooding without loss of capability to perform safety functions.

Figure 1.2-5 of this report shows the AP1000 building layout.

The containment building is the containment vessel and the structures contained within the containment vessel. The shield building comprises the structure and annulus area that surrounds the containment building. The containment building is an integral part of the overall containment system, which contains the release of airborne radioactivity following a postulated DBA and provides shielding for the RCS during normal operations. The containment and shield buildings are an integral part of the PCS. The auxiliary building protects and separates all of the seismic Category I mechanical and electrical equipment located outside the containment building. The auxiliary building contains the MCR, I&C systems, dc system, fuel handling area, mechanical equipment areas, containment penetration areas, and main steam and feedwater isolation valve compartments.

The turbine building houses the main turbine, generator, and associated fluid and electrical systems. It also houses the makeup water purification system. No safety-related equipment is located in the turbine building.

The annex building serves as the main personnel entrance to the power generation complex. The building includes the health physics area, the non-Class 1E ac and dc electric power systems, the ancillary diesel generators and their fuel supply, other electrical equipment, the technical support center, and various HVAC systems. No safety-related equipment is located in the annex building.

The diesel generator building houses two diesel generators and their associated HVAC equipment. No safety-related equipment is located in the diesel generator building. The building is a nonseismic structure designed for wind and seismic loads in accordance with the Uniform Building Code.

The radwaste building contains facilities for segregated storage of various categories of waste prior to processing, for processing by mobile systems, and for storing processed waste in shipping and disposal containers. No safety-related equipment is located in the radwaste building. It is a nonseismic structure designed for wind and seismic loads in accordance with the Uniform Building Code. The foundation for the building is a reinforced concrete mat on grade.

The overall plant arrangement utilizes building configurations and structural designs to minimize the building volumes and quantities of bulk materials (concrete, structural steel, and rebar), consistent with safety, operational, maintenance, and structural needs. The plant arrangement provides separation between safety-related and non-safety-related systems to preclude adverse interaction between safety-related and non-safety-related equipment. Separation between redundant, safety-related equipment and systems provides confidence that the safety design functions of the AP1000 can be performed. In general, this separation is achieved by partitioning an area with concrete walls.

1.3 Comparison with Similar Facility Designs

The AP1000 standard design contains many features that are not found in currently operating reactor designs. For example, a variety of engineering and operational improvements provide additional safety margins and address Commission policy statements regarding severe accidents, safety goals, and standardization. The most significant improvement to the design is the use of safety systems that rely on passive means, such as gravity, natural circulation, condensation and evaporation, and stored energy, for accident prevention and mitigation. DCD Tier 2, Table 1.3-1, “AP1000 Plant Comparison with Similar Facilities,” provides a detailed comparison of the principal design features of the AP1000 standard design with the certified AP600 design and a typical two-loop plant.

1.4 Identification of Agents and Contractors

Westinghouse is the principal AP1000 designer. The following organizations provided the principal subcontracting services for the design of the AP1000:

- Avondale Industries, Incorporated
- Bechtel North American Power Corporation
- Burns & Roe Company
- Chicago Bridge & Iron Services, Inc.
- MK-Ferguson Company
- Southern Electric International

Westinghouse received additional support from the following organizations:

- SOPREN/ANSALDO of Italy
- University of Western Ontario of Canada
- Ente Nazionale per l'Energia Eletrica (ENEL) of Italy
- Badan Tenaga Nuklir Nasional (BATAN) of Indonesia
- Ente per le Nuove tecnologie, l'Energie e l'Ambiente (ENEA) of Italy
- Badan Pengkajian dan Penerapan Teknologi (BPPT) of Indonesia
- FIATof Italy

- INITEC of Spain
- Asociacion Espanola de la Industria Electrica (UNESA) of Spain
- Union Temporal Empresas (UTE) of Spain
- Perusahaan Listrik Negara/Badan Pengkajian dan Penerapan Teknologi (PLN/BPPT) of Indonesia
- Oregon State University
- Electricité de France (EdF)
- Shanghai Nuclear Engineering Research & Design Institute (SNERDI) of China
- Mitsubishi Heavy Industries (MHI) of Japan
- Unterausschuss Kernenergie (UAK) of Switzerland
- Desarrollo Tecnologico Nuclear (DTN) of Spain
- Fortum of Finland

1.5 Summary of Principal Review Matters

The procedure for certifying a design is conducted in accordance with the requirements of 10 CFR Part 52, Subpart B, and is carried out in two stages. The technical review stage is initiated by an application filed in accordance with the requirements of 10 CFR 52.45, “Filing of Applications.” This stage continues with reviews by the NRC staff and the ACRS and ends with the issuance of an FSER that discusses the staff’s conclusions related to the acceptability of the design. The administrative review stage begins with the publication of a Federal Register notice that initiates rulemaking, in accordance with 10 CFR 52.51, “Administrative Review of Applications,” and includes a proposed standard design certification rule. The rulemaking culminates with the denial of the application or the issuance of a design certification rule.

The staff performed its technical review of Westinghouse’s application for certification of the AP1000 standard design in accordance with the requirements of 10 CFR Part 52, Sections 52.47, “Contents of Applications”; 52.48, “Standards for Review of Applications”; and 52.53. The staff evaluated the technical information required by 10 CFR 52.47(a)(1)(i) and provided by the applicant, in accordance with NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants.” That evaluation is the subject of this report.

In addition to these safety standards, the staff followed Commission guidance provided in the SRMs for all applicable Commission papers, including those referenced throughout this report. In particular, SECY-93-087, “Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs,” issued April 2, 1993; SECY-94-084, and SECY-95-132, “Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems (RTNSS) in Passive Plant Designs (SECY-94-084),” issued May 22, 1995, identify staff positions generic to passive light-water reactor (LWR) design certification policy issues. SECY-96-128, “Policy and Key Technical Issues Pertaining to the Westinghouse AP600 Standardized Passive Reactor Design,” issued June 12, 1996; SECY-97-044, “Policy and Key Technical Issues Pertaining to the Westinghouse AP600 Standardized Passive Reactor Design,” issued February 19, 1997; and SECY-98-161, “The Westinghouse AP600 Standard Design as it Relates to the Fire Protection and the Spent Fuel Pool Cooling Systems,” issued July 1, 1998, identify staff positions on issues specific to the AP600 design. In SRMs dated July 21, 1993, June 30, 1994, June 28, 1995, January 15, 1997, and June 30, 1997, the

Commission provided its guidance on these matters as they pertain to passive plant designs. Unless otherwise noted, the staff reviewed the AP1000 application using the newest codes and standards endorsed by the NRC.

Chapter 20 of this report discusses the staff's evaluation of the technically relevant unresolved safety issues, generic safety issues, and Three Mile Island requirements (10 CFR 52.47(a)(1)(ii) and (iv)). Chapter 2 of this report presents the staff's evaluation of the site parameters postulated for the design as required by 10 CFR 52.47(a)(1)(iii). Section 19.1 of this report summarizes the staff's evaluation of the design-specific PRA (10 CFR 52.47(a)(1)(v)), and Section 14.3 of this report provides the evaluation of the ITAAC required by 10 CFR 52.47(a)(1)(vi).

Selected chapters of this report, particularly Chapter 14, discuss the staff's evaluation of the interface requirements and representative conceptual designs (10 CFR 52.47(a)(1)(vii) through (ix)). The staff also implemented the Commission's Severe Accident Policy Statement, dated August 8, 1985, and the Commission's SRMs related to SECY-90-016, "Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements," issued January 12, 1990; SECY-93-087; SECY-94-084; SECY-95-132; SECY-96-128; and SECY-97-044, in its resolution of severe accident issues. Section 19.2 of this report discusses the staff's evaluation of severe accident issues.

The regulations in 10 CFR 52.47(a)(2) describe the level of design information needed to certify a standard design. In addition, the February 15, 1991, SRM associated with SECY-90-377, "Requirements for Design Certification Under 10 CFR Part 52," issued November 8, 1990, sets forth the Commission's position on the level of design information required for a certification application. The staff followed this guidance in preparing this report. The staff also followed the guidance of SECY-92-053, "Use of Design Acceptance Criteria During 10 CFR Part 52 Design Certification Reviews," issued February 19, 1992, and SECY-02-0059, "Use of Design Acceptance Criteria for AP1000 Standard Plant Design," issued April 1, 2002. To allow for the use of rapidly developing technology, the staff based its safety determinations on design acceptance criteria (DAC) for certain technical areas. The DAC are part of the Tier 1 information proposed for the AP1000 design. Section 14.3 of this report includes the staff's evaluation of the Tier 1 information, including DAC and ITAAC.

As part of its technical review, the staff issued numerous RAIs to gain sufficient bases for its safety findings, thereby meeting the requirement in 10 CFR 52.47(a)(3) to advise the applicant on whether additional technical information required submission. Appendix E of this report provides an index of the applicant's responses to these RAIs.

Section 1.2.1 of this report discusses the scope of the design to be certified. Because of the unique nature of the AP1000 design, the applicant implemented an extensive testing program to provide data on the passive safeguards systems. These data validate the safety analysis methods and computer codes and provide information to assess the design margins in the passive safety system performance. Chapter 21 of this report discusses the staff's evaluation of the testing program required pursuant to 10 CFR 52.47(b)(2). Because the AP1000 is designed as a single unit (i.e., no safety systems will be shared at a multi-unit site), 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 5, "Sharing of Structures, Systems, and

Components," and 10 CFR 52.47(b)(3) do not apply to this design. Any applicant wishing to construct multiple units at a single site will be required to address these regulations in its application.

In DCD Tier 2, Section 1.2.1.1.2, the applicant states that the plant design objective is 60 years. Throughout this report the staff makes reference to the applicant's 60 year design objective. These statements, however, do not affect the bases of the staff's evaluation. In accordance with the Atomic Energy Act of 1954, as amended, and 10 CFR 50.51(a), the staff based its review on a license duration of 40 years.

1.6 Summary of Open Items

As a result of the staff's review of Westinghouse's application for certification of the AP1000 design (including any additional information provided to the NRC through April 21, 2003), the staff identified several issues that remained open at the time the DSER was issued. In addition, the staff identified additional issues after the issuance of the DSER. The staff considers an issue to be open if the applicant has not provided requested information and the staff is unaware of what will ultimately be included in the applicant's response. Each open item was assigned a unique identifying number which indicates the section in this report where it is described. For example, Open Item 4.4-1 is discussed in Section 4.4 of this report.

The DSER was issued with 174 open items. When the FSER was prepared, the staff discovered Open Item 3.7.2-1 had not been included in DSER Section 1.6, "Summary of Open Items." After issuance of the DSER, two new issues were identified through discussions with the ACRS, Open Items 5.2.3-2 and 5.2.3-3. In addition, 28 issues connected to Open Item 14.2-1 were identified during the supplemental review concerning the initial plant test program. This report includes a discussion of these open items. As set forth throughout this report, all open items have been resolved.

1.7 Summary of Confirmatory Items

The NRC staff's review of Westinghouse's application for certification of the AP1000 design, as documented in the DSER, identified several confirmatory items. An item is identified as confirmatory if the staff and Westinghouse have agreed on a resolution of a particular item, but the resolution has not yet been formally documented in the DCD. Each confirmatory item was assigned a unique identifying number. The number indicates the section in this report where the confirmatory item is described. For example, Confirmatory Item 7.2.3-1 is discussed in Section 7.2.3 of this report.

The DSER was issued with 27 confirmatory items. After issuance of the DSER, two additional confirmatory items were identified, Confirmatory Items 3.8.2.6-1 and 3.8.5.5-3. This report includes a discussion of these confirmatory items. As set forth throughout this report, all confirmatory items have been resolved.

1.8 Index of Exemptions

In accordance with 10 CFR 52.48, the staff used the current regulations in 10 CFR Part 20, "Standards for Protection Against Radiation"; Part 50, "Domestic Licensing of Production and Utilization Facilities"; Part 73, "Physical Protection of Plants and Materials"; and Part 100, "Reactor Site Criteria"; in reviewing Westinghouse's application for certification of the AP1000 design. During this review, the staff recognized that the application of certain regulations to the AP1000 design would not serve the underlying purpose of the rule, or would not be necessary to achieve the underlying purpose of the rule.

In a letter dated December 3, 2002, Westinghouse submitted a list of exemption requests. These exemptions are discussed in the sections of this report listed below.

Section	Exemption
8.2.3.2	Exemption from GDC 17, "Electric Power Systems," requirement for a physically independent circuit (i.e., a second off-site electrical power source)
15.2.9	Exemption from 10 CFR 50.62, "Requirements for Reduction of Risk from Anticipated Transients without Scram (ATWS) Events for Light-Water-Cooled Nuclear Power Plants," requirement for automatic startup of auxiliary feedwater system
18.8.2.3	Exemption from 10 CFR 50.34(f)(2)(iv) requirements for safety parameter display console

1.9 Index of Tier 2* Information

The NRC staff has determined that certain changes to or departures from information in the DCD that are proposed by an applicant or licensee who references the certified AP1000 design will require NRC approval before the change can be implemented, in accordance with the design certification rule. This information will be referred to as Tier 2* in the proposed design certification rule. At the time the DSER was issued, the staff had not completed its review of the Tier 2* information pertaining to the AP1000 design. This was Open Item 1.9-1 in the DSER.

DCD Introduction Table 1-1, "Index of AP1000 Tier 2 Information Requiring NRC Approval for Change," provides a list of the items designated as Tier 2* information. The staff has now completed its review of the Tier 2* information pertaining to the AP1000 design. For the reasons set forth throughout this report regarding Tier 2* information, the staff finds such information acceptable. Therefore, Open Item 1.9-1 is resolved.

1.10 COL Action Items

COL applicants and licensees referencing the certified AP1000 standard design must satisfy the requirements and commitments identified in the DCD, which is the controlling document used in the certification of the AP1000 design. In addition, the AP1000 DCD identifies certain general commitments as "Combined License Information Items," and in this report as "COL Action Items." These COL action items relate to programs, procedures, and issues that are outside the scope of the certified design review. These COL action items do not establish requirements;

rather, they identify an acceptable set of information to be included in a plant-specific safety report. An applicant for a COL must address each of these items in its application. It may deviate from or omit these items, provided that the deviation or omission is identified and justified in the plant-specific safety report.

Westinghouse included a summary of COL action items in DCD Tier 2, Table 1.8-2, “Summary of AP1000 Standard Plant Combined License Information Items,” and provided an explanation of the items in the applicable sections of the DCD. At the time the DSER was issued, the staff had not completed its review and cross-reference of the COL action items. This was Open Item 1.10-1 in the DSER.

In addition, the staff identified a number of new COL action items as a result of its review. These are highlighted throughout this report. The applicant revised the DCD to incorporate these new COL action items. The staff reviewed the revised DCD and found it to be acceptable. Appendix F to this report provides a cross-reference between the COL action items identified in this report and the COL information referred to in the DCD. Therefore, Open Item 1.10-1 is resolved.

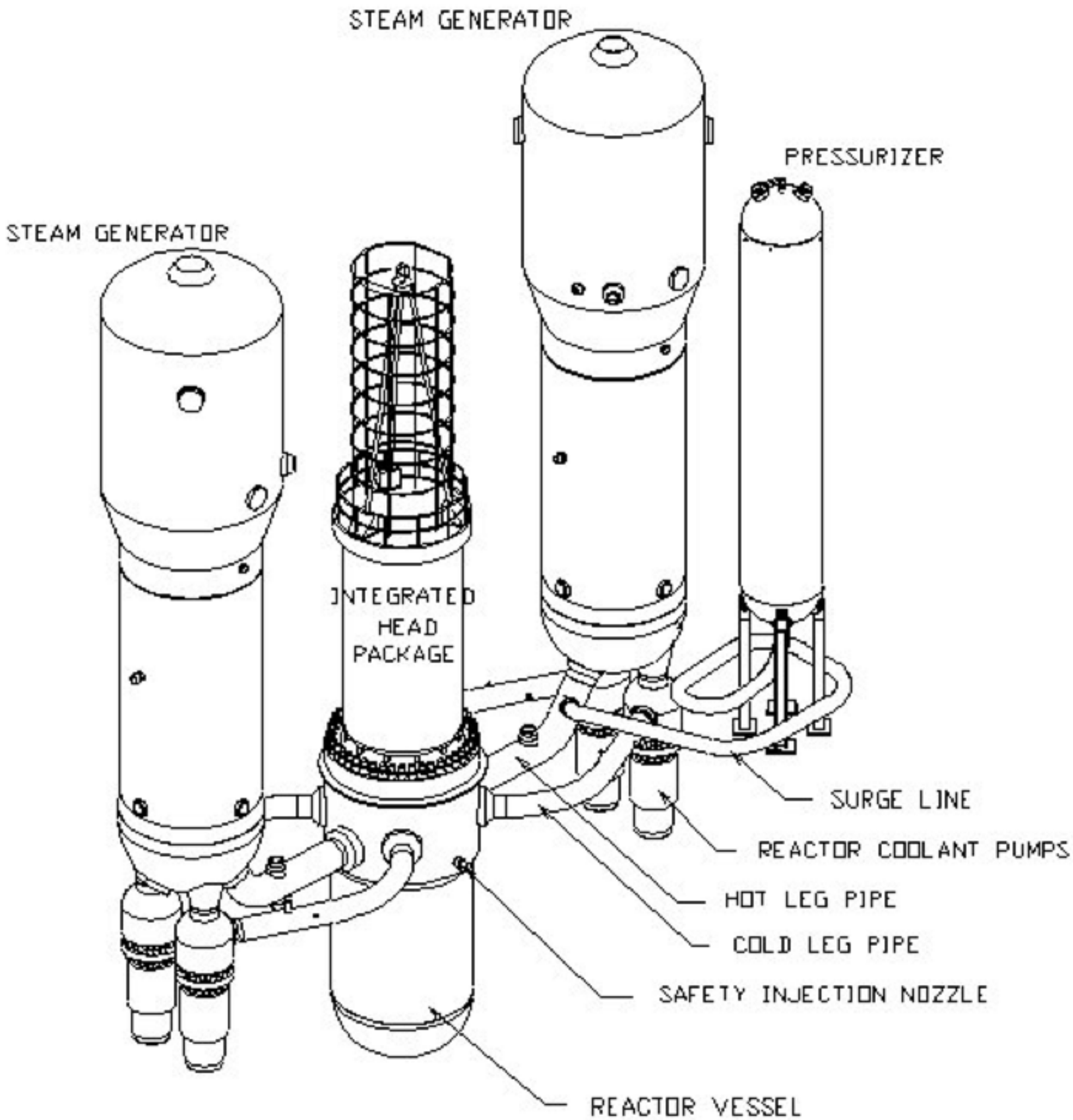


Figure 1.2-1 AP1000 Reactor Coolant System

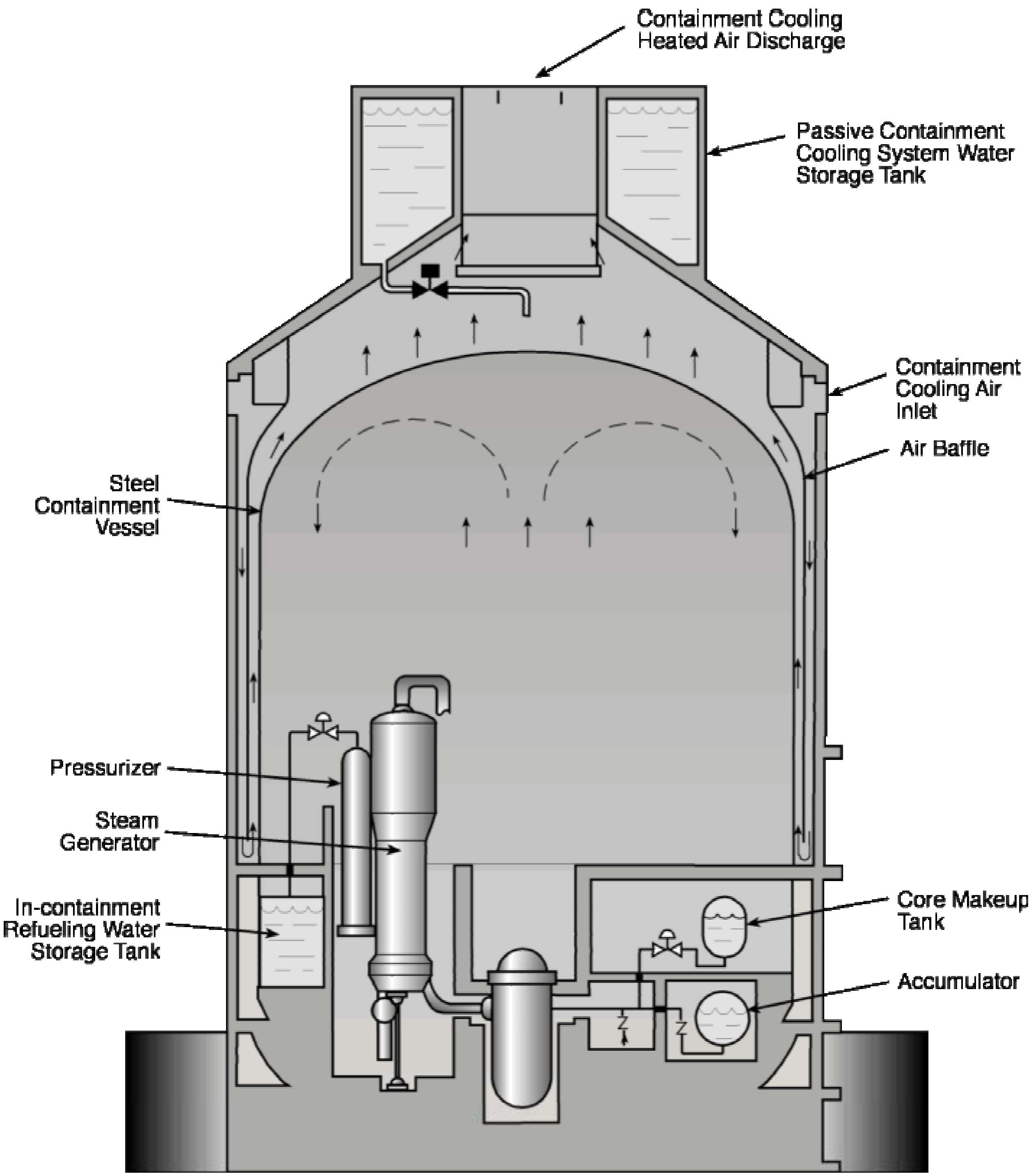


Figure 1.2-2 AP1000 Passive Safety Injection System Post-LOCA, Long Term Cooling

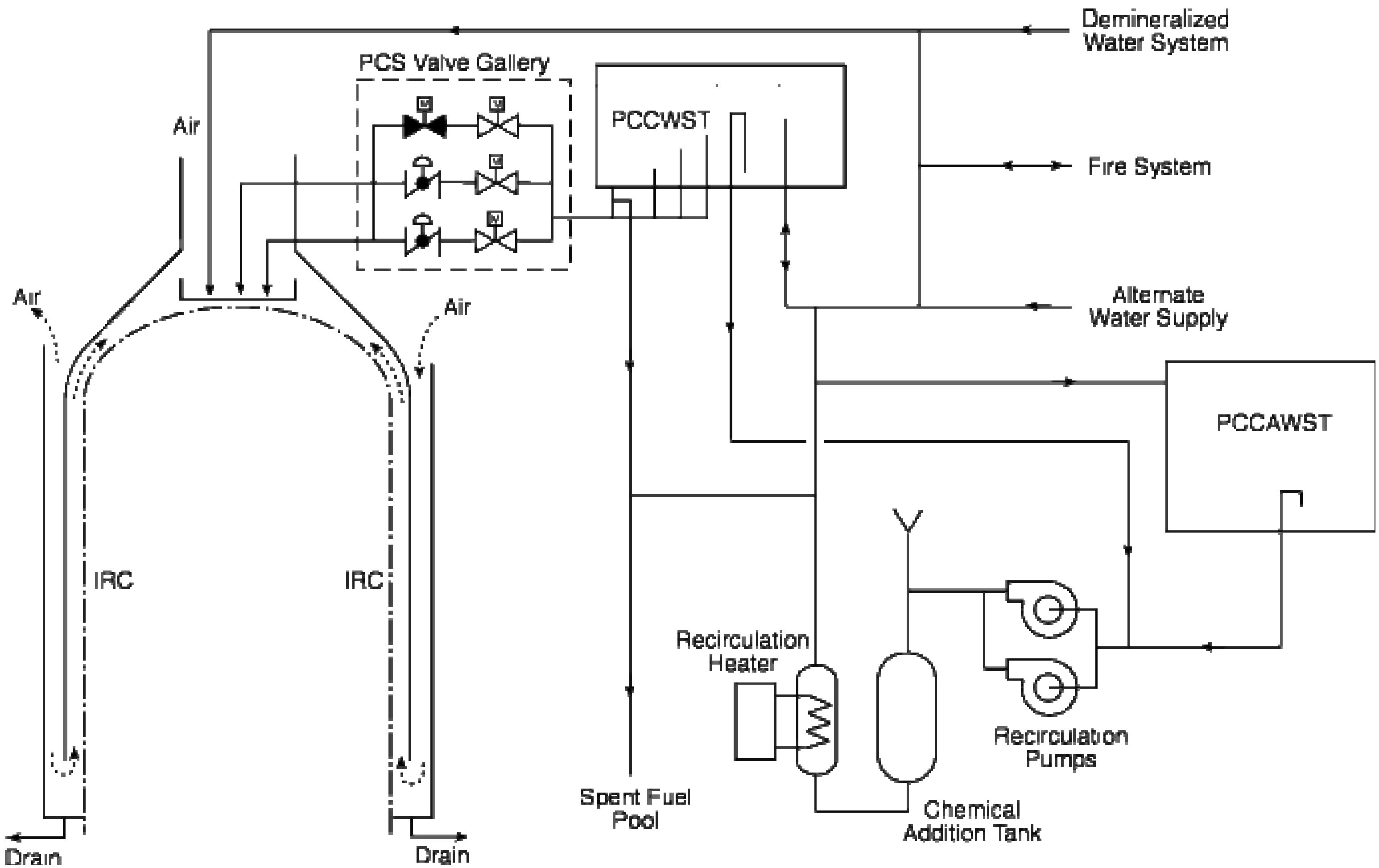


Figure 1.2-3 AP1000 Passive Containment Cooling System

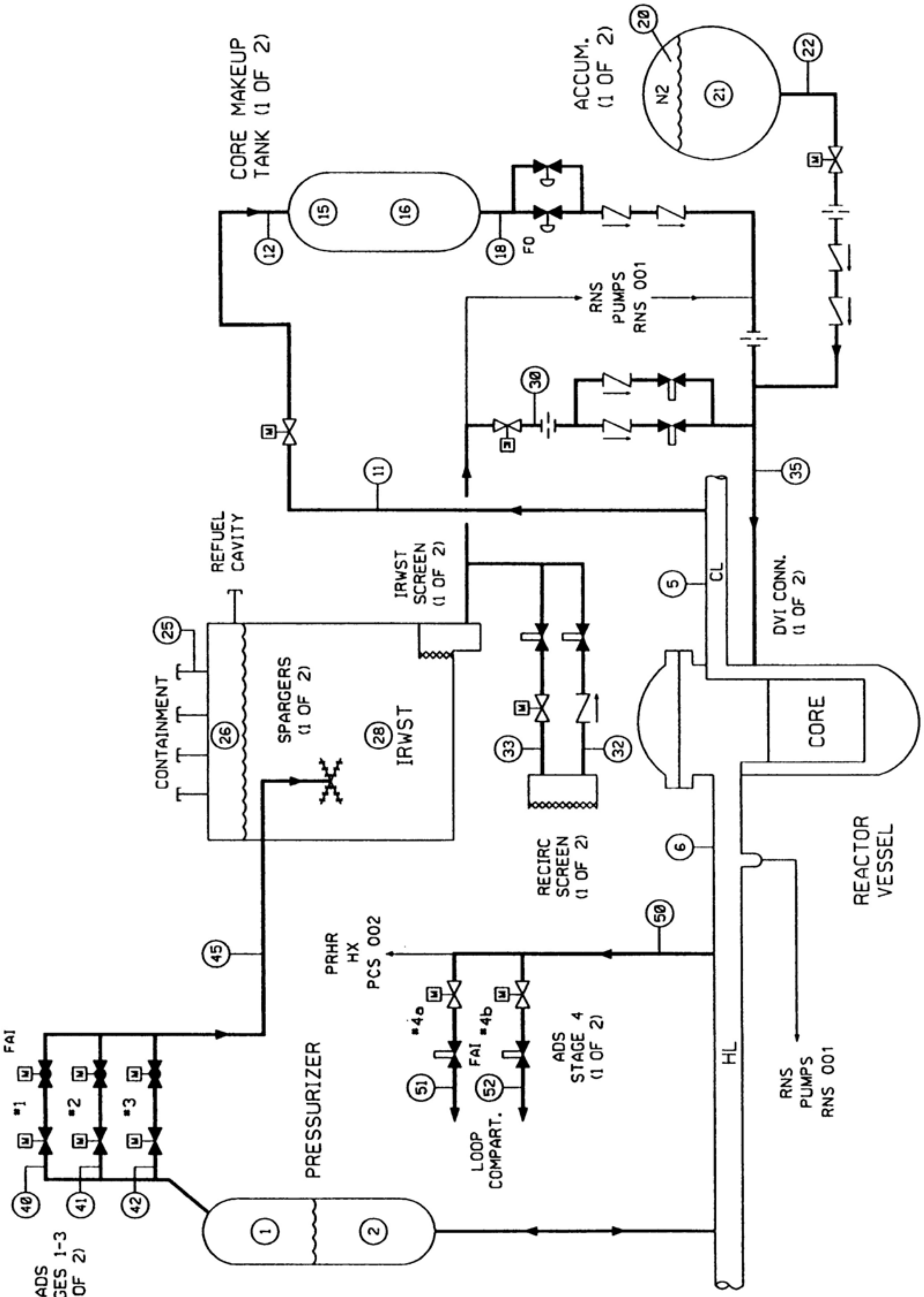


Figure 1.2-4 AP1000 Safety Injection Systems

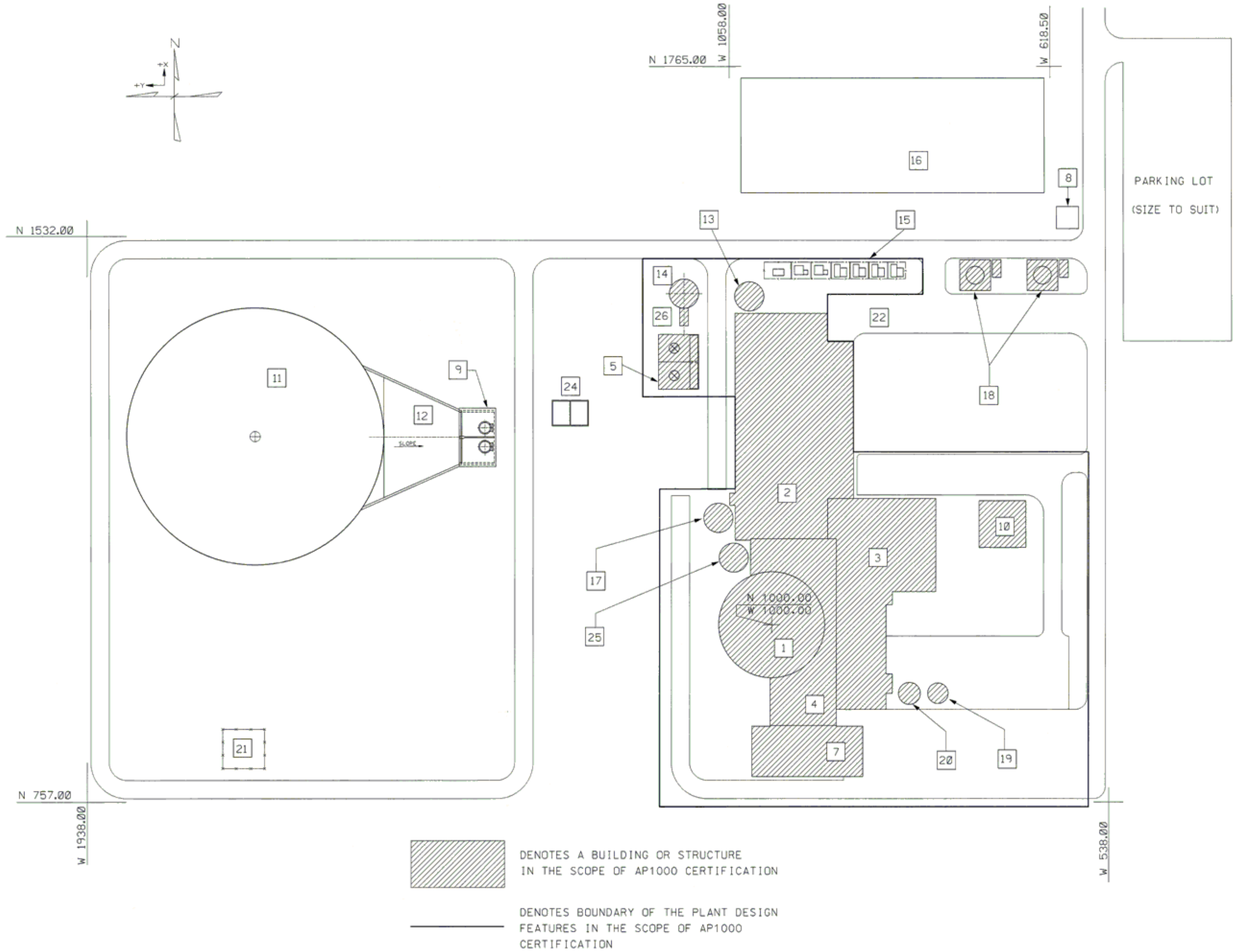


Figure 1.2-5 AP1000 Plant Layout (Sheet 1 of 2)

Figure 1.2-5 AP1000 Plant Layout
(Sheet 2 of 2)

1. Containment/Shield Building
2. Turbine Building
3. Annex Building
4. Auxiliary Building
5. Service Water System Cooling Towers
7. Radwaste Building
8. Plant Entrance
9. Circulating Water Pump Intake Structure
10. Diesel Generator Building
11. Circulating Water System Cooling Tower
12. Circulating Water System Intake Canal
13. Fire Water/Clearwell Storage Tank
14. Fire Water Storage Tank
15. Transformer Area
16. Switchyard
17. Condensate Storage Tank
18. Diesel Generator Fuel Oil Storage Tank
19. Demineralized Water Storage Tank
20. Boric Acid Storage Tank
21. Hydrogen Storage Tank Area
22. Turbine Building Laydown Area
24. Waste Water Retention Basin
25. Passive Containment Cooling Ancillary Water Storage Tank
26. Diesel-Driven Fire Pump/Enclosure

World

How two cutting edge U.S. nuclear projects bankrupted Westinghouse

By Tom Hals and Emily Flitter

May 2, 2017 5:48 AM EDT · Updated 8 years ago

Aa

FILE PHOTO: The Vogtle Unit 3 and 4 site, being constructed by primary contactor Westinghouse, a business unit of Toshiba, near Waynesboro, Georgia, U.S. is seen in an aerial photo taken... Purchase Licensing Rights Read more

WILMINGTON, Del./NEW YORK (Reuters) - In 2012, construction of a Georgia nuclear power plant stalled for eight months as engineers waited for the right signatures and paperwork needed to ship a section of the plant from a factory hundreds of miles away.

The delay, which a nuclear specialist monitoring the construction said was longer than the time required to make the section, was emblematic of the problems that plagued Westinghouse Electric Co as it tried an ambitious new approach to building nuclear power plants.

The approach - building pre-fabricated sections of the plants before sending them to the construction sites for assembly - was supposed to revolutionize the industry by making it cheaper and safer to build nuclear plants.

But Westinghouse miscalculated the time it would take, and the possible pitfalls involved, in rolling out its innovative AP1000 nuclear plants, according to a close examination by Reuters of the projects.

Those problems have led to an estimated $13 billion in cost overruns and left in doubt the future of the two plants, the one in Georgia and another in South Carolina.

Overwhelmed by the costs of construction, Westinghouse filed for bankruptcy on March 29, while its corporate parent, Japan's Toshiba Corp, is close to financial ruin [L3N1HI4SD]. It has said that controls at Westinghouse were "insufficient."

The miscalculations underscore the difficulties facing a global industry that aims to build about 160 reactors and is expected to generate around $740 billion in sales of equipment in services in the coming decade, according to nuclear industry trade groups.

The sector's problems extend well beyond Westinghouse. France's Areva is being restructured, in part due to delays and huge cost overruns at a nuclear plant the company is building in Finland.

Even though Westinghouse's approach of pre-fabricated plants was untested, the company offered aggressive estimates of the cost and time it would take to build its AP1000 plants in order to win future business from U.S. utility companies. It also misjudged regulatory hurdles and used a construction company that lacked experience with the rigor and demands of nuclear work, according to state and federal regulators' reports, bankruptcy filings and interviews with current and former employees.

"Fundamentally, it was an experimental project but they were under pressure to show it could be a commercially viable project, so they grossly underestimated the time and the cost and the difficulty," said Edwin Lyman, a senior scientist at the Union of Concerned Scientists, who has written and testified about the AP1000 design.

Westinghouse spokeswoman Sarah Cassella said the company is "committed to the AP1000 power plant technology", plans to continue construction of AP1000 plants in China and expects to bid for new plants in India and elsewhere. She declined to comment on a detailed list of questions from Reuters.

PROBLEMS FROM THE START

By early 2017, the Georgia and South Carolina plants were supposed to be producing enough energy to power more than a half a million homes and businesses. Instead, they stand half-finished. (For a graphic see tmsnrt.rs/2oQEKgE)

Southern Co, which owns nearly half the Georgia project, and SCANA Corp, which owns a majority of the South Carolina project, have said they are evaluating the plants and could abandon the reactors altogether.

"We will continue to take every action available to us to hold Westinghouse and Toshiba accountable for their financial responsibilities under the engineering, procurement and construction agreement and the parent guarantee," Southern said in a statement. A spokesman declined to elaborate.

The projects suffered setbacks from the start. In one instance, to prepare the Georgia plant for construction, Westinghouse and its construction partner in 2009 began digging out the foundation, removing 3.6 million cubic yards of dirt.

But half of the backfill – the material used to fill the excavated area - failed to meet regulatory approval, delaying the project by at least six months, according to William Jacobs, the nuclear specialist who monitored construction of the plant for Georgia's utility regulator.

He declined to be interviewed.

But the source of the biggest delays can be traced to the AP1000's innovative design and the challenges created by the untested approach to manufacturing and building reactors, according to more than a dozen interviews with former and current Westinghouse employees, nuclear experts and regulators.

Unlike previous nuclear reactors, the AP1000 would be built from prefabricated parts; specialized workers at a factory would churn out sections of the reactor that would be shipped to the construction site for assembly. Westinghouse said in marketing materials this method would standardize nuclear plant construction.

Westinghouse turned to Shaw Group Inc, which held a 20 percent stake in Westinghouse, to build sections for the reactors at its factory in Lake Charles, Louisiana. There, components for two reactors each in Georgia and South Carolina would be manufactured.

LAKE CHARLES

Seven months after work began in the May 2010, Shaw had already conducted an internal review at the behest of the Nuclear Regulatory Commission (NRC) to document problems it was having producing components.

In a letter to the NRC, Shaw's then-executive vice president, Joseph Ernst, wrote: "The level and effectiveness of management oversight of daily activities was determined to be inadequate based on the quality of work."

He laid out a laundry list of deficiencies ranging from Shaw's inability to weed out incorrectly made parts to the way it stored construction materials.

Ernst did not respond to a phone call seeking comment.

Over the next four years, regulatory and internal inspections at Lake Charles would reveal a slew of problems associated with the effort to construct modular parts to fit the new Westinghouse design, NRC records show.

When a sub-module was dropped and damaged, Shaw managers ordered employees to cover up the incident; components were labeled improperly; required tests were neglected; and some parts' dimensions were wrong. The NRC detailed each one in public violation notices.

Then there was the missing and illegible paperwork.

The section that was delayed more than eight months by missing signatures would become one of 72 modules fused together to hold nuclear fuel. The 2.2 million pound unit was installed more than two years behind schedule.

It was not until June 2015 that the Lake Charles facility was building acceptable modules, according to a report by Jacobs. By then, Shaw had been bought by Chicago Bridge & Iron.

Gentry Brann, a CB&I spokeswoman, said the company put the Lake Charles plant under new management and installed new procedures after the 2013 acquisition. She said Westinghouse was to blame for subsequent delays, citing "several thousand" technical and design changes made after work had already started on various components.

Westinghouse declined to comment.

THE NRC

To some extent, Westinghouse also was hamstrung by the NRC, which imposed stringent requirements for the new reactors. To comply, Westinghouse made some design changes that were tiny tweaks; others were larger.

For instance, before the NRC would issue the utilities an operating license for the Georgia plant, it demanded changes to the design of the shield building, which protects against radiation leaks. The regulator said the shield needed to be strengthened to withstand a crash by a commercial jet, a safety measure arising from the Sept. 11, 2001 attacks.

The NRC issued the new standard in 2009, seven years after Westinghouse had applied for approval of its design. The company, in bankruptcy court filings, said the NRC's demand created unanticipated engineering challenges.

A spokesman for the NRC, Scott Burnell, said the changes should not have come as a surprise, since the agency had been talking about the stringent requirements for several years.

Westinghouse changed its design to protect against a jet crash, but at that point the NRC questioned whether the new design could withstand tornadoes and earthquakes.

Westinghouse finally met the requirements in 2011, according to a report by Jacobs.

By 2016 Westinghouse began to grasp the scope of its dilemma, according to a document filed in its bankruptcy: Finishing the two projects would require Westinghouse to spend billions of dollars on labor, abandoning them would mean billions in penalties.

Westinghouse determined it could not afford either option.

Graphic: Cost overruns at Westinghouse's nuclear plants - tmsnrt.rs/2qnmtML

Reporting by Tom Hals in Wilmington, Delaware; additional reporting by Makiko Yamazaki in Tokyo; editing by Paul Thomasch

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SOUTH CAROLINA SPENT $9 BILLION TO DIG A HOLE IN THE GROUND AND THEN FILL IT BACK IN

Cost is often raised as a critical objection to combating climate change. But South Carolina shows what's possible.

Akela Lacy

February 6 2019, 6:00 a.m.

Unit one of the V.C. Summer Nuclear Station near Jenkinsville, S.C., photographed on Sept. 21, 2016. Photo: Chuck Burton/AP

THE OBJECTION RAISED most frequently when it comes to a Green New Deal is its cost. It's preposterous; it's too expensive; we just can't afford it.

But before scoffing at the prospect of the wealthiest nation in the history of the world funding such a project, it's worth taking a look at what one of the country's poorest states was recently able to spend.

South Carolina, in a bid to expand its generation of nuclear power in recent years, dropped $9 billion on a single project — and has nothing to show for it.

The boondoggle, which was covered widely in the Palmetto State press but got little attention nationally, sheds light on just how much money is genuinely available for an industrial-level energy transformation, if only the political will were there.

There are no firm figures tied to a Green New Deal, but former Green Party presidential candidate Jill Stein's proposed version of the project would have cost between $700 billion and $1 trillion. The new plan, being crafted with the help of progressive groups like the Sunrise Movement and pushed to the top of the House legislative agenda by Alexandria Ocasio-Cortez and other progressives, promises more substantial change on a much shorter schedule. In addition to moving the U.S. to 100 percent renewable energy in 10 years, upgrading all residential and industrial buildings for energy efficiency, and eliminating greenhouse gases from manufacturing and agriculture, it includes a jobs guarantee and a recognition of the rights of tribal nations. Ocasio-Cortez and Massachusetts Sen. Ed Markey are planning to introduce legislation for the plan this week, Axios reported.

In South Carolina, lawmakers greenlighted a multibillion-dollar energy project and stuck utility customers with the tab. "In the private sector," former Nuclear Regulatory Commissioner Gregory Jaczko told The Intercept, "you would never be able to justify this."

The saga, and related nuclear project failures, calls into question the role of new nuclear energy production in the effort to decarbonize the economy. New plants, Jaczko said, take too long to build for the urgency of the climate crisis and simply aren't cost effective, given advances in renewable energy. "I don't see nuclear as a solution to climate change," Jaczko said. "It's too expensive, and would take too long if it could even be deployed. There are cheaper, better alternatives. And even better alternatives that are getting cheaper, faster."

The Nuclear Boondoggle

It started in 2008. SCE&G and Santee Cooper announced plans to add two nuclear reactors to the V.C. Summer Nuclear Station in Jenkinsville, South

Carolina, and contracted Westinghouse Electric Company, owned by Toshiba, to handle construction. The state's Public Service Commission (PSC) approved the plan in early 2009, with construction slated to begin in 2012, and the first reactor set to begin operating in 2016.

In late 2011, SCE&G announced the project's first delay in a quarterly report to the Office of Regulatory Staff, which represents utilities in front of the PSC, citing "module redesign, production issues, manpower issues and Quality Assurance and Quality Control (QA/QC) issues." The company estimated an 11-month setback and said its contractor, the Shaw Group, operating out of a facility in Louisiana, reported that the issues had been resolved. But SCE&G said they were still monitoring the situation "carefully" and considered "it to be a focus area for the project." The Shaw facility would later face a federal probe over unrelated allegations that workers broke protocol and falsified records, which employees admitted to.

The company alerted more delays in mid-2013, citing manufacturing issues. Soon, Santee Cooper asked SCE&G to bring in another company to manage the project. Not long after that, both companies announced the project would cost $1.2 billion more than they'd expected. Again, they pushed back the project's completion date.

Documents released as the project unraveled show that both SCE&G and Santee Cooper were well aware of shortcomings, mismanagement, and lack of oversight that eventually made the reactors impossible to complete, years before Westinghouse declared bankruptcy and both companies pulled out.

"They were allowed to charge the customers for all the money that they spent, plus a return," Jaczko explained. "Even though they failed to deliver the project."

Only 48 percent of South Carolinians know about the failed program, according to an October statewide poll surveying electric ratepayers.

"The utilities are incredibly powerful political lobbies in the state," Jaczko said. "It's now $2.3 billion that they're gonna be able to get," he said, and that doesn't include the rate of return Dominion says it's entitled to.

"It's insane for a project that's done nothing, and never will. And is just a giant hole in the ground," he said. "Well, a filled-in hole now, at this point."

V.C. Summer Nuclear Station's unit two's turbine, right, and containment unit, center, are shown under construction near Jenkinsville, S.C., on Sept. 21, 2016. Photo: Chuck Burton/AP

Left With the Tab

Thanks to a state law passed in 2007, residents in South Carolina are footing the bill for a massive failed nuclear reactor program that cost a total of $9 billion. Analysts say that corporate mismanagement and poor oversight means residents and their families will be paying for that failed energy program — which never produced a watt of energy — for the next 20 years or more.

South Carolina Attorney General Alan Wilson has since called parts of the law, the Base Load Review Act, "constitutionally suspect," and state senators have voted to overturn it — but that wouldn't necessarily get ratepayers off the hook for paying for the failed project.

Both the Justice Department and the Securities and Exchange Commission opened separate investigations into the failed project, and at least 19 lawsuits have been filed against one company involved.

The two South Carolina companies, South Carolina Electric & Gas and Santee Cooper, a state-owned utility, spent $9 billion on a plan to build two nuclear reactors and eventually canceled it due to a series of cost miscalculations and corporate buyouts that left one construction company bankrupt and sent shockwaves all the way to Japanese tech giant Toshiba.

Dominion Energy, an energy giant in the region, has since bought out SCE&G's parent company, SCANA Corp., for $7.9 billion — almost the entire cost of the failed project — pledged to partially refund ratepayers and cut electricity rates, which SCE&G hiked at least nine times throughout the project's first eight years in order to pay for it.

When asked about the failed project, South Carolina Republican Rep. William Timmons laughed. He said ratepayers would still pay "a substantial portion" of the bill. "The SCANA portion, which is — approximately half has been substantially dealt with, with their restructuring and the purchase of Dominion," he told The Intercept. "What's left now is the Santee Cooper portion, and I think that's still yet to be decided."

"It is a major issue that the legislature's dealing with," Timmons said. The congressman didn't have any updates on how or when the remainder of the bill would resolved.

After Dominion bought out SCANA and settled their portion of the bill, ratepayers are still responsible for about $2.3 billion. "For nothing, they get nothing," Jaczko told The Intercept.

"They basically pay money up front for a project that never materialized, and now are still gonna be asked to pay for it. And that is a significant break from the way that traditional rate recovery used to work," he said.

"It used to be that you didn't start charging for a plant unless it was done and operating. Whether it was a nuclear plant, or a coal plant, or any other kind of thing."

But because nuclear power involves heavier upfront capital costs and financing charges, Jaczko explained, states looking to revive nuclear power tried to bypass those extra costs by passing laws allowing companies to save money by recovering the cost of financing the projects during the period of construction.

"Even the law that was written in South Carolina envisioned the fact that the project could get canceled. But of course everybody promised that that wouldn't happen," Jaczko said.

Sen. Tim Scott told The Intercept that it was hard to pin the blame for the disastrous project on any one entity. "But certainly the Westinghouse bid coming back three times higher than their original estimation made the likelihood of success challenging. And then all the decisions that were made pending that being an accurate price all fell apart," he said. He did not answer a question of whether ratepayers would have to pay $2.3 billion for nothing.

For conservatives and corporate-friendly Democrats, the idea of spending absurd amounts of money on a comprehensive national plan to wean the economy off dirty energy and create sustainable jobs is out of the question. It's an idea much easier to swallow when its stated purpose is corporate profit, as in South Carolina. Or at the federal level, national defense. President Donald Trump signed into law last summer a $717 billion defense bill, up from $600 billion in 2016, and around $300 billion in 2000. In December the president tweeted that U.S. military spending was "Crazy!"

For scale, the national deficit for fiscal year 2019 is just shy of $1 trillion. Of the $4.4 trillion federal budget, military spending across agencies makes up close to $800 billion. The federal government spent about $1.1 trillion on health care in 2018. The latest government shutdown cost the U.S. an estimated $11 billion, the Congressional Budget Office reported. Trump requested $5.7 billion for a border wall, and Republicans in the House found it.

But $9 billion and zero nuclear reactors later, ratepayers in South Carolina have no say after their legislators played with the state's resources and lost. If one state can throw away $9 billion on a project that never happened, legislators in Washington will have a difficult time claiming that they can't find federal dollars to finance a plan that 81 percent of registered voters support.

"We can pay for a Green New Deal in the same way we pay for — whether it's wars, or tax cuts, or any of the other great social programs that we have," Greg Carlock told The Intercept. He's a senior adviser at Data for Progress, where he authored a report outlining policy proposals for the Green New Deal. Unlike Ocasio-Cortez, Carlock says he disagrees with the argument that you have to tax the wealthy, or the middle class, to pay for a Green New Deal. Instead, he argues, Congress should just authorize new spending, like it does for everything else.

"There has been a really well-crafted narrative to bring up fears about deficit spending and the debt," Carlock said. "I think that we, one, have to just break out of this fear that somehow this number that we call debt is a bad thing. Because it's not the same kind of debt that a household has, or that a business has," he said.

"The driver of inflation is not how many ones and zeros we've put out there," Carlock said. "The driver of inflation is the availability of limited biophysical resources that that money is trying to go out and buy. And that's why, when you think about this from a sustainability perspective, a Green New Deal that tries to improve the sustainability of our natural resources, is actually meant as a deflationary role."

"The greatest threat to our economy and inflation is not the debt, it's the climate crisis," he added, "which will put an even greater strain on our resources. The whole point of a Green New Deal is to mitigate those threats, and it will be cheaper than the cost of future climate disasters."

Investing in clean energy, sustainable jobs, and a basic standard of health care would actually save money in the long run — tens to hundreds of billions of dollars per year, according to a climate assessment released under the Trump administration this year. The argument that the money isn't there just doesn't hold up.

"Any politician whose first question about the Green New Deal is how to pay for it isn't taking seriously the millions who will die if we fail to take action on the scale scientists say we need," Stephen Hanlon, communications director for the Sunrise Movement, said in a statement to The Intercept.

"What we are talking about is a putting millions of people to work so they can buy food for their families, etc. This is the greatest investment in the American economy in generations, and that kind of investment pays substantial dividends," Hanlon said.

"We will pay for this the same way we paid for the WWII (sic) and the original New Deal: deciding it's a priority as a nation and that we can't afford not to take action."

Meanwhile, a $28 billion nuclear project in Georgia is headed for a similar fate.

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Residual Risk

An Account of Events in Nuclear Power Plants Since the Chernobyl Accident in 1986

May 2007

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Please note that the present report can be downloaded free of charge at:

http://www.greens-efa.org/cms/topics/dokbin/181/181995.residual_risk@en.pdf

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The authors are grateful for any comments you might wish to transmit.

Picture credit cover page: Oak Ridge National Laboratory

"Die Menschen lernen nur aus Katastrophen. Schade!"
[People only learn from catastrophes. Too bad!]

Graffiti on a wall close to the Gorleben Nuclear Site in Germany

Preface

Proponents of nuclear fission are trying to jump on the climate change bandwagon to resuscitate nuclear power after decades of stagnation. Unfortunately, some UN climate change strategists, as well as parts of the European Commission, have bought into the nuclear lobby's arguments. While we clearly need to reform our wasteful and polluting energy industry to meet today's energy and environmental challenges, however, grasping at even more dangerous straws cannot be the answer.

It is wrong to try and counteract the risk of global warming through an expansion of nuclear energy and the consequential nuclear risks. Promoting nuclear as a sustainable energy source, as the nuclear lobby in Brussels and elsewhere is trying to do, is misleading. Any technology that can produce such devastating consequences as those in 1986 from the Chernobyl disaster can never be sustainable. Nuclear energy is a high risk technology.

We can lull ourselves into a false sense of security by trying to forget about past catastrophes. However, the fact that there has not been another accident with a core meltdown since Three Mile Island does not mean that it will never happen again. Every year there are thousands of incidents, occurrences and events in nuclear installations and, simply because there was no catastrophic radioactive leakage, the world reacts as if there was no problem.

The Forsmark incident last summer shattered this complacent approach to nuclear incidents. It may have only been a matter of minutes by which an accident on the scale of Chernobyl was prevented from happening in Sweden. The main difference between Forsmark and previous incidents is that the real risk of Forsmark was publicised, whereas previous incidents were brushed under the table.

The Forsmark incident triggered the commissioning of the 'Residual Risk' Project. Why are there reports on Forsmark but not on Maanshan in Taiwan? Why is it that a hydrogen explosion that threatens safety relevant equipment at the German nuclear power plant Brunsbüttel, did not attract more than regional attention? How long did the huge hole in the reactor vessel head of the American Davis Besse plant remained undiscovered? Who has ever heard the story of the man that, with his vehicle, broke through all the gates at the Three Mile Island (USA) plant, entered the turbine hall and remained undiscovered for four hours? The collective repression of risks also results from lacking, false or incomplete information.

The publication of 'Residual Risk' is aimed at raising public awareness on the risks of nuclear power. It must be taken into consideration that the incidents, which were dealt with by experts from various countries, are not necessarily the most serious ones that there have been. The incidents presented in the study are particularly significant and they were made public. This illustrates how frequently we have been at the edge of disaster.

The International Atomic Energy Agency (IAEA) created International Nuclear Event Scale (INES) as a communication tool for operators and safety authorities, with incidents classified on a scale from 1 to 7. However, most countries either do not supply any or supply very incomplete information to the system. Moreover, only incidents with radiological impacts are classified in higher categories. Using this method, a 'near miss' can be classified as simply a Level 2 incident. This study shows that the use of the INES scale is misleading and accentuates the tendency to systematically underestimate the risk potential of nuclear incidents.

The permanent risk of a core meltdown is a strong argument against the use of nuclear power. The lifetime extension of nuclear power plants heightens the risk of a major accident considerably. The question of how to dispose of nuclear waste safely not only remains unanswered, no answer can be imagined. Every country using nuclear power could build a nuclear bomb if it decided to do so. These dangers are no less terrifying given the challenges of climate change.

However, there are not only wrong answers. There are also real solutions to climate change. To be able to reduce greenhouse gas emissions and fight climate change, as well as addressing current energy wastage, we need a new approach for a modern and sustainable energy supply. Energy savings and efficiency and an ambitious expansion of renewable energies are the sensible and sustainable solution, as was demonstrated in the Greens study 'Vision Scenario'.
(http://www.greens-efa.org/cms/topics/dokbin/155/155777.a_vision_scenario_for_climate_and_energy@en.pdf)

I hope that the work of the authors of "Residual Risk" will help increase awareness of the inherent risks of nuclear power. I also hope that we will succeed in once and for all ending the discussion about the lifetime extension of nuclear power plants or the construction of new plants.

My thanks go to the team of authors and to the coordinator of the project, Mycle Schneider. Without the financial support of the Altner-Combecher Stiftung für Ökologie und Frieden and Hatzfeldt Stiftung this project could not have been realised.

Rebecca Harms

9 May 2007
Brussels

Residual Risk

An Account of Events in Nuclear Power Plants Since the Chernobyl Accident in 1986

May 2007

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Residual Risk

An Account of Events in Nuclear Power Plants Since the Chernobyl Accident 1986

Contents

1. Introduction

> *If our understanding of our past is incomplete or inaccurate then we are not well equipped to make sense of the present. More specifically, if we do not make the effort to learn what the influences were that shaped our past, then we are hopelessly unequipped to detect and respond to similar influences today.*
>
> *For example, to simply characterize the Three Mile Island accident as a minor mechanical failure which was allowed to escalate into a major accident through serious operator errors is a gross and dangerous distortion of the truth, actively concealing important human errors in nuclear plant design organizations, operating utilities and the regulatory authorities. If we cannot identify these errors in the glare of hindsight, then we have little hope of anticipating them in the future.*
>
> David Mosey
> Nuclear Safety Engineer, Canada
> Author of *Nuclear Accidents*[1]

1.1 Purpose and background of the study

Fifty years ago, on 25 March 1957, the EURATOM Treaty was signed. Article 1 stipulates that *"it shall be the task of the Community to contribute to the raising of the standard of living in the Member States and to the development of relations with the other countries by creating the conditions necessary for the speedy establishment and growth of nuclear industries"*. Half a year later, on 10 October 1957, the fire at a Windscale reactor releases large amounts of radioactivity. For the first time, contaminated milk and vegetables had to be destroyed following an accident at a nuclear power plant. Nevertheless, the accident – like many less significant events that followed – had surprisingly little effect on public opinions and on the strategies of government and industry.

The growth of the nuclear industries continued. It is in March 1979, more than twenty years after the Windscale fire, that the core-melt accident at the US Three Mile Island (TMI) plant shocked the world. Thereafter and in response to TMI, the nuclear industry and plant operators implemented massive upgrading programs to operational reactors, plants under construction and those on the drawing board were revised. Nevertheless, no new nuclear plants were ordered in the United States since TMI, over a hundred projects having been abandoned. In the West, by the mid-1980s the nuclear power industry was in stagnation.

Then in 1986 the Chernobyl disaster in the Ukraine, the worst nuclear power plant accident to date, sending radioactive clouds around the planet that hit collective consciousness as *worst-case scenario*.

What happened since Chernobyl? No major accident, no large radioactive release, no massive evacuations, no widespread areas of radiologically contaminated land. So everything is fine? Has the risk from nuclear power plants been mastered and safety been improved to "acceptable standards"?

These are questions that are at the basis of the present study. The authors quickly realized that there are no comprehensive international statistics on incidents and accidents and

[1] David Mosey, *Reactor Accidents,* Second Edition, Nuclear Engineering International, 2006

even definition and safety significance of nuclear "incidents" are highly controversial. Operators and nuclear safety authorities prefer speaking about "events".

The International Atomic Energy Agency (IAEA), that maintains an international nuclear event database confidential to its members, did not reply to repeated information requests for this report. In some countries, like France, Germany and the USA, one-line listings of nuclear events reported by nuclear operators to the safety authorities of the respective countries are publicly accessible. However, they are established according to very different criteria that make the statistical comparison entirely meaningless. A simple look at the figures available per country does not give any indication as to whether incidents in one country are more frequent or more serious than in another country. Finally, the absence of information on another country is, of course, no indication that everything is perfect there.

The present analysis is a glance at available information on a narrow number of events in a limited number of countries. The specific knowledge of the participating research teams about their respective countries and regions was essential for the selection of events.

After a brief overview of the status of nuclear power in the world, in Chapter 3 the report provides a presentation of the main causes that can lead to nuclear accidents. Design errors, construction and manufacturing problems can lead to material defects and failures of equipment, components and entire systems. Problems can be triggered by external or internal events. Primary and secondary loss of coolant and fires can lead to serious events. Deficiencies of documentation and operating manuals have played a role in a number of events.

The significance of systemic issues is often underestimated. They are presented in Chapter 4. It is stunning how often the same type of event happens over and over again. Voluntary or involuntary violation of rules and procedures as well as the lack of systematic verification and control can obviously have significant effects on nuclear safety. In many instances identification and assessment of the root causes of a given event turns out extremely difficult. A further problem is the appearance of generic faults that are technical or organizational problems that can be multiplied throughout one specific facility or several plants. Sometimes problems are identified that concern all units of a given reactor series type around the world, which can exceed tens of reactors.

While there are no internationally agreed criteria for the reporting and classification of nuclear incidents and accidents, there is the International Nuclear Event Scale (INES), inspired by the former French event scale, developed by the IAEA and theoretically applied in all nuclear countries (see Annex 1). However, INES has been designed as communication tool rather than as technical rating index. Often operators and safety authorities argue about the appropriate level to be applied to a given event.

Chapters 5 and 6 of the present report present INES as well as the US and German reporting systems. Chapter 7 provides an exemplary overview of event statistics in France, Germany and the USA and Chapter 8 selected events in France and the USA according to differing methodologies. The statistics in these chapters could lead the reader to conclude that there is an incredible number of incidents in France compared to relatively few in Germany, the USA and other countries. This is unlikely to be so. The availability and classification of data is very different from one country to the other. And it is by no means the purpose of the present study to compare the safety performance of countries.

Finally, Chapter 9 provides the reader with the presentation of a selection of 17 events from 9 countries. The authors have extracted exclusively incidents that took place in light water reactors (pressurized and boiling water reactors). The vast majority of nuclear reactors currently operating in the world are light water reactors, 357 of a total of 435 units. There are

264 pressurized water reactors (PWR) and 93 boiling water reactors (BWR). This does, of course, not mean that there are no serious incidents and accidents in other nuclear reactor types and nuclear facilities other than power reactors. Examples include the sodium fire at the Japanese fast breeder reactor Monju in 1995 or the more recent leak at the UK thermal oxide reprocessing plant (THORP) that was discovered in April 2005. Both facilities are still shut down since the respective events took place.

Some examples of specific events are mentioned in this report that make reference to facilities other than power plants. Throughout the report the authors have attempted to illustrate incident patterns with specific examples. But mainly, the report concentrates on the most common reactor technology.

The final selection of incidents reflects the attempt to extract examples for event patterns rather than looking for the most extreme cases. The location attached to each event is sometimes not more than just the first place that a specific problem has been identified. In many cases, similar or even identical events are multiplied throughout a large number of nuclear facilities, sometimes spread out over a period of decades.

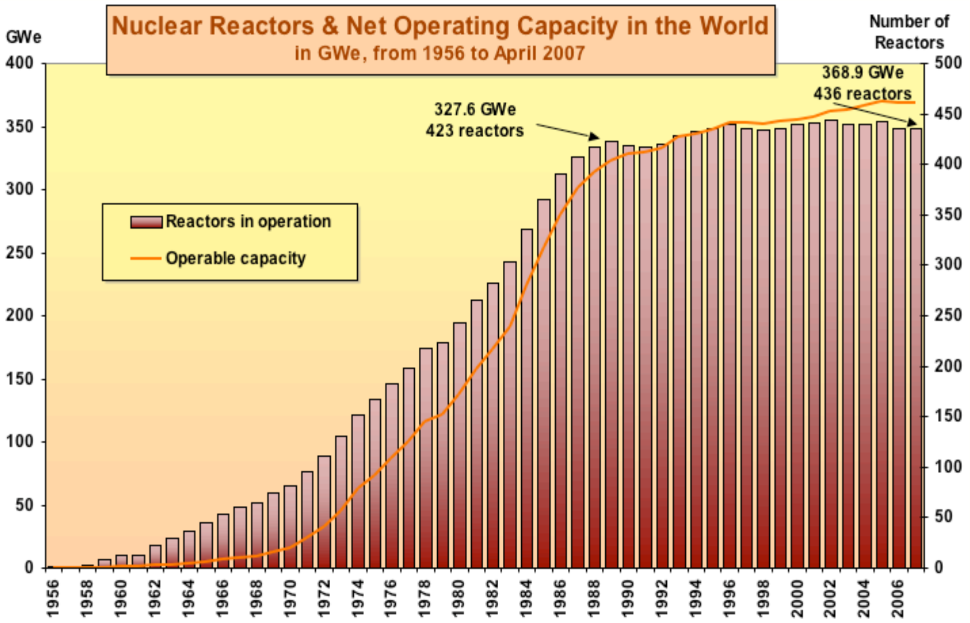
There is no doubt that this event list could have covered events other than those selected. Other experts might have come up with different examples. However, there seems to be a rather broad expert consensus that most of the 17 events constitute particular significant examples for a specific event pattern.

1.2 Overview of status and trends in the nuclear industry with focus on the European Union

1.2.1 Nuclear power reactors worldwide

At the time of Chernobyl accident (1986) there were some 384 nuclear power reactors in operation and more than 50 in construction. The most severe accident in the history of nuclear power in Chernobyl in 1986 slowed the practical application of this technology. This is clearly demonstrated on the following figure, where the number and capacity of operating reactors is shown.

Figure 1: Nuclear Reactors in the World (by number and installed capacity)



Source: IAEA-PRIS 07

The number of operating reactors reached 423 in 1989 and since that time their number has been almost constant. As of April 2007 there are 436 nuclear power reactors in operation worldwide.

The following table shows the relative numbers and age of commercial reactors in operation, under construction and their relative share in electricity and commercial primary energy consumption in different countries.

Table 1: Significance of Nuclear Programs by Number of Operating Reactors by Country

Countries	Nuclear Reactors				Power	Energy
	Operate	Average Age	Under Construc-tion	Planned	Share of Electricity (in 2006)	Share of Com.Primary Energy (in 2005)
USA	103	25	0	2	20%	8%
France	59	20	1	0	78%	38%
Japan	55	20	1	12	25%	10%
Russia	31	23	5	6	17%	5%
Korea RO (South)	20	12	1	7	40%	14%
United Kingdom	19	26	0	0	24%	9%
Canada	18	20	0	2	13%	6%
Germany	17	23	0	0	28%	11%
India	17	17	6	4	3%	1%
Ukraine	15	17	2	0	46%	14%
Sweden	10	26	0	0	50%	33%
China	10	4	5	13	2%	1%
Spain	8	23	0	0	24%	10%
Belgium	7	24	0	0	56%	19%
Czech Republic	6	13	0	0	31%	13%
Taiwan	6	23	2	0	22%	9%
Slovakia	5	17	0	2	57%	21%
Switzerland	5	29	0	0	40%	21%
Hungary	4	19	0	0	33%	10%
Finland	4	25	1	0	27%	19%
Bulgaria	2	19	2	0	38%	20%
Argentina	2	26	1	1	9%	3%
South Africa	2	20	0	1	6%	2%
Mexico	2	13	0	0	5%	2%
Brazil	2	13	0	1	4%	2%
Pakistan	2	19	1	2	2%	1%
Lithuania	1	19	0	0	80%	38%
Slovenia	1	23	0	0	40%	21%
Armenia	1	24	0	0	36%	23%
Romania	1	8	1	0	9%	3%
Netherlands	1	31	0	0	5%	1%
Iran	0	0	1	2	0%	0%
Turkey	0	0	0	1	0%	0%
Korea DPR (North)	0	0	0	1	0%	0%
EU27	145	22	5	2	30%	15%
Total	436	22	30	58	16%	6%

Sources: IAEA-PRIS 2007, BP 2006, WNA 2006, MSC 2007

The net electricity generating capacity of the operating reactors is about 369 GW. Due to the uprating of existing reactors and higher capacity of the new reactors as compared to shut-down units, the installed capacity slightly increased during the last decade. This cannot be directly compared though to the growth rate of competing power generation technologies although the installed capacity developments suggest that nuclear power has not attracted capital investment. For example since 1992, the US utilities alone have built over 270 GW of new natural gas fired power plants, 10 times the total nuclear capacity added through new build and uprating over the same period.[2] And the installed capacity of world wind power has increased from 5 GW in 1995 to over 59 GW in 2005 and is projected to more than double by 2010.

Nuclear power reactors produce about 15% of the total electricity generation worldwide and their relative share is on a downward trend.

At the time of the Chernobyl accident and up to 2001 there were constantly more than 50 reactors under construction. By the middle of April 2007, only 29 units are listed by the IAEA as under construction.[3] It has to be mentioned that for 11 of them construction started between 1975 and 1988. Fast growing economies in Asia (Japan, China, Korea, India and Pakistan) remain the centre of expansion of nuclear industry, accounting for 15 of the 30 reactors under construction and for 25 of the last 35 reactors that have been connected to the grid during recent years.

1.2.2 Types of nuclear power reactors

The most prevalent design is the Light Water Reactor (LWR – essentially, both PWR and BWR types), with 357 units in operation around the world, accounting for 82% of all operating reactors. The individual unit capacity of these reactors is the largest, with a net electrical output of up to 1500 MWe. Within this category the Pressurized Water Reactor (PWR), including the Russian designed WWER, is the most widely used reactor type with 264 units in operation (as of the middle of February 2007).

The other type of LWR is the Boiling Water Reactor (BWR) with 93 units in operation.

Another design deployed is the Pressurized Heavy Water Reactor (PHWR). 42 units of this type are in operation, mainly in Canada.

The Chernobyl reactor, that experienced the accident in April 1986, was of so-called Light Water Graphite Moderated Reactor (LWGR) design, also known as RBMK. The remaining three Chernobyl RMBK units are now closed down and the six RBMK units under construction at the time of the Chernobyl accident, including two at Chernobyl, have been abandoned. 16 power reactors of this type remain in operation – 15 in Russia and 1 in Lithuania.

Gas Cooled, Graphite Moderated Reactors (Magnox and Advanced Gas Cooled Reactors - AGR) were developed in the United Kingdom. 18 units of this type are in operation in the UK, but there are no plans for further development of these reactors.

Fast Breeder Reactors (FBR) were and are still the hope of the nuclear industry for further expansion. However, due to many factors, mainly scientific and technological difficulties, their development practically stopped. A number of units have been abandoned, either prior to commissioning (Kalkar, Germany) or after serious technical difficulties or

[2] http://www.world-nuclear.org/sym/2005/bowman.htm

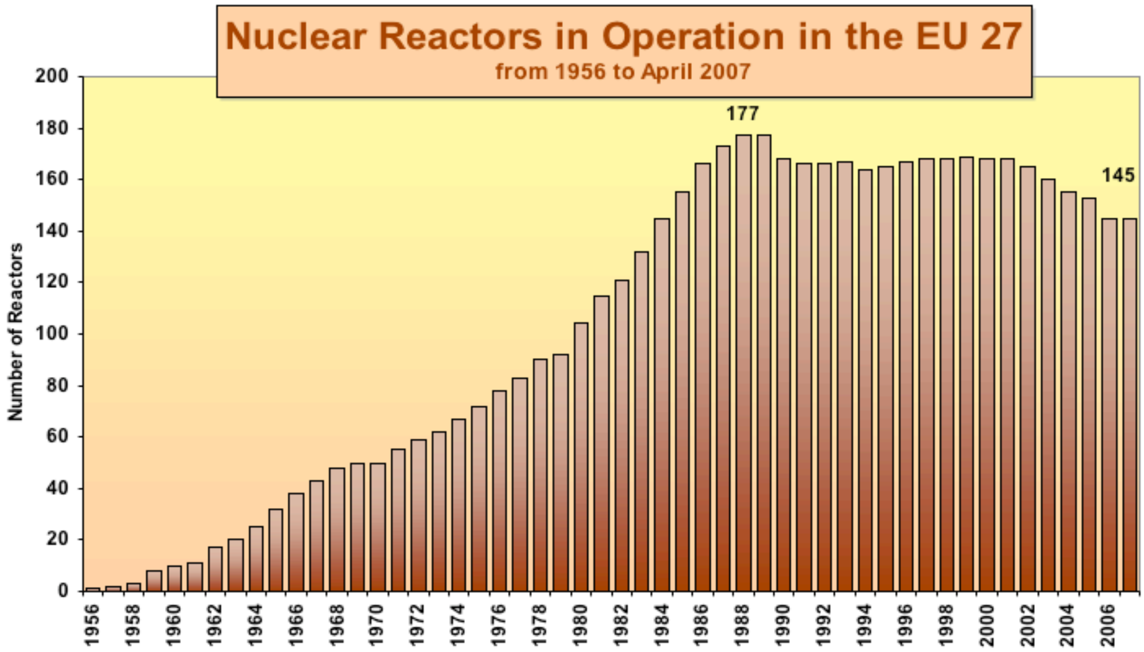
[3] We are indicating 30 units under construction in Table 1 because, contrary to the IAEA, we are taking into account the French Flamanville-3 unit, because groundwork has started and construction has been authorized just prior to the French Presidential elections.

economic decisions (Superphénix, France; Shevchenko, Kazakhstan; PFR, UK). The Monju reactor in Japan has experienced a serious fire in 1995 and has since been shut down. Today there are only two fast breeder reactors in operation, one in Russia, one in France (Phénix in France, has been downgraded to research reactor status) and two are in the construction phase (in Russia and India).

1.2.3 Nuclear power reactors in the European Union

The evolution of the number of operating reactors in EU-27 countries is shown on the following figure.

Figure 2: Nuclear reactors in operation in the European Union 1956 to April 2007



Source: IAEA – PRIS 2007

The Chernobyl accident practically stopped the growth of nuclear power in the then EU-15 and significantly slowed down its development in Central and Eastern European countries. In Western Europe the most recently power reactor to be commissioned was at the end of 1999 (Civaux-2, France). Five nuclear power reactors, which had started construction prior to the break up of the Soviet Union, were commissioned between 1996 and 2002 in three countries in Central and Eastern Europe (Cernavoda-1, Romania, Mochovce-1 and -2, Slovak Republic and Temelin-1 and -2, Czech Republic).

125 power reactors are presently operated in 8 countries in Western Europe (EU-15) and 20 power reactors in seven countries in Central and Eastern Europe. In addition five nuclear power reactors are operated in Switzerland. The total number of operating units in Europe significantly declined during recent years, as first generation reactors have been shut down. Currently there are only two reactors under construction in Western Europe, both being Generation III European Pressurized Water Reactors (EPR) at Olkiluoto-3 in Finland and most recently at Flamanville, France, for which the construction license was issued in March 2007. Three reactors are still in various stages of construction in Central and Eastern European countries (Belene-1 and -2, Bulgaria and Cernavoda-2, Romania), where work started between 1983 and 1987.

There are eight countries for which nuclear power provides 40% or more of total electricity generation; all these countries are in Europe (Belgium, Bulgaria, France, Lithuania, Slovak Republic, Sweden, Switzerland, and Ukraine). Of the sixteen countries that get more than 25% of their electricity from nuclear power plants, thirteen are in Europe. This means that nuclear power is still very important for the electricity supply in Europe and this situation will subsist in the short and medium term.

However, it is in Europe that the decline of the nuclear industry has been the fastest over the past two decades, while the decline in the USA corresponded to the TMI accident of 1979. All of the currently 103 operating units in the USA have been ordered in the decade from 1963 to 1973. Reactor orders that had been registered up to 1978 have all been cancelled. In fact, a total of 138 orders have been cancelled between 1970 and 1994, many in advanced stages of construction[4].

1.2.4 Design and operational safety

Prior to the Three Mile Island Unit 2 accident in 1979, it was quite typical for nuclear safety experts to assert that the likelihood of a severe accident in a commercial power plant was of the order of one in a million per reactor per year of operation (10^{-6}/a), notwithstanding the fact that the pioneering probabilistic safety assessment of its time (WASH-1400) estimated a likelihood far more frequent (one in 17,000 per year, or about 6×10^{-5}/a). The occurrence of the TMI-2 accident after less than 1,000 reactor-years of operating experience with commercial power reactors was a wakeup call for the nuclear industry.

Apposite to the European situation was, however, the Chernobyl accident in 1986 - resulting in a large radioactivity release that spread contamination widely throughout Europe – and which provoked a significant re-examination of nuclear safety. Numerous improvements in human factor aspects of plant operation, procedures, training, and to a lesser extent changes in plant design were carried out at European nuclear plants in the decade that followed the accident.

Over the last decade many LWRs in Europe were backfitted and supposedly upgraded with filtered venting systems, bunkered residual heat removal plant and hydrogen burning or passive auto-catalytic recombiner equipment as a means of avoiding containment failure in severe accidents, and as a means of reducing the release fraction (the amount of released radioactivity) from severe accidents. Some power plants were also equipped with digital instrumentation and control systems.

Significant modernization measures were implemented also at Russian PWRs in Central and Eastern European countries.

In recent years a number of first generation reactors were finally shut down in Germany, UK, Bulgaria, Spain, Sweden and Lithuania (22 units between 2002 and 2006). It is expected that after 2009 there will be no more such reactors operating in Europe.

Four Generation III units are in operation in Japan; all are Advanced Boiling Water Reactors (ABWRs).

After accidents in Three Mile Island and Chernobyl a large number of measures were introduced in order to improve the safety during reactor operation: improvement of operational procedures, implementation of comprehensive quality systems, development of emergency operating procedures, intensive training of personal including simulator training, etc. All these measures were expected to result in significant improvements of operational safety during the following years. However, there is evidence, as can be seen from many of

[4] CEA, *Nuclear Power Plants in the World*, Edition 2001; It is interesting to note that the listing of the cancelled units in the world has disappeared from more recent editions of the same publication.

the examples considered in this report, that despite these measures there was little or no further improvement during recent years and concerns have been expressed in many international forums regarding complacency in the industry.

A number of more recent incidents in the nuclear industry continue to illustrate shortcomings in the design of the systems, safety documentation, and safety culture. A total number of 23 Level 3 (serious incident) and one Level 4 (accident, Tokai Mura, Japan, 1999) events have occurred in nuclear power facilities worldwide since the introduction of the International Nuclear Event Scale (INES) in 1991 (see Annex 11.1).

Even leaders of the nuclear industry have publicly expressed their concerns. Hajimu Maeda, Chairman of the World Association of Nuclear Operators (WANO) warned that "*loss of motivation to learn from others...overconfidence...(and) negligence in cultivating a safety culture due to severe pressure to reduce costs following the deregulation of the power market*." Those troubles, if ignored, "*are like a terrible disease that originates within the organization*" and can, if not detected, lead to "*a major accident*" that will "*destroy the whole organization. We must avoid the pitfalls of self-satisfaction which threaten us*". "*Even a minor accident could be a disaster*," echoed Bruno Lescoeur, executive vice president, generation & trading, of Electricité de France (EDF), *"because it could question the acceptability of nuclear energy in France, and perhaps in the world."* Armen Abagyan of Rosenergoatom said lack of attention to operational events—he cited events in Russia, France, and the U.S.—"*may lead to a new burst of antinuclear opposition and adversely affect both Russian and the world nuclear industry.*"[5]

IAEA Director General Mohamed El Baradei said that an accident or significant safety incident would cripple the nuclear industry. "*We cannot afford another accident*," he added. El Baradei stated that there would still be a lot of work that needs to be done in the area of safety, particularly in the area of applying safety standards and safety culture uniformly across the industry.[6]

[5] Statements made during the biennial general meeting of the World Association of Nuclear Operators (WANO) held in Berlin, on 13-14 October 2003.

[6] Statements made in a video presentation at the American Nuclear Society meeting in New Orleans in November 2003.

2. Definitions: Incidents or Accidents? Events!

The Chernobyl accident caused damage which went much further than anyone could have imagined up to that point. (...) The range of damage suffered seems almost limitless. No precise figures are available, but the costs of the accident over the last two decades are estimated to have risen to the level of hundreds of billions of dollars.

Julia A. Schwartz
Head of Legal Affairs, OECD Nuclear Energy Agency

There seem to be as many terms and definitions as sources for what could be called a nuclear incident. The dictionary defines the term *incident* as "an event or occurrence" and *accident* as *"unfortunate incident that happens unexpectedly and unintentionally, typically resulting in damage or injury"*.[7]

On the main basis of (western) design the probabilistic approach identifies all "incidents" that are reasonably foreseeable on a frequency and severity basis so these are "foreseeable incidents" and not random accidents.

The selection of events in this report is not based on the IAEA's INES index. Certain events can be considered of great significance or large potential risk but are not rated beyond a low level on the INES scale, because of the particular criteria definition. The INES scale attempts to translate the severity of a given event only from a point of view of immediate radiological impact but not from the potential risk.

The joint IAEA–OECD Nuclear Energy Agency (NEA) Incident Reporting System (IRS) claims providing information on *"safety-significant events from the global nuclear community"*[8].

The IAEA's INES defines events as "deviations" (Level 0), "anomalies" (Level 1), "incidents" (Level 2) "serious incidents" or "near accidents" (Level 3) and "accidents" (Levels 4 to 7) – see Annex 11.1.

There is also the term "near miss" that the US National Academy of Engineering defines as *"an almost complete progression of events - a progression that, if one other event had occurred, would have resulted in an accident. (...) A near miss can be considered a particularly severe precursor."*[9] However, the near miss criteria are neither applied in the selection of events for the IRS nor in the INES rating.

There is no objective, internationally recognized definition for particularly severe incidents that bear the potential for severe accidents. In many occasions the direct material, environmental and health consequences of an event are strictly zero. However, this does not provide any indication on how close a given situation has come to an event with serious consequences. Sometimes it is only time that makes the difference – if material stress had been prolonged, rupture would have occurred (see e.g. the hole in the vessel head at Davis Besse incident in the US of 2002). Sometimes safety systems would not have been operable in case they had been needed (see e.g. inoperable pressure relief valves at Gravelines in France

[7] Oxford American Dictionaries

[8] IAEA/NEA, *Nuclear Power Plant Operating Experiences – From the IAEA/NEA Incident Reporting System 1999-2002,* December 2003

[9] J.R. Phimister, V.M. Bier, H.C. Kunreuther (eds.), *Accident Precursor Analysis and Management: Reducing Technological Risk Through Diligence*, National Academy of Engineering, Washington, DC USA, 2004, page 198; available at http://www.riskinstitute.org/PERI/PTR/Accident+Precursor+Analysis+a

in 1989, or reactor sump clogging at Barseback in Sweden in 1992 and at many other plants around the world). In many cases an additional event could have turned a benign incident into a severe accident (see loss of off-site power at Maanshan in Taiwan in 2001 and Forsmark in Sweden in 2006).

In this report the reader is provided with the main characteristics of a given event and their interpretation. It is explained why particular events have been selected. While the responsibility for the final selection is with the project team, it is clear that other choices could have been made, even if the choice of a number of cases seems to be based on a broad international consensus amongst experts.

The selection of events in this report is not based on the IAEA's INES. Certain events can be considered of great significance or large potential risk but, because of the particular criteria definition, these have not been rated beyond a low level on the INES scale. The INES scale does not adequately translate the severity of a given event.

3. Overview of the Main Causes and Contributing Factors Leading to Nuclear Events

This section of the report discusses some of the main causes and contributing factors that have lead to events in nuclear facilities in the more than 8,000 reactor-year of operating experience accumulated since the Chernobyl Unit 4 disaster. It is important to realize that questions about "safety culture" underlie many of the events and accidents at nuclear facilities. The IAEA defines the term "safety culture" as "that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance". The IAEA's International Nuclear Safety Analysis Group (INSAG) reported in 2002: *"Most incidents and accidents in the nuclear industry have occurred because someone has failed to take the relevant precautions or has failed to consider or question in a conservative way decisions that they have made or the steps which were taken to implement them."*[10]

The historical record of such events (insofar as public domain documents is concerned) is incomplete for a number of reasons:

- In many countries, even though reporting systems exist that require nuclear facility operators to report operating experience to the regulatory authority, the resulting reports and reporting system data are often considered to be (commercially) confidential information, or contain proprietary information that cannot be released to the public.
- Event databases such as the database of events reported to IAEA and the NEA of the OECD in the "Incident Reporting System" are often confidential. Not all events are publicly reported, and some INES reports for events, which do attract press attention, are not themselves publicly released, leading to incomplete information in the public domain. This is sometimes true even for events categorized at INES Level 3 (an example is the Kozloduy Unit 5 control rod insertion failure incident in 2006 - the incident itself was widely reported, but no public report appeared in the publicly-accessible area of the IAEA Nuclear Events Web-based System – NEWS - data base). Even though summary level reports for the IAEA/NEA Incident Reporting

[10] See, INSAG-15, "Key Practical Issues in Strengthening Safety Culture", September 2002, page 1

System are periodically published, neither the facilities at which the events take place nor the date of occurrence (other than that it happened within a three-year period covered by the report) are identified. Another difficulty is that the INES Level is often identified and released to the press before any formal and painstaking inquiry into the incident ha concluded and, often, the INES Level is quietly upgraded once the inquiry has concluded.

Examples reported below to illustrate the main causes and contributing factors to events at nuclear facilities are entirely based on publicly available sources.

3.1 Design Faults

The engineering design of hazardous plants, such as nuclear facilities, is carried out in compliance with a complex quality assurance program that covers individual components, assemblies and trains of engineered equipment and plant, and the buildings and services that house and contain the nuclear plant.

Design verification is achieved as a responsibility of the so-called Design Authority who acts to type approve the many thousands of pre-manufactured components, instruments and systems that are bought-into the nuclear plant, and who provides the assemblage of these separately sourced components, etc., and sets out the sophisticated management routines and procedures to oversee the safe operation of the overall the plant.

At stages and when completed, the plant and its systems are scrutinized by an Independent Reviewer and then, dependent in detail on the country of installation and its municipal legislation, the plant design and operating procedures are subject to a regulatory regime or Nuclear Regulator that centers about the nuclear safety of operation and when the plant under internal and external fault events. All of the EU27 states require the plant, both in condition and design status, to be periodically reviewed throughout its operational lifetime.

Underpinning the robustness of the nuclear safety case is a requirement of providing the safety trains and abnormal event management with redundancy and diversity: For example, redundancy is where two pumps are provided instead of one, and diversity is where there is an entirely independent response, such as a bursting membrane as well as a pressure relief valve, to avoid a common-mode or common–cause failure. However, as plants and systems have becoming increasingly more complex, particularly from the lessons learnt from the TMI and Chernobyl incidents, a greater element of passive response has been introduced with the aim that whatever the prevailing abnormal circumstances the plant will settle to a safe and contained state, not being reliant upon active safety systems.

These approaches to achieving nuclear safety require excellence and painstaking detailed checking with formulation of design features that could never be realistically demonstrated other than in a real and severe event (ie such as the reactor core corium melt management system proposed for the EPR). Even so, the overall design and regulatory approaches are strengthened by a presumption that each aspect of the plant function has to be demonstrably safe in that it operates at levels of 'acceptable risk and tolerable consequences'.

Even with such precautions, however, both detailed design errors and deeper-rooted errors in the design philosophy or approach can and have nevertheless occurred.

For a *detailed design* error to persist and reveal itself in a plant event, not only the original design must be in error, but the design checker within the organization that created the design has to miss the error. In addition, the design review - conducted by personnel or organizations not involved in the original design - also has to miss the error. Thus, it can be seen that all design errors that manifest themselves in plant events are the result of not one but multiple misjudgments or the like.

Errors of *design approach* can and have been deep rooted, remaining hidden until revealed by exceptionally challenging circumstances. For example, the lateral bulkhead design of the SS *Titanic* (which stopped short for forming completely watertight cells throughout the height of the hull) was entirely inadequate because the situation of striking an iceberg so far south in the Atlantic crossing was never foreseen and, if it had been, then the risk would have been assessed and, if unacceptable, the bulkhead design set for an outcome of tolerable consequences. Design approach errors are fundamental, passing by the Design, Reviewing and Regulatory authorities.

The threats and challenges to nuclear plants is not static, with certain of these being unforeseen at the time of the design and commissioning.

Challenges such as the risk of flooding and extreme weather conditions might evolve throughout the service lifetime (and throughout its decommissioning and radioactive waste management periods). Such changes, perhaps brought about by Global Warming, might not be readily defended against and might beyond the original composite of 'acceptable risk and tolerable consequences'. Similarly, threats against nuclear plants might evolve but much more rapidly with events such as the 9/11 terrorist attacks heralding an absolute requirement that such hazardous plants be safeguarded, a feature that was certainly absence in the Generation I and II nuclear power plants, and which is being found to be difficult to incorporate into the present Generation III nuclear plants such as the AP and EPR series PWRs.

Design errors have been identified since 1986 as root or contributing causes in numerous cases, including the following examples:

a) A fire at Unit 2 of the Palo Verde nuclear power plant in the United States on 04 April 1996 was identified as resulting from an electrical grounding design error. The result of the error was simultaneous fires in the main control room and in the safe shutdown equipment room. Damage from the control room fire resulted in loss of one train of control room emergency lighting circuits, some general plant essential lighting, and the loss of plant fire detection and alarm panels. The fire in the safe shutdown equipment room affected equipment that supported post-fire safe shutdown capability in event of a control room fire. Investigation of the fire resulted in the discovery that the same design error had been made on all three units at Palo Verde.[11]

   The Palo Verde incident involved elements of lack of redundancy and diversity.

b) Japan's prototype fast-breeder, sodium (roughly 1,530t) cooled nuclear reactor Monju (280 MWe) was built at a cost of about $5 billion and was designed to burn a combination of plutonium-uranium mixed oxide fuel and to produce more plutonium than it consumes. After a decade of technical delays and costly preparations Monju started operation in April 1994 and was connected to the grid in August 1995. On 8 December 1995, when running at 40% of nominal power, about 750kg of liquid sodium leaked from the secondary cooling system and caused a subsequent fire. The leaked sodium melted parts such as a ventilation duct and a catwalk, and was piled up on the floor, covering some 4,400 sq. m. The floor temperature reached 700 to 750^{0}C, but it did not melt. The Monju sodium leak was the largest ever from a fast breeder reactor.

[11] See US Nuclear Regulatory Commission Information Notice Nr. 97-01

The cause for the incident was the faulty design of the temperature sensor pocket in the sodium coolant pipes. In the 1995 accident one of these pockets had broken off, which started the leaking of the pipe. Other pockets also were found with signs of cracks. The investigations of the incident discovered questionable operating procedures, inadequate manuals, and sloppy crisis management - all rendering the Monju case a result of failed detailed design and inadequate institutional controls and quality assurance.

For more than 10 years, Monju has been undergoing safety inspections and a modification program. Every year plans to restart Monju in the near future are announced but, to date, the reactor remains shutdown.

c) The 10 April 2003 fuel damage accident at Paks Unit 2 (which occurred during chemical cleaning of 30 fuel assemblies in a tank in the spent fuel pool, outside the reactor) was identified by the IAEA as due in part to eight separate design errors. This event was categorized as INES Level 3. (See 9.2.4.1 for details on the accident.)

d) New control rod drive mechanisms were installed in Kozloduy unit 5 in July 2005 during the annual outage. The unit restarted in beginning of September and was operated on full power. However on 1 March 2006 after a main coolant pump trip it appeared that 22 of total 61 control rods could not be moved with control rod driving mechanisms. The root cause for this incident was design changes of driving mechanisms, which were not properly authorized and tested. The event was classified as INES Level 2. Thus, during eight months the reactor was operated at full power with an insufficient number of operable control rods. (See 9.2.3.2 for details on the event).

   The Kozloduy incident included elements of faulty detailed design and institutional failure to conduct type approval quality assurance controls.

3.2 Construction and Manufacturing Problems

Even when the design of a nuclear facility is correct, errors during construction can nonetheless result in an event at the facility. This is particularly the case when the design specifications are not respected during construction, and the as-built system is not verified to conform to the design.

Construction errors have been identified as root or contributing causes in the following exemplary events:

a) At an unnamed Japanese nuclear power plant in the 1999-2002 time period, a crack was discovered on a pipe. Investigation of the event found that a vinyl chloride tape was placed on the piping during plant construction to identify the pipe. During preoperational testing, high temperature water was passed through the piping for a short period. The high temperature decomposed the tape, producing chloride ions. During each subsequent plant start-up, the chloride ions reacted with the pipe metal and moisture, resulting in chloride stress corrosion cracking on the outer surface of the pipe. During periodic inspection, a hydrostatic test was performed, and the cracking propagated to the inner surface, resulting in a leak.[12] This is an example of where the original design intent was thwarted by a temporary modification.

b) In the 1960s, for the on-site fabrication of the UK's Magnox reactors, separate preformed steel plates forming the 15m diameter primary pressure vessel were temporarily tack welded in place with steel channels located on the outer surface to enable full welding to be completed. Once that the pressure vessel had been tested the mass concrete biological shield was cast to completely enclose the reactor pressure vessel. Under irradiation the pressure vessel shell itself became very radioactive so that only remote monitoring was possible. In the 1990s when concern was expressed about the extent of irradiation and embrittlement of the steel pressure vessel, a spider robot was designed to crawl over the outer surface of each pressure vessel to inspect for crack development of the shell but, much to the surprise of the robot designers, the spider encountered the tack welded channel sections and was unable to proceed further, all at great expense and considerable delays in proving the period safety review.

   Thus incident, occurring at a number of the Magnox nuclear power stations, was simply because the failure to record the continuing presence of the tack weld channel sections on the as-built design.

3.3 Material Defects

Nuclear safety is dependent on the proper performance of the various materials used to construct and maintain structures, systems, and components in nuclear facilities. When incorrect material is used in an environment that is not conducive to the material, component failures can result. Material degradation mechanisms in nuclear power plants include irradiation embrittlement, fatigue, corrosion fatigue, stress corrosion cracking, corrosion, thermal ageing, wear, and erosion.[13]

Material selection in the engineering design process usually assumes a set point failure. For example, for the design of a welded joint it is assumed that a hypothetical defect or flaw exists in the weldment with the size of this flaw is assumed to be just below the limit of non-destruction examination so that the weld would pass through the inspection quality control. The flaw is assumed to develop and propagate under the specified service conditions (embrittlement, thermal cycling, etc) to failure, which is required to be within the design requirement in terms of age, time, number of cycles etc. This cautious approach enables the component design to be matched to a prescribed service or replacement life.

Material defects have been identified as root or contributing causes in numerous events, including the following examples:

a) The Davis-Besse reactor vessel head hole, detected in 2002

[12] NEA-5168, "Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 1999-2002", page 16
[13] See, IAEA, "Material Degradation and Related Issues at Nuclear Power Plants", Proceedings of a Technical Meeting held in Vienna, Austria, 15-18 February 2005, published September 2006, pages 2-3

In evaluating events involving ostensible materials problems, it is often a matter of judgment whether an event is properly ascribed to "material defects". For example, it is well known in industry that carbon steel is subject to corrosion when exposed to acidic solutions and it is well recognized that LWR primary coolant (which contains boric acid) can corrode carbon steel. When such corrosion occurs, concluding that it is the result of a material defect is misleading – there was nothing wrong with the material per se – rather, a problem can occur when the material is not regularly inspected for corrosion damage and repaired before the corrosion damage results in failure.

Thus, the Davis-Besse reactor vessel head corrosion event but was also due to an inappropriate detailed design of the reactor head penetration sealing to avoid the acid getting in contact with the vessel head material and, in addition to this, a prolonged institutional failure to conduct proper surveillance, combined with a lack of management procedures mandating further investigation of the root cause, such as following through the reason at the discovery of carbon steel corrosion products trapped in the main containment air sampler filters). (See 9.2.1.2 for further details on the event).

b) Reactor Pressure Vessel Shroud Cracking

Boiling water reactor core shroud cracking occurred at a number of nuclear power plants in the 1996-1999 time period, and was identified as one of a handful of problems discussed in the joint IAEA/NEA Incident Reporting System report for this period.[14]

c) Graphite Moderator Degradation – Magnox and AGR Plants, UK

The mainstay of the UK's reactor development program was the graphite moderated, gas cooled reactor design that was applied to the 1st generation Magnox, to the development marquee AGR and planned for but abandoned series of high temperature, graphite moderated reactors. Graphite was chosen as the moderator because of its high neutron moderation characteristic, that it lessened the need uranium fuel enrichment (natural uranium in the Magnox and minimal enrichment for the AGR)), it could be used in a dual role for plutonium breeding, and that, in conjunction with a carbon dioxide primary coolant, higher steam turbine temperatures could be achieved thereby winning considerable gains in overall thermal efficiency of the plant.

However, the speed at which the UK developed its commercial, power generating reactors outstripped the acquisition, mostly by empirical means, of the in-core characteristics and degradation of graphite. This resulted in a number of design and operation difficulties, namely:

i) Early experience in the Magnox reactors indicated that the in-core neutron flux accelerated radiolytic oxidation (weight loss) over that anticipated from the data obtained from the lower pressure research reactor cores. To

[14] Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 1996-1999", pages 10-11

offset this, a continuous trace of methane was injected into the primary circuit with the desired result but, unbeknown at the time, the methane also accelerated the corrosion of the reactor core support steelwork to the extent that in the early 1970s all of the Magnox reactors had to be significantly derated in output. Even so, the extent of the moderator weight loss in the four remaining operational Magnox reactors, at Oldbury and Wylfa, is now in excess of 20 to 30% of the first commissioned level, so much in fact that slightly enriched fuel is now required to maintain criticality in the cores.

ii) In light of the steelwork corrosion in the Magnox reactors, the follow on AGR internal steelwork was chosen to be corrosion resistant to permit a tolerable level of methane injection. However, the reactor circuit operating conditions, particularly the higher pressure, has accelerated graphite oxidation to the extent that the four AGR reactors at Hunterston and Hinkley Point (2,400MWe in total) have been shut down for the last 6 months while the graphite core residual strength safety case is reviewed.[15]

The Magnox and AGR core difficulties have resulted in considerable financial impact and loss of the nuclear safety margin, particularly for the AGR where sufficient core residual strength is necessary to prevent core collapse in the event of a multiple boiler tube failure. The failure illustrates the risks involved in the rapid development of a reactor series where unproven extrapolation has to be relied upon in material selection.

3.4 Failures of Equipment, Components, and Systems

Nuclear power plants are typically designed using a "single failure criterion", which means that systems are designed such that following an initiating event, a single failure is assumed and then the remaining available equipment is evaluated to ensure that all essential safety functions can still be performed. The single failure criterion has been a fundamental nuclear safety design principle and analysis assumption since the 1960s. There is a difference though from country to country on the decision whether the single failure criterion is applied to active systems only or also to passive system.

Unfortunately, operating experience has consistently shown that a surprisingly large proportion of all equipment failures are so-called "common-cause" or "common-mode" failures - that is, multiple trains of equipment are failing due to a common-cause. Previous common-cause failure data indicates that about 10% of all equipment failures are in fact common-cause failures in which two or more trains of equipment fail.[16] Data compiled by the US Nuclear Regulatory Commission (NRC) in 1999 indicates that common-cause failures account for the following percentages of all failures for the indicated component types:

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[15] Large J H, *Brief Review of the Documents Relating to the Graphite Moderator Cores at Hinkley Point B and Other Advanced Gas-Cooled Reactors*, R3154 5 July 2006 - http://www.largeassociates.com/3154%20Graphite%20AGR/R3154-Graphite%20FINAL%2028%2006%2006.pdf

[16] See EPRI, *Classification and Analysis of Reactor Operating Experience Involving Dependent Events*, EPRI NP-3967, June 1985, page 5-3; more recent report indicate a similar pattern; see for example, NRC Regulatory Issue Summary 99-003, "Resolution of Generic Issue 145, Actions to Reduce Common-Cause Failures", 13 October 1999

a. Air-operated valves (AOVs), 37.8%.
b. Batteries & battery chargers, 4.8%.
c. Check valves, 30.6%.
d. Circuit breakers, 11.7%.
e. Diesel generators, 9.7%.
f. Heat exchangers, 62%.
g. Motor-operated valves (MOVs), 7.5%.
h. Pumps (auxiliary feedwater, emergency service water, emergency core cooling), 8.0%
i. Relief valves, 11.8%.
j. Safety valves, 13.6%.
k. Strainers, 24.1%.

The NEA has initiated the International Common-cause Data Exchange Project. The most recent reporting of the project (in the Incident Reporting System report for the period from 2002-2005) indicates that despite improvements in maintenance, training, design documentation, updating of safety analysis reports, and many other industry initiatives to improve performance, about eleven percent (11%) of all common-cause failures are complete system failures.

Taken together, this indicates that about 1% of all component failures represent common-cause failures resulting in complete failure of all similar components (10% of all failures are common-cause failures, and 11% of the common-cause failure represent complete system failures). The results vary across different classes of components, but the general average for all components in the program supports the one percent (1%) complete common-cause failure rate. The study also found that most of the failures that lead to complete failures are due to human actions.

3.5 External Events

This section of the report is concerned with potential risks originating with events occurring outside the plant. Such events can result from natural phenomena hazards and from man-made hazards. Exemplary types of external event hazards include (a thorough analysis of external events typically involves the assessment of more than one hundred different events):

- Flooding (due to extreme rainfall, tidal effects, storm surges, seiche, tsunami, dam failure, levee failure, etc.)
- High winds (tornado, hurricane, cyclone, wind-blown debris, tornado missiles)
- Extreme weather (high temperature, low temperature, hail, snow, sleet, icing, humidity, extreme drought, extreme water temperature)
- Aircraft impact (takeoff, landing, air corridor accidents, fire fighting aircraft accidents, military aircraft, hijacking & terrorism)
- Adverse electromagnetic environment (electromagnetic interference, lightning, electromagnetic pulse due to conventional means)
- Pipeline accidents
- Onsite or nearsite transportation accidents (road, sea, river, rail)
- Explosions (blast waves, missiles)
- Gas clouds (toxic, asphyxiates, combustible)
- Liquid releases (flammables, toxic, radioactive, corrosive)
- Near-site accidents at industrial or military facilities

- Biofouling hazards (zebra mussels, asiatic clams, clogging of intake and service water structures)
- Seismic events
- Volcanic hazards (dust, debris, lava flows, mass movements, ground motion, etc.)

For most external events, nuclear facilities are required to withstand prescribed levels of severity referred to as the Design Basis – these include design basis earthquake, design basis wind speed, etc. Some extreme levels and types of external events are categorically excluded from the design, often due to low frequency of occurrence arguments (such as meteorite impact) or lack of event possibilities in the nuclear facility region (such as no volcanoes present in the region where the facility is located).

The Design Basis approach is dependent upon both *a priori* and *post priori* knowledge which is used to forecast the chance or probability that a specific event will occur in the future but utter dependence upon this has several pitfalls: For example, the future occurrence of the event may not be described by the same probability distribution as the past, this might be particularly pertinent to severe weather conditions, flooding, etc., possibly due to climatic change; the forecasting model may not fit the historical data very well, particularly where the chance levels under consideration (~1 in 1,000,000) are very remote; and/or the probability of chance may be corrupted by human intervention such that malicious acts might properly be considered to be inevitable rather than an act of chance.

There are several examples where external events have affected nuclear facilities since 1986, including the following:

a) An external flooding event (due to a storm surge topping local flood protection provisions) occurred on 27 December 1999, affecting the Blayais nuclear power plant in France, causing all four units to be shut down and rendering some safety systems inoperable at Units 1 and 2 (see 9.2.7.1 for details). This event was rated as INES Level 2. As a result of the Blayais flooding, a site-specific reassessment of flooding potential was undertaken for French nuclear facilities. The Belleville, Bugey, and Chooz nuclear power plant sites were found to need new, higher maximum flood design levels.

b) The Indian Ocean tsunami on 26 December 2004 (resulting from a very large undersea earthquake off the coast of Indonesia) caused flooding at the Kalpakkam nuclear site in India. IAEA characterized the resulting wave as a "huge tsunami".[17] Water from the tsunami caused $3.5 million in damage at the site, and caused water level in the operating unit to rise, resulting in tripping of the reactor. Although this specific event was rated as INES Level 0, the event is noted here due to the potential for tsunamis to affect this and other coastal nuclear facility sites around the world.

c) Two external fires (wild fires that started with a controlled burn offsite) affected various facilities at Los Alamos National Laboratory in the United States on two occasions (the so-called "Dome Fire" in 1996, and the so-called "Cerro Grande Fire" in 2000). Such fires can also affect nuclear power plants, as demonstrated by a loss of offsite power resulting from a wild fire near the Diablo Canyon nuclear power plant on 04 April 2001.

[17] IAEA Staff Report, 08 August 2005, http://www.iaea.org/NewsCenter/News/2005/tsunami.html

d) A Fujita Scale 2 tornado passed near the Davis-Besse nuclear power plant in the United States in 1998. Although the wind speed experienced at the plant site was within the design basis, significant damage occurred to the plant electrical switchyard and to non-safety related buildings. Lightning strikes resulted in opening and closing of breakers. A total loss of offsite power occurred, and two of three emergency response communications systems were disabled. The plant computer system also failed due to loss of power. Rain entered the turbine hall owing to large holes in the turbine hall roof caused by storm damage. A pair of tornadoes (one rated at Fujita Scale 4, but at F1 or F2 near the power plant) passed near to the Calvert Cliffs nuclear power station on 28 April 2002.[18] A tornado affected the Quad Cities site in the United States in 1996.[19]

e) Hurricane Andrew struck the Turkey Point nuclear power plant in the United States in 1992, with sustained winds of 233 km per hour and peak gusts at 282 km per hour (a hurricane Intensity Level 4 on a scale of 5). Safety-related structures at the nuclear power plant were designed for a maximum wind speed of 378 km per hour. Owing to the lead-time available before the hurricane reached the site area, drains were plugged to prevent water entering the plant, and operators were stationed in the diesel generator building as a precaution. Although safety related structures did not suffer any damage, offsite power was lost to the site for five days. During this time period, one of the diesel generators had to be shut down due to overheating. Offsite communication was lost and plant access roads were blocked by debris. Helicopters had to be used to bring fuel and consumables to the plant site. Families of plant staff were taken to the plant and fed, to allow operators to work in a "non-emotional" environment. A water tower collapsed causing major damage to the fire protection system piping, the water supply system, electrical services, and instrumentation. Some non-safety-related buildings were destroyed during the storm. In addition, an effluent stack at a fossil-fired unit at the Turkey Point site structurally failed. Over $90 million in damage was caused at the plant site.

f) Offsite power was lost to the Maanshan nuclear power plant in Taiwan during a tropical storm in 2001 (see 9.2.5.1 for details). Similar losses of offsite power due to salt spray effects have affected the Pilgrim nuclear power plant in the United States.

g) So-called "biofouling" incidents continue to occur, resulting in unscheduled plant shutdowns and some impacts on safety systems (particularly service water systems). Electricité de France shut down two Paluel reactors in the summer of 2005 as a precautionary measure when heavy storms resulted in the accumulation of an unusually high amount of seaweed that was interfering with the water intake at the plant.[20]

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[18] http://www.somd.com/news/headlines/2002/04/tornado/; http://www.weatherbook.com/laplata.html; http://www.erh.noaa.gov/er/lwx/Historic_Events/apr28-2002/laplata.htm
[19] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/admin-letters/1997/al97003.html
[20] Nuclear Engineering International, 13 July 2005

3.6 Internal Events

This section of the report is concerned with potential risks originating with events occurring inside the plant, but due to causes not associated with the normal operation of plant systems. Such events include fires, rupture of primary system components leading to Loss of Coolant Accident (LOCA), flooding resulting from pipe breaks, and internally generated missiles resulting from turbine failures.

3.6.1 Loss of Coolant Accident (LOCA)

On 20 January 2003 Kozloduy unit 3 was operated at 98 % of rated power. At 04:14 AM the reactor protection system was automatically actuated by a low pressure in the primary system (PI<115 bars) signaling a primary coolant leak. At the same time a safety injection signal was actuated (at PI=105 bars). All safety injections and confinement spray pumps started as designed. At 04:35 the leaking part of the primary system was isolated and the leak was compensated. Soon after this the primary system pressure and the pressurizer level were restored. During the event the safety injection and confinement spray pumps were in operation for about 60 min.

During the revision the leak was found at a pipeline (38 x 4mm) and the estimated leak size was equivalent to a diameter of 22,5 mm. The direct cause of the pipe leak was a mechanical damage due to a long time vibration and friction of a pipe to a part of the structural components. Deficiencies of the surveillance program for pipes in the confinement also contributed. The damaged pipe was not included in the non-destructive testing program and surprisingly the visible mechanical damage was not discovered by visual inspections.

It appeared that at least for several hours the personnel did not check the readings of systems for early detection of leaks from the primary side, which indicates serious degradation of the safety culture. This incident shows that the role of Leak Before Break Concept has to be dramatically re-considered as an important line in the Defense in Depth Concept (several levels of protection). The event was rated at Level 1 on the INES scale only, in spite of the fact that according to INES guidelines the starting assessment for events with real leakage from primary system is to be considered a Level 2 event.

3.6.2 Fires

Most frequently fires in nuclear power plants are detected quickly and manually suppressed before significant damage can be done. In other cases, the automatic fire suppression systems are actuated and these quickly suppress the fires. Such benign outcomes are not always the case and nuclear power plant probabilistic safety studies often identify specific fires as important contributors to core damage frequency. Serious fires have occurred in the past two decades, and can be expected to continue to occur in the future.

There are numerous examples of **turbine failures** since 1986 (most accompanied by a fire due to the combustion of hydrogen leaking from generator cooling systems and/or fire due to leakage and combustion of turbine lubricating oil):

a) In 1989, Unit 1 of the Vandellos nuclear power plant, a now shut down gas-graphite moderated reactor in Spain, suffered a turbine failure and subsequent turbine hall fire. Suppression of the fire took six hours. During the fire, a rubber expansion joint in the turbine hall failed, resulting in seawater flooding of the lower levels of both the turbine hall and the reactor building (in the latter case, this flooding occurred due to violation of administration controls that left a door open). Considerable equipment failures ensued, including failure of two of four main coolant circulators, two feedwater pumps, the turbine building sump pumps, the control air system, area lighting in many plant buildings, the shutdown heat exchanger, the public address system[21] and the condenser control valves. Smoke entered the control room, and fire suppression systems were automatically actuated in numerous areas despite the lack of fire in those areas. This event was rated as INES Level 3. The resulting damage was so significant that it was decided to permanently close and decommission the plant.

b) In 1991, a turbine hall fire occurred at Unit 2 of the Chernobyl nuclear power plant in Ukraine due to an electrical short circuit resulting from the inadvertent operation of one of the turbines as an asynchronous motor. This resulted in turbine rotor displacement, and release of hydrogen from the generator cooling system and release of lubricating oil from the turbine systems. As a result of the lack of smoke discharge provisions in the turbine hall and insufficient cooling of steel structures, the turbine hall roof collapsed. The collapse resulted in the disabling of three of the five main feedwater pumps and one of three emergency feedwater pumps. Ultimately, both main and emergency feedwater were totally disabled before the fire could be suppressed. Reactor cooling was maintained only by increasing main circulating pump seal cooling flow. The fire was suppressed three and a half hours after it began. According to the Finnish safety authority STUK, *"only some very extraordinary measures to remove residual heat saved the plant unit, with a small margin, from a severe reactor accident."*[22] Ultimately, the decision was taken to permanently close and decommission the unit owing to fire damage.

c) In 1993, a turbine hall fire at the Narora nuclear power plant in India resulted in a prolonged station blackout. The fire burned for more than ten hours before it was suppressed. During the course of the fire, smoke entered the main control room. No control room indications were available due to the loss of electrical power. Emergency control panel indications were also blacked out. The main control room was evacuated. The plant remained shut down for repairs from March 1993 until January 1995. The fire was rated INES Level 3.

d) Turbine hall fires resulting in prolonged shutdowns occurred at the Salem reactor in 1991, and at the Fermi Unit 2 in 1993, both plants in the United States. In both cases, turbine failures were the initial event leading to the fires. The Salem event resulted in generation of turbine ejected debris missiles that impacted numerous plant structures.

3.6.3 Secondary cooling circuit and other pipe failures

Another type of event that has periodically occurred over the period since 1986 involves secondary pipe failures due to erosion corrosion. The most recent example of this type of event took place at the Mihama nuclear power plant in Japan in 2005 when a pipe

[21] The system by which control room operators can communicate with personnel in other areas of the plant by way of announcements.
[22] see http://www.stuk.fi/julkaisut/tr/stuk-yto-tr168.pdf

failed due to erosion corrosion, resulting in the deaths of five workers and injuries to six more workers. It was later revealed that the pipe wall thickness of the failed pipe had not been checked since the plant went into operation in 1976. After the Mihama-3 pipe failure, two additional erosion-corrosion-related pipe failures occurred at the South Ukraine nuclear power plant in Ukraine. On 19 May 2005, a high-pressure heater line ruptured at Unit 2; and on 26 August 2005, a condensate pipe ruptured at the same plant.[23] The lack of surveillance of this piping appears difficult to justify considering the previous operating experience with secondary pipe failures, which included:

a) A feedwater line break at the Surry Unit 2 plant in December 1986 that resulted in four deaths and two serious injuries.[24]

b) Discovery in 1987 of significant erosion-corrosion of safety-related feedwater piping at the Trojan nuclear power plant in the United States, resulting in the replacement of the affected piping.[25]

c) Failure of an extraction line at Arkansas Nuclear One Unit 2 in April 1989 due to erosion-corrosion.[26]

d) Failure of an extraction line at the Fort Calhoun nuclear power plant in the United States due to flow-accelerated corrosion.[27]

e) Failure of a moisture separator drain line at Millstone Unit 3 in the United States in December 1990, causing failure of adjacent line due to pipe whip damage, resulting from erosion-corrosion.[28]

f) Failure of feedwater regulating valve bypass lines at the San Onofre Unit 2 plant in the United States in July 1990 due to erosion-corrosion.[29]

g) Failure of a low-pressure heater drain pipe at Surry Unit 1 in the United States in March 1990 due to erosion-corrosion.[30]

h) Failure of the main feedwater piping at Loviisa Unit 1 in Finland in May 1990 due to erosion-corrosion.[31] On 25 February 1993, a feedwater pipe ruptured at the adjacent Unit 2 reactor.[32]

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[23] IAEA, "Material Degradation and Related Issues at Nuclear Power Plants", Proceedings of a Technical Meeting held in Vienna, Austria, 15-18 February 2005, published September 2006, page 15
[24] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1986/in86106.html, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1986/in86106s1.html
[25] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/gen-letters/1989/gl89008.html, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1987/in87036.html
[26] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1989/in89053.html
[27] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1997/in97084.html
[28] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1991/in91018.html
[29] ibidem
[30] ibidem
[31] ibidem
[32] IAEA, "Material Degradation and Related Issues at Nuclear Power Plants", Proceedings of a Technical Meeting held in Vienna, Austria, 15-18 February 2005, published September 2006, pages 40-42

i) Failure of a moisture separator re-heater line at Millstone Unit 2 in the United States in November 1991 due to erosion-corrosion. [33]

j) Failure of a condensate line at Sequoyah Unit 1 in the United States in November 1994 due to erosion-corrosion.[34]

Corrosion affected piping in other systems as well as in secondary steam-related systems. Essential service water systems can be affected by several types of corrosion. On 25 August 2004, a circumferential break occurred in one train of a two-train essential service water system at the Vandellos Unit 2 reactor in Spain. This break left only a single train of equipment supplying essential cooling to safety-related equipment such as the diesel generators, the residual heat removal system, and others. After repairs, the other train of essential service water was checked and it too had to be repaired.[35]

3.7 Human Errors and Violations of Rules and Procedures

Humans make mistakes. For this reason, in technologies with potentially high consequences in case of an untoward or unplanned for event, actions undertaken by humans should be checked by other persons to provide additional insurance of correct execution. Even this does not ensure perfection, because the failure of the "checker" to identify and correct the mistake made by the person in the first instance results in the mistake continuing to exist.

Unfortunately, the likelihood of human errors is not so small as to make such combinations of errors very unlikely. It is thus not at all surprising that human errors are among the causes of events in nuclear facilities. Deliberate violations of procedures - whatever the motivation (goodwill or ill advised) – also not surprisingly results in events in nuclear facilities.

Human errors and violations of procedures have been identified as root or contributing causes in the following examples of events:

a) At Unit 1 of the Kozloduy nuclear power plant, during an outage in May 1998, a spill of chemical cleaning fluid resulted in the contamination of the water tank used for three emergency core cooling and confinement spray systems. Plant management decided – contrary to safety requirements – to drain the emergency water tank. This left the emergency core cooling system and spray system without a water supply for 24 hours, contrary to license requirements. This event was categorized as INES Level 2 due to a serious reduction in defence-in-depth and the adverse safety culture of the plant executives and personnel.[36] Note that this event occurred at a pressurized water reactor that does not have a containment.

b) Japan: Data Falsification in TEPCO reactors. Staggered by a series of scandals, all 17 boiling water reactors operated by Tokyo Electric Power Co. were shut down between September 2002 and April 2003 for extensive safety checks after revelations erupted in late August 2002 that TEPCO personnel had systematically concealed findings on core internal inspections from regulators. (see 9.2.8.3 for more details).

[33] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1991/in91018s1.html
[34] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1995/in95011.html
[35] IAEA, "Material Degradation and Related Issues at Nuclear Power Plants", Proceedings of a Technical Meeting held in Vienna, Austria, 15-18 February 2005, published September 2006, pages 49-52
[36] See Committee on the Use of Atomic Energy for Peaceful Purposes (Bulgaria), 1998 Annual Report, page 10

In all three cases above, human errors were deliberate violations of requirements – not unfortunate mistakes.

3.8 Deficiencies in Documentation

Deficiencies in documentation is another of the factors causing events in nuclear facilities, where it is often a matter of judgment to decide whether a given event was caused by human error or documentation deficiencies. For example, if a procedure is changed, but the persons executing the procedure are not properly trained in the change, is the event that results due to a deficiency in documentation (i.e., the documentation does not describe what is actually practiced in the field) or is it a deficiency in training (i.e., the procedure was not executed correctly because the persons performing the procedure were not trained properly in its use)? Nonetheless, it is clear that documentation deficiencies can be a root or contributing cause to nuclear events.

> Example: In 2001 a shortfall of the specified filling level of the flooding tanks during the start up of the Philippsburg-2 plant in Germany was detected late because of wrong data interpretation (see 9.2.3.1 for further details).

3.9 Malicious Impacts

Note: The following section will focus only on the situation in the US. This shall not preclude any judgment about the quality of the respective security arrangements in the US or any other countries.[37,]

The potential for sabotage attacks at nuclear power plants poses a unique risk and deserves special consideration. All nuclear power plants, no matter how low their probability of severe accidents, are vulnerable to catastrophic meltdown and large radiological release in the event of a well-planned sabotage attack. Therefore, every nuclear plant should have a highly effective security organization that is prepared at all times to immediately and successfully respond to a range of external and internal threats.

However, dangerous security weaknesses at nuclear plants are all too common. While there has not been a documented case of sabotage at a nuclear power plant resulting in a radiological release, numerous incidents over the last twenty years have revealed serious security vulnerabilities that could have been exploited in the event of an attack. These vulnerabilities should be considered comparable to vital safety systems that are non-functional. A broken security system would be unable to prevent a successful attack, just like a broken safety system would be unable to prevent a serious accident. However, security vulnerabilities are distinct because intentionally caused events are of a different character than randomly occurring accidents. An insider who is aware of a security vulnerability can provide the information to external attackers, therefore increasing the likelihood of a successful attack.

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[37] Publicly available case-specific studies and papers include:

- Large J H. Marignac Y, Submission to the International Atomic Energy Agency - Convention on the Physical Protection of Nuclear Material (CPPNM) – IAEA InfCirc/274 & InfCirc/225/Rev.4 - *IAEA Requirements on Design Basis Threat Assessment - Non Compliance of Eurofab LTA shipment from US to France on UK Vessel: Security and Physical Protection Issues*, IAEA 20 September 2004;
- Large J H & Schneider M, *Vulnerabilities of Nuclear Plants to Terrorism*, Oxford Research Group Seminar, Rhodes House, Oxford, December 2002

But no such correlation exists between a broken safety system and the random occurrence of an accident initiator.

A key factor in assessing the effectiveness of security programs at nuclear power plants are performance tests. These range from tests of the intruder detection systems to full-scale "force-on-force" exercises involving simulated attacks by mock adversary teams with paramilitary equipment and training.

In this section, we discuss several security-related incidents that have occurred at U.S. nuclear plants since the Chernobyl accident that are notable for the severity of the weaknesses that they revealed. Typically, after events like these, the U.S. Nuclear Regulatory Commission (NRC) will take steps to address the vulnerabilities that were exposed. However, even after the revamping of the NRC's security programs in the aftermath of the 11 September 2001 attacks, incidents of concern continue to occur, often brought to the attention of the public through whistleblowers, indicating that the systemic problems in security are not being addressed.

Compiling information about security problems at nuclear plants is a far harder task than compiling information about safety problems. In the United States, most information about nuclear plant security is classified as "safeguards information" and is only disseminated to individuals with proper authorization and who are determined to have a "need to know" the information. However, prior to the 11 September 2001 attacks in the United States, a substantial amount of security-related information was available to the public. After 11 September 2001, the NRC, along with all other government agencies, took steps to greatly reduce the amount of information available to the public that was deemed useful to terrorists. Much of the information provided in this section comes from the archives of the Union of Concerned Scientists. Although some of the documents referenced below are no longer readily available to the public through the NRC website or other easily accessible sources, none of these documents are considered "safeguards information" and hence are not restricted from distribution.

The events discussed are examples of four categories of security event: (1) specific threats against nuclear plants that were neutralized before occurring; (2) actual breaches of security; (3) gross failures of preparedness of the security force as revealed through performance tests; and (4) general decline of the "security culture" that would severely impair security response in the event of an incident.

a) Potential sabotage against the Palo Verde nuclear plant and Diablo Canyon nuclear plants in 1989. On 30 May 1989, a number of members of the environmental activist organization Earth First!, including the founder, Dave Foreman, were arrested by the U.S. Federal Bureau of Investigation for plotting to cut the transmission lines carrying power to the Palo Verde nuclear plant near Phoenix, Arizona and the Diablo Canyon nuclear plant near San Luis Obispo, California. The plot was not far advanced at the time of the arrests, and questions remain regarding whether the conspirators were entrapped by an undercover FBI agent who had infiltrated the group. As a result, the security significance of this event is unclear.

b) Unauthorized forced entry and site area emergency at Three Mile Island Unit 1 on 7 February 1993[38]. (see 9.2.8.1 for details)

3.9.1 Security Failures Prior to the 11 September 2001 Attacks[39]

Between 1991 and 2001, the NRC conducted a program known as the Operational Safeguards Response Evaluation (OSRE). This program consisted of performance exercises designed to evaluate whether nuclear power plant security forces could effectively defend against an adversary team with a defined set of characteristics: number, weaponry, equipment and tactics. This set of characteristics is known as the design basis threat (DBT). Although the details of the design basis threat are classified as "safeguards information" by the NRC, it is well-known that no more than three external attackers were used in these exercises. In these wargame-type exercises, a mock adversary force would carry out a series of four attack scenarios, with the objective of simulating the destruction of enough plant equipment to cause a core meltdown (known as a target set). The NRC would then evaluate the performance of the nuclear plant security force in preventing the adversary team from achieving its goal.

In the course of the ten-year program, the NRC conducted 81 OSRE exercises. All operating U.S. nuclear plants had at least one OSRE, and several had two. According to NRC data, in 37 of the exercises, or about 46%, the mock adversary force was able to simulate causing a meltdown in at least one of the four scenarios tested. This means that if a real terrorist assault had occurred during this time, by a group of adversaries with capabilities at or below the design basis threat, there was a substantial chance that the attack would have been successful in causing a catastrophic core melt.

Special attention should be paid to the last 11 OSREs conducted prior to the 11 September 2001 terrorist attacks, when the program was terminated. Those tests can be regarded as a measure of the level of preparedness of U.S. nuclear power plants against terrorism just before 11 September 2001 and provide a rough sense of the likelihood that a terrorist ground attack at a U.S. nuclear plant would have been successful had al Qaeda chosen such a target and mode of attack. These OSREs were also distinct because they were graded by NRC under a revised procedure for determining the significance of the failures. NRC data reveals that the OSRE failure rate in this period, judged by the loss of at least one target set, was seven out of eleven, or 64%; a failure rate higher than the average over the entire decade.[40] Thus it appears that the overall level of security at U.S. nuclear plants declined over the course of the OSRE program.

This period was also characterized by an unusually high level of public disclosure of nuclear plant security information by the NRC, and fairly detailed public inspection reports of the OSRE exercises taking place at that time. This transparent era came to an abrupt end after 11 September 2001, when the NRC, along with other U.S. government agencies, severely restricted the amount of security-related information available to the public.

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[38] U.S. Nuclear Regulatory Commission, *"Unauthorized forced entry into the protected area at Three Mile Island Unit 1 on February 7, 1993"* NUREG-1485, 1 April 1993.

[39] Edwin S. Lyman and David Lochbaum, *"Protecting Vital Targets: Nuclear Power Plants,"* in *Homeland Security: Protecting America's Targets (Vol. III: Critical Infrastructure)* (James J.F. Forest, ed.), Praeger Security International, Westport, Connecticut, 2006, p. 157-173.

[40] U.S. Nuclear Regulatory Commission, *"Physical Security Significance Determination Process,"* Powerpoint presentation at NRC public meeting, 30 August 2001, slide no. 17.

Below are three excerpts from OSRE inspection reports of that period that reflect some of the problems that nuclear plant security forces were experiencing. The severity of these problems provides a stark indication of the lax security that was present at many nuclear plants on the eve of 11 September 2001.

> a) Farley Nuclear Plant, Columbia, Alabama, July 2000.[41] During the July 2000 OSRE, the security force at Farley could not prevent the mock adversary team from simulating the destruction of entire target sets in two out of four exercises (and therefore simulating a meltdown); and simulating the destruction of "significant plant equipment" in a third exercise.
>
> Part of the reason for this poor performance was the "failure to adequately perform multiple portions of the response strategy." Adversaries were not detected in time to allow security officers to defend pieces of vital safety equipment; responders could not leave defensive positions without making themselves vulnerable to the adversary; and some security officers were outside of the protected area and took too long to respond after the attack.
>
> b) Oyster Creek Generating Station, Forked River, New Jersey, May 2001. During the May 2001 OSRE, the security force at Oyster Creek failed to protect a target set from destruction from the mock adversary team in one out of four exercises. However, NRC determined the failure to be the result of a flaw in the protective strategy for a two-target target set, as well as performance errors by the responders. The strategy at issue required the plant armed responders to leave one of the two targets completely undefended and concentrate forces to defend the other target. However, the security officers protecting the second target were vulnerable to being killed by the adversaries, and this is exactly what happened during the exercise. The adversaries were therefore able to destroy both targets and cause core damage.
>
> c) Vermont Yankee Generating Station, Brattleboro, Vermont, August 2001.[42] The August 23, 2001 OSRE at Vermont Yankee was the last one conducted by the NRC before the program was terminated after the 11 September 2001 attacks. Of the 11 OSREs preceding the 11 September 2001 attacks, this was the worst, the only one assigned a "yellow" finding by NRC, indicating the failure had "substantial safety significance" and resulted from a "broad programmatic problem." However, because the inspection report was not filed before the NRC revamped its policy on release of security information after 11 September 2001, specific details about what warranted such a harsh finding never became publicly available.

3.9.2 Security Failures After the 11 September 2001 Attacks

The 11 September 2001 attacks made it clear to U.S. officials that they had to take seriously the threat of catastrophic terrorism against critical infrastructure facilities. The NRC pledged to increase the level of security at U.S. commercial nuclear facilities. Yet at the same time, it greatly reduced the amount of security-related information available to the public, so

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[41] U.S. Nuclear Regulatory Commission, *"Farley Nuclear Plant – NRC Inspection Report 50-348/01-07 AND 50-364/01-07,"* letter to Mr. D.N. Morey, Vice President, Southern Nuclear Operating Company, 21 June 2001.

[42] U.S. Nuclear Regulatory Commission, *"Vermont Yankee Generating Station – NRC Inspection Report 50-271/01-010,"* letter to Mr. Michael A. Balduzzi, Senior Vice President and Chief Operating Officer, Vermont Yankee Nuclear Power Corporation, 28 November 2001.

that it became more difficult for the public to assess whether the steps the NRC was taking were appropriate and whether nuclear plant operators were complying with them. Thus no official information was released of the type described above, such as specific force-on-force test results.

After several years in which the NRC's security information policy was in flux, it decided on an approach in which it would issue an annual summary report of security findings, with few details about the nature of the violations and no discussion of the specific plants involved. It would also issue redacted cover letters of security inspection reports, which would simply mention whether or not a security concern was found.

The NRC issued its first summary report on 30 June 2006, covering the period from 29 October 2004 to 31 December 2005.[43] In that period, the NRC conducted 111 "baseline" security inspections and 23 force-on-force tests. 104 violations were found during the baseline inspections, of which 99 were judged to be of "very low safety significance." (It is not clear from this data how many inspections found at least one violation, since it is possible that more than one could be found in a single inspection.)

Three violations were found during the force-on-force tests, all of which were judged to be of "very low safety significance" and did not result in any fines or other enforcement actions. On the surface, this would appear to be an improvement over the pre-11 September 2001 performance. However, so little is publicly known about the exercises compared to the period before 11 September 2001 --- NRC even keeps secret the procedure for determining the safety significance of a security violation --- that the relationship between the two sets of data is not clear.

Despite the NRC's attempts to keep a tight lid on security information, problems continue to emerge, usually revealed by whistleblowers concerned that nuclear plant managers and the NRC are not taking their concerns seriously. Security allegations that came to light at several nuclear plants in 2005 and 2006 are troubling indications that the security culture at the NRC and within the industry has not undergone the radical shift needed to be able to cope with the emerging threat after the 11 September 2001 attacks.

In December 2005, the nuclear power watchdog groups NC WARN and Union of Concerned Scientists disclosed a number of security allegations that had been brought to their attention by security personnel at the Shearon Harris nuclear plant in New Hill, North Carolina. In response to the NC WARN-UCS letter, the NRC sent an inspection team to the site to investigate the allegations. None of these issues had previously been noticed by NRC inspectors.

The allegations included broken security doors leading to vital areas that management refused to fix despite repeated complaints from security officers; widespread cheating on the security certification exams administered to security officers by the state of North Carolina; and the issuance of merchandise "gift cards" in lieu of overtime payments in order to keep excessive overtime hours off the books. All three of these allegations were substantiated, although the NRC claimed the last one was due to a misunderstanding. In any event, the NRC

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[43] U.S. Nuclear Regulatory Commission, "Annual Status Report on the Results of the Security Inspection Program Conducted by the United States Nuclear Regulatory Commission," attachment to letter to James Inhofe, Chairman, Committee on Environment and Public Works, U.S. Senate, 30 June 2006.

claimed that these events were of “very low safety significance.”[44] This mischaracterization provides a window into the NRC’s questionable perception of the dangers posed by such chronic and severe security violations.

The NRC only conducts one force-on-force test for regulatory compliance purposes every three years at each nuclear power plant, using the allegedly independent Composite Adversary Force. In between, the licensee conducts training drills, which the NRC may observe. In these drills, the licensee typically uses an adversary force composed of the site's own security officers.

Whistleblower complaints brought to light in August 2006 by the Union of Concerned Scientists at the South Texas Project nuclear plant near Bay City, Texas, also resulted in a special security inspection by the NRC. These included an allegation that during a force-on-force security drill being observed by both the NRC and the Federal Bureau of Investigation (FBI), the mock adversary team was instructed by management to intentionally lose the exercise. The NRC substantiated the concern of the employee who reported it, but claimed that it was a misunderstanding of the management’s intention.[45]

Another troubling incident involved the discovery of a hole drilled into a stainless steel pipe connected to the pressurizer at the Turkey Point Unit 3 nuclear reactor in Florida, which led the NRC to dispatch an “Augmented Inspection Team” to investigate, a sign of the potential serious nature of what could have been an intentional attempt to sabotage the plant. Further details on this situation are not available.[46]

In summary, despite all the public attention on the risks of nuclear power plant attacks since 11 September 2001, the NRC and the US nuclear industry do not appear to have responded with the appropriate level of vigilance, and nuclear plants remain vulnerable to the rapidly evolving terrorist threat.

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[44] U.S. Nuclear Regulatory Commission, *“NRC Staff Responds to Security Concerns at Harris Nuclear Plant Near Raleigh*, press release, 22 March 2006, http://www.nrc.gov/reading-rm/doc-collections/news/2006/06-005ii.html.

[45] U.S. Nuclear Regulatory Commission, Letter to Edward Markey, U.S. House of Representatives, 22 December 2006.http://www.nrc.gov/reading-rm/doc-collections/congress-docs/correspondence/2006/markey-12-22-2006.pdf

[46] U.S. Nuclear Regulatory Commission, *“NRC Sends Augmented Inspection Team to Review Equipment Damage at Florida Nuclear Power Plant”,* press release, 31 March 2006, http://www.nrc.gov/reading-rm/doc-collections/news/2006/06-011ii.html.

4. Systemic Issues

4.1 Recurring Events

The term "events" is widely used in the nuclear lexicon as a synonym for "failures, incidents and accidents".

In public discussions the argument is often stressed, that an important component of nuclear safety is the lessons learned from failures, incidents and accidents that have occurred in the past. Therefore analysis and evaluation of operational events have been performed by nuclear regulators on their respective national level as one of the most vital nuclear safety activities for decades. An international exchange system of operational experience also exists, the Incident Reporting System (IRS, see chapter 5.2), which is based on national information of the respective regulators on a selection of incidents considered significant.

Nuclear operators maintain other exchange systems on experiences with events, on the utility level, but also within "Owners Groups" operating reactors from the same supplier. WANO also operates a worldwide event reporting system.

A widely held opinion is that gross failures and damaging events from the past could not happen again in future and can be excluded because of the learning processes provided through the existing exchange systems. If that was true, the analysis of events and failures over time should show that certain types of events, which happened long ago, would not recur. To implement experience feedback, "corrective actions" have been developed after each event. The expert language term "corrective actions" means a defined bundle of tools to prevent the specific type of event happening again. Depending on the event, the tools can consist of e.g. general information to the operators, changes in operating management regime, enhancing the information base of the operation staff by better displays of the actual status of the plant, technical changes in the safety system and/or other parts of the plant. Given the implementation of those corrective actions, previously identified or experienced events should not happen again.

However, event analysts learn by their practical experience that some of the actual events recall similar events from earlier times. The OECD NEA published a first investigation on that issue in 1999[47]. The result was not in accordance with widespread belief, but fits with the experience of event analysts until now. Four types of recurring events were identified:

1. Loss of residual heat removal while at mid-loop (Pressurized Water Reactor).
2. Failure of valves to operate.
3. Service water degradations due to biofouling.
4. Boiling water reactor (BWR) power oscillations.

> The NEA Report points out: *"The history of loss of RHR [Residual Heat Removal][48] at midloop conditions was reviewed. There were over 20 such events in the time period 1980-1996, i.e. more than one per year. The events were widely publicized and there were numerous communications by the regulatory bodies. Even so, this scenario continued to occur even though the corrective actions were well known.*

[47] OECD-NEA, *Recurring Events,* CSNI, September 1999

[48] Residual heat removal is the evacuation of heat that is still generated by the nuclear fuel when the reactor has been shut down.

Another recurring event identified was instability in boiling water reactors. A usual design criterion for boiling water reactors is that either the reactor remains stable by design, or else instabilities are detected and corrected. However, over the period 1982-1995 about ten instances of BWR instability were detected. These instabilities were quite large, e.g. with neutron power oscillating between 40 and 90% power. In spite of this, experts generally agreed that the risk attendant to BWR instability is quite low. Corrective actions for these oscillations or instabilities were not well defined and, in some cases, utilities were somewhat surprised when inadvertent instability was experienced.

A third example of recurring events was reduction or interruption of service water due to build-up of marine life, including clams, barnacles, shrimps, and mollusks. Seven such cases were noted over the period 1980-1997. Service water plays an important role in transporting energy from key systems to the ultimate heat sink."[49]

The investigations of the now identified effect of "recurring events" were continued. A second NEA report, using a broader background of experience with events and failures, identified nine classes of recurring events, which include the formerly identified types[50]:

1. Loss of RHR at mid-loop.
2. BWR instability.
3. PWR vessel head corrosion.
4. Hydrogen detonation in BWR piping.
5. Steam Generator Tube Rupture.
6. Multiple valve failures in ECCS.
7. Service water system biofouling.
8. System level failures due to human factors considerations.
9. Strainer clogging.

The NEA experts continued with an attempt to identify reasons for the persisting situation[51]:

"It was seen that the history for some recurring events is, at least, up to 20 years. This raises questions as to why the corrective actions had not been implemented in a timely manner. Several possibilities exist:

- *The operating organisation failed to take timely action, or was not aware of the events, or thought it was not applicable.*
- *The regulatory authority was not aware of the events, or had not imposed the licensee to take timely corrective actions.*
- *Work on the appropriate corrective action was in progress, but not fully implemented.*
- *The event was considered to be of lesser importance and risk than other plant modifications, and thus was not being pursued as rapidly as needed.*
- *Overall, the operating experience feedback programme was not fully effective.*

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[49] CSNI Technical Opinion Papers No. 3, *Recurring Events*, OECD 2003, NEA No. 4388
[50] quoted in CSNI Technical Opinion Papers No. 3, *Recurring Events*, OECD 2003, NEA No. 4388
[51] ibidem

- *The root cause of the event had not been correctly identified, and thus the corrective actions were not responsive.*
- *The contributing factors or causes were not appropriately taken into account in identifying the corrective actions.*
- *What was thought to be a solution was, in fact, not one or the problem was generic, and what was a fix for one aspect did not cover all aspects.*

It is likely that all of these possibilities play a role in delaying action."

The NEA concludes with*: "Recurring events are important to safety in that they can indicate deficiencies in the plant safety culture, gaps in the national operating experience feed back systems, loss of continuity in skilled and knowledgeable operations and engineering staff, or lack of attention to design and operational factors such as plant ageing."*

The knowledge and experience from "lessons learned" up to now does not really impact in practice on the operation of nuclear power plants. A report published by the NEA in 2006[52] deals with that ongoing debate. It provides a number of quite alarming statements:

"Now, however, questions are being raised about whether the lessons from operating experience are being used commensurate with their importance to safety. For example, recent concerns have been voiced that:

- *lessons may be learned but they are subsequently forgotten over time;*
- *often nothing is done in response to information learned about others' experiences;*
- *there is a tendency to consider foreign operating experience as not relevant to one's own situation; and*
- *more generally, operating experience reporting is not meaningful if it is not used to promote operational safety."*

The NEA continues:

"The fundamental logic supporting the need for a vigorous operating experience programme is that serious accidents are almost always preceded by less serious precursor events and that by taking actions to prevent recurrence of similar events, one is thereby reducing the probability of serious accidents."

and

"Nuclear power plants are highly complex installations, with several redundant and diverse mechanical, electrical and control systems. There are dozens of such systems and thousands of individual components in a typical plant. Experience over the years has shown that all plants experience individual component and system failures from time to time, almost always with no safety consequences. Many of these operating events at nuclear power plants include contributions from human and organisational factors. If no steps are taken to correct the root causes of these failures, they will recur and, accompanied by other failures or perhaps human errors, will lead to a more serious event or accident."

[52] Regulatory Challenges in Using Nuclear Operating Experience, OECD 2006, NEA No. 6159

Also in 2006 the third Edition of the NEA's "Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System" was published[53], which covers the years 2002-2005. In its conclusion the report states inter alia:

> *"About 200 events have been reported by the participating countries during that period…*
>
> *Almost all of the events reported during that period have already occurred earlier in one form or another. It shows that despite the existing exchange mechanisms in place at both national and international levels, corrective measures, which are generally well-known, may not reach all end-users, or are not always rigorously or timely applied.*
>
> *Recently, some top regulators expressed their concerns with respect to the international effort devoted to operational experience. They notably noticed that:*
>
> - *A worldwide observation is that operating experience feedback (OEF) needs to be much improved in the international arena.*
> - *There is a tendency to consider that foreign OEF is not relevant.*
> - *The global effort in the area of event reporting does not appear to be functioning as it should.*
> - *The focus of existing networks (IRS, etc.) should move from event reporting towards a synthesis of the given information and to combining it with other available knowledge on the respective topic, e.g. insights from risk studies and other research."*

The widespread belief that nuclear safety will be actually enhanced because of a lessons-learned process turns out ill-conceived as illustrated by the above-cited reports. It is an open question whether the actual discussions within the nuclear expert community can lead to an improvement of nuclear safety in the reality of nuclear power plant operation. The discussion runs in high ranking international expert circles. Nevertheless, their analyses are based on a broad overview on real nuclear events. On the other hand, nuclear safety itself is mainly influenced by day-by-day behavior of people who are very close to nuclear installations, people like the operating shift managers, maintenance workers, designers of system details in case of system changes, etc. There is a big distance between these different groups of people with all their different attitudes and thinking. Therefore it is unclear whether tools can be found, to interact in a way that a real enhancement in safety is accessible.

It seems rather that the actual discussion on "recurring events" has identified a field of strong limitations for the implementation of an enhancement of nuclear safety, which could not be surmounted in real life.

4.2 Violation of Rules and Procedures

The enormous risk potential of nuclear power plants requires a comprehensive set of safety measures. The proper functioning of complex safety systems depends on the interaction of many technical and administrative conditions. The technical design has to meet the requirements of the possible operative range. Additional provisions are necessary to retain the

[53] Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System, OECD 2006, NEA No. 6150

operating conditions within the permitted limits. Thus the safety of the plant has to be ensured as well by a complex set of regulations applying to safety related processes covering technical, management, personal and organizational aspects. Binding procedures are implemented as a requirement for the action of the staff. The compliance with rules and regulations is important to safety in all phases of planning and operation of the plant.

When important effects are disregarded during the design phase, the capability and the behavior of the plant are not verified for all event sequences and conditions. Incorrect or insufficient design assumptions may cause the malfunction or total loss of functions later. Inadequate operation and maintenance of equipment can cause a degradation of properties that may affect safety related functions. Insufficient inspection and testing can allow for failures going undetected for a long time. Poor surveillance of major operating parameters can allow for systems to run beyond their design basis with the risk of damage or ineffectiveness of these systems. Incomplete documentation can lead to misinterpretations.

Due to such circumstances a wide range of possible failures may affect safety and cause malfunction or total loss of functions required to cope with accidents. The violation of rules and regulations can impact on safety as much as technical failures can.

The malfunctioning of a cooling pump, for example, might be caused by technical failures but also by design characteristics inappropriate for specific operational conditions (e.g. capacity, medium, loads). It might also be caused by an insufficient amount (pressure, temperature, composition) of coolant but also by lacking supply of required utilities like electricity, control, lubricant. The malfunctioning might also be the effect of personal failures or ineffective regulations.

Rules and procedures can be disregarded consciously or inadvertently. Weaknesses in staff education and training, incomplete technical knowledge, missing awareness of the safety related context just as inappropriate ergonomic constitution of regulations will influence their implementation adversely. There are many reasons that render plausible the violation of rules and regulations; the compliance with regulations is laborious and time-consuming. Procedures become more complicated and deviate from usual day-by-day practice. Regulation is often perceived by staff as unnecessary additional paperwork and largely exaggerated control procedures.

The violation of rules and procedures is not automatically apparent. Control measures to check staff behavior and the efficiency of rules and procedures cannot cover all possibilities of violation and certain can be bypassed. In many cases the resulting effects do not appear in close temporal or technical context: Insufficient maintenance may induce a malfunction only after years. Design errors may induce damage only under unusual or rare conditions (e.g. specific loads, specific operational states, specific events). From there a large number of unreported cases may be expected. However, the compliance with rules and procedures is assumed in safety analysis in general. Special functions of safety related equipment are checked within the regular proceedings under test conditions. Other functions depending mainly on the application of rules and procedures cannot be checked totally this way.

All in all the potential and the safety significance of possible consequences of this systemic issue are supposed to be very high.

a) In 2001 a shortfall of the specified filling level of the flooding tanks during the start up of the Philippsburg-2 plant in Germany was detected late because of wrong data interpretation. Subsequent investigations revealed that significant deviations from requirements during start-up and violations from related instructions seemed to be common probably for several years and took place in a similar way in other German nuclear plants too. (see 9.2.3.1 for further details)

4.3 Lack of Systematic Verification and Control

One of the key safety principles for design and operation of nuclear power plants is to ensure an exceptionally high level of quality. This is related to the design of the technical properties of equipment but also to the performance of all measures and tasks necessary for its safe operation. To meet the intended high quality level an appropriate system of verification and control has to be established complementarily. A comprehensive set of quality assurance measures has to be developed in a systematic way and implemented into the operational routines.

Testing and inspection procedure prior to initial operation shall make sure that the design and as-built states are in compliance with planning and approval. Periodical tests during operation shall verify the orderly status and function of components. This is mainly aimed at potential degradations of safety related properties due to operational conditions. Moreover there are features that are tested only once. For these it is assumed, sometimes wrongly, that the features are in a constant state as built or designed. Also, the performance of safety related tasks (e.g. inspection, maintenance, repair, technical changes) is accompanied by a set of administrative control measures and regulatory hold points, e.g. permission, surveillance, final inspection.

Even though the quality assurance regime is comprehensive it is possible for the system of verification and control to be incomplete. Mistakes during planning, execution and documentation of test routines or misinterpretation of test results have been reported. This may be a consequence of the incomplete reliability of human performance. Another reported fact is that failures were built in as a result of test routines, e.g. due to inadequate handling of equipment. In addition as a systemic weakness the test routine cannot exactly anticipate and simulate all real conditions, loads and attitudes. Another problem may be the quality assurance of the performance of verification and controlling itself. This means the thorough and safety-conscious design and implementation of related administrative routines is necessary.

Failures built-in during construction, changes and/or plant misassembly may remain undetected for a long time, if the affected function is not covered by frequent routine tests. And, of course, there are a number of extreme functions that cannot be routinely non-destructively tested (ie primary containment, certain location internal crack propagation, etc). When the affected function is only required in the case of accidents the normal operation may give no indication of a malfunction. Lack of safety awareness in a given context may cause the insufficient design and performance of test routines and lead to relevant properties and possible deviations are not being rechecked systematically. In some cases, when the equipment has no active safety function (e.g. buildings, structures) usually the dimensioning and the as-is state is not verified again after initial approval. Such failures can often only be detected by chance or when upgrades are performed. Even after more than twenty years lifetime failures built in during construction have been identified. Due to this there is no exact information about the possible number of latent failures. The potential consequences are not analyzed, because they cannot be analyzed.

All in all, the existing system of planning, construction/performance and quality assurance is no guarantee for the faultless state of the plant. This means there is always a latent residual risk.

The effectiveness of safety systems to cope with a fault sequence is only demonstrated when the actual operating conditions are in compliance with design assumptions. Latent failures due to insufficient verification and control were not accounted for in the fault analysis. They may cause a variation of event sequences the safety systems are not designed for.

Past examples of lack of system and verification control include the following:

> The German Biblis nuclear power plant is situated in a region exposed to earthquake risk. After the initial operation of the plant the maximum possible earthquake loads at the site were verified according to state of the art. As a result of reinvestigation characteristic parameters for the design of buildings and mounting parts were updated. The dimensioning of the mounting of safety related components was recalculated regarding the updated design assumptions. Several thousand heavy-duty dowels were mounted for the fixation of piping and other components.
>
> The justification of the changes was checked by several instances. Finally the installation of the dowels was approved. Later it was discovered that dowels were assembled incorrectly. Subsequent investigation showed that most of the dowels were affected and should be replaced. The total number of affected dowels was about 15,000. They have been mounted in a way, fixing piping and other components, not corresponding to the standard necessary to withstand certain design basis accidents (DBA) like earthquakes. This means, that the affected plant in reality was not able to cope adequately with design basis accidents.
>
> The provided system of verification and controlling was ineffective and not suitable to ensure a sufficient quality level. The interface between the different test procedures and instances were obviously not adjusted as well as they should have been.
>
> There are reasons that make plausible the ineffectiveness of the provided measures: The work is performed under difficult conditions. In an existing plant the location of mountings may be difficult to access and exposure to intolerable working conditions like dirt, high temperature or radiation may be involved. In addition, tasks during outage are usually carried out under time pressure.
>
> Eventually the common-mode failure was discovered by chance and not as a result of systematic control. Possibly the failure could have remained undiscovered. In case of an earthquake, safety related components (e.g. piping, vessel) might have collapsed and been severely damaged. The function of the different safety systems might have been affected resulting in uncontrollable plant states. The plant is not designed to cope with such type and degree of damage.

4.4 Difficulty of Root Cause Identification and Assessments

The complicated technical configuration and the multitude of functional interrelations facilitate highly complex fault event trees that might affect the safety of a nuclear power plant and indeed any nuclear facility. A combination of initial events and subsequent failures may cause a loss of required systems leading to dangerous situations, which have to be avoided. There are many intersections that facilitate a great number of different event courses. Just as well a great number of influencing variables has to be regarded: different operational modes, malfunctions, malpractices, internal and external loads. The worst case to be covered might be the result of the most adverse combination of contributing factors. This includes the identification of relevant root causes possibly initiating serious consequences as the event tree unfolds.

In view of the enormous risk potential, the consideration of the most probable sequences seems to be inadequate to guarantee the required extraordinary safety level. However, it is documented that some design features are limited by a insufficient level of assumptions. Scenarios that really happened have been insufficiently or non comprehensively integrated into the definition of the design basis. This might have been due to the fact that some hazard scenarios are difficult to reliably forecast and describe.

For example the probability and the magnitude of impact of specific external events like earthquakes or flooding can only be determined with a high degree of uncertainty. Other external influences caused by disturbances of the grid or loss of essential infrastructure might have been considered only partially. But they become more and more important because of an increasing change of external conditions, in particular the increase in frequency and magnitude of extreme weather events due to climate change. As a result loads generated by scenarios that were supposed to be extreme have been excluded from the design basis but in reality plants may now have to cope with such events.

a) The unusual storms on 27 December of 1999 led to off-site power loss and the partial flooding of the Blayais nuclear power plant site with 900 MW_e reactors. (see 9.2.7.1 for details)

b) On 25 July 2006 a short circuit in an outdoor switching station of the grid near the Swedish Forsmark nuclear power plant caused the emergency shutdown of the reactor (scram) and, in a complex scenario, led to a number of subsequent failures at the plant. (see 9.2.5.2 for details)

4.5 Generic Faults

The capability of a nuclear power plants to cope with accidents is determined by design assumptions. The safety systems are configured to prevent and, in the case of occurrence, to control a generic set of fault conditions or sequences. Typical event sequences that might result in critical plant states have to be considered. The event spectrum should cover the range of probable failures such as the range of adverse loads and required functions.

The plant's behavior and possible event sequences are analyzed to determine the requirements to be met by the design, e.g. functionality, capacity and efficiency of installations but also preconditions like procedures, tests, tools and qualified staff.

For reasons of practicability and in view of the application of calculation programs a number of settings have to be defined. Complex interrelations are simplified to make real event situations transferable to a model. Circumstances important for the course and the control of the events have to be defined, e.g. initial conditions, system parameters, system availability, special phenomena have to be considered and the possible coincidence of different independent failures. The assumptions are not only derived from a scientific context but also postulated by engineering judgment. So the quality of design is limited by knowledge and experience. Hence the assumptions have to be verified even over the period of operation. Over the years experience feedback has been used to enhance the design characteristics and to achieve a better standardization in the range of safety concepts.

The simplification of complex information and situations is necessary but holds the risk that facts highly relevant for safety might be misinterpreted due to incomplete knowledge or uncertainties.

The control of accidents is only demonstrated for a course of events as defined in the design. If generic issues remain unconsidered even in the case of a design basis accident the plant may run into uncontrollable states. The standardization of design contains the risk of multiplying such errors throughout a number of facilities. Examples include the following:

> In July 1992 a leaking pilot valve in the Swedish boiling water reactor in Barseback caused a safety valve for the reactor vessel to open. Insulating material was washed into the suppression pool and affected the emergency core cooling system (see 9.2.6.1 for details).

The phenomena that became obvious in Barseback are transferable to other reactors in Sweden and elsewhere. By the end of 2003, it had become clear that all 34 French 900 MW reactors were facing the same problem. This is an example of generic weakness of safety analysis, which may concern a large number of facilities. The French nuclear reactors have the highest degree of standardization in the world, which is a significant advantage when it comes to experience feedback, but they are also particularly prone to generic faults.[54]

4.6 Decline in Design and Fabrication quality

The high quality of nuclear equipment components and systems is a precondition to assure high levels of safety. However, during recent years concerns have been frequently expressed among experts regarding the quality of nuclear design and manufacturing. A non-comprehensive list of examples includes the following:

> **Delivery by Atomstroyexport, Russia to Tianwan-1, China, of steam generators with damaged tubes.**
>
> Licensing and commissioning of Tianwan-1 (WWER, 1000 MW, grid connection in May 2006) was delayed by a regulatory investigation and ensuing repairs of steam generator tubing. Four steam generators were delivered in 2004 by the Russian nuclear industry under the project's turnkey contract. Non-destructive tests after trial operation of the unit without fuel showed that as many as 2,000 tubes have different cracks and defects. After thorough investigation more than 700 tubes were plugged before start-up. There is some evidence that the steam generator tubes might have suffered damage during sea transportation. The start-up of the unit was delayed by more than two years.
>
> **Design, fabrication and supply by AREVA NP to the Paks nuclear power plant, Hungary, of a fuel cleaning system with insufficient safety features.**
>
> A chemical system designed to clean 30 partially burned fuel assemblies from magnetic deposits outside of the reactor, was developed, manufactured and delivered by AREVA NP (then Framatome ANP) to the Paks nuclear power plant unit 2 (WWER-441 MW) in 2003 with design shortcomings and without full scope safety analysis. These design safety deficiencies finally caused insufficient cooling of 30 fuel

[54] Numerous generic faults have been detected in French nuclear power plants over the years. In the latest one, revealed by the French nuclear safety authority on 26 February 2007 and concerning all 58 French pressurized water reactors, it was found out that during periodical tests of key safety devices the error margins of the given test had not been taken into account. In other words, a number of tests would have registered as failed if the error margin had been counted in. This generic fault was given a level 1 INES rating.

assemblies, which were heavily damaged. The event was classified as Level 3 (accident) on the INES scale.

Design, fabrication and supply by Westinghouse to the Temelin nuclear power plant, Czech Republic, of fuel assemblies, that are bending and twisting, causing problems with control rod insertion.

By the middle of 3rd fuel cycle of Temelin unit 1 (WWER, 931 MW) there were 11 control rods (neutron absorbers) that could not be entirely inserted and at the end of the fuel cycle their number had increased to 30. In the beginning of the 4th fuel cycle (October 2005 – June 2006) there were two control rods that could not be inserted properly and at the end of the cycle their number had increased to 51. The results of the last drop test of control rods performed on 2 June 2006 demonstrated a step change in further deterioration of fuel assemblies - two neutron absorbers came to a halt above the bottom of the reactor core and the unit was shutdown about four months before the planned outage. Despite improvements to the design, in the beginning of September 2006 Temelin unit 1 started the next fuel cycle, presenting again seven control rods unable to reach full insertion. Similar problems are experienced in Temelin unit 2.

Design, fabrication and delivery by Atomstroyexport, Russia to Kozloduy unit 5, Bulgaria, of a set of control rod drive mechanisms, not properly tested after implementing design changes.

New control rod drive mechanisms were installed in Kozloduy unit 5 (WWER, 953 MW) in July 2005 during the annual outage. The unit restarted in the beginning of September 2005 and was operated at full power. However, on 1 March 2006 after a main coolant pump trip triggered the shut down of the reactor, it appeared, that three control rods remained in the upper end position. The follow-up tests identified that 22 of a total of 61 control rods could not be moved with control rod drive mechanisms. The total number of control rods unable to scram (to drop due to gravity only) remains unknown. Presumably their number was between 22 and 55. Thus, for eight months the reactor was operated at full power with an insufficient number of operable control rods.

The post incident investigation showed that the fixating electromagnets were made of improper metal and the phenomenon “detention” took place. After several months of operation this resulted in fixation and inoperability of drive mechanisms. Control rod drive mechanisms of this faulty design were delivered and installed to Tianwan unit 1 (China) and Kalinin 3 (Russia).

Significant lack of safety culture and repeated delays in the construction of Olkiluoto-3, Finland

Construction of Olkiluoto-3 (PWR, 1600 MW) is being undertaken by AREVA NP under a turnkey contract. Construction started in the beginning of 2005 and according to the original schedule the unit would have to be commissioned on 30 April 2009.

Pouring of the reactor building base slab was delayed by questions about the strength of the concrete used, according to Finnish safety authorities STUK and main contractor AREVA NP. In the summer of 2006, STUK released a harsh report on the OL3 project[55]. It noted in particular:

"Detailed design (e.g. dimensioning calculations for determination of required concrete strengths and reinforcement as well as final site drawings) had not been carried out, and the time and the amount of work added for accomplishing the design had clearly been under-estimated. An additional problem was caused by the fact that the plant vendor was not familiar with the Finnish practices. (...)
The case studies seem to indicate that TVO's [the utility that ordered OL3] supervision activities have not reached their goal to institute a high-level safety and quality culture in the supply chain and the construction organisation. Although an abundance of technical non-conformancies have been identified in the manufacturing of different equipment, components, and in construction as well, and these have been recorded in non-conformance reports, the observations made during the investigation show that the plant vendor and its subcontractors have not essentially improved their working practices or attitudes toward safety."

On the specific issue of training in safety culture STUK notes significant omissions by the project management:

"The so-called safety culture training to all those participating in the plant delivery, as stipulated in IAEA regulations and in discussions between STUK and TVO, has in practice not been provided in most cases. One expert of TVO's quality organisation stated in the interview that, as far as he knew, this training had not been provided in any organisation. It has not been defined what the content of the training should be and who should be responsible for its provision."

On the attitude of AREVA NC as the vendor, the Finnish safety authorities note:

"At this stage of construction there has already been many harmful changes in the vendor's site personnel and even the Site Manager has retired and [has been] replaced. This has made overall management, as well as detection and handling of problems difficult. (...) The incompetence in the constructor role becomes obvious in the preparations for concreting of the base slab. (...) The consortium has a habit of employing new people for problem solving, which seems to have resulted in even more confusion about responsibilities."

Manufacturing of the reactor pressure vessel and steam generators, carried out in Japan, is also behind the original schedule, those delays were connected with the qualification of welders for the manufacturing work. The delay in construction of the reactor is currently estimated at about a year and a half. The unit shall now start commercial operation at the turn of the year 2010-2011. AREVA's loss is estimated at € 700 million at least. AREVA's 2006 operating income was hit hard by delays in construction of Olkiluoto-3. The group's operating income was down almost 65 % in first-half 2006 compared to first-half 2005.

[55] STUK, "Management of Safety Requirements in Subcontracting During the Olkiluoto-3 Nuclear Power Plant Construction Phase", Investigation Report 1/06, translation dated 1 September 2006; for full report see http://www.stuk.fi/stuk/tiedotteet/en_GB/news_419/_files/75831959610724155/default/STUK Investigation report 1_06.pdf

5. Classification Systems

5.1 The International Nuclear Event Scale (INES)

The International Nuclear Event Scale (INES) was introduced in 1990 by the IAEA and the OECD's Nuclear Energy Agency (NEA). On its website the IAEA has referenced INES – User's manual under the headline "Public Information Management". The foreword to the manual explains the background of the INES scale: *"Its primary purpose is to facilitate communication and understanding between the nuclear community, the media and the public on the safety significance of events occurring at nuclear installations."*[56]

The underlying objective developed for the INES scale is the differentiation between events that involve some radiation release or that have some kind of radiological effect (see Annex 1 for a detailed presentation of the scale). No event without radiological impact could go beyond Level 3. However, even the definition of Level 3 leaves a small number of events that would fit into the classification because either there is still some radiological effect or it is labeled "near accident – no safety layers remaining".

While, besides the application of the highest level for the Chernobyl accident, any of the event classifications suggested by the IAEA in its INES user manual could be debated, the most difficult classification concerns events that do not lead to immediate radiological consequences but do represent a significant degradation of the safety situation or the safety culture at a given site.

The INES manual notes: *"Each country has different arrangements for reporting minor events to the public, and it is difficult to ensure precise international consistency in rating events at the boundary between Level 0 and Level 1. Although information will be available generally on events at Level 2 and above on the scale, the statistically small number of such events, which also varies from year to year, makes it difficult to provide meaningful international comparisons."*

A key objective of the INES scale by nuclear operators and nuclear safety authorities is to supply decision makers and the public rapidly, that is within hours of an event, with a meaningful evaluation of the severity of the event. However, often it is complex to analyze and understand the potential implications of an event in a nuclear facility and the INES rating does not provide any information that would assist emergency planning decisions to be taken (most likely it would be issued too late anyway). It is even more difficult to attempt to fit an event into the scheme elaborated under the INES scale. The INES manual counts 102 pages and, in case of a significant event, operators and officials usually have other short-term priorities than making sure that the rating fits the manual. In many cases, the original INES rating is corrected much later upwards. It remains a serious question whether the short-term reassuring effect does not have two negative side effects: in the case of a serious accident, decision makers and the public might delay taking appropriate counter measures and it might seriously undermine public confidence in communication by the nuclear operators and safety authorities.

[56] see http://www.world-nuclear-news.org/pdf/INES/INES-2001-E.pdf

5.2 The US–NRC Incident Reporting System

The United States Nuclear Regulatory Commission (NRC) classifies the significance of nuclear plant events using four primary methods: (1) abnormal occurrences reported annually to the US Congress, (2) emergency conditions declared to trigger appropriate responses from local, state, and federal authorities, (3) accident sequence precursors evaluated to assess adequacy of safety margin, and (4) events reported to the International Atomic Energy Agency using the International Nuclear Event Scale (INES). These methods examine nuclear plant events independently using different criteria. Consequently, some events get reported under only one method while other events are reported by two or more methods.

A federal law passed in 1974 requires the NRC report abnormal occurrences to the Congress. The law defined "abnormal occurrences" as events determined by the NRC to be significant from a public health perspective. The NRC developed criteria to shape its determinations. The criteria guide the NRC in reporting events involving (a) moderate exposure to, or release of, radioactive material, (b) major degradation of essential safety equipment, or (c) major deficiencies in design, construction, operation, or management controls of nuclear power reactors. In its reports to Congress on events at nuclear power plants satisfying the criteria to be deemed "abnormal occurrences," the NRC often also informs the Congress about other items of interest; issues not satisfying any of the "abnormal occurrence" criteria but still considered important. For the purposes of this study, only those events NRC reported to Congress as abnormal occurrences have been used.

Federal regulations enacted in 1980 following the reactor meltdown at the Three Mile Island nuclear plant in Pennsylvania require emergency plans to be developed. These requirements include a four-tiered emergency classification system. The lowest level emergency – called a Notification of Unusual Event – is triggered when conditions indicate a potential degradation in the level of safety at the plant. When an actual degradation or potentially substantial degradation in safety levels is identified, an Alert is declared. When an actual or likely major failure of plant functions needed for public protection has occurred, a Site Area Emergency is declared. When actual or imminent reactor core damage with the potential for loss of containment integrity occurs, a General Emergency is declared. As the emergency classification level increases, more local, state, and federal entities get engaged in emergency response activities. For the purposes of this study, only events classified at the Site Area Emergency or General Emergency level have been used.

In the mid-1970s prior to the Three Mile Island accident, the NRC initiated its accident sequence precursor (ASP) program. The objective of the ASP program was to characterize the risk of nuclear plant events, determine if events have generic implications, and provide feedback to the nuclear industry on lessons learned from operating experience. The NRC selects events estimated to have a risk of reactor core damage greater than 1×10^{-6} (one in a million chance) per reactor year for further analysis. The NRC evaluates specific plant design features and operating procedures to derive the final risk value for the events. For this study, only events determined by NRC to have a final risk of greater than or equal to 1×10^{-4} (one in a 10,000 chance) have been used.

The International Nuclear Event Scale was developed in 1989. The NRC has responsibility for assessing events occurring at US nuclear power reactors and submitting reports as appropriate to IAEA.

Significant nuclear plant events can populate one or more of these reporting categories. For example, the March 2002 discovery of degradation to the reactor vessel head at the Davis-Besse nuclear plant in Ohio resulted in NRC reporting it as an abnormal occurrence to the Congress, reporting it to IAEA, and evaluating it under the ASP program. But because the damage was discovered during a refueling outage when the head was not even attached to the reactor vessel, no emergency of any level was declared. Conversely, the February 1993 intrusion by an unauthorized person within the Three Mile Island nuclear plant in Pennsylvania caused a Site Area Emergency to be declared, but the event was not reported to Congress as an abnormal occurrence and the NRC did not evaluate it under their ASP program.

While events may get reported via two or more of these four processes, this study counted an event only once. The following hierarchy was applied: (1) abnormal occurrence reports, (2) emergency classification declarations, (3) INES reports, and (4) ASP program reports. Thus, an event appears in this study as an ASP report only when it was not also reported via all three of the other processes.

5.3 The German Incident Reporting System

Events occurring in German nuclear power plants are reported to the regulatory authority according to a defined reporting system. From 1985 onwards the reporting system was defined in "Criteria for particular events in nuclear power plants"[57], released by the Federal Ministry of the Interior, which was superseded by the "Regulation on the nuclear safety delegate and on the reporting of incidents and other events"[58] of October 1992.
Relevant for the classification of reportable events is the significance for safety issues and the degree of urgency to inform the regulatory authority. There is an obligation to report in cases that more particularly fall under the following categories:

- disposal and release of radioactive materials,
- contaminations and carryover,
- damage, failure or malfunction of the safety system or other safety-related systems or components,
- damages and leakages to the piping system and vessels,
- criticality events,
- crash of loads,
- handling and transport events,
- external events,
- fire, explosion or flooding,
- events that take place before the license for initial commissioning of the plant is granted.

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[57] *„Meldekriterien für besondere Vorkommnisse in Kernkraftwerken"*
[58] *Verordnung über den kerntechnischen Sicherheitsbeauftragten und über die Meldung von Störfällen und sonstigen Ereignissen (Atomrechtliche Sicherheitsbeauftragten- und Meldeverordnung –AtSMV)*

The classification of the events has to be conducted according to the actual evaluation at the time of detection. In an Annex to the Regulation a number of criteria for the classification of reportable events is indicated.

The report categories for reportable events are defined as:

- Category S ("Sofortmeldung", immediate reporting): Events, which have to be reported to the regulatory authority immediately, so that inspections or measures can be initiated at very short notice. These are events, which show some kind of acute safety-related deficiencies.
- Category E ("Eilmeldung", urgent reporting): Events that have to be reported to the regulatory authority within 24 hours. Due to safety issues the cause has to be identified and resolved within a reasonable timeframe. Normally these are potential (not immediate) safety-related significant events.
- Category N ("Normalmeldung", normal reporting): Events that have to be reported to the regulatory authority within five working days. Usually these events have low impact on safety issues within the approved plant status routine. These events are notified in order to identify weak spots in advance.
- Category V ("Vor Inbetriebnahme", prior to commissioning): The regulatory authority has to be informed not later than 10 working days after these events in view of safe operation later on.

The report to the regulatory authority is transmitted by phone (categories S and E) as well as by written document (all categories).

6. Role and Problems of Scale – Public Communication or Technical Rating?

The concept of simple categories that translate complex technical events into a degree of severity clearly stems from the operators' and safety authorities' legitimate desire and civic obligation to communicate quickly after an event in an intelligible manner to decision makers and to the public. Unfortunately, particularly over 15 years of practice with the INES scale reveals two major problems:

• The public has a tendency to consider the rating as a technically precise evaluation of the severity of a given event. In other words, the media and even environmental NGOs will not pay much attention to an event that has been given a Level 0 or a Level 1 rating. In fact, even Level 2 events can go completely unheard of. On the other hand, there are events that get a low rating because they do not have any immediate impact but constituted a significant potential risk (see chapter 8).

• Especially operators, sometimes also safety authorities, tend to underrate events because they have a clear interest to present the operational result of their plants free from any high incident/accident rating. In numerous cases the ratings are therefore revised in later stages of the analysis. Of course, sometimes these revisions also take place because the complete extent or potential consequences of an event had not been understood in the immediate aftermath.

7. Gross Event Numbers as Declared by Authorities

7.1 Available INES Numbers

The IAEA database containing the incidents that have been reported by member states with their respective INES rating is not publicly available and the IAEA has not responded to several explicit information requests. A small number of the most recent events in nuclear facilities (less than 20 from previous months) is available online with short descriptions at the IAEA's website (see http://www-news.iaea.org/news/topics/default.asp) but the selection and publication criteria remain unclear.

7.2 IAEA-NEA IRS Statistics

The Incident Reporting System (IRS) has been set up in 1980 and is now managed jointly by the OECD's NEA and the IAEA. All countries operating nuclear power reactors except for Taiwan and Italy are members of the system.

According to the latest overview available[59], about 80 reports are received per year on a voluntary basis from operators of currently 435 operating reactors. The number of reports has been decreasing steadily. The IRS management has only speculated about the reasons (decline of reportable events, lack of resources in some member states) In total some 3,000 events have been covered in the system between 1980 and 2002. There is no clear definition, which events should be reported. *"Events reported to the IRS are those of Safety significance for the international community in terms of causes and lessons learned."*[60]

While the exchange of information on nuclear events that is otherwise not publicly available should be of mutual interest to operators and safety authorities, the statistics of the IRS system are simply meaningless. The French example illustrates the situation: The operator EDF identifies annually between 10,000 and 12,000 events relative to safety, radiation protection, environment and transport of which 700 to 800 are declared as "significant events" or "incidents" of which about 10 are reported to the IRS.[61]

7.3 Country statistics

7.3.1 Nuclear Event Statistics in the USA

Since the Chernobyl accident, the NRC has reported 48 events involving nuclear power reactors to the US Congress as abnormal events, events at 3 nuclear power reactors involved the declaration of a Site Area Emergency, 18 events were reported by the NRC to the IAEA under the International Nuclear Event Scale, and 49 other events had a risk of 1 x 10^{-4} (one in 10,000) per reactor per year of operation or greater per the NRC's accident sequence precursor (ASP) program. While events may have been reported to Congress and also to IAEA, there is no duplication in the tallies. If an event was counted as an abnormal occurrence report and was also reported to IAEA, it was not counted in the IAEA total to

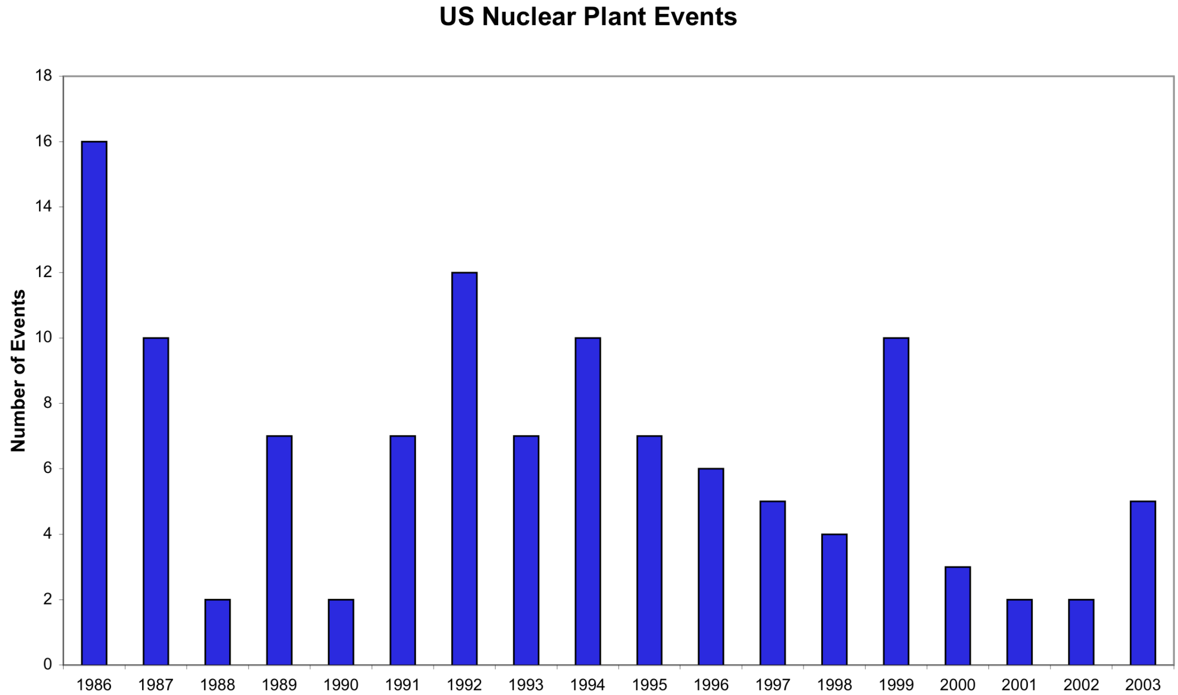
[59] IAEA/NEA, *Nuclear Power Plant Operating Experiences – From the IAEA/NEA Incident Reporting System 1999-2002,* December 2003
[60] ibidem
[61] Martial Jorel, Directeur de la sûreté nucléaire, IRSN, personal communication, e-mail 19 February 2007

avoid double-counting a single event. In fact, a total of 22 events were rated on the INES scale: of which 6 below scale, 7 Level 0, 3 Level 1, 5 Level 2 and 1 Level 3.

There have been 118 events meeting the above criteria at US nuclear power reactors since the Chernobyl accident.

Figure 3 plots the number of events per year. The results for the past three years reflect work in progress – the NRC is currently reviewing 50 events that occurred over this period under their ASP program and it is likely that one or more will be found to have a risk of 1 x 10^{-4} or greater when the NRC finishes its work later this year or early next year. Any such events would be in addition to the single event for 2006 shown in the graph.

Figure 3: Incidents Subject to "Abnormal Occurrence" Report in the US 1986-2003



7.3.2 Nuclear Event Statistics in France

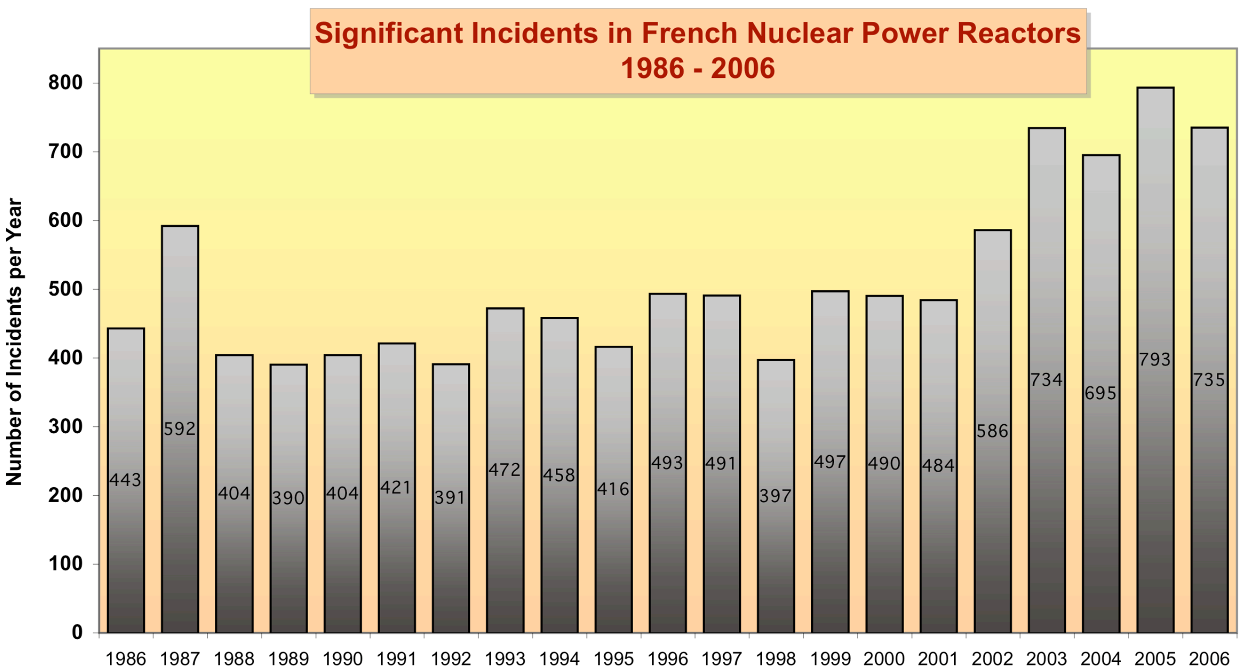
With 58 pressurized water reactors and one fast breeder reactor, France operates the largest number of nuclear power reactors in the EU, second only to the US in the world, and generates about 45% of the nuclear electricity in the EU. France also operates over 200 other nuclear facilities, from research reactors to fuel chain facilities like uranium conversion and enrichment plants, fuel fabrication and reprocessing plants as well as a number of radioactive waste storage and disposal sites.

As indicated in the previous chapter, the utility EDF declares a very large number of events every year, 10,000 to 12,000 of which 700 to 800 are considered "significant events" or "incidents".[62] The Institute for Radiation Protection and Nuclear Safety (IRSN) "examines all of these events in regular internal meetings" in order to apply a hierarchy. Certain events

[62] unless specified otherwise, the following data and quotes are from Martial Jorel, op.cit.

are considered “precursors” that put into jeopardy several lines of defense and, “under different circumstances could have led to serious consequences for safety, or even a major accident”. The conditional probability for this type of event leading to damage of the core is higher than one in a million (10^{-6}) per reactor per year. Other events, considered “outstanding” (marquant), are characterized by unusual aspects, for example a new scenario, unexpected causes or potential significant consequences for safety. The evaluation of these events shall contribute to draw lessons for the prevention of operational risks. Every three months, a meeting between the operator EDF, the nuclear safety authorities (ASN) and IRSN provides the basis for the classification of the events.

Figure 4: Total number of significant incidents in French Nuclear Power Plants 1986-2006



Source: IRSN 2007

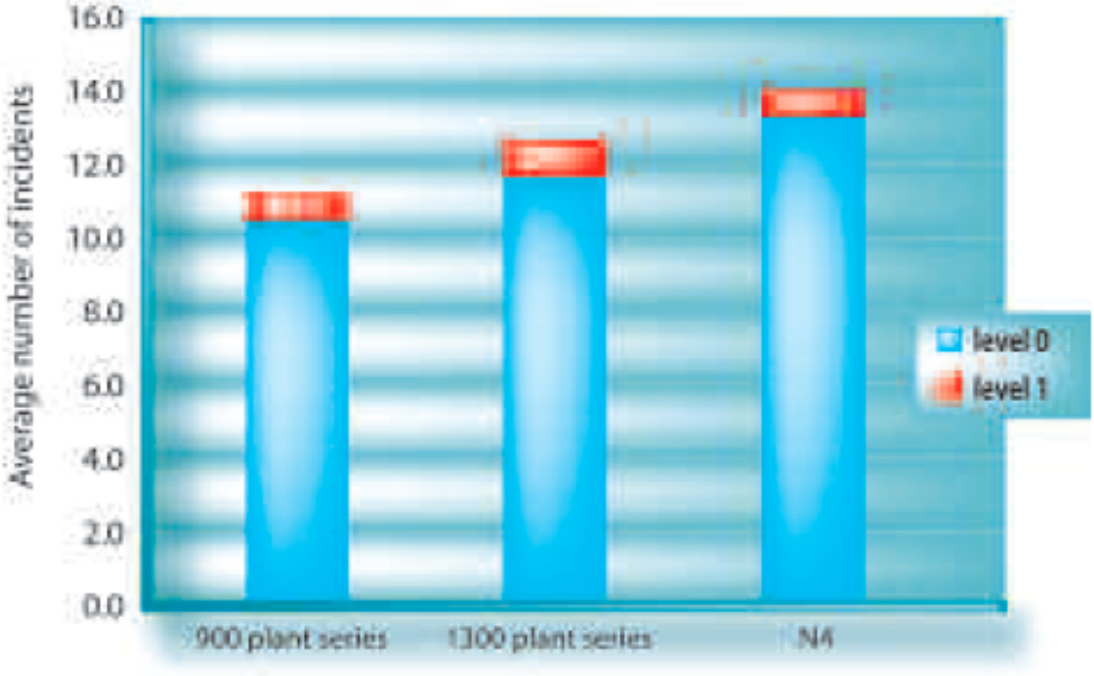
Annually the classification of these events leads to the analysis of approximately:

- 200 outstanding events (244 in 2006);
- 100 events retained in the framework of national lessons learned feedback;
- 20 precursor events;
- 2 to 3 in depth analysis.

It remains unclear, which of these events get what INES Level attribution according to which criteria. In its annual report 2005 the nuclear safety authority has provided the distribution of events by type of reactor.

It is remarkable that the average number of incidents increases from around 10 per 900 MW reactor per year to almost 12 per 1300 MW reactor per year and more than 13 per 1500 MW (N4) reactor per year. In other words, the more recent plants – by technology and by operational age – encounter more incidents than the older ones. While neither operator nor safety authorities indicate specific reasons for this, age alone is certainly not an appropriate nuclear safety indicator.

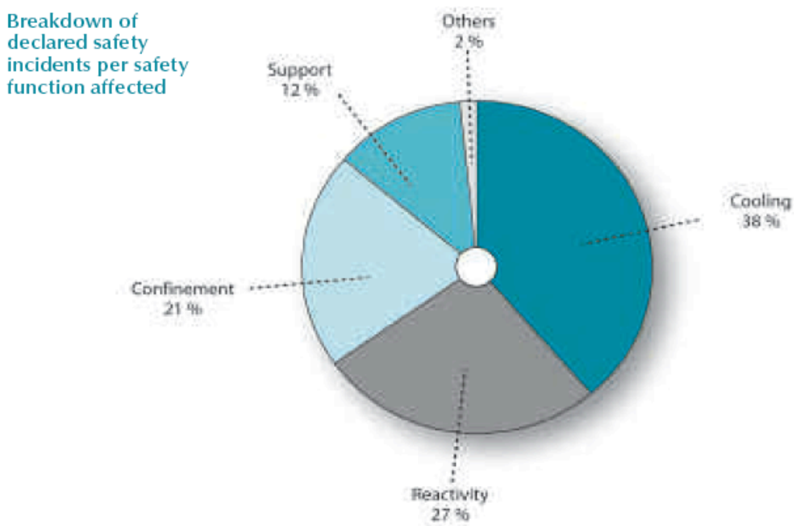
Figure 5: Number of significant events in 2005 per unit according to the reactor series



Source: ASN, Annual Report 2005

While 59% of the incidents reported from French nuclear power plants in 2005 occurred during operation over one third (37%) occurred while the reactor was shut down. Close to three quarters (73.7%) of the incidents concerned safety issues, 22.2% radiation protection and 4.1% environmental issues. A further breakdown of safety function related issues shows that 38% affected cooling, 27% control of reactivity, 21% the confinement of radioactivity and 12% various support functions (see figure 6). The latter share being on the rise over previous years.

Figure 6: Nuclear Incidents in France in 2005 by affected safety function



Source: ASN, Annual Report 2005

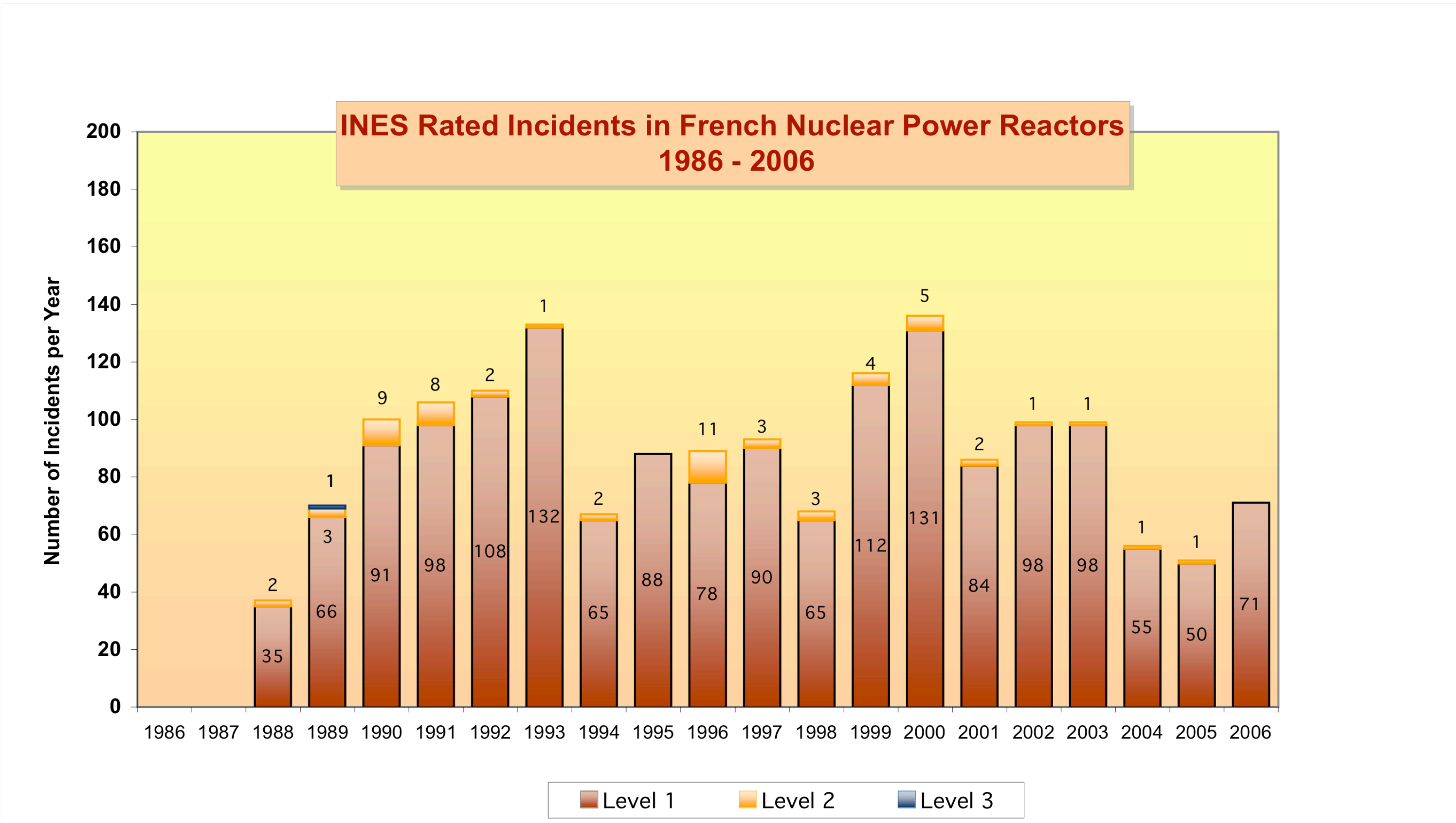
Between 1986 and 2006 a total of 10,786 significant events in French nuclear power plants were declared, of which 1,615 were rated INES Level 1 and 59 Level 2. Only one event has been given a Level 3 rating, an event that took place at the Gravelines nuclear power plant. In August 1989 it was found that the plant had been operated for about one year with a severely degraded primary circuit overpressure protection system.

It is difficult to judge the evolution of safety related incidents over time. Reporting practices, operator practices, safety authorities attitude and the technical environment changes constantly. However, certain trends can be extracted from available statistics (see following table and graphs).

After a period of relative stabilization, the total number of reported incidents from nuclear power plants doubled between 1998 and 2005. At the same time the number of incidents rated on the INES scale has gone from a peak of 131 Level 1 incidents in 2000 to 50 in 2005 before re-increasing to 71 in 2006.

The number of Level 2 events has sharply decreased from a peak of 11 in 1996 to about one per year over the last few years with none in 2006, the first time since 1995. However, it is remarkable that the peak of Level 2 events happened just the year after a zero run.

Figure 7: Annual numbers of significant events in French nuclear power reactors 1986-2006 by rating on the International Nuclear Event Scale (INES)



Source: IRSN 2007

7.3.3 Nuclear Event Statistics in Germany

In Germany there are about 120-140 reportable events in nuclear power plants each year. For the most part these events are reported as Category N ("Normalmeldung"). Only 2% to 3% of the reportable events are classified as urgent or to be reported immediately (Category E or S). In the period from 1991 to the third quarter of 2006 only three reports of Category S were issued.

For the number of reported events a declining trend can be identified for the period of 1991 to 2000 (1991: 250 reported events).

The most of the events are reported because:

- at least one of the safety devices, the safety system or one redundancy of the safety system is not available or
- there are existing safety-related deviations from the specified status of the safety system.

Furthermore there are:

- numerous indications of systematic faults of the safety system or safety-related systems or parts of the plant or
- Reductions of the wall-thickness below the reference value at equipment of the safety, main steam or feedwater systems.

These events are reported as category N.

Most of the urgent reports (category E) have been issued because:

- safety devices are just available in the number necessary by design to control an accident, without providing redundancy,
- of malfunctions of safety valves, blow-off valves or pressure relief valves or
- of fractures or cracks with leakage that necessitate a plant shutdown.

Classification according to INES

Due to the reports to the International Atomic Energy Agency events occurring in German nuclear power plants are also classified using the INES. Most of the events (more than 2,200 events since 1991) are classified as INES 0, because they are considered deviations where operational limits and conditions were not exceeded and which are properly managed in accordance with adequate procedures. These events are without safety significance. Only about 2-3%, which means 72 events from 1991 on, are classified INES 1 or higher.

INES Level 1 events

Most of the events have been classified as INES 1 because they are considered deviations from the authorized regime for the safe operation of the nuclear power plant. This may be due to equipment failure, human error or procedural inadequacies. Among these events are for example:

a) Pipe rupture due to a hydrogen explosion in the spray system in the Brunsbüttel nuclear power plant, 2001 (see 9.2.4.1 for more details) and

b) Design error of emergency power supply control and control of emergency cooling and residual heat-removal system (partial failure of the residual heat removal system as well as possible failure of the core flooding and refilling systems) also in the Brunsbüttel nuclear power plant, 2002.

INES Level 2 events

In German nuclear power plants three events were given an INES Level 2 since 1991:

a) During two of these events, the emergency and heat-removal system was affected. This concerns two consecutive events, which both occurred at the Philippsburg-2 plant in 2001. A shortfall of the specified filling level of the flooding tanks during the start up of the plant was detected late because of false data interpretation. The effectiveness of core cooling was however assured with the lower filling level.
The proper refilling of boric acid did not take place because of the incorrect position of a manually operated valve which in turn lead to the failure of three safety systems that would have been essential in case of a critical plant state. It took the operators 15 days to detect the under-boration and four days more to resolve it. Additional analysis showed, however, that sub-criticality remained guaranteed on the long-run even in failure mode condition.

b) In 1998 lack of verification at the Unterweser plant led to the unavailability of three main steam safety valve stations after the plant had been in standby mode**.** The safety of the plant was not endangered because of three redundant installations.

Human errors contributed to all three INES Level 2 events (erroneous data interpretation, undetected incorrect position of a valve or omission to verify) to some degree, which have not been in accordance with the requirements of system engineering. According to the incident reports, there was no acute state of danger for the safety of the plant.

8. Selected incidents and accidents in the USA and France

8.2.1 Selected events in the USA

The seven events at US nuclear power reactors for which the NRC calculated core damage risk values of 1×10^{-3} per reactor year or greater are summarized in this section. The 1×10^{-3} (or 1 in 1,000 years or a 0.1% probability per year) cut-off may seem a low risk, but consider the proper context. If the entire fleet of 103 reactors operating in the US had an average risk of 1×10^{-3}, about 4 reactor meltdowns would be projected to occur over their 40-year licensed lifetimes.

a) On 3 April 1991 workers at the Shearon Harris pressurized water reactor in New Hill, North Carolina discovered damaged piping and valves within the alternate minimum flow system provided for the pumps in the emergency core cooling system. Most of these pumps are in standby mode during normal operation and start when needed to supply makeup water for cooling the reactor core. Because some of these emergency pumps deliver water at low pressure, they cannot supply water to the reactor vessel until pressure drops low enough. The alternate minimum flow system at Shearon Harris provided a place for the pump output to go until pressure dropped low enough for the water to be sent to the reactor vessel. The piping and valve damage was serious because had an accident occurred, water needed to cool the reactor core would have instead poured out onto the floor through the ends of broken components. The NRC calculated the severe core damage risk from this event to be 6×10^{-3} or 0.6% per reactor year. The event was not rated on the INES scale.

b). On 6 March 2002, workers discovered significant corrosion in the carbon steel reactor vessel head at the Davis-Besse pressurized water reactor in Oak Harbor, Ohio (see 9.2.1.2 for details). The NRC calculated the severe core damage risk from this event to be 6×10^{-3} or 0.6% per reactor year and rated it INES Level 3.

c) On 13 June 1986, control room operators at the Catawba Unit 1 pressurized water reactor in Clover, South Carolina received indications of a reactor coolant system leak exceeding 1 gallon per minute. The normal makeup pumps could provide sufficient water to the reactor coolant system to compensate for this leakage. Five hours after the initial indication, the leak rate jumped to nearly 130 gallons per minute. This leak rate exceeded the makeup capacity of the pumps. As the water level in the pressurizer dropped due to more water leaving the reactor coolant system than was being added, the operators manually shut down the reactor. The operators also took steps to reduce the leak rate and measures to recover the pressurizer water level.
It was later determined that a weld on the letdown or bleed system piping had cracked to cause the initial leak. The letdown system allows a continuous flow of about 45 gallons per minute of reactor cooling water to go to a system that purifies it and adjusts its chemical parameters as necessary. Five hours later, the nameplate—a metal label identifying the manufacturer and operating parameters—vibrated loose from a power transformer and fell onto an electrical circuit board. The nameplate caused an electrical short that, among other things, caused the flow control valve in the letdown piping to fully open. The higher flow rate through the letdown piping caused the crack to propagate.
The NRC calculated the severe core damage risk from this event to be 3×10^{-3} or 0.3% per reactor year. The event was not rated on the INES scale.

d) On 17 September 1994, operators at the Wolf Creek pressurized water reactor in Burlington, Kansas made mistakes as they opened and closed valves. The reactor had been shut down 28 hours earlier for refueling. The residual heat removal system was being used to remove the large amount of decay heat still being produced by the irradiated fuel in the shut down reactor core. The erroneous valve line-up allowed nearly 9,200 gallons (35 m^3) of reactor cooling water to flow to the refueling water storage tank. The inadvertent drainage of reactor coolant water was stopped after about one minute by an operator who closed a valve.
The NRC investigated the event and concluded that, had operator intervention not occurred, the reactor core cooling by the residual heat removal system would have failed in about 3 ½ minutes. The NRC reported that restoration of reactor core cooling would have been complicated because the water in the piping for the cooling pumps would have been replaced by steam in further 2½ minutes. The operators would have had to vent the piping and refill it with water before restarting the pumps needed to restore reactor core cooling. The NRC estimated that the water level inside the reactor vessel would have dropped below the reactor core in about 30 minutes had the operators been unable to restore cooling water flow. The NRC calculated the severe

core damage risk from this event to be 3×10^{-3} or 0.3% per reactor year and rated it Level 2 on the INES scale.

e) On 6 February 1996, the Catawba Unit 2 pressurized water reactor in Clover, South Carolina automatically shut down from 100 percent power after main transformer problems disconnected the reactor from the electrical grid. The loss of offsite power signaled both of the emergency diesel generators to start and provide electricity to vital equipment needed to cool the reactor core. One of the emergency diesel generators started and powered its assigned equipment, but the second diesel generator failed due to a faulty capacitor in its battery charger. Workers repaired this diesel generator and connected it to its loads about 3 hours into the event. Workers repaired the transformer and reconnected the reactor to its electrical grid about 37 hours into the event.
The loss of offsite power deprived the reactor of all the equipment normally used to cool the reactor core. The initial failure of one emergency diesel generator deprived the reactor of half of the emergency equipment used to cool the reactor core during accidents. The NRC calculated the severe core damage risk from this event to be 2.1×10^{-3} or 0.21% per reactor year and rated it Level 1 on the INES scale.

f) On 27 December 1986, the control room operators at the Turkey Point Unit 3 pressurized water reactor in Florida City, Florida manually shut down the reactor after a malfunction in the turbine control system caused an unplanned, undesired rapid power increase. The condition should have caused an automatic shut down of the reactor, but there was a failure in the reactor protection circuit that forced the operators to respond. Shortly after the reactor shut down, the pressure in the reactor coolant system increased. A power-operated relief valve opened to limit the pressure increase by discharging some water from the system. The power-operated relief valve successfully curbed the pressure rise, but it failed to re-close when pressure dropped. Reactor cooling water poured out through the stuck open power-operated relief valve, as it had done during the March 1979 reactor meltdown at Three Mile Island. Unlike at Three Mile Island, the operators at Turkey Point Unit 3 recognized the problem and promptly closed a second valve downstream of the stuck open valve to terminate the loss of coolant accident. The combination of the reactor's failure to automatically shut down when conditions warranted it and an equipment failure causing a loss of coolant accident were key factors in the NRC calculating the severe core damage risk from this event to be 1×10^{-3} or 0.1% per reactor year. The event was not rated on the INES scale.

g) On 20 March 1990, the Alvin W. Vogtle Unit 1 pressurized water reactor was in the 25th day of a refueling outage. The reactor coolant system was drained for mid-loop operation. In this configuration, the upper portions of the reactor vessel and the steam generators were emptied of water to allow inspections and maintenance on components such as the steam generators and pressurizer. The reactor core in the lower portion of the reactor vessel remained covered with water. A single residual heat removal pump circulated water through the reactor core to remove decay heat, maintaining the water temperature at approximately 90ºF. One of the two main power transformers and one of the two emergency diesel generators were out of service for maintenance. The containment equipment hatch was open.
A truck in the plant's electrical switchyard backed into a support column for a transmission line providing power to the in-service transformer. A phase-to-ground

electrical fault de-energized the transformer and disconnected the reactor from its electrical grid.

The only available emergency diesel generator automatically started on the loss of offsite power, but it shut down about 80 seconds later due to sensor problems in its control circuit. The operators declared a Site Area Emergency when ac power had not been restored 15 minutes into the event.

About 18 minutes into the event, operators manually restarted the available emergency diesel generator, but it shut down about 70 seconds later. About 36 minutes into the event, operators manually restarted the available emergency diesel generator in emergency mode, which bypassed most of the protective trips for the diesel generator. They connected the emergency diesel generator to its electrical bus and restarted the residual heat removal pump to re-established reactor core cooling. In the 41 minutes it took to restore reactor cooling, the reactor water temperature increased from 90ºF to 136ºF.

Workers closed the containment equipment hatch about 80 minutes into the event. Their efforts were slowed by lack of procedural guidance.

The interruption of reactor core cooling coupled with delay in re-establishing containment integrity represented a risky situation because things could have led to a reactor meltdown without a barrier against release of radioactivity to the environment. The NRC calculated the severe core damage risk from this event to be 1×10^{-3} or 0.1% per reactor year. The event was not rated on the INES scale.

These events reflect a range of reactor safety challenges. Three events involved an actual loss of reactor coolant inventory while two others involved the potential for loss of reactor coolant inventory. Loss of reactor coolant inventory events have two high risk components. First, they involve reductions in the amount of water available to cool the reactor core and prevent damage from overheating. Second, they involve a breach in at least one of the barriers between lethal radioactive materials and the environment. Loss of reactor coolant inventory events pose an increased risk of core meltdown coupled with decreased likelihood of containing radioactive releases. Two events involved a loss of offsite power with impairment of the onsite backup power supplies that complicated reactor core cooling capabilities. Loss of power events have high risk because electricity is needed to power and control equipment used to cool the reactor core and provide containment integrity. Four events occurred or were discovered while the reactors were shut down while three occurred while the reactor was operating, illustrating the fact that reactor cooling must be provided at all times and not just when the reactor operates. All events occurred at pressurized water reactors, even though this type of reactor comprises about two-thirds of the US reactor fleet.

If there is a common thread among these events, it is complication of the initial cause by pre-existing or undetected equipment problems. Nuclear power plant safety relies on a defense-in-depth concept seeking to put many barriers between a problem and harm to the public. This concept is embodied in multiple backups intended to cope with a pump or valve failure with a fully redundant pump or valve that performs the necessary safety function. These high-risk events demonstrate the vulnerability when nuclear power reactors operate with pre-existing and undetected impairments – it takes fewer steps to reach nuclear disaster.

8.2.2 Selected events in France

The French nuclear safety authorities ASN have provided the authors with a database containing a list of about 10,800 events declared by EDF between 1986 and 2006. ASN had also been requested to provide the present project with a selection of maximum 20 events n nuclear power plants that ASN considers as the "most significant" ones. ASN responded that "the incidents considered by ASN as the most significant are the events that have been subject to a rating on the INES scale superior or equal to [Level] 2".[63]

The French IRSN, the French nuclear safety authorities' Technical Support Organization (TSO), has provided the authors, also on request, with a list of events that took place between 1986 and 2006 considered the most significant by the organization. IRSN has selected 18 events in French nuclear power plants and 18 events in nuclear reactors outside France.[64]

The INES rating of the 18 events that took place in France since 1986 selected by IRSN as the most significant was as follows:

- 1 x INES Level 3
- 9 x INES Level 2
- 7 x INES Level 1
- 1 x unrated

Considering the fact that over the period there were 59 events that were given an INES Level 2 rating, it is remarkable that seven of the 18 selected by IRSN as the most significant events were given a lower rating.

The IRSN selection is additional evidence of the limited technical meaning of the INES rating. It is all the more surprising that the French safety authorities, that had received the information transmitted by IRSN to the authors a full week prior to its own response, simply point to INES Level 2 and 3 events.

IRSN has chosen the events according to "a number of technical elements principally based on the contribution in terms of experience feedback for the safety of the installations". The selected incidents also "illustrate the main safety problems and the specific risk for each type of nuclear installation". The selection therefore "does not correspond to a simple sorting according to a single criterion, as for example the rating on the INES scale". IRSN comments further on the INES scale by stating that "it should be recalled that this scale is aimed at providing the public with synthetic data on the severity of the incident, while the analysis carried out by IRSN aims at providing technical elements contributing to the decisions to be taken in order to increase the safety level of the facilities."

The list provided by IRSN attempts to collect, beyond any concern of hierarchy, incidents with different real or potential consequences and of a different degree of real or potential severity. The selection has been made with help of computerized databases that

[63] Marc Stoltz, Director for the Environment and Emergency Situations, ASN, personal communication, e-mail dated 23 February 2007

[64] The request was asking for a maximum of 20 events each in France and outside France.

”ease the comparison of technical data, the identification of recurring events and the elaboration of statistical elements”.

The IRSN selection covers the following events[65] in French nuclear power plants (by chronological order):

• **12 January 1987, Chinon-B3**, not rated on INES scale
The particularly cold conditions during the winter 1986-87 led to the freezing of several materials and systems significant for the safety of the unit, in particular at the level of feed water intake from the Loire river.

• **16 August 1989, Gravelines-1**, INES Level 3
The mounting of an inappropriate type of screws onto pressure relief valves on the primary circuit would have rendered the overpressure protection system inefficient. The valves would have opened and closed significantly later than under design basis conditions. The operators did not agree to the Level 3 rating and initiated, in vain, a procedure to get it downgraded to Level 2.

• **30 October 1990, Cruas-4**, INES Level 1
The explosion of a 6.6 kV commutator caused a fire that entailed the loss of one of the two electrical safety circuits. The destruction of the commutator was caused by the degradation of elastic washers due to the exposure to heat. Subsequently, the second line was found to be affected in the same way.

• **23 September 1991, Bugey-3**, INES Level 2
A leak was identified during the decennial primary circuit pressure test on the support of the control rod drive mechanisms that was going through the reactor vessel head.

• **29 January 1994, Bugey-5**, INES Level 2
The reactor was shut down and the primary coolant level was decreased to working level in order to carry out some maintenance operations. The water flow level at the primary pumps and the motor intensity fluctuated for eight hours without any operator intervention. The technical specifications explicitly require close supervision of these parameters under these operational conditions because fluctuation can indicate the degradation of the primary pumps leading to their potential loss and thus the risk of core degradation. The safety authorities identified “significant malfunctioning”: the manual was erroneous, the operators had not received any specific training for this “particularly delicate” operation, the situation has been considered falsely as “normal and safe”, the visit of the safety engineer in the control room did not lead to any corrective action.[66] The event had originally been given an INES 1 rating.

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[65] The following short description of the incidents also draws on other sources, in particular on the bulletin of the French nuclear safety authorities.
[66] Bulletin Sûreté Nucléaire, n°97, 3/1994

• 12 May 1998, Civaux-1, INES Level 2
While the unit was shut down, a 25 cm diameter pipe cracked open due to thermal fatigue and a large leak (30 m3 per hour) occurred in the primary cooling circuit. It took 10 hours to isolate the leak. An 18 cm long crack was on a weld was identified. The unit, which is one of the four most modern French reactors (N4, 1500 MW), had been operating only for six months. (see 9.2.2.2 for details)

• 10 June 1999, Tricastin, then identified on all 58 EDF units, INES Level 1
Polyamide cages, non-qualified for accidental situations, instead of metal cages have been built onto ball bearings of coolant safety injection pumps. First identified at the Tricastin site, the problem turned out to be spread over all of EDF's nuclear power plants.

• 11 March 1999, Tricastin-1, INES Level 1
Following a series of organizational and human errors, a technician has penetrated into a protected, highly radioactive area of the reactor (red zone) and has received a dose of about 340 mSv (17 times the current legal limit for worker exposure).

• 27 December 1999, Blayais-2, INES Level 2
The unusual storms at the end of 1999 led to the flooding of the Blayais nuclear power plant site. Certain key safety equipments of the plant were flooded, for example the safety injection pumps and the containment spray system of units 1 and 2. The electrical system was also affected. For the first time, the national level of the internal emergency plan (PUI) was triggered. The IAEA's Operational Safety Review Team (OSART) report on Blayais notes "The plant's communication department has had a hard task after the 1999's flood to recover the lost credibility, but now the situation is considered to be good again."[67] (see 9.2.7.1 for further details)

• 2 April 2001, Dampierre-4, INES Level 2
Following human and organizational errors, the correct core loading scheme has not been implemented. The situation could have led to a criticality risk.

• 21 January 2002, Flamanville-2, INES Level 2
The installation of inappropriate condensers due to an inappropriate procedure led to the simultaneous loss of several control-command boards and systems while the unit was operating as well as to the destruction of two safety significant pumps during the shut down sequence.

• 24 December 2003, all 900 MW reactors (34 units), INES Level 2
The misconception of the reactor sump filters induced the potential risk of debris blocking the cooling function in case of the need for recirculation under post-accident conditions. The problem has been subsequently identified not only in all of the French 900 MW reactors but also in many other plants around the world.

[67] IAEA, *Report of the Operational Safety Review Team (OSART) Mission to the Blayais Nuclear Power Plant*, 2 - 18 May 2005, IAEA-NSNI/OSART/05/131

• 24 January 2004, Fessenheim-1, INES Level 1
Following the erroneous operation of an auxiliary circuit valve, ion exchange resins[68] have been introduced into the primary cooling circuit. Their presence could have threatened the integrity of the primary pump joints as well as the proper functioning of the control rods. Both elements are essential to control and shut down the reactor.

• 22 March 2004, all 58 EDF reactors, INES Level 2
An insulation default at an electrical switchboard, experienced on unit 2 of the Penly nuclear power plant, was triggered by a steam leak close to electrical equipment that was to be qualified to resist accidental conditions. The non-conformity of the cabling has been subsequently identified on all of the French nuclear power plants and led to large-scale verification and remediation operations.

• 16 May 2005, Cattenom-2, INES Level 1
The sub-standard of the secondary coolant pump power supply cabling led to a fire in the electricity funnel. As a consequence one of the two safety circuits had to be disconnected. The operator EDF triggered its local (Level 1) internal emergency plan (PUI) The technical emergency center (CTC) has been activated for a few hours. The nuclear safety authorities issued a nine-line press release. Details of the event have never been published.

• 7 April 2005, Gravelines-3, INES Level 1
During the year 2006 the operator has noticed the presence of provisional pieces of equipment on both of the reactor protection control command lines. These pieces were applied during the previous reactor outage and had been left there by mistake. Under accidental conditions certain automatic sequences would not have taken place in a normal way.

• 30 September 2005, Nogent-1, INES Level 1
A certain number of material failures added to a human error during the restart of the reactor led to the hot water and steam penetrating the four rooms containing the control command boards of the reactor protection system. Under normal conditions these rooms are independent from each other and should never be put in danger simultaneously. In the case of an accident, this incident could have made it difficult for the operator to bring back the reactor into safe state. EDF has activated its internal emergency plan and the nuclear safety authority ASN activated its national emergency organization for a few hours. ASN issued a 10-line press release.

• 21 December 2005[69], Chinon-B (four units), INES Level 1
An ill-conceived surveillance of the tertiary cooling water intake canal led to its significant silting up. The collapse of the sand hill could have led to the heat sink loss of all four reactors.

[68] Synthetic material used to selectively remove dissolved contaminants such as heavy metals or radionuclides from water by replacing or exchanging them with other constituents.
[69] As dated by IRSN, the safety authorities technical support organization. According to a database transmitted by ASN have dated the incident on 30 December 2005 and notes it as declared by EDF on 4 January 2006; Marc Stoltz, database transmitted by e-mail to the project coordinator, personal communication, 23 February 2007

9. Residual Risk Project Selection of Nuclear Events 1986-2006

9.1 Definition of selection criteria

Hundreds of significant events take place in every major nuclear country every year, several thousand worldwide. There is no internationally agreed methodology for an established reporting threshold and type classification of these events. In fact, even official organizations in a given country often do not agree about the classification of events. The IAEA INES has been developed for public communication purposes and as such has served operators and nuclear safety authorities usefully. It is therefore not surprising that operators frequently underrate incidents, at least in the short term, and even attempt to negotiate with safety authorities to lower a given rating.

However, INES is not an appropriate tool for the technical evaluation of the risk level entailed by a specific event or its potential significance for nuclear safety.

In the absence of a recognized uniform evaluation tool, the authors have questioned nuclear safety authorities and technical support organizations and have studied published listings and event evaluation reports from the past 20 years.

The authors of the present study neither wish to present a ranking of nuclear incidents nor claim to have identified *the* most significant events.

The following selection of events is based to some extent on the evaluation that has been provided by national organizations in France (on request), on accident probability calculations in the case of the USA (severe core damage probability) and on the appreciation of the experts involved in the project. In most of the cases there is a consensus as to the particular significance of the incidents.

The IAEA did not respond to repeated information requests.

9.2 Selection of events by type of incident

Rather than attempting to provide a world overview, an ambition that would have gone far beyond the scope of the project, the authors chose to select a number of events that seem typical or particularly severe for a given family of events. Many times the significance of a given incident is considerably amplified by the fact that it reveals a generic problem for a number of plants and, indeed, sometimes for an entire series of reactors (>10), and sometimes for an entire reactor type (>100).

The availability and paucity of information also played a significant role for the selection. The fact that events from certain countries are discussed while most of the 31 nuclear countries are not represented is no indication of the frequency or absence of events. The core of the report provides numerous other examples that could equally have been selected as exemplary. However, there are countless events that are insufficiently documented or not documented at all. And, no doubt, there are many incidents that the international public has never heard of.[70]

[70] In the United Kingdom, for example, incident reporting has become extremely restrictive in the few years following the 9/11 terrorist attacks with the Nuclear Security Regulations 2003 rendering it an offence for any person to provide information on nuclear sites and/or activities that could assist at the planning and/or implementation of a malicious act.

The events are presented by event family rather than by country or date. However, there are numerous events that would qualify for several event categories. The dates either indicate the point of discovery of an event or the beginning of an incident or the first time that a generic problem has been identified.

9.2.1 Advanced Material Degradation (before break)

There are many material degradation mechanisms (see chapter 3) that can lead either to severe damage of safety relevant systems or render them inoperable. The following two examples illustrate how close – literally millimeters – to severe accident conditions nuclear power plants have come in the past 20 years.

9.2.1.1 3 April 1991 Shearon Harris (USA)

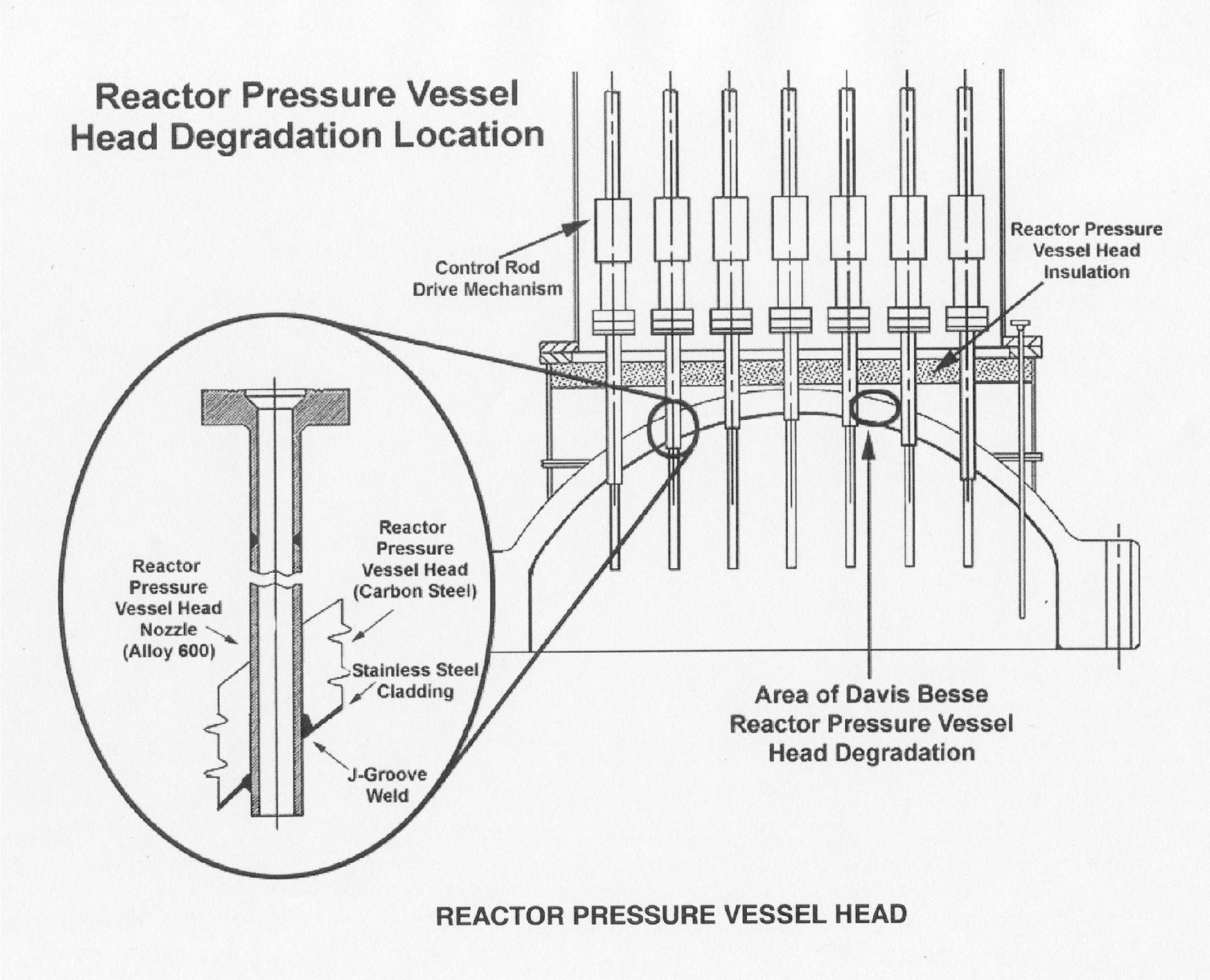
On 3 April 1991, workers at the Shearon Harris pressurized water reactor in New Hill, North Carolina discovered damaged piping and valves within the alternate minimum flow system provided for the pumps in the emergency core cooling system. Most of these pumps are in standby mode during normal operation and start when needed to supply makeup water for cooling the reactor core. Because some of these emergency pumps deliver water at low pressure, they cannot supply water to the reactor vessel until pressure drops low enough. The alternate minimum flow system at Shearon Harris provided a place for output of the pumps until pressure dropped low enough for the water to be sent to the reactor vessel. The piping and valve damage was serious because, had an accident occurred, water needed to cool the reactor core would have instead poured out onto the floor through the ends of broken components. The NRC calculated the severe core damage risk from this event to be 6×10^{-3} or 0.6% per reactor year, an accident probability as high as in the case of the Davis-Besse incident (see hereafter).

9.2.1.2 6 March 2002 Davis Besse (USA)

On 6 March 2002, workers discovered significant corrosion in the carbon steel reactor vessel head at the Davis-Besse pressurized water reactor in Oak Harbor, Ohio. The head is bolted onto the reactor pressure vessel containing the reactor core during operation. There are sixty-nine holes in the head that allow control rods inside the reactor vessel to be connected to their external motors. There are stainless steel tubes, called control rod drive mechanism nozzles, through each hole and welded to the stainless steel inner liner of the head. It is believed that one of these tubes developed a crack around 1991. By 1996, the crack extended all the way through the metal wall of the control rod drive mechanism nozzle and began leaking borated reactor coolant water. The leak rate was small, less than 1 gallon per minute, but it persisted for nearly 6 years.

Rust-laced boric acid "river" flowing through inspection ports on the reactor head and down onto the reactor flange during the refueling outage in 2000.

Figure 8: Davis Besse reactor pressure vessel degradation



When the leaked water evaporated, it left behind dry boric acid crystals. Boric acid is very corrosive to carbon steel. It began eating through the carbon steel head. By 2002, there was a pineapple-sized hole in the head. The boric acid had completely eaten through the 150mm thick carbon steel wall to expose the stainless steel liner. The liner was applied to the inner surface of the carbon steel reactor vessel and head for protection against the corrosive borated water. The liner was not intended to be pressure-retaining, but for years it was the only barrier preventing a loss of coolant accident. As boric acid widened the hole, the stress loading of the liner increased. A government study estimated that the hole would have widened to the point where the liner ruptured in another 2 to 11 months of operation by Davis-Besse. Because Davis-Besse ran 18 months between refueling outages, had the damage been missed during the 2002 outage, it seems likely that a loss of coolant accident would have occurred.

Many warning signs had been overlooked since the leak began in 1996. During refueling outages in 1998 and 2000, workers discovered boric acid blanketing large portions of the reactor head. Nearly a decade earlier, the company had committed to the NRC to completely clean up all boric acid spills to check if there was corroded metal underneath. Workers attempted to remove the boric acid from the head, but management did not extend the outage duration to allow them to finish the work. During 1999, small rust flakes blowing up into the air from the widening hole clogged the filters on monitors inside the containment that continuously sampled the air for radioactivity. Management sent workers into containment to replace the filters. During the refueling outage in 2000, workers removed bucket after bucket of boric acid crystals and rust flakes from the air conditioning coils inside containment. The company's management explained to the NRC in August 2002 that it overlooked these, and many other warning signs, because it placed generating revenue ahead of assuring safety.

Had the 5mm stainless steel liner ruptured, a hole with a diameter of approximately 250mm would have created a medium-sized loss of coolant accident. While Davis-Besse was equipped with emergency systems to mitigate such an accident, these backup systems were also found to be impaired. The worst problem involved the containment sump used during the second phase of accident mitigation. In the first phase, emergency pumps transfer water from a large storage tank adjacent to the containment building into the reactor vessel to compensate for the cooling water pouring out the 250mm diameter breach. The water pouring out of the reactor drains to the bottom of the containment building where it collects in a concrete pit called the containment sump. Before the storage tank empties in about 30 to 45 minutes, the operators realign the emergency pumps to take water from the containment sump and send it to the reactor vessel. Workers found that the debris created by water jetting out through the hole (e.g., insulation and coatings scoured off piping and components) in addition to pre-existing debris inside containment (e.g., paint applied to the inner surface of the containment dome

The large hole in the reactor vessel head around the vessel head nozzle.

was peeling and falling to the floor during routine plant operation) would be transported by the flowing water to the containment sump where it would clog the protective screens and deprive the emergency pumps of the water they needed. Before Davis-Besse restarted in March 2004, workers enlarged the containment sump screens by a factor of 25 and upgraded insulation and coatings so as to reduce potential debris sources.

The NRC calculated the severe core damage risk from this event to be 6×10^{-3} or 0.6% per reactor year and rated it INES Level 3.

9.2.2 Significant Primary Coolant Leaks

A loss of coolant accident in a nuclear power plant is always highly significant to the safe state of the facility since the failure to evacuate the heat from the reactor core can threaten the integrity of the nuclear fuel. There are hundreds of kilometers of tubes in a nuclear power plant and the thousands of steam generator tubes represent the largest part of the primary circuit boundary. That is where heat from the primary circuit is transferred to the secondary circuit. Steam leaving the generators drive the turbines that produce the electricity. Leaks can appear in any of the operational or backup safety systems.

9.2.2.1 18 June 1988, Tihange-1 (Belgium)

Tihange 1 is an 870 MWe pressurized-water reactor located at Tihange, Belgium. On 18 June 1988, while the reactor was operating, a sudden leak occurred in a short, unisolable section of emergency core cooling system (ECCS) piping. The operator noted increases in radioactivity and moisture within the containment and a decrease of water level in the volume control tank. The leak rate was in the order of 1,300 liters per hour, and the source of leakage was a crack extending through the wall of the piping.

The crack, which was in the base metal of the elbow wall and not in the weld or heat-affected zone, 90mm long on the inside surface of the elbow and 45mm long on the outside surface. A crack indication also existed in the spool connecting the elbow to the nozzle in a hot leg. That indication was in the heat-affected zone at the weld connecting the spool to the elbow. The indication is circumferential, extends 100mm on the inner surface of the spool. Circumferential cracks are considered much more dangerous than longitudinal crack because they have a higher risk of not leaking before they break (which makes early detection more difficult). Two smaller crack indications exist in the vicinity of the weld connecting the elbow to the check valve. The origin of the defects is identified as thermal fatigue (material stress due to thermal shocks from alternate exposure to heat and cold).

The risk of a pipe rupture in the emergency core cooling system is considerable in the case of the activation of the emergency safety injection system – large quantities of cooling water are injected in case of a loss of coolant accident – in an already degraded safety situation.

A much smaller similar leak had been detected at a similar location at the US Farley-2 plant in December 1987, but it had developed slowly and not abruptly as in the Tihange case. Subsequently, the phenomenon has been identified at the French Dampierre plant (in 1992 at unit 2 and in 1996 at unit 1) and later all 34 of EDF's 900 MW reactors were found subject to the problem. The safety authorities have in a first step only asked the operator to increase maintenance and monitoring activities on the affected plants. In the summer of 2001 the experimental modification of the circuits has been authorized in two units (Fessenheim-1 and Dampierre-2). It is only at the end of 2003 that the identical modification has been authorized for the other 32 units. The current status of that program is not known. However, between the identification of the problem and the licensing of an engineered solution over 15 years went by.

9.2.2.2 12 May 1998, Civaux-1 (France)

The Civaux-1 reactor was shut down for five days, when during start-up tests, on 12 May 1998 at 19h45 a 250mm diameter pipe of the main residual heat removal system cracked open and a large leak (30,000 liters per hour) occurred in the primary cooling circuit. The reactor core needs to be cooled permanently, even when it is shut down, in order to evacuate the significant amount of residual heat of the fuel. By 3:00 hours in the morning on

13 May 1998 stand-by teams from the nuclear safety authorities and its technical backup as well as additional staff from the operator EDF and the builder Framatome are activated.

It took nine hours to isolate the leak and a stable situation is reached at 5h40. It was first decided to cool the core via the steam generators, but because of the relatively low burn-up – and therefore relatively low heat output - of the fuel, the attempt fails. The unit, which is one of the four most modern French reactors (N4, 1500 MW_e), the last but one reactor to have been commissioned in France and had been operating only for six months at 50% power level maximum prior to the event. Then, the safety authorities give permission to continue cooling with the remaining line of the shutdown cooling system with modified physical parameters (low pressure, two phase flow). This state is reached on Sunday 17 May 1998 and the permanent activation status of the standby teams is lifted, after five days, in the morning of Monday 18 May 1998.

An 180mm long crack on a weld was identified and 300 m^3 of primary coolant were leaked into the reactor building. The origin of the crack was accelerated thermal fatigue because a cold leg was mounted much too close to hot water piping. Repeated thermal shock initiated the crack within a few months of operation.

In June and July 1998 the fuel was unloaded at Civaux-1 but also on the two other then operating French 1500 MW_e reactors at Chooz and similar crack indications were identified there as well.

EDF later admits that the second level of the internal emergency plan (PUI, national level) had been reached during the night of 12-13 May 1998. Apparently in agreement with the safety authorities, it was not activated. The reason is unclear. However, it should be noted that the head of the safety authorities had scheduled a large press conference in the morning of 13 May 1998 in order to release his report to the Prime Minister on the contaminated spent fuel shipment affair that had raised considerable media attention since its original revelation in France by Libération on 6 May 1998. In fact, certainly in part due to the “competing” media event, hardly anything has been published in France on the Civaux incident.

EDF suggested rating this event Level 1 on the INES scale. The safety authorities immediately decided on Level 2.

The technical problems with the N4 reactors had significant impact on their electricity generation for the year.

9.2.2.3 9 February 1991 Mihama-2 (Japan)

A steam generator tube rupture occurred at Mihama Unit 2 on 9 February 1991. This is the first such incident in Japan where the emergency core cooling system was actuated. Mihama-2 is a 470 MWe pressurized water reactor. The primary coolant flows through several thousand tubes making up the bundles in each steam generator (two in this case) where the heat is transferred to secondary water, which leaves the reactor containment in the form of steam to run the turbines and generate power.

At 12h24 on 9 February 1991, Mihama-2 plant personnel received an "attention" signal from the steam generator. At 13h20 sampling analysis indicated a radioactivity concentration only slightly higher than normal in one of the steam generators, which would signal a small primary leak. At 13h45 hours, plant personnel manually started a third charging pump because of decreased pressure and water level in the pressurizer. At 13:48 hours, personnel began to manually reduce reactor power. At 13:50 hours the reactor shut down automatically because of "low pressurizer water level" and the emergency coolant safety injection was activated. Leakage from the primary to the secondary circuit was essentially terminated at 14h48 hours.

The utility investigated the rupture and found that it was a complete circumferential tube failure. The utility found that the failure mechanism was high cycle fatigue caused by vibration. By design, all tubes in specific locations in the steam generator are supposed to be supported by anti-vibration bars. However, the subject tube was not found to be supported appropriately because of a reported "incorrect insertion" of the adjacent anti-vibration bars.[71]

The Mihama incident triggered the adoption of an audit system by the utility TEPCO under which non-nuclear power sections of the company would audit nuclear power stations. However, the Nuclear and Industrial Safety Agency (NISA) has been highly critical of the scheme: "An audit team of five employees, who are with the Audit and Operational Development Department, merely conducts a nuclear power audit at each plant site twice a year for three days each. Since the initiation of the audit system, the auditing program has not been reassessed at all. In addition, the audit team informs the power station of the items it has decided to audit before actually carrying out the audit. Thus, the value of the system is suspect. Moreover, because the audit team includes members who are not engaged in nuclear-related work and because such an audit requires high expertise, the thoroughness of the audit is open to question."[72]

9.2.3 Reactivity Risks

The basic principle of a nuclear reactor is controlled nuclear fission. There are various means to control the nuclear chain reaction, in particular the insertion of control rods into the core and the injection of borated water. Both means aim to slow down the nuclear reaction by introducing neutron absorbing substances (e.g. boron) and/or physical neutron "breaks". Any disturbance of the system has potential far reaching consequences, especially in case of an accident that needs fast and efficient control of the nuclear reaction.

9.2.3.1 12 August 2001, Philippsburg (Germany)

In August 2001 in the German Philippsburg nuclear power plant a deviation from the specified boron concentration – a neutron absorber needed to slow down or stop the nuclear reaction – in several flooding storage tanks during restart of the plant was reported to the authorities. Later the report was completed by the fact that also the liquid level had not reached the required value fixed in the operational instructions for the start-up and was only implemented with a delay.

Subsequent investigations revealed that significant deviations from requirements during start-up and violations from related instructions seemed to be common probably for several years and took place in a similar way in other German nuclear plants. The over all extent of the violations was not clearly comprehensible from the available documentation.

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[71] US-NRC, Information Notice No. 91-43, 5 July 1991

[72] NISA, *Interim Report on the Falsified Self-imposed Inspection Records at Nuclear Power Stations,* Nuclear and Industrial Safety Agency, 1 October 2002,

The flooding tanks are used for the storage of large quantities of boron-treated water. A special boron concentration has to be adjusted in the coolant to control the reactivity in the reactor core. The water quantity is dimensioned to ensure a sufficient heat transfer from the reactor core at any time and to compensate for the potential loss of coolant in the primary circuit. Temporary other coolant inventories, especially the content of the primary circuit, can be depleted into the storage tanks due to performance of particular maintenance or test activities. The water management has to ensure a sufficient amount and a sufficient boron concentration in the coolant to control all possible events at any time. The emergency cooling will only work effectively if it is operated according to design basis conditions.

Due to the violation of rules and regulations the available amount of conditioned cooling water was repeatedly insufficient during the start-up sequence. During these occasions the efficiency of the emergency cooling system and the capability of the plant to cope with possible accidents were limited. Possible accidents during start up could have led to uncontrollable states of the plant.

The deviation from specified values was accepted. Administrative control measures to ensure the orderly performance of procedures were ineffective or missing.

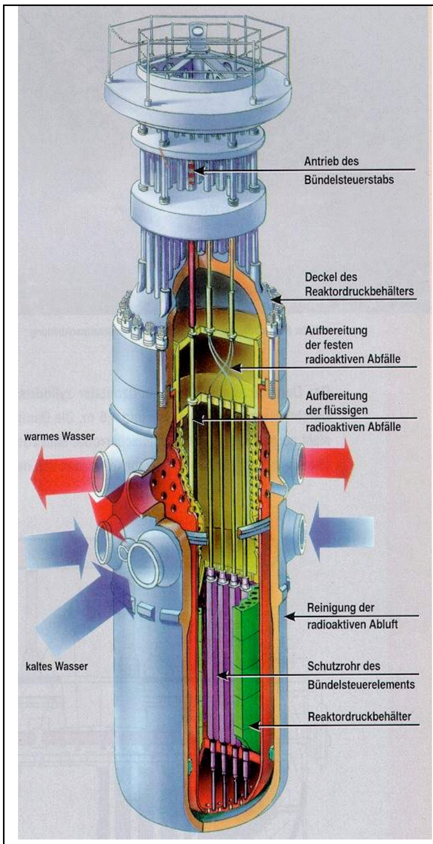
The findings of the comprehensive assessment gave reasons to start an extensive discussion on the importance of safety management in nuclear power plants. It was estimated that the continuous and systematic violation of rules and regulations in general holds the potential for severe consequences in many safety related contexts. The safety authority requested the systematic implementation and enhancement of safety management. The discussion how to control the effectiveness of safety management and to ensure the required standard of safety performance is not yet completed. Different approaches were presented and have to be verified in view of practicability and efficiency by future experience.

There are many other incidents that demonstrate the incompleteness of administrative measures to ensure safety.

9.2.3.2 1 March 2005 Kozloduy-5 (Bulgaria)

The Bulgarian Kozloduy nuclear power plant is state owned. Six units were constructed at the site, all of them of the Russian WWER design. The units were connected to the grid in 1974, 1975, 1980, 1982, 1987 and 1991 accordingly. Units 1-4 are WWER-440 Model 230 and units 5-6 are WWER-1000 Model 320. Units 1&2 were shutdown in 2002 and Units 3&4 were shutdown in 2006 as part of the Bulgarian EU accession agreement.

Introduction



During the annual repair and refueling period July – August 2005 all driving mechanisms of Cluster Control Rod Assemblies (CCRAs) of unit 5 were replaced, as a part of the modernization program. This program was partially financed under a EURATOM loan. The new driving mechanisms were designed and manufactured by the Russian company Gidropress. Some new materials were introduced in their design, trying to increase their operational life up to 30 years. These machines were tested in one of the Russian WWER-1000 plants, but they were installed only for the control rod assemblies in bank No 10. During reactor operation this bank of control rod assemblies controls the reactor power and is almost permanently in motion. No driving mechanism was tested in banks 1-9, which stay in their top position, waiting for a scram signal (to drop down and thus shut down the reactor).

It is unclear whether design changes as well tests were authorized by the Russian Nuclear Safety Authority. It is still even unclear weather the manufacturer of this equipment was licensed by the Russian Nuclear Authority.

Development and causes of the incident

On 1 March 2006 Kozloduy unit 5 was operated at full power. At 06:08 AM due to electrical failure, one of the four main circulation pumps tripped. Following this initiating event, to enable rapid power reduction the system automatically reduced the power to 67% of nominal capacity. In the process of power reduction the operators identified that three control rod assemblies remained in upper end position.

The follow-up movement tests of remaining control rod assemblies identified that in total 22 out of 61 could not be moved with driving mechanisms. The number of control rod assemblies, unable to scram (to drop due to the gravity only) remains unknown. Presumably their number was between 22 and 55. Multiple attempts have been made to set in motion the drives remaining in upper position and as a result only eight of them recovered their design characteristics.

At 12:45, more than six and one-half hours after detecting the failure, the reactor was shut down with the use of the boron system - feeding the primary circuit with highly borated water that absorbs neutrons and slows down the nuclear reaction. Then the reactor was cooled-down and actions were taken to clarify the case. Three of the driving mechanisms (that remained in upper end position) were dismantled and investigated. As a result of the visual inspections, measurements and experiments, it was identified that the direct cause of lack of movement was “detention” in the foreheads of the movable and immovable poles of the fixing electromagnet. Once driving mechanisms are set in motion, the “detention” phenomenon is no more observed and the rods perform as designed.

The general designer has proposed short-term corrective measures, mainly including periodical operability testing of the control rod assemblies of banks 1-9. The Bulgarian Nuclear Safety Authority (BNSA) accepted the proposed corrective measures and provided regulatory agreement for restarting unit 5 without any specific requirements or remarks.

In respect to the incident at unit 5, all control rod assemblies at unit 6 were tested in motion with driving mechanisms. Reportedly control rod assemblies perform as designed.

After testing of all driving mechanisms and replacement of some of them the reactor was restarted on 10 March 2006.

As a result of this incident the planned change of driving mechanisms to unit 6 in 2006 was canceled.

Severity of the incident

Control rod insertion failures are considered very serious and lead to a severely degraded state of safety in case an accident-initiating event occurs. The WWER-1000 scram system is designed to put the reactor in safe shutdown if one control rod assembly at the most is jammed in the upper position.

Operation of Kozloduy unit 5 at full power during eight months with tens of inoperable control rods is an unprecedented example in the history of nuclear power. This mode could be defined as Anticipated Transient Without Scram waiting to happen. In case of steam line break, or other initiating events, leading to fast cooling down of reactor and increase of reactivity, the ineffective scram system could not prevent severe damage of reactor core.

The INES manual defines events 2 and 3 as follows:

- Level 2 - Incidents with significant failure in safety provisions but with sufficient defense in depth remaining to cope with additional failures.
- Level 3 - Incidents in which a further failure of safety systems could lead to accident conditions, or a situation in which safety systems would be unable to prevent an accident if certain initiators were to occur.

According to these definitions the incident at Kozloduy unit 5 should clearly have been classified as Level 2 or 3. However, it took the Bulgarian authorities a long time to admit the seriousness of the incident as is illustrated by the following chronology of events.

An "information incident"

On 2 March 2006, when Kozloduy unit 5 was already shut down, Bulgarian media were informed that there was a need of "planned repair" and affirmed the reason as "necessity of system checks and additional repair work". There was no word about multiple failures in the reactor scram system.

On 10 March 2006 the Bulgarian society was informed that the "planned repair" was completed successfully and that the unit restarted operation. Bulgarian Minister of Economics and Power Mr. Ovcharov stated that now no problems in providing electricity to consumers could be expected.

On 14 March 2006 for the first time the Bulgarian nuclear safety authorities (BNSA) on their web-site made a statement about the failures in the reactor scram system. According to the safety authorities: "The root causes of the event have to be identified and adequate corrective measures for cause elimination shall be established until the unit's shut-down". It also stated: "According to the preliminary report of the nuclear power plant "Kozloduy" the event rating is evaluated as **"0" Level** of the International Nuclear Event Scale".[73]

On 24 April 2006 the German "Tagesspiegel" published an article in which an independent expert stated that the severity of the incident is higher, presumably INES Level 2 or 3. In response the Chairman of BNSA confirmed that the event would be INES **Level 0**[74] and "the BNSA Deputy Director stated that there was **no serious failure** in the emergency protection system of Kozloduy Unit 5".[75]

On 25 April 2006 for the first time BNSA informed the International Atomic Energy Agency about the incident. However the report says: "In the preliminary event report sent to the BNSA, the Kozloduy nuclear power plant rated the event as INES **Level 1**. The final INES rating will be determined by the BNSA after completing all ongoing analyses and published in NEWS".[76]

On 25 April 2006 Bulgarian Minister Mr. Ovcharov declared to the media "nothing happened on 1 March at Kozloduy nuclear power plant, and the Bulgarian society was informed about the incident in unit 5. (…) According to Ovcharov there was nothing different from normal activities that the nuclear power plant and BNSA have to perform. Ovcharov added that on 12 March BNSA has delivered comprehensive information about the event."[77]

On 02 May 2006, during a press conference, for the first time the Kozloduy management stated that there were safety shortcomings in the design of driving mechanisms and improper activities of the personal.

On 08 May 2006, during a press conference in its headquarters, BNSA announced its decision to increase the risk level of the incident that took place at the Kozloduy nuclear power plant unit 5 at 1 March 2006. According to the statement of the Chairman the final assessment is INES Level 2.[78]

The main lesson learned from this incident is that there are tremendous shortcomings in safety culture at corporate and governmental level in Bulgaria.

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[73] cf. http://www.bnsa.bas.bg/news/060314_bg.html
[74] http://www.mediapool.bg/show/?storyid=116655
[75] Bulgarian Press Agency (BTA), Sofia, April 24 2006
[76] http://www-news.iaea.org/news/topics
[77] http://www.mediapool.bg/show/?storyid=116685
[78] http://www.bnsa.bas.bg/news/060508_bg.html

9.2.4 Fuel Degradation (outside reactor core)

9.2.4.1 Paks (Hungary) 2003

Four units are operated at the Hungarian Paks nuclear power plant, all of them WWER-440 V-213. The units were connected to the grid in 1982, 1984, 1986 and 1987. The thermal power of each unit is 1,375 MW and the total electrical power capacity of the Paks nuclear power plant is 1,755 MW. [79]

Introduction

The Paks nuclear power plant management scheduled 24 steam generator decontamination operations between 1996 and 2001 at units 1-3. The last step, passivation, was not carried out carefully and became the fundamental cause of magnetic deposits generation. They formed a significantly thick layer on fuel assemblies and reduced cooling water flow and heat transfer. Due to the increased and asymmetrical outlet coolant temperature the power of the units had to be decreased step by step and at least part of the fuel assemblies had to be replaced. Such anomaly was found in unit 2 in 1998 and resulted in its shutdown and the replacement of the entire core. In 2000 new deposits were detected in unit 3, which had to be shut down in February 2003 and the full core was replaced. When the unit was restarted core asymmetry was detected and the unit has been operating at reduced power. In 2000-2001 differential pressure measurements revealed the limitation of the cooling capacity of the fuel assemblies between 10-65 %. Chemical cleaning of the fuel assemblies has become indispensable in order to make use of the remaining fuel capacity that represented still an additional 2-3 fuel cycles. In other words, without cleaning a significant economic loss would have to be accepted.[80]

Chemical cleaning technology during 2000-2001

In 2000 and 2001 the Paks nuclear power plant contracted Siemens GmbH for the cleaning of 170 “cold” fuel assemblies (stored in the fuel pool for more than one year and with low remaining decay heat) in a 7-assembly cleaning container. The specially designed cleaning tank was installed under 10 meters of borated water in a service shaft of the spent fuel pool. 170 fuel assemblies were cleaned during approximately 10 weeks without any damage and were used in the subsequent refueling of Paks units.[81]

[79] See Third National Report of Republic of Hungary to the CNS, 2004
[80] See Report of the IAEA Expert Mission to Paks NPP, 16-25.06.2003
[81] See Fuel assemblies chemical cleaning, Report of Paks NPP and Framatome ANP, 2002

Chemical cleaning technology during 2002-2003

Decisions influenced by time pressure. In 2002 the Paks management decided to upgrade the cleaning process and equipment in order to solve the fuel cleaning problem during annual maintenance. In November 2002 the nuclear power plant commissioned Framatome ANP (the legal successor of Siemens KWU, now AREVA NP) for the designing and manufacturing of the new cleaning system, which was to be installed and ready for use by March 2003. This decision resulted in a very aggressive schedule for design, fabrication, installation, testing and operation of it. In December 2002 Framatome ANP presented preliminary design, which was not agreed with the Russian manufacturer of the fuel and with the Russian scientific manager of WWER-440. The Paks nuclear power plant submitted a license application to Hungarian Atomic Energy Agency (HAEA) on 18 December 2002 and on 24 January 2003 HAEA provided a license for the ex-core fuel cleaning, with only one comment on the safety analysis.

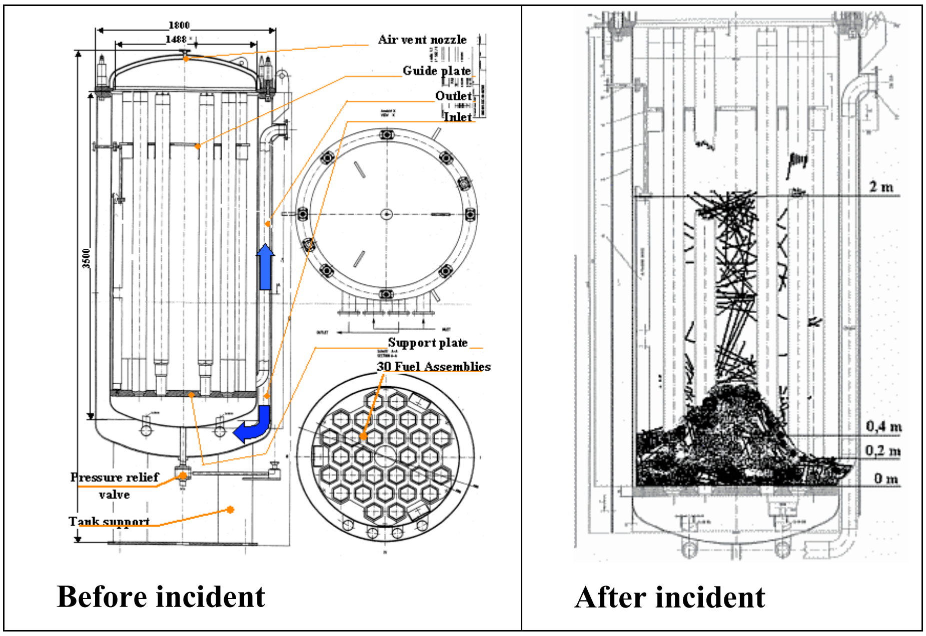
Loss of simplicity and passive safety features

The first most important requirement was to increase the number of fuel assemblies that could be cleaned simultaneously. This resulted in the design of a big vessel, housing 30 assemblies (about 3,550 kg of partially used fuel) and the cleaning technology for it. Measurements of differential pressure of each fuel assembly appeared to be not possible and no measurement of temperatures or other parameters within the tank were provided. Thus there were no means to monitor cooling of each individual fuel assembly. The second requirement was to clean the assemblies during annual maintenance, in a very short time period after the reactor shutdown. Both of these requirements resulted in a big increase of the heat generated in a relatively small closed space. Thus, the simplicity and passive safety features of the initial cleaning facility were lost.

Safety deficiencies in the design of the new cleaning system

- Location of a pressure relief valve at the bottom instead at the top of the tank, which led to malfunctioning of the cooling function;
- Inadequate sizing of the submersible pump, whose redundancy and back-up system was also inadequate. The low-capacity pump had to operate for several hours after completion of the cleaning which was clearly beyond its design specifications;
- The tank design did not assure precise positioning of the bottom end of the fuel assemblies in the cleaning tank;
- Only one fuel guide plate in the cleaning tank was utilized, which cannot assure proper alignment of the fuel assemblies. The possible bypass flows around the fuel assemblies – thus not fulfilling its cooling function – were not fully taken into account;
- Instrumentation, trend recording and alarms provided to detect off normal conditions were inadequate.

Figure 9: Paks Fuel Cleaning Tank Before and After the Incident



Incomplete safety analysis

A number of significant aspects of this cleaning project were unique and unproven. It was to be the first time that a large number of assemblies with significant decay heat were being cleaned. However, the safety analysis performed for the fuel cleaning provided only a simple analysis of the cooling conditions of the fuel. Even that analysis identified that in the event of loss of cooling during cleaning, boiling in the tank could occur within only 9,2 minutes. The approach proposed by Framatome ANP to respond to a loss of cooling was to stop the cleaning operation and to open the cover of the tank in order to flood the fuel. However the emergency lifting of the lid was not analyzed and there were no practical exercises. There was no analysis provided for the effects on the fuel assembly cooling if it was not properly installed in the tank, or of blockage of a fuel channel during the cleaning process. The safety analysis submitted with the license application also did not address the possibility of serious fuel cladding failure and the radiological releases expected from a single fuel element failure or multiple fuel failure. The lack of this information during the event contributed to an initial misdiagnosis of the incident.[82]

Improper management of cleaning and lack of safety culture

Cleaning operations were not integrated within the organization of maintenance operations. The responsibility was turned to Framatome ANP with strong over-reliance on a prominent company. Paks nuclear power plant operators did not monitor the cleaning equipment or process indications. The cleaning procedures were not developed, reviewed and approved by operating personnel. The operational and safety parameters and limits for the cleaning operation were not defined. No emergency procedures were developed and activities of the personnel after the incident were not effective, improper and even leading to more negative consequences. There was an accumulation of defaults in the safety culture.

[82] See IAEA Expert Mission op.cit.

Nuclear Safety Authority approach

The Hungarian safety authority (HAEA) clearly underestimated the safety significance of the proposed unproven design for the new cleaning system and did not use a conservative approach in its safety assessments. HAEA considered only a modification of a component, rather than the installation of a new system. The engineering design did not address the single fault criteria for safety systems. In addition operational limits for cooling, and fuel failure were not developed. The fault conditions and indications related to inadequate cooling of the fuel were not properly addressed. Time pressure combined with confidence generated by previous successful operations, contributed to a very weak assessment of a new design and operation.

Development and causes of the incident

The Unit 2 of Paks nuclear power plant finished its 19th fuel cycle, the reactor was shutdown and the annual maintenance started at 28 March 2003. The fuel assemblies were fully unloaded and stored in the storage pool. It was planned to clean 60 "cold" fuel assemblies and 210 "hot" assemblies. On 10 April 2003 the cleaning program for the 4th charge of hot assemblies was accomplished by 16:40. The lid of the container was not lifted due to the engagement of the crane in other operations. The cooling of the fuel assemblies inside the cleaning container was accomplishing in Mode B with the use of submersible pump.

Early signs of developing incident

At 19:20 the pressurizer level had increased by approximately 70 mm in about 20 minutes. This level change was also detected in the water level measurement of the cooling pool. The only possible reason for this could be draining of the cleaning tank and drying of the hot assemblies that could lead to their damage. However, nobody paid attention to these important indications.

At 21:53 unexpectedly higher dose rate and noble gas release were detected in the chemical system and the dosimetry systems of the exhaust stack showed a sudden increase in released noble gas activity. The radiation monitors in the reactor hall indicated alarm level. The dose rate near the cleaning equipment increased drastically and the reactor hall area was evacuated.

The cleaning tank lid was unlocked at 02:15 PM on 11 April and immediately a staggering activity increase ($3{,}1 \times 10^7$ MBq/10 min noble gas release) was observed. At the same time, the water level in the storage pool lowered by approximately 70 mm.

At 04:20 the lifting cable broke, the lid removing operation was interrupted and the damaged cover remained in a partially lifted position.

At 07:45 release of iodine isotopes to the atmosphere accumulates to 142,6 GBq.

At 24:00 the daily noble gas release is 160 TBq.

The event was rated INES Level 2.

In the evening of 16th April 2003, after several attempts, the container lid was finally removed and video inspection showed that all 30 fuel assemblies inside the container had been severely damaged. The event was re-rated to INES Level 3.[83]

[83] See footnotes IAEA Expert Mission op.cit. and Bulletins and official statements of Paks NPP and press releases of Hungarian Atomic Energy Agency from May and April 2003

Radiation conditions, doses and releases to the environment

Radioactivity releases into the atmosphere. Radioactive isotopes with an activity of 410 TBq (noble gases), 360 GBq (iodine-131 equivalent), and 2,5 GBq (long-lived aerosols) were released into the atmosphere in the first two weeks. One half of the noble gases, predominantly Xe-133 and Kr-85m, and most (95 %) of the activity of the iodine, was released in the first day. A release of this nature would be expected to cause a temporary increase in the environmental gamma dose rate within a few km of the release point in the downwind direction of the wind. The nine monitoring stations measuring gamma-dose-rates and located within the 1,5 km vicinity of the Paks nuclear power plant have not shown any increase. In the first hours of the incident the environmental impacts of the noble gas plume were detected by the telemetric environmental monitoring station A1 located 2,000 m north of the stack (downwind direction) - increase up to 260 nSv/h.

The level of environmental effect can be illustrated by the comparison with previous years and with emissions from other European nuclear power plants.

Table 2: Radioactive emissions from Paks in comparison with French nuclear power plants

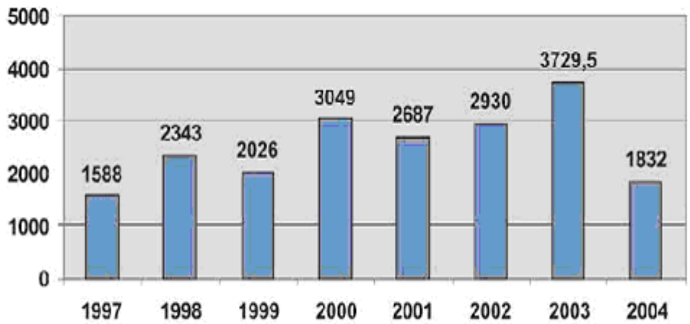
Emissions	Noble gases, [TBq]	I-131 + Aerosols, [GBq]
Paks average annual, 1999-2001	53	< 2
Paks 10.04 - 23.04.2003	410	363
Paks total 2003	517	412
Total emissions from 58 French reactors	109[84]	2

Sources: National Reports under the IAEA Convention on Nuclear Safety and Report of the IAEA Expert Mission to Paks NPP, 16-25.06.2003

The radioactive noble gas emissions following the Paks event correspond to roughly four times the cumulated annual emissions of all 58 French pressurized water reactors and 180 times of their cumulated radioactive iodine and aerosol releases.

Doses to the personnel and to the public. The Paks personnel collective dose for 2003 was the highest during last years and twice as high as in 2004, as shown in the following figure.

Figure 10: Collective dose in the vicinity of the Paks nuclear power plant (in man-mSv)[72]



[84] including noble gases and tritium gas

The calculation results show that the 2003 contributory dose from the airborne and liquid discharges to the group of population within 3 km distance from the plant site was 113 nSv for adults and 185 nSv for children. These doses were higher than the values calculated for the previous years due to the huge emissions from the incident to the environment.[85]

Restart of operation. Unit 2 was restarted in August 2004 and shut down on 8 December 2004 for refueling and major maintenance. In 2004 a new refueling procedure was specially developed to bypass the service pool and the unit was returned to service in March 2005. [86]

Clean-up operations. Due to their complexity clean-up operations started only about 3.5 years after the incident. On 29 January 2007 Paks nuclear power plant reported that the whole amount of damaged fuel was removed from the cleaning tank.[87]

The main lesson learned: Spent nuclear fuel represents a high risk potential not only when it is in the reactor core; providing sufficient cooling to spent fuel after unloading from the reactor core is a safety measure of highest priority, especially under conditions not envisaged in the original design; underestimation of these risks leads to incidents with very serious consequences. A number of findings and lessons learned are not new and most of them are typical for incidents in nuclear facilities.

9.2.4 Fires and Explosions

Fires and explosions are part of the most dangerous events in a nuclear power plant because they can affect several safety relevant systems at the same time. They can also lead to different level problems including physical destruction of parts, excessive heat, impenetrable smoke and missiles.

9.2.4.1 14 December 2001, Brunsbüttel (Germany)

During power operation in December 2001 in the German Brunsbüttel boiling water reactor several unusual signals lit up in the main control room. The signals were interpreted as a steam leakage in the area of the pressure vessel head spray line. The head spray line is used for cooling the inner surface of the reactor pressure vessel head and the flange area upon plant shutdown and only has operational functions.

The leakage and the increase of containment pressure were stopped by manually closing the drainage valve. The operator drew the conclusion that a small flange leakage had happened. The operator decided to bring the plant back to full power the same day.

Following this initial event, additional investigations were performed because records of temperature measurements indicated an accumulation of fluid and gas in different parts of the spray system. Theoretical analyses in view of possible radiolysis reactions were initiated. To clarify the remaining questions an on-site inspection of the containment was arranged. The operator decided to shut down the plant in February 2002, two months after the initial event. During the inspection a high degree of damage to the spray system piping was discovered. Some parts of the 5.6 mm diameter pipes were ruptured. An approximately 2.7 m long piping section had burst and was completely destroyed. Some sections of the piping were missing.

[85] See Radiation protection status in 2003, http://www.npp.hu/kornyezet/radprot_a_2003.htm
[86] See Nucleonics Week 3 February 2005
[87] See Information Report, Institute of Isotopes, Chemical Research Centre, Hungarian Academy of Sciences

A retrospective review revealed that the records of the temperature measurement had been conspicuous since restart of the plant in 2001. Indications of an excessive accumulation of hydrogen gas were identified. It was determined that a hydrogen explosion had taken place.

Prior to this event the possibility of severe explosions caused by radiolysis gas during normal operation was nearly excluded, although the principle of radiolysis gas reactions had been explored. Protective measures for this type of event were not developed the same way as for other phenomena.

The review of the event demonstrated the need for systematic investigation of potential radiolysis gas accumulation. It was realized that systems that were considered of primarily operational function without direct safety significance were not investigated with the same depth as identified primary safety systems. The Brunsbüttel event demonstrated that even on the primarily operational level there can be a considerable contribution to risk.

Experts recommended a graded proceeding to cope with the risk of radiolysis gas reactions. This covers complementary measures to avoid, to detect and to control the consequences of a radiolysis gas accumulation.

Fortunately the degree of damage in Brunsbüttel did not affect any safety devices or functions. This was not the consequence of an elaborated safety concept but due to fortunate circumstances. A higher degree of damage in case of an extended accumulation of hydrogen gas is easily imaginable.

The Brunsbüttel event is an example of a significant weakness in the safety concept. The design did not meet all probable event sequences. Well-known phenomena holding a high risk potential were insufficiently taken into account. This might be also a hint to potential vacancies and risks that are hidden in the nuclear power plant design and that have gone undetected or remained unexpected so far.

9.2.5 Station Blackout

A nuclear power plant generates electricity. But in order to do so safely, the permanent supply of electricity to the power plant is indispensable. Most of the safety devices like pumps, motors, lights, control-command functions etc. need power to operate. A station blackout, the total cut-off of all power supply is considered a high-risk operating condition for each nuclear facility. Therefore every nuclear power plant has several external and internal power sources.

9.2.5.1 18 March 2001 Maanshan (Taiwan)

In March 2001 the Taiwanese nuclear power plant in Maanshan, two 950 MW_e pressurized water reactors, was affected by a total loss of external and internal power supply. The plant is situated near the sea. Salt deposit on insulators due to foggy weather caused instability of the 345 kV high voltage grid.

On 17 March 2001 at 3h23 both units of the plant were shut down automatically and kept in hot standby. On 18 March 2001 at 0h41 the plant looses all four trains of 345 kV of offsite power. A breaker opens the connection to the 161 kV external supply. In the following minutes it is attempted to reconnect the 345 kV grid. Finally during a switch to the 345 kV grid a short circuit in a 4 kV power switch of one redundancy of the emergency power line occurred and caused a cable fire. The CO2 extinguishing system is actuated. The shift to the 161 kV grid was provided to run automatically but the power breaker was affected by the cable fire nearby, before the CO2 extinguishing system was actuated.

Two emergency diesels of unit 1 were unable to provide power to both essential buses. The plant enters alert condition. Heavy smoke is coming out of the control building below the control room. At 0h56 the firemen rush to the smoking part of the plant but lack adequate lighting and ventilation equipment. The operator manually connects the first emergency diesel generator to the essential bus but it provides power only for 40 seconds and then fails. At 1h06 the staff attempts to restore the second emergency diesel generator but the building is full of smoke and there is no sufficient lighting available. At 1h41 the operator calls the local fire department to request additional lighting and ventilation equipment to assist expelling the smoke.

At 2h19 the operator gives an emergency call to the Atomic Energy Council (AEC), which sets up an emergency control centre and calls 17 AEC staff from their homes. Finally at 2h54 the so-called swing emergency diesel generator, which can provide power to either one of the units, is successfully connected to unit 1. The plant is connected to an external power supply (161 kV) only at 22h12 and the diesel is disconnected.

It turned out that the operator should have declared the event much earlier, as soon as the station blackout situation occurred. The breaker fault at the 4 kV essential bus is considered as the main cause of the event. The breaker and the switchgear got totally destroyed by the fire (see figure 11).

The Atomic Energy Council stated later in an enquiry report: *"This incident was viewed as the most notable event over the 22-year history of nuclear electricity generation in Taiwan."*[88]

[88] Atomic Energy Council, *The Station Blackout Incident of the Maanshan NPP unit 1,* Taiwan, 18 April 2001

Figure 11: Breaker Damage at Maanshan During Station Blackout

Normal Breaker

Damaged Breaker

Normal breaker arrangement at a switchgear

Damaged breaker arrangement at a switchgear

9.2.5.2 25 July 2006, Forsmark, Sweden

In 2006 a short circuit in an outdoor switching station of the grid nearby the Swedish Forsmark nuclear power plant caused the emergency shutdown (scram) of unit 1 and, in a complex scenario, led to a number of subsequent failures at the plant. Due to a design error, the disconnection of the plant from the grid and the switch to house load operation – the power plant uses its own power to operate essential auxiliaries – did not function as planned.

In the following course of events an inappropriate converter adjustment led to the failure of the attempt to connect safety related equipment to the emergency power supply. The start up of two of the four emergency diesel generators was aborted, which lead to a partial blackout even in the main control room. The failures in the electrical power supply system were followed by various malfunctions. Due to the lacking indication of important parameters for a period of time the exact state of the plant and the consequences of potential actions to perform were unclear. The shift team decided nevertheless to try to reconnect the plant to the grid, which was performed successfully.

The Forsmark incident revealed a weakness in the plant's safety concept. As a root cause for the unexpected extent of the event, the insufficient separation of safety levels has been identified. A disturbance originating in the external grid was not blocked at the grid connection level. The disturbance could pass several safety barriers and affected safety related equipment of different redundancies. The equipment was not designed for such electrical transients. The potential of external disturbances as a root cause for serious events was obviously underestimated in the design.

An elementary conclusion of the incident was, that an important principle of the safety concept, that no single individual malfunction can affect several different safety systems, was not maintained.

The Forsmark incident provoked subsequent investigations by Swedish and foreign authorities (e.g. Germany, Switzerland) to verify the transferability of the event sequence. The most important contributing factors were identified as follows:

- The electrical selectivity of protective adjustments was insufficient.
- The start up of the emergency power diesel generators was not independent of the orderly functioning of the AC/DC-converter.
- The communication between the operator of the plant and the operator of the grid was poor. Sufficient measures to avoid unacceptable consequences caused by potential disturbances coming up from work in the external grid were not agreed.
- Weakness in the shift management of the plant facilitated that a failure remained undetected and led to delayed disconnection from the grid.

These findings were seen as indications of weakness of the plant's safety management in general. Accordingly subsequent to the review of the technical dimension of the incident further safety related issues were brought into discussion.

A possible contributing factor was a weakness in the interpretation of the safety significance of staff activities during normal operation. The protective means might have been adjusted in a way that turned out inadequate for their required safety performance. The AC/DC-converter was adjusted with priority to the optimization of battery loading but contrary to a required safety function. The adverse adjustment caused that in consequence of the electrical transient the current flow was disrupted in both flow directions. The separation from the AC-Voltage grid was a necessary protective measure to block the electrical transient. But inappropriately the current flow of DC-voltage from the batteries supplying safety related equipment was disrupted simultaneously. This led to the loss of emergency diesel generators.

In retrospect the management of Forsmark concluded that in view of the progress of the company's safety culture a gradual deterioration over the last few years had taken place. A systematic investigation aimed on internal structures and conditions was started.

Overall it seems only due to fortunate circumstances, that the adverse combination of technical and organizational failures could be brought under control.

9.2.6 Generic Issues – Reactor Sump Plugging

In many occasions a technical issue is discovered through an incident in an individual nuclear power plant that turns out to be valid for several plants, sometimes for dozens or even more units. Occasionally these discoveries are made by pure coincidence, in particular during maintenance work.

One of the issues that turned out to be generic on an international scale is the problem of the potential plugging of the filter system of the reactor sump. In the case of a loss of coolant accident, the leaked water is caught under the reactor vessel in order to be pumped back into the system. The loss of the recirculation function would be a severe handicap in many accident scenarios. The phenomenon was first discovered in a Swedish nuclear power plant and later in many other reactors around the world.

9.2.6.1 28 July 1992, Barseback-2 (Sweden)

In July 1992 a leaking pilot valve in the Swedish boiling water reactor in Barseback caused a safety valve for the reactor vessel to open. Safety functions like reactor scram, high-pressure safety injection, core spray and containment spray systems were initiated automatically in response to the event. The steam jet from the open safety valve was impinging on thermally insulated equipment. The amount of dislodged insulating material exceeded the estimated amount significantly. Insulating material was washed into the suppression pool and affected the emergency core cooling system. The strainers on the suction side of the sump pumps became partially plugged with mineral wool. This caused a decreasing pressure across the strainers and indications of cavitation in one pump. Increasing consequences were avoided because a back flushing of the strainers was carried out successfully.

The emergency core cooling system is essential for the heat removal. In case of a leak the reactor coolant is collected and has to be circulated through the sump of the building. An improper pressure drop in the suction line of a pump as indicated in Barseback may cause cavitation followed by the damage of the pump. If the back flushing is unsuccessful the heat removal might become disabled and the risk of overheating of the core is increased.

A small pipe leak or an inappropriately opened valve is supposed to be considered as design basis accident. The Barseback incident illustrated that design conditions to control this type of accident were incorrectly assessed and the issue turned out to be a generic fault.

The simplified model was based on a leak occurring in a naked steal pipe as imaged in technical drawings. The actual situation on-site was disregarded. It was characterized among other things by insulation material surrounding the leaking pipe and exposed to the leak stream. The dimension and the impact of material dislodging were underestimated. The following course of adverse effects seems to be predictable but insufficiently considered. The phenomena that became obvious in Barseback are transferable to other reactors in Sweden and elsewhere.

In 1993, at Perry Unit 1 (USA), the emergency core cooling system (ECCS) strainers twice became plugged with debris. On 16 January 1993, ECCS strainers were plugged with suppression pool particulate matter, and on 14 April 1993, an ECCS strainer was plugged with glass fiber from ventilation filters that had fallen into the suppression pool. On both occasions, the affected ECCS strainers were deformed by excessive differential pressure created by the debris plugging.

On 11 September 1995, at Limerick Unit 1 (USA), following a manual scram caused by a stuck-open safety pressure relief valve, operators observed fluctuating flow and pump motor current on one of the cooling systems. The operator later attributed these indications to a thin mat of fiber and sludge that had accumulated on the suction strainer.[89]

By the end of 2003, it had become clear that all 34 French 900 MW reactors were facing the same problem.

This is an example of generic weakness of safety analysis, which may concern a large number of facilities. The phenomena of sump clogging have been investigated in many countries operating nuclear power plants.

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[89] NRC, *Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology",* December 2004

More than ten years after the Barseback incident the sump clogging issue became urgent again in the German Biblis nuclear power plant. Randomly it was discovered that the suction strainers of the sump pumps in the emergency core cooling system were not dimensioned in accordance with the approved specification. Significant changes were implemented during the construction phase. The documentation was never updated. For years, the surface and the configuration of the sump strainers did not reach the specified state. The basic design of the sump strainers and the compliance with the specification were not verified since the commissioning of the plant. Even the Barseback incident did not trigger a general and systematic review. During the whole period of operation a leak in the primary cooling circuit might have caused an extent of sump clogging that would have led to a loss of the core cooling system, essential to control this type of accident.

Subsequently experts started discussing variables influencing sump clogging: e.g. specific behavior of different insulation materials, retention at structures, transport effects, debris on the sump strainers, deposition of insulation material inside the core and overall the evaluation of influences on the function of pumps and the efficiency of core cooling. The complex interrelations are not yet entirely clarified. Uncertainties in view of the capability of nuclear power plants to control sump clogging in case loss of coolant accidents remain and indicate a latent weakness in the design of vital safety systems.

9.2.7 Natural Events

There are various types of natural events that can impact on the safe operation of a nuclear facility, in particular earthquakes, wild fires, storms and lightning. Floods can originate in heavy rainfalls, dam breaks, storms and tsunami type phenomena or a combination of these phenomena. On the other side, droughts can lead to low water levels in rivers needed for cooling and extended heat periods can overheat containments beyond design specifications. The changing weather patterns that accompany global climate change are now established to trigger an increasing frequency of extreme weather events that might more frequently exceed design basis specifications of nuclear facilities around the world.

9.2.7.1 27 December 1999, Blayais-2 (France)

The unusual storms at the end of 1999 led to the flooding of the Blayais nuclear power plant site. Certain key safety equipments of the plant were flooded, for example the safety injection pumps and the containment spray system of units 1 and 2. The electrical system was also affected. For the first time, the national level of the internal emergency plan (PUI) was triggered. The IAEA's Operational Safety Review Team (OSART) report on Blayais notes "The plant's communication department has had a hard task after the 1999's flood to recover the lost credibility, but now the situation is considered to be good again."[90]

At the end of 1999 heavy weather caused high degree of damage to the French electricity grid. Many high-voltage towers broke down and the Blayais site suffered the loss of the grid. Units 1, 2 and 4 were operating. Unit 3 was down for refueling. First, at 18h00, the auxiliary 225 kV power supply for the four reactors at the site is lost after a tree fell on the lines. A second line is automatically linked up and the three reactors keep operating but an hour and a half later the second line is also lost. At the same time flooding of roads makes access to the site very dangerous. On the site itself, flying objects and debris render any intervention dangerous. A cleaning staff person is caught by the storm and breaks a leg. The operator and security relay is delayed. At 20h50 the units 2 and 4 scram (shut down automatically) in order to auto-protect

[90] IAEA, *Report of the Operational Safety Review Team (OSART) Mission to the Blayais Nuclear Power Plant*, 2 - 18 May 2005, IAEA-NSNI/OSART/05/131

against excessive tension on the 400 kV power evacuation line that they supply. The switch to house load operation – the power plant uses its own power to operate essential auxiliaries – as planned after the disconnection from the grid, failed. Following the loss of the auxiliary lines, the emergency diesel generators start up in order to provide on-site power. Forty minutes later unit 4 is brought back on the auxiliary 225 kV supply and the diesels are stopped, but the grid connection fails in the case of unit 2 that remains on diesel supply until 23h20.

Water is pushed over the protective dyke. The water invades the site through underground service tunnels. At around 22h00 water penetrates the fuel building of units 1 and 2. Around midnight at unit 2 the flooding of the safety injection and containment spray system pumps – essential in the case of a loss of coolant accident to supply coolant and decrease pressure and radioactivity levels in the reactor building – is identified as well as the non-availability of a number of associated valves. At 00h30 unit 1 scrams probably due to debris that was sucked into a service water system. No unit on site produces power at this point. External staff on standby is called into the plant one by one. At 2h00 the flooding of the safety injection and containment spray system pumps of unit 2 is identified. At 2h50 the internal emergency plan (PUI level 1, local) is activated and the relay staff takes up its shift. Shortly after EDF's national crisis teams are activated. At 7h00, at unit 1, the flooding of two of the four pumps of the auxiliary cooling system is identified. At 9h00 the national nuclear safety authority requests the activation of the national level of the internal emergency plan (PUI level 2) as precautionary measure in the case of the loss of the two remaining pumps of the auxiliary system (which did not occur). PUI level 2 implies the automatic information of 150 EDF staff, the Nuclear Safety Authorities, the Institute for Radiation Protection and Nuclear Safety (IRSN)[91] and the Directorate of Defense and Civil Security (DDSC).

Later it was revealed that rooms containing electrical feeders led to the loss of certain electrical switchboards.

Numerous pumps were operated for almost 44 hours to evacuate over 100,000 m3 of water that had flooded the various buildings.

Basic flood protection criteria were violated at Blayais. Safety related equipment was placed at a level at least as low as the maximum water level. The invading of external water was not blocked due to unsuitable protection measures at the lower platforms, e.g. fire doors. The water could penetrate and reach reactor safety equipment. The design assumptions concerning flooding events were insufficient. The adverse coincidence of strong winds and rising tide as happened was disregarded. Furthermore the planning to raise of the protective dyke at the site as recommended in a safety analysis report had been delayed.

Up to the occurrence of this event the design was considered safe. The consequences of partial flooding of the site and appropriate counter-measures were not analyzed. More serious consequences were been avoided only because of a number of lucky circumstances: The emergency power supply by diesel generators functioned without disturbance for several hours until the site was successfully reconnected to the grid. And an accident, which would have led to the need to operate the safety systems lost by flooding, did not take place during this period.

The event had a significant aftermath. The safety authorities carried out 20 inspections in four months at the site. Unit 2 was down for over four months. Numerous upgrading actions had to be implemented. Investigations about the flooding risk were requested by the nuclear safety authority not only at all the other 18 nuclear power plant sites, but also at five other major nuclear sites including Pierrelatte and Marcoule.

[91] At the time of the event, there were still two separate entities, the Institute of Nuclear Protection and Safety. (IPSN) and the Office for the Protection against Ionizing Radiation (OPRI) that have merged after to form the IRSN.

9.2.8 Security Events and Malicious Acts

The possibilities for malicious acts in a nuclear facility are only limited by imagination. Reality has already demonstrated an impressive number of criminal activities in and around nuclear plants. Systematic falsification of technical documentation and manipulation of equipment test conditions, theft of equipment, radioactive and nuclear materials, threats and armed attacks. It is obvious that the potential threat dimension has significantly changed after the 11 September 2001 events. Especially the recent systematic deployment of suicide bombers of international sub-national organizations makes the protection of a nuclear facility and its radioactive inventory highly vulnerable.

9.2.8.1 7 February 1993, Three Mile Island (USA)

On Sunday, 7 February 1993, at approximately 06:53, an unauthorized vehicle traveling at around 60 km/hr entered the owner-controlled area (OCA) of the Three Mile Island nuclear power plant through the outbound lane of a two-lane access road. Although a guard booth was present at the entrance to the OCA, no physical barriers were present to delay access. The vehicle continued onward to the protected area (PA) of the nuclear plant and collided with one of the entry gates, which failed, allowing the vehicle to pass through. It then crashed through a corrugated metal door and entered the turbine building of the Unit 1 reactor, which was operating at full power. The vehicle stopped 19.2 meters inside the turbine building, striking and damaging a resin liner and the insulation on an auxiliary steam line. When the vehicle was approached by security officers at 07:02, the driver was nowhere to be found.

After some initial confusion as to the exact nature of the event (one technician reported that the turbine building door had been blown down by "wind"), the shift supervisor declared a Site Area Emergency at 07:05, the second highest emergency classification level. This was the second time this had occurred at the TMI plant (the first being the TMI Unit 2 meltdown in 1979).

The response to the event by the TMI operator, GPU Nuclear Corporation, was marred by glitches that revealed wider problems with the security and emergency operations at TMI. In particular, a sequence of bad decisions resulted in a delay of more than forty-five minutes in notifying the utility's off-site emergency personnel of the incident, although the requirement is that all off-site notifications be completed within fifteen minutes of an emergency declaration. The plant had a phone-based pager system, located outside of the control room in the shift supervisor's office that could automatically notify State and local officials and the utility's Initial Response Emergency Organization (off-site emergency personnel) in the event of an emergency. However, the shift supervisor and other responsible personnel were unable to access the pager system. This is because the shift supervisor on duty in the control room had ordered the control room fire doors locked as a security precaution upon learning of the intrusion.

As a result, the shift supervisor ordered one of the control room personnel to manually make all notifications from a telephone in the control room. However, the telephone numbers for the offsite emergency personnel were not available in the control room, but were in the shift supervisor's office. So the control room doors had to be unlocked so that the numbers could be retrieved. But instead of using the pager system in the shift supervisor's office, the list of phone numbers was brought back into the control room, resulting in further delays. If the intrusion had been a radiological sabotage attack on the plant, precious minutes would have been lost in executing the emergency response plan, putting plant employees and the public at risk.

These problems should have come as no surprise to TMI management. In fact, numerous deficiencies in off-site notification procedures at TMI had been observed during emergency planning drills only months before the incident. The TMI operator had apparently not corrected those deficiencies.

The intruder was not apprehended until 10:57, four hours after he entered the site, when he was discovered hiding in a small space under the condenser pit in the turbine building. The condenser pit was first searched hours earlier, but the search was halted because lighting was insufficient. (The second search team came with a brighter flashlight.) The unarmed intruder was a mentally ill man who had recently been discharged from a psychiatric hospital and who apparently said before the event that he was "going to do something to become famous."

The NRC sent an Incident Investigation Team to investigate the event and concluded that "the event resulted in no actual adverse reactor safety consequences and was of minimal safety significance." But if the intruder had had malicious intent, the outcome could have been significantly worse. While detonation of a car bomb in the turbine building would not necessarily have led to core damage by itself, if coordinated with an attack on another system like the transmission lines leading into the plant, the attack could have been devastating. It is also possible at some nuclear plants that destruction of a single "target" could result in significant core damage. Therefore, at such plants, the potential exists for a single knowledgeable adversary equipped with explosives to cause a core melt unless access to the vulnerable target is denied to the intruder.

In any case, the event did reveal significant deficiencies in the utility's security and emergency response programs, as well as in the NRC's regulations. At the time, the NRC did not require that nuclear plants be protected against forced vehicle intrusions. Partly as a result of this incident, the NRC amended its regulations to require the deployment of vehicle barrier systems. The goal of these requirements was to provide protection against a vehicle bomb as well as against forced vehicle intrusions. However, the current requirements do not provide protection against multiple vehicle bombs (in which the first bomb is used to breach a vehicle barrier, enabling a second vehicle to enter the protected area), even though such tactics are being increasingly used by paramilitary groups around the world.[92]

9.2.8.2 July 2000, Farley (USA)

Between 1991 and 2001, the NRC conducted a program known as the "Operational Safeguards Response Evaluation," or OSRE. This program consisted of performance exercises designed to evaluate whether nuclear power plant security forces could effectively defend against an adversary team with a defined set of characteristics: number, weaponry, equipment and tactics. (This set of characteristics is known as the "design basis threat," or DBT. Although the details of the DBT are classified as "safeguards information" by the NRC, it is well-known that no more than three external attackers were used in these exercises.) In these war-game-type exercises, a mock adversary force would carry out a series of four attack scenarios, with the objective of simulating the destruction of enough plant equipment to cause a core meltdown (known as a target set). The NRC would then evaluate the performance of the nuclear plant security force in preventing the adversary team from achieving its goal.

During the July 2000 OSRE at the Farley Nuclear Plant in Columbia, Alabama, the security force at Farley could not prevent the mock adversary team from simulating the

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[92] Iraqi insurgents, for example, use the two truck tactics. Two suicide truck bombs were used against the Abi Tamaam Police Station in eastern Mosul on 19 October 2006. "The first truck bomb exploded near the station's entry control point, blowing down protective walls and creating a sizeable crater in the road. The second truck, unable to penetrate the police station's perimeter due to the crater and debris left over from the first truck bomb, detonated in the street." (see www.defenselink.mil/news/NewsArticle.aspx?ID=1766) While the action failed, it is obvious that the objective was that the first truck bomb clears the way for the second one.

destruction of entire target sets in two out of four exercises (and therefore simulating a meltdown); and simulating the destruction of "significant plant equipment" in a third exercise.

Part of the reason for this poor performance was the "failure to adequately perform multiple portions of the response strategy." According to an NRC inspection report of the exercise, adversaries were not detected in time to allow security officers to defend pieces of vital safety equipment; responders could not leave defensive positions without making themselves vulnerable to the adversary; and some security officers were outside of the protected area and took too long to respond after the attack.

The OSRE failures at Farley were so severe that the NRC initially proposed to issue a "yellow" finding, the second-worst category, indicating the poor results had "substantial safety significance" and resulted from a "broad programmatic problem." However, the plant operator, the Southern Nuclear Operating Company, contested the finding, arguing that the test was unfair because the mock adversary team used certain equipment and tactics that were "beyond the designed or required capability" of its protective strategy. It also argued that the exercises did not accurately simulate real conditions and therefore should not be considered representative of real attacks. Finally, it argued that even if the attacks had been real, plant operators would have been able to arrest any core damage before any radioactivity was released.

At the time, the OSRE program was subject to an aggressive challenge by the nuclear industry, which was being repeatedly embarrassed by the widespread security failures that the exercises revealed, and being required to make expensive upgrades to their security programs to correct them. In particular, the industry argued that the OSREs were unfair because the adversary team did not utilize the same capabilities at each site.

The NRC ultimately relented under pressure and concluded that only one of the two exercises in which a target set was destroyed represented a conclusive failure of the protective strategy. It then reduced the significance of the OSRE failure to "white," meaning that it did not represent a "broad, programmatic problem." But the reason for this was not because the exercise found the Farley response strategy was effective, but because the adversaries used tactics, which the Farley security force were not expecting. Of course, if this exercise had been a real attack, it isn't likely that the attackers would voluntarily refrain from using certain weapons or tactics because it would be unfair to the Farley security force.

9.2.8.3 29 August 2002, 17 TEPCO Reactors (Japan)

The Tokyo Electric Power Company (TEPCO) is the largest electricity utility in Japan and one of the largest in the world. It operates 17 boiling water reactors – as many units as operate in the whole of Germany – with a total installed capacity of 17,300 MW. TEPCO was also one of the most respected large companies in Japan.

On 29 August 2002 the Japanese Nuclear Industrial Safety Agency (NISA), shocked the nation with the public revelation of a massive data falsification scandal at TEPCO. At that point 29 cases of "malpractice" had been identified, including the falsification of the operator's self-imposed inspection records at its nuclear power plants over many years (see Annex 4 for a chronology of events). In the follow-up, all of the 17 TEPCO units had to be shut down for inspection and repair. The case is unique in the world, not only because of the extent of malpractice but also in its effect on the national power system of a country (see figure 12). It was also reported later that these practices had gone on for as long as 25 years and the total number of events is put at nearly 200.[93]

The 29 original cases of malpractice identified include the following:

• Five cases involved the entry of false dates as the dates of discovery of specific problems. When the safety authorities requested countermeasures and instructed the examination of the parts concerned, the operator did not report to the agency the problem, which it had already identified.
• Five cases involved inadequate record keeping and falsification. In one case, the licensee failed to keep a record of aging degradation incidents, such as cracks or indications of cracks found in the core shroud by an outside contractor. In another case, the licensee did not conduct follow-up inspections of the results of analysis that an outside contractor had carried out regarding causes of detected flaws. In other cases, although faults such as cracks were identified or repaired, the operator "ordered an outside contractor to delete the record of initiation or repair of the faults in order to cover up the problem, and the licensee falsified the date of discovery of the incident".[94]

The problem was not limited to TEPCO nuclear power plants. On 20 September 2002 additional cases of malpractice were revealed. Two other nuclear operators, Chubu Electric Power Company and Tohoku Electric Power Company, had failed to report to the safety authority that cracks had been identified in the recirculation system pipes of their reactors – a crucial part of the emergency core cooling system in case of a loss of coolant accident (see also 9.2.6.1).

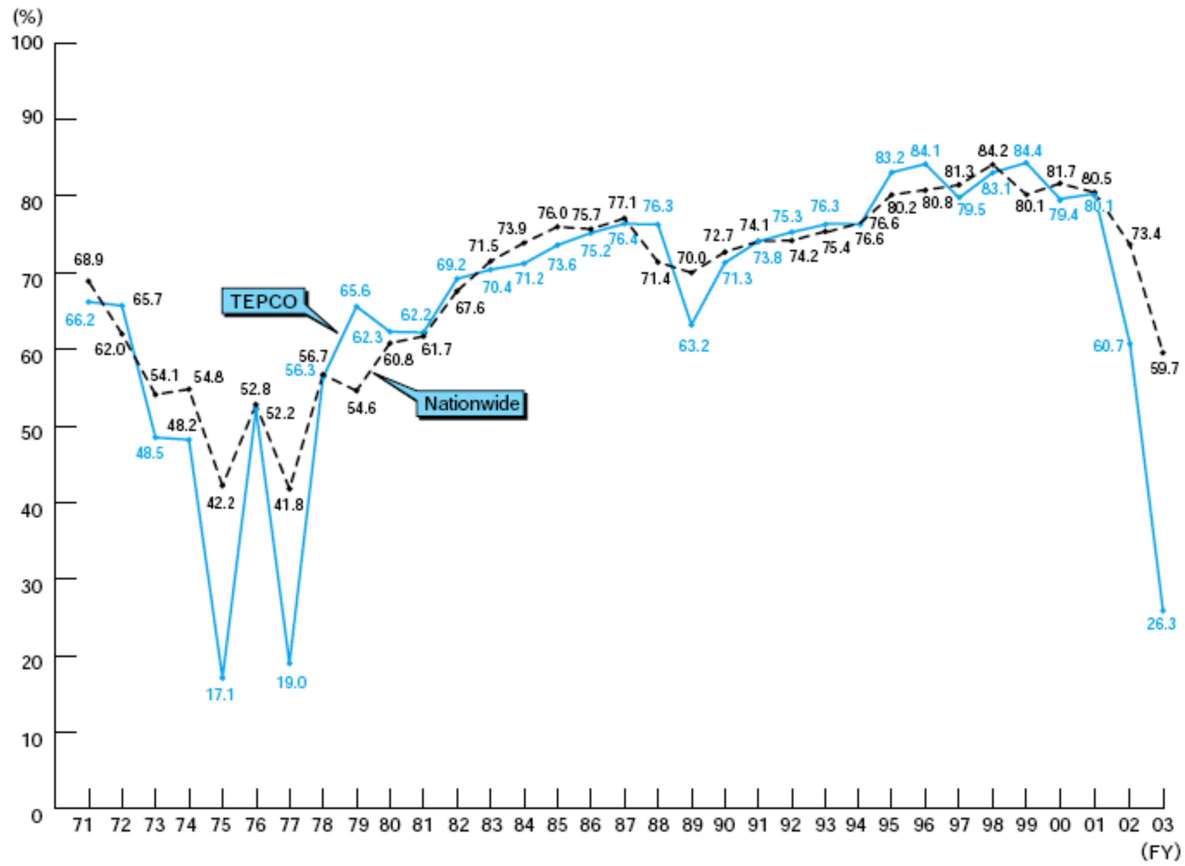
In its interim report, dated 1 October 2002, the official nuclear safety agency NISA concluded:

> *"As nuclear safety regulatory authorities, NISA regards the recent cases as a very serious problem, not only with safety arrangements at licensees who have performed inappropriate acts but also with Japan's nuclear safety regulatory administration itself. The cover-up cases have made us painfully aware that we must frankly reflect on what we have done, take the plunge and mend our ways. As nuclear safety regulatory authorities, we must seriously recognize that the relevant cases caused tremendous anxiety among local residents living near nuclear facilities, and destroyed public trust in nuclear safety regulations."*[95]

On 12 December 2002 the *Association to Accuse TEPCO of Its Nuclear-Damage Cover-Ups* filed a complaint to the district public prosecutor's offices in Niigata, Fukushima and Tokyo to pursue TEPCO for its responsibility in a series of falsification cases. The complainant consists of 982 citizens of Niigata Prefecture, 509 of Fukushima Prefecture, and 1,689 from all over the country, amounting to a total of 3,180 people.[96]

Figure 12: Load Factor Crash in Japan as Consequence of Data Falsification Scandal

[93] "TEPCO said that it discovered falsifications of technical data on nearly 200 occasions from 1977 to 2002 at three nuclear power plants, and reported them to the Ministry of Economy, Trade and Industry as requested." see
[94] NISA, *Interim Report on the Falsified Self-imposed Inspection Records at Nuclear Power Stations*, 1 October 2002
[95] ibidem
[96] http://cnic.jp/english/newsletter/nit93/nit93articles/nw93.html



Sour
ce: TEPCO

Other cases of data falsification have been reported in Japan. In one of the latest ones, revealed on 15 November 2006, a computer program used by a Chugoku Electric thermal power plant had been altered to reduce the temperature difference shown between intake and outflow water. While there is no immediate safety significance to the event – intake outflow difference in temperature is limited for environmental protection reasons – the incident gives an idea of the criminal energy that is present amongst some of the plant operators and management. Subsequent checks of all nuclear and thermal power plants revealed similar alterations at seven nuclear reactors at various plants of different operators.[97] "At some the outflow temperature was lowered, while at others the intake temperature was raised, indicating that the data was falsified independently at each plant and that data falsification was routine practice."[98]

On 5 March 2007, *World Nuclear News* reported:

"Tokyo Electric Power Company admitted six further occasions when workers failed to record safety issues at nuclear plants to the Nuclear Industrial Safety Agency on 1 March, in addition to three already known. One of the new events concerns the breakdown during trial of a diesel back-up generator at Kashiwazaki-Kariwa 3 that went unrecorded in 1995. An emergency shutdown of one of the Kashiwazaki-Kariwa units in 1992 was also unrecorded. Another concerned the exceeding of thermal output by 0.1% at Fukushima 1 on five occasions between 1991 and 1998 for which workers entered figures below actual

[97] Kashiwazaki-Kariwa (Tokyo Electric), Fukushima I (Tokyo Electric), Onagawa (Tohoku Electric), Tsuruga (Japan Atomic Power Company), Ohi (Kansai Electric)
[98] http://cnic.jp/english/newsletter/nit116/nit116articles/nw116.html#datafals

output. "We apologize from the bottom of our heart for causing anxiety to the public and local residents, " said Tepco vice President Katsutoshi Chikudate."

The scandal of the data falsification, cover-up and misleading of safety authorities does not seem to end. On 3 April 2007, the industry online news magazine Nuclear Engineering International reported under the headline "Japanese criticality revealed":

"Hokuriku Electric has admitted to a criticality incident almost eight years ago at its Shika 1 BWR.

The 18 June 1999 event was not reported until recently after regulators instructed utilities to examine their records and declare any previously undisclosed incidents. According to the utility, during the 15-minute localised criticality, temperatures increased slightly in the 540 MWe unit. However, no other consequences arose from the event.

Following the announcement by Hokuriku, the director general of Japan's Nuclear and Industrial Safety Agency (NISA) handed the president of Hokuriku a document ordering the company to submit a report as stipulated by law. NISA ordered the immediate halt of operations at Shika 1 so that a full safety inspection could be carried out. NISA also warned other power suppliers to take actions to prevent similar accidents.

According to Hokuriku, the incident occurred in the fifth periodic inspection of the BWR after three of the 89 control rods had moved out of position during preparations for a routine test. The reactor reached a state of criticality, setting off the automatic 'stop' signal. However, the control rods were not automatically inserted at that point as the isolation valves were closed for the test. Some 15 minutes later the operators reopened the valves, and the control rods were reinserted.

The Hokuriku incident has been followed by two similar, though unconfirmed, incidents in which two of 89 control rods at Tohoku Electric's Onagawa 1 reactor failed in 1988, and three of 185 control rods at Chubu Electric's Hamaoka 3 were found to be out of position during a 1991 inspection.

Both events were apparently caused by malfunctioning valves, which affected water pressure in the control rod drive systems."

10. Summary and Conclusions

Residual Risk

An Account of Events in Nuclear Power Plants Since the Chernobyl Accident in 1986

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Fifty years ago, on 25 March 1957, the EURATOM Treaty was signed. Article 1 stipulates that *"it shall be the task of the Community to contribute to the raising of the standard of living in the Member States and to the development of relations with the other countries by creating the conditions necessary for the speedy establishment and growth of nuclear industries".* Half a year later, on 10 October 1957, the fire at a Windscale reactor in the United Kingdom released massive amounts of radioactivity with, as a direct consequence and for the first time in Europe, very large quantities of contaminated milk and vegetables having to be destroyed.

Nevertheless, the Windscale accident had surprisingly little effect on public opinion Europe wide. In the UK the then fledgling civil nuclear industry pressed on with its designs for the first nuclear power stations, Magnox, which like Windscale had no secondary containment whatsoever and the UK government maintained its military imperative of plutonium production, seemingly ignoring the risk of a second radioactive release with its continued operation of the second identical Windscale reactor.

By the mid 1960s nuclear power was firmly established in Europe and its expansion continued apace. However, in March 1979 with a total worldwide experience of more than 1,000 years reactor operation, the pressurized water reactor (PWR) at Three Mile Island (TMI) in the United States sustained a severe fuel core melt and the potential for a very significant release of radioactivity to the environment. Such was the impact of TMI and although the nuclear industry implemented substantial upgrading programs in reactors and reactor designs thereafter, no nuclear plant has been ordered in the United States since and over one hundred projects have been completely abandoned. In Europe the majority of nuclear power plants that had been ordered and/or were under construction at the time of TMI were continued with, in account of design modification delays and construction times, installed capacity continuing to rise until by the end of 1985 a total of 155 power reactors were installed and in operation in the European Union.

In fact by 1986 the European nuclear industry was generally quite buoyant because it had, after all, ridden out the TMI storm albeit having to implement some significant backfitted and expensive safety measures. But then Chernobyl occurred, the worst nuclear power plant accident to date, resulting in a massive and hitherto unimaginable radioactive release that spread contamination widely throughout Europe, with its food and agricultural bans preying on the collective conscious of the general public.

The inexplicable nature and very severity of Chernobyl necessitated significant re-examination of nuclear safety, public explanations were demanded from the industry and its regulators; it practically stopped construction of new nuclear power plants. In the 27 current Member States of the European Union a peak of 177 power reactors was reached within two years of the Chernobyl accident. Thereafter and although a number of pre-Chernobyl ordered reactors had been completed and commissioned, plant closures outweighed new commissionings and resulted in a steady decline of operational reactors in Europe down to the level of 145 units of today.

The lessons learned from TMI had not been sufficient to prevent the Chernobyl accident.

At first the worldwide nuclear industry response to the Chernobyl disaster was defensive: it arose because of defective Soviet technology, demoralized operatives, lack of secondary containment, and so on, so much so that Chernobyl was a peculiarly Soviet accident *'just waiting to happen'* and that *'it could never happen here'*. Away from public scrutiny, however, the nuclear regulatory authorities in the European Union and elsewhere have been implementing revised regulatory regimes. These have required the operators to incorporate numerous improvements in human factor and management procedural aspects of plant operation, enhanced training programs and, where practicable, backfitting modifications and revisions to existing plants.

Significantly, for new nuclear builds the regulatory philosophy has nudged the plant designers to increase the role of passive systems to hold or return the plant and its nuclear processes to a stable, safe state; the outcome of abnormal incidents is now more firmly related to the radiological consequence and individual risk of health detriment; incidents and projected radioactive releases have now to be quantified so that an effective off-site emergency response might be prepared in advance; and, perhaps, most of all, the nuclear industry had to be 'transparent' and demonstrate that for continuing operation of its nuclear plants the *'risks were acceptable and the consequences tolerable'*.

Today, 21 years since Chernobyl with 8,000 reactor-years experience accumulated worldwide this post-Chernobyl period has passed without major accident, large-scale contamination and severe radiological consequences – is this an achievement or just simply luck?

To answer this question we have scrutinized the safety records of nuclear power plants in selected countries since Chernobyl, noting that large numbers of abnormal events continue to occur. We endeavor to analyze in depth a selection of these events although there are significant obstacles to a systematic and comparative analysis, including:

- Comparing severe events affecting different types of nuclear power plants worldwide is difficult because, first, there are many terms and definitions describing what could be called a nuclear incident and, second, there is no objective, internationally agreed and recognized definition for particularly severe events, both internal and external, that bear the potential for severe radiological consequences.
- Systems evaluating such nuclear events and their potential are not harmonized and are varying markedly from country to country. The quantification or indices determined do not provide a comparable indication of either safety levels or safety achievement.
- Even in case of the International Atomic Energy Agency's INES (IAEA's International Nuclear Event Scale) the values attributed to the events are those reported by the operators of the affected plants or of the national regulatory authorities. There is no system of independent evaluation to make comparisons meaningful and, moreover, in some states the nuclear safety regulator may not be entirely free of political persuasion.

- The INES definitions also exclude a large number of events from technically appropriate rating only because they do not involve any immediate radiological effect. On the whole, there seems to be a tendency towards underestimating the importance of events. Although the IAEA developed the INES from the basis of the former French national event scale, it is the national nuclear authorities of the IAEA member states that determine the final index of the event potential, particularly in that the IAEA gives no direction on how 'cliff edge' situations are to be evaluated in the INES.
- No reporting system has been devised that can unambiguously classify the events and accidents rooted in a huge variety of possible causes. For example was the Davis-Besse reactor pressure vessel head hole (see 9.2.1.2 for details) a (i) materials defect, (ii) management failure which arose from an inadequate, plant-wide safety culture, (iii) a cascade of human errors linking inspection and surveillance, and/or a (iv) quality assurance program failure, or yet some other cause?
- In general a caution approach is adopted when the *possible* progression of a pulled-up (arrested) event is postulated. Analysis is tending to be based on those remaining downstream safety systems and countermeasures coming into play promptly and effectively, qui in contrast to the fact that a number of upstream safety systems had already failed, which is portraying an optimistic view of what could have resulted into a much more serious event.
- Whilst reactor shutdowns are generally publicly known, the events that cause them are not always publicized. The international nuclear event database maintained by the IAEA is confidential to its members[99], and some countries tend to keep details of nuclear event reporting as privileged information that is not subject to public disclosure. Furthermore, post 9/11 much more information relating to plant performance under abnormal operation situations is being held back.

The IAEA does not impose nor require that much discipline for signatory countries when evaluating and reporting incidents. In other words, since there are no clearly established internationally agreed benchmarks to describe, categorize and risk assess events from one country to another, it is not clear how useful statistics could be arrived at. Thus, any one country that reports a large number of events could be revealing a severe safety problem in that country or, on the other hand, it could also be the honest characterization of a specific reporting system with unusual openness in communicating events.

This opportunity for anomaly is revealed by comparing just three countries, France, Germany and the United States.

In recent years the French nuclear power plant operator, EDF, has reported annually between 600 and 800 *'significant incidents'* (increasing tendency) to the nuclear safety authorities. Of over 10,000 events that were reported between 1986 and 2006, most were considered below the INES scale or Level 0 while 1,615 incidents were rated INES Level 1 and 59 Level 2. One event has been given a Level 3 rating[100]. In comparison, since the implementation of INES in 1991 Germany reported over 2,200 events as Level 0 or below, while 72 events were rated Level 1 or higher. On its part, the US Nuclear Regulatory Commission, over the same time period, has only

[99] The International Atomic Energy Agency did not respond to repeated information requests by the coordinator of the present study.
[100] Gravelines-3 incident, dated 16 August 1989

reported 22 events to the IAEA and rated them on the INES scale, of which 6 below scale, 7 Level 0, 3 Level 1, 5 Level 2 and 1 Level 3.

This apparent disharmony arises because there are simply no common criteria established to compare frequency and severity of nuclear events from country to country. In this respect, any reliance upon the present collage of INES rated events statistics to establish an international safety evaluation would be grossly misleading.

The **first conclusion** of this study is that many nuclear safety related events occur year after year, all over the world, in all types of nuclear plants and in all reactor designs and that there are very serious events that go either entirely unnoticed by the broader public or remain significantly under-evaluated when it comes to their potential risk (see the 16 selected events hereafter).

A recent joint IAEA/NEA (Nuclear Energy Agency of the OECD) Report on "Nuclear Power Plant Operating Experiences" covering the years 2002-2005 concluded:

> *"Almost all of the [200] events reported during that period have already occurred earlier in one form or another. It shows that despite the existing exchange mechanisms in place at both national and international levels, corrective measures, which are generally well-known, may not reach all end-users, or are not always rigorously or timely applied."*

The widespread belief that nuclear safety will be actually enhanced because of a lessons-learned process turns out ill-conceived. It is an open question whether the actual discussions within the nuclear expert community can lead to an improvement of nuclear safety in the reality of nuclear power plant operation.

Abnormal events are triggered by a variety of reasons: some are directly a result of design errors, sometimes fundamental or sometimes apparently trivial; other events can be traced back to latent construction, manufacturing and materials faults and/or deficiencies that have remained hidden in the plant; and there are unforeseen and unprepared for external events that unexpectedly challenge the plants and their safety systems; and finally there is the human dimension, including simple slip ups, omissions and misunderstandings, or more complex and deeply rooted institutional errors and, of increasing concern following 9/11, the possibility of organized malicious acts against nuclear plants.

Some of these events and incidents that have occurred could have evolved into serious accidents, had the defects, malfunctions, etc. not been discovered in time (near-misses); other incidents might be taken as early warnings or as precursors of serious accidents; and there are the so-called recurring events whereby a pattern of failures is repeated time after time at different plants. Sometimes, there develops an element of self-congratulation by the nuclear industry when an incident is brought to a 'successful' close, so much so that this overrides the various serious concerns that the incident should not have been triggered in the first place.

Not that those who lead the worldwide nuclear industry are complacent over these issues. During a biennial general meeting of the World Association of Nuclear Operators (WANO)[101], Chairman Hajimu Maeda warned of a creeping lethargy that begins with "*loss of motivation to learn from others...overconfidence...(and) negligence in cultivating a safety culture due to severe pressure to reduce costs following the deregulation of the power market*." Those troubles, if

[101] WANO, General Meeting, Berlin, October 2003

ignored, “*are like a terrible disease that originates within the organization*” and can, if not detected, lead to “*a major accident*” that will “*destroy the whole organization”.*

Nuclear plants are complex, hazardous facilities. It follows that this very complexity spawns a multifaceted array of potential failure mechanisms and routes, so many in fact that it is seemingly impossible to marshal these into any semblance of order.

The **second conclusion** is that no great reliance should be placed on the International Nuclear Event Scale (INES), either for determining the absolute severity of one abnormal event from another nor, indeed, for determining the absolute safety achievements of any one country. However, in one respect the INES can be quite revealing: as three countries operating much the same type of nuclear power plant, under much the same regulatory and management systems in place, should not produce such disparencies in their respective nuclear safety achievements, the summarized data above are solely an indicator of their openness and/or reporting practices within INES.

The **third conclusion** of this research is that because the INES reporting system serves very little purpose there is need for its overhaul and modification – if at all possible – to provide a comprehensive reporting system that identifies not just the severity and potential impact of abnormal incidents, which the present INES barely achieves, but which sets out unifying rules of post-accident analysis and categorization so that existing trends may be monitored and emerging cause of failure identified. Such a revised INES reporting system should include facility to analyze and categorize human actions, including terrorist acts.

A selection of significant events that might assist in the framework development of a new INES reporting and analyzing system is annexed to this summary. These events illustrate the major categories of cause of failure in plants over the past 20 years but, that said, given the complexity of engineered systems and the ingenuity of mankind there are other causes of accidents that have yet to be discovered.

The present report should be seen as a precursor investigation into what should be a longer-term extensive study into the identification, notification, systematic analysis and evaluation, risk assessment, classification and lessons-learned action implementation of safety relevant events in *all* nuclear facilities in *all* countries.

So long as nuclear plants and facilities continue to operate there will remain a residual risk. Precursive events cannot be eliminated, the possibility of a future severe accident cannot be entirely excluded and it is unwise to dismiss the possibility of any undesirable incident occurring on the grounds of its remote probability alone. Finally, it is folly indeed to assume that all initiating events might be reasonably foreseen – after all, who foresaw the nature and mode of operandi of the 9/11 attacks?

Sixteen Selected Significant Events in Nuclear Power Plants in Nine Countries *Since* the Chernobyl Accident in 1986

The Residual Risk Project Team has selected 16 events from nine countries that illustrate that nuclear reactor safety remains far from perfect. This is not a ranking of the most significant events but rather a selection of known significant events that also reflect the specific knowledge and experience of the members of the Residual Risk Project Team. The selected events are presented in more detail in chapter 9. They were classified into nine categories (for easy reference, the respective chapter numbers are indicated in brackets).

Advanced Material Degradation (before break) (see 9.2.1)

3 April 1991 Shearon Harris (USA) (see 9.2.1.1)

On 3 April 1991 workers at the Shearon Harris pressurized water reactor in New Hill, North Carolina discovered damaged piping and valves within the alternate minimum flow system provided for the pumps in the emergency core cooling system. The piping and valve damage was serious, had an accident occurred the water needed to cool the reactor core would have instead poured out onto the floor through the ends of broken components. The NRC calculated the severe core damage risk from this event to be 6 x 10^{-3} or 0.6% per reactor year. The event was not rated on the IAEA INES scale.

6 March 2002 Davis Besse (USA) (see 9.2.1.2)

On 6 March 2002, workers discovered a pineapple-sized hole in the carbon steel reactor vessel head at the Davis-Besse pressurized water reactor in Oak Harbor, Ohio. The boric acid of the primary coolant had completely eaten through the 6-inch (15 cm) thick carbon steel wall to expose the 5 mm thin stainless steel liner. A government study estimated that the hole would have widened to the point where the liner ruptured in another 2 to 11 months of operation. Because Davis-Besse ran 18 months between refueling outages, had the damage been missed during the 2002 outage, it seems likely that a loss of coolant accident would have occurred. The NRC calculated the severe core damage risk from this event to be 6 x 10^{-3} or 0.6% per reactor year and rated it INES level 3.

Significant Primary Coolant Leaks (see 9.2.2)

18 June 1988, Tihange-1 (Belgium) (see 9.2.2.1)

On 18 June 1988, while the pressurized water reactor was operating, a sudden leak occurred in a short, unisolable section of emergency core cooling system (ECCS) piping. The leak rate was in the order of 1,300 liters per hour. The source of leakage was a crack – 9 cm long on the inside surface of the pipe and 4.5 cm long on the outside surface – extending through the wall of the piping. The risk of a pipe rupture in the emergency core cooling system is considerable if the emergency safety injection system is activated as large quantities of cooling water are injected in case of a loss of coolant accident in an already degraded safety situation.

12 May 1998, Civaux-1 (France) (see 9.2.2.2)

The Civaux-1 pressurized water reactor was shut down for five days, when, during start-up tests, a 25 cm diameter pipe of the main residual heat removal system cracked open and a large leak (30,000 liters per hour) occurred in the primary cooling circuit. The reactor core needs to be cooled permanently, even when it is shut down, in order to evacuate the significant amount of residual heat of the fuel. It took nine hours to isolate the leak and reach a stable situation. An

18 cm long crack on a weld was identified and 300 m3 of primary coolant had leaked into the reactor building. The unit had been operating for only six months at 50% power level maximum prior to the event. The operator, EDF, suggested rating this event at level 1 on the INES scale, but the safety authorities decided on level 2.

9 February 1991 Mihama-2 (Japan) (see 9.2.2.3)

A steam generator tube rupture occurred at Mihama-2 pressurized water reactor. This was the first such incident in Japan where the emergency core cooling system was actuated. The utility investigated the rupture and found that it was a complete circumferential tube failure. The utility found that the failure due to high cycle fatigue caused by vibration. By design, all tubes in specific locations in the steam generator are supposed to be supported by anti-vibration bars. However, the subject tube was found not to be supported appropriately because of a reported "incorrect insertion" of the adjacent anti-vibration bars.

Reactivity Risks (see 9.2.3)

12 August 2001, Philippsburg (Germany) (see 9.2.3.1)

A deviation from the specified boron concentration – a neutron absorber needed to slow down or stop the nuclear reaction – in several flooding storage tanks during the restart of the plant was reported to the authorities. In addition, the liquid level had not reached the required value fixed in the operational instructions for the start-up and was only implemented with a delay. The emergency core cooling system will only work effectively if it is operated according to the design basis conditions. Subsequent investigations revealed that significant deviations from start-up requirements and violations from related instructions seemed to be common probably for several years and took place in other German nuclear plants.

1 March 2005 Kozloduy-5 (Bulgaria) (see 9.2.3.2)

In the process of power reduction at the Russian designed pressurized water reactor (WWER) the operators identified that three control rod assemblies remained in the upper end position. The follow-up movement tests of the remaining control rod assemblies identified that 22 out of 61 could not be moved with the driving mechanisms. The exact number of control rod assemblies unable to scram (to drop due to the gravity only) remains unknown but it is thought to be between 22 and 55. The WWER-1000 scram system is designed to put the reactor in safe shutdown if one control rod assembly at the most is jammed in the upper position. The operator had originally rated the incident INES level 0, but the safety authorities finally admitted to a level 2 rating.

Fuel Degradation (outside reactor core) (see 9.2.4)

Paks (Hungary) 2003 (see 9.2.4.1)

Design deficiencies of a chemical system built to clean 30 partially irradiated fuel assemblies from magnetic deposits in a special tank (outside of the vessel of the pressurized water reactor) caused insufficient cooling of all assemblies, which were heavily damaged. A subsequent IAEA investigation identified eight separate design errors. The system was developed, manufactured and delivered by AREVA NP. During the accident radioactive releases were about four times the noble gases and almost 200 times the Iodine-131 and aerosols released by all 58 French pressurized water reactors during the whole of 2003. The event was reclassified as Level 3 on the INES scale after an initial Level 2 rating.

Fires and Explosions (see 9.2.5)

14 December 2001, Brunsbüttel (Germany) (see 9.2.5.1)

A hydrogen explosion caused a high degree of damage to the spray system piping of the boiling water reactor. The head spray line is used for cooling the inner surface of the reactor pressure vessel head and the flange area upon plant shutdown. Some parts of the 5.6 mm diameter pipes were ruptured. An approximately 2.7 m long piping section had burst and was completely destroyed. Some sections of the piping were missing. Prior to this event the possibility of severe explosions caused by radiolysis gas during normal operation was nearly excluded.

Station Blackout (see 9.2.6)

18 March 2001 Maanshan (Taiwan) (see 9.2.6.1)

The pressurized water reactor was affected by a total loss of external and internal power supply. Power supply is crucial to evacuate residual heat from the reactor core. The plant is situated near the sea. Salt deposit on insulators due to foggy weather caused instability of the high voltage grid. During a switch to the grid a short circuit in a power switch of the emergency power line occurred and caused a cable fire. A breaker and switchgear was totally destroyed by the fire and the diesel generators could not be started up manually because of heavy smoke. It took about two hours to restore power supply.

25 July 2006, Forsmark, Sweden (see 9.2.6.2)

A short circuit in an outdoor switching station of the grid nearby the boiling water reactors caused the emergency shutdown (scram) of unit 1 and, in a complex scenario, led to a number of subsequent failures at the plant. Due to a design error, the disconnection of the plant from the grid and the switch to house load operation – where the power plant uses its own power to operate essential auxiliaries – did not function as planned. An inappropriate converter adjustment led to the failure of the attempt to connect safety related equipment to the emergency power supply. The start up of two of the four emergency diesel generators was aborted, which lead to a partial blackout even in the main control room. Due to the lack of information about the important parameters for a period of time the exact state of the plant and the consequences of potential actions to perform were unclear. The shift team decided nevertheless to try to reconnect the plant to the grid, which was performed successfully.

Generic Issues – Reactor Sump Plugging (see 9.2.7)

28 July 1992, Barseback-2 (Sweden) (see 9.2.7.1)

A leaking pilot valve in the boiling water reactor in Barseback initiated automatically safety functions like reactor scram, high-pressure safety injection, core spray and containment spray systems. The steam jet from an open safety valve was impinging on thermally insulated equipment. Insulating material was washed into the suppression pool and affected the emergency core cooling system, which is essential for heat removal in case of a leak the reactor coolant. Similar incidents occurred in several countries and the problem turned out to apply to many, if not most, of the light water reactors in the world.

Natural Events (see 9.2.8)

27 December 1999, Blayais-2 (France) (see 9.2.8.1)

The Blayais nuclear power plant site was flooded after heavy storms resulting in certain key safety equipments of the plant being under over 100,000 m3 of water, for example safety injection pumps and the containment spray systems of units 1 and 2. The electrical system was also affected. Power supply was interrupted. Flying objects and debris rendered any intervention dangerous. All four units on the site were shut down. For the first time, the national level of the internal emergency plan (PUI) was triggered. The event was given an INES Level 2 rating.

Security Events and Malicious Act (see 9.2.9)

7 February 1993, Three Mile Island (USA) (see 9.2.9.1)

An unauthorized vehicle entered the owner-controlled area (OCA) of the Three Mile Island (TMI) nuclear power plant. No physical barriers were present to delay access. The vehicle continued to the protected area (PA) of the nuclear plant, smashed one of the entry gates, before crashing through a corrugated metal door and entering the turbine building of the Unit 1 reactor, which was operating at full power. The vehicle stopped 19 meters inside the turbine building, striking and damaging the insulation on an auxiliary steam line. A Site Area Emergency, the second highest emergency classification level, was declared. This was the second time this had occurred at the TMI plant (the first being the TMI Unit 2 meltdown in 1979). The intruder was not apprehended until four hours after he entered the site.

July 2000, Farley (USA) (see 9.2.9.2)

During an “Operational Safeguards Response Evaluation,” or OSRE – war-game-type exercise to evaluate whether nuclear power plant security forces could effectively defend against an adversary team – the security force at Farley could not prevent the mock adversary team from simulating the destruction of entire target sets in two out of four exercises (and therefore simulating a core meltdown); and simulating the destruction of “significant plant equipment” in a third exercise.

29 August 2002, 17 TEPCO Reactors (Japan) (see 9.2.9.3)

The Tokyo Electric Power Company (TEPCO) operates 17 boiling water reactors and was also one of the most respected large companies in Japan. On 29 August 2002 the Japanese Nuclear Industrial Safety Agency (NISA), shocked the nation with the public revelation of a massive data falsification scandal at TEPCO. At that point 29 cases of “malpractice” had been identified, including the falsification of the operator’s self-imposed inspection records at its nuclear power plants over many years. In the follow-up, all of the 17 TEPCO units had to be shut down for inspection and repair. It was reported later that these practices had gone on for as long as 25 years and the total number of events is put at nearly 200 so far. However, revelations of cover-ups and malpractice have extended to all major nuclear operators in Japan and continue to date. In the latest case, in early April 2007 Hokuriku Electric has admitted to a criticality incident at its Shika-1 boiling water reactor. The event had been covered up for almost eight years.

11 Annexes

11.1 IAEA International Nuclear Event Scale (INES)

11.2 Chronology of Data Falsification at the Fukushima Nuclear Power Plant in Japan

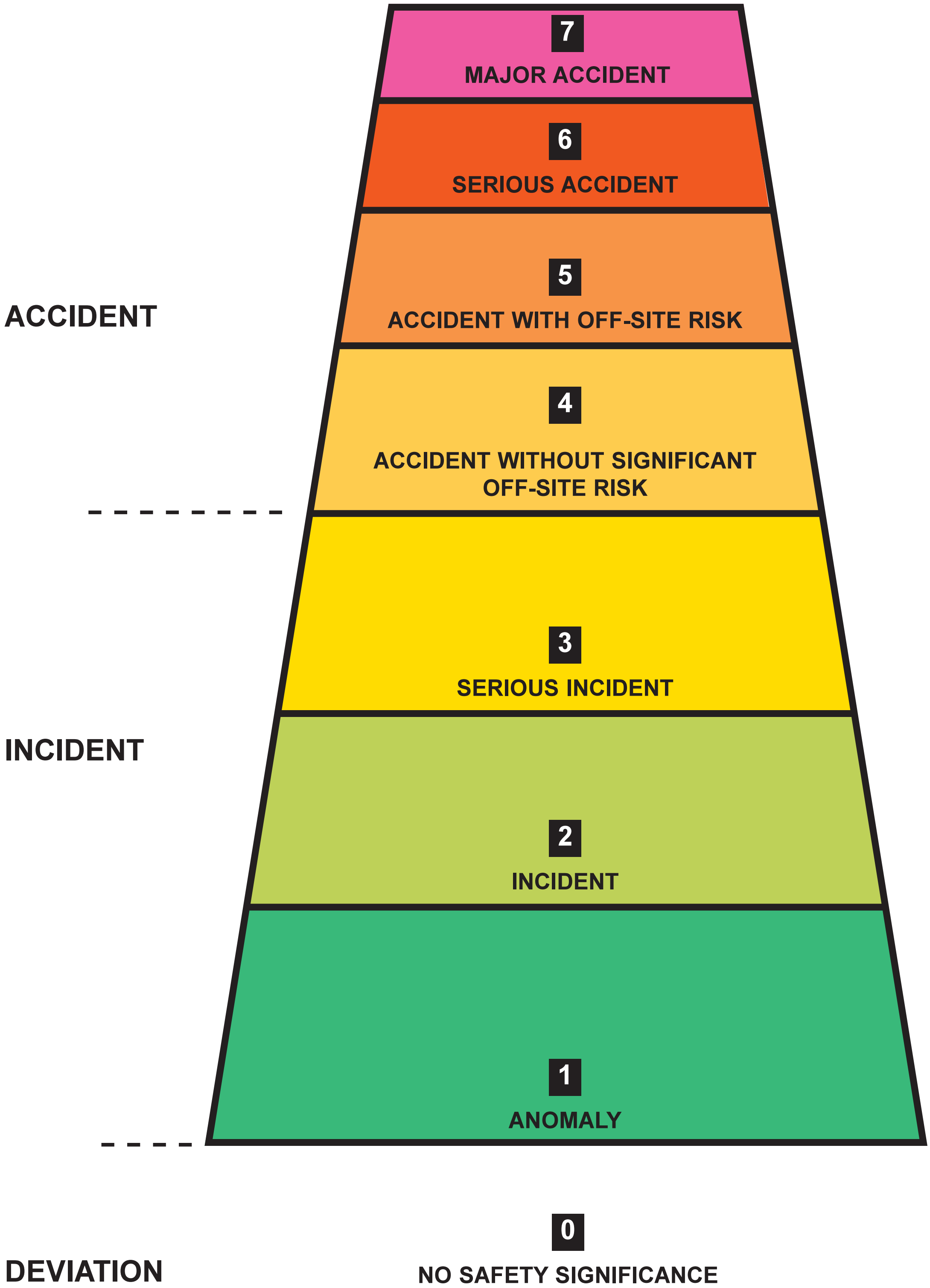
11.3 Biographical Notes on the Authors

Annex 1

11.1 IAEA International Nuclear Event Scale (INES)

The International Nuclear Event Scale

For prompt communication of safety significance



General Description of the Scale

The International Nuclear Event Scale (INES) is a means for promptly communicating to the public in consistent terms the safety significance of events reported at nuclear installations. By putting events into proper perspective, the Scale can ease common understanding among the nuclear community, the media, and the public. It was designed by an international group of experts convened jointly in 1989 by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development. The Scale also reflects the experience gained from the use of similar scales in France and Japan as well as from consideration of possible scales in several other countries.

The Scale was initially applied for a trial period to classify events at nuclear power plants and then extended and adapted to enable it to be applied to any event associated with radioactive material and/or radiation and to any event occurring during transport of radioactive material. It is now operating successfully in over 60 countries.

The INES Information Service, the communication network built up on request receives from and disseminates to the INES National Officers of 60 Member States, Event Rating Forms that provide authoritative information related to nuclear events. Event Rating Forms are circulated when events are significant for:

- operational safety (INES level 2 and above)
- public interest (INES level 1 and below)

The communication process has therefore led each participating country to set up a structure which ensures that all events are promptly rated using the INES rating procedure to facilitate communication whenever they have to be reported outside.

Events are classified on the Scale at 7 levels; the upper levels (4–7) are termed accidents and the lower levels (1–3) incidents. Events which have no safety significance are classified below scale at level 0 and are termed “deviations”. Events which have no safety relevance are termed “out of scale”. The structure of the Scale is shown opposite, in the form of a matrix with key words. Each level is defined in detail within the **INES User’s Manual**. Events are considered in terms of three safety attributes or criteria represented by each of the columns: off-site impact, on-site impact, and defence in depth degradation.

The second column in the matrix relates to events resulting in off-site releases of radioactivity. Since this is the only consequence having a direct effect on the public, such releases are understandably of particular concern. Thus, the lowest point in this column represents a release giving the critical group an estimated radiation dose numerically equivalent to about one-tenth of the annual dose limit for the public; this is classified as level 3. Such a dose is also typically about one-tenth of the average annual dose received from natural background radiation. The highest level is a major nuclear accident with widespread health and environmental consequences.

The third column considers the on-site impact of the event. This category covers a range from level 2 (contamination and/or overexposure of a worker) to level 5 (severe damage to the reactor core or radiological barriers).

All nuclear facilities are designed so that a succession of safety layers act to prevent major on-site or off-site impact and the extent of the safety layers provided generally will be commensurate with the potential for on- and off-site impact. These safety layers must all fail before substantial off-site or on-site consequences occur. The provision of these safety layers is termed “defence in depth”. The fourth column of the matrix relates to incidents at nuclear installations or during the transportation of radioactive materials in which these defence in depth provisions have been degraded. This column spans the incident levels 1–3.

An event which has characteristics represented by more than one criterion is always classified at the highest level according to any one criterion.

Events which do not reach the threshold of any of the criteria are rated below scale at level 0.

The back page of this leaflet gives typical descriptions of events at each level together with examples of the classification of nuclear events which have occurred in the past at nuclear installations.

Using the Scale

- The detailed rating procedures are provided in the INES User’s Manual. This leaflet should not be used as the basis for rating events as it only provides examples of events at each level, rather than actual definitions.
- Although the Scale is designed for prompt use following an event, there will be occasions when a longer time-scale is required to understand and rate the consequences of an event. In these rare circumstances, a provisional rating will be given with confirmation at a later date. It is also possible that as a result of further information, an event may require reclassification.
- The Scale does not replace the criteria already adopted nationally and internationally for the technical analysis and reporting of events to Safety Authorities. Neither does it form a part of the formal emergency arrangements that exist in each country to deal with radiological accidents.
- Although the same Scale is used for all installations, it is physically impossible at some types of installation for events to occur which involve the release to the environment of considerable quantities of radioactive material. For these installations, the upper levels of the Scale would not be applicable. These include research reactors, unirradiated nuclear fuel treatment facilities, and waste storage sites.
- The Scale does not classify industrial accidents or other events which are not related to nuclear or radiological operations. Such events are termed “out of scale”. For example, although events associated with a turbine or generator can affect safety related equipment, faults affecting only the availability of a turbine or generator would be classified as out of scale. Similarly, events such as fires are to be considered out of scale when they do not involve any possible radiological hazard and do not affect the safety layers.
- The Scale is not appropriate as the basis for selecting events for feedback of operational experience, as important lessons can often be learnt from events of relatively minor significance.
- It is not appropriate to use the Scale to compare safety performance among countries. Each country has different arrangements for reporting minor events to the public, and it is difficult to ensure precise international consistency in rating events at the boundary between level 0 and level 1. The statistically small number of such events, with variability from year to year, makes it difficult to provide meaningful international comparisons.
- Although broadly comparable, nuclear and radiological safety criteria and the terminology used to describe them vary form country to country. The INES has been designed to take account of this fact.

Examples of Rated Nuclear Events

- The 1986 accident at the Chernobyl nuclear power plant in the Soviet Union (now in Ukraine) had widespread environmental and human health effects. It is thus classified as Level 7.
- The 1957 accident at the Kyshtym reprocessing plant in the Soviet Union (now in Russia) led to a large off-site release. Emergency measures including evacuation of the population were taken to limit serious health effects. Based on the off-site impact of this event it is classified as Level 6.
- The 1957 accident at the air-cooled graphite reactor pile at Windscale (now Sellafield) facility in the United Kingdom involved an external release of radioactive fission products. Based on the off-site impact, it is classified as Level 5.
- The 1979 accident at Three Mile Island in the United States resulted in a severely damaged reactor core. The off-site release of radioactivity was very limited. The event is classified as Level 5, based on the on-site impact.
- The 1973 accident at the Windscale (now Sellafield) reprocessing plant in the United Kingdom involved a release of radioactive material into a plant operating area as a result of an exothermic reaction in a process vessel. It is classified as Level 4, based on the on-site impact.
- The 1980 accident at the Saint-Laurent nuclear power plant in France resulted in partial damage to the reactor core, but there was no external release of radioactivity. It is classified as Level 4, based on the on-site impact.
- The 1983 accident at the RA-2 critical assembly in Buenos Aires, Argentina, an accidental power excursion due to non-observance of safety rules during a core modification sequence, resulted in the death of the operator, who was probably 3 or 4 metres away. Assessments of the doses absorbed indicate 21 Gy for the gamma dose together with 22 Gy for the neutron dose. The event is classified as Level 4, based on the on-site impact.
- The 1989 incident at the Vandellos nuclear power plant in Spain did not result in an external release of radioactivity, nor was there damage to the reactor core or contamination on site. However, the damage to the plant’s safety systems due to fire degraded the defence in depth significantly. The event is classified as Level 3, based on the defence in depth criterion.
- The vast majority of reported events are found to be below Level 3. Although no examples of these events are given here, countries using the Scale may individually wish to provide examples of events at these lower levels.

Basic Structure of the Scale

(Criteria given in matrix are broad indicators only)
Detailed definitions are provided in the INES User's Manual

	CRITERIA OR SAFETY ATTRIBUTES		
	OFF-SITE IMPACT	ON-SITE IMPACT	DEFENCE IN DEPTH DEGRADATION
7 MAJOR ACCIDENT	MAJOR RELEASE: WIDESPREAD HEALTH AND ENVIRONMENTAL EFFECTS		
6 SERIOUS ACCIDENT	SIGNIFICANT RELEASE: LIKELY TO REQUIRE FULL IMPLEMENTATION OF PLANNED COUNTERMEASURES		
5 ACCIDENT WITH OFF-SITE RISK	LIMITED RELEASE: LIKELY TO REQUIRE PARTIAL IMPLEMENTATION OF PLANNED COUNTERMEASURES	SEVERE DAMAGE TO REACTOR CORE/RADIOLOGICAL BARRIERS	
4 ACCIDENT WITHOUT SIGNIFICANT OFF-SITE RISK	MINOR RELEASE: PUBLIC EXPOSURE OF THE ORDER OF PRESCRIBED LIMITS	SIGNIFICANT DAMAGE TO REACTOR CORE/RADIOLOGICAL BARRIERS/FATAL EXPOSURE OF A WORKER	
3 SERIOUS INCIDENT	VERY SMALL RELEASE: PUBLIC EXPOSURE AT A FRACTION OF PRESCRIBED LIMITS	SEVERE SPREAD OF CONTAMINATION/ACUTE HEALTH EFFECTS TO A WORKER	NEAR ACCIDENT NO SAFETY LAYERS REMAINING
2 INCIDENT		SIGNIFICANT SPREAD OF CONTAMINATION/ OVEREXPOSURE OF A WORKER	INCIDENTS WITH SIGNIFICANT FAILURES IN SAFETY PROVISIONS
1 ANOMALY			ANOMALY BEYOND THE AUTHORIZED OPERATING REGIME
0 DEVIATION	**NO**	**SAFETY**	**SIGNIFICANCE**
OUT OF SCALE EVENT	NO SAFETY RELEVANCE		

The International Nuclear Event Scale

For prompt communication of safety significance

LEVEL/ DESCRIPTOR	NATURE OF THE EVENTS	EXAMPLES
ACCIDENTS **7** **MAJOR ACCIDENT**	• External release of a large fraction of the radioactive material in a large facility (e.g. the core of a power reactor). This would typically involve a mixture of short and long-lived radioactive fission products (in quantities radiologically equivalent to more than tens of thousands of terabecquerels of iodine-131). Such a release would result in the possibility of acute health effects; delayed health effects over a wide area, possibly involving more than one country; long-term environmental consequences.	Chernobyl NPP, USSR (now in Ukraine), 1986
6 **SERIOUS ACCIDENT**	• External release of radioactive material (in quantities radiologically equivalent to the order of thousands to tens of thousands of terabecquerels of iodine-131). Such a release would be likely to result in full implementation of countermeasures covered by local emergency plans to limit serious health effects.	Kyshtym Reprocessing Plant, USSR (now in Russia), 1957
5 **ACCIDENT WITH OFF-SITE RISK**	• External release of radioactive material (in quantities radiologically equivalent to the order of hundreds to thousands of terabecquerels of iodine-131). Such a release would be likely to result in partial implementation of countermeasures covered by emergency plans to lessen the likelihood of health effects. • Severe damage to the installation. This may involve severe damage to a large fraction of the core of a power reactor, a major criticality accident or a major fire or explosion releasing large quantities of radioactivity within the installation.	Windscale Pile, UK, 1957 Three Mile Island, NPP, USA, 1979
4 **ACCIDENT WITHOUT SIGNIFICANT OFF-SITE RISK**	• External release of radioactivity resulting in a dose to the critical group of the order of a few millisieverts.* With such a release the need for off-site protective actions would be generally unlikely except possibly for local food control. • Significant damage to the installation. Such an accident might include damage leading to major on-site recovery problems such as partial core melt in a power reactor and comparable events at non-reactor installations. • Irradiation of one or more workers resulting in an overexposure where a high probability of early death occurs.	Windscale Reprocessing Plant, UK, 1973 Saint-Laurent NPP, France, 1980 Buenos Aires Critical Assembly, Argentina, 1983
INCIDENTS **3** **SERIOUS INCIDENT**	• External release of radioactivity resulting in a dose to the critical group of the order of tenths of millisievert.* With such a release, off-site protective measures may not be needed. • On-site events resulting in doses to workers sufficient to cause acute health effects and/or an event resulting in a severe spread of contamination for example a few thousand terabecquerels of activity released in a secondary containment where the material can be returned to a satisfactory storage area. • Incidents in which a further failure of safety systems could lead to accident conditions, or a situation in which safety systems would be unable to prevent an accident if certain initiators were to occur.	Vandellos NPP, Spain, 1989
2 **INCIDENT**	• Incidents with significant failure in safety provisions but with sufficient defence in depth remaining to cope with additional failures. These include events where the actual failures would be rated at level 1 but which reveal significant additional organisational inadequacies or safety culture deficiencies. • An event resulting in a dose to a worker exceeding a statutory annual dose limit and/or an event which leads to the presence of significant quantities of radioactivity in the installation in areas not expected by design and which require corrective action.	
1 **ANOMALY**	• Anomaly beyond the authorised regime but with significant defence in depth remaining. This may be due to equipment failure, human error or procedural inadequacies and may occur in any area covered by the scale, e.g. plant operation, transport of radioactive material, fuel handling, waste storage. Examples include: breaches of technical specifications or transport regulations, incidents without direct safety consequences that reveal inadequacies in the organisational system or safety culture, minor defects in pipework beyond the expectations of the surveillance programme.	
DEVIATIONS **0** **BELOW SCALE**	• Deviations where operational limits and conditions are not exceeded and which are properly managed in accordance with adequate procedures. Examples include: a single random failure in a redundant system discovered during periodic inspections or tests, a planned reactor trip proceeding normally, spurious initiation of protection systems without significant consequences, leakages within the operational limits, minor spreads of contamination within controlled areas without wider implications for safety culture.	**NO SAFETY SIGNIFICANCE**

* *The doses are expressed in terms of effective dose equivalent (whole dose body). Those criteria where appropriate can also be expressed in terms of corresponding annual effluent discharge limits authorized by National authorities.*

International Atomic Energy Agency
Wagramerstrasse 5
A-1400 Vienna, Austria

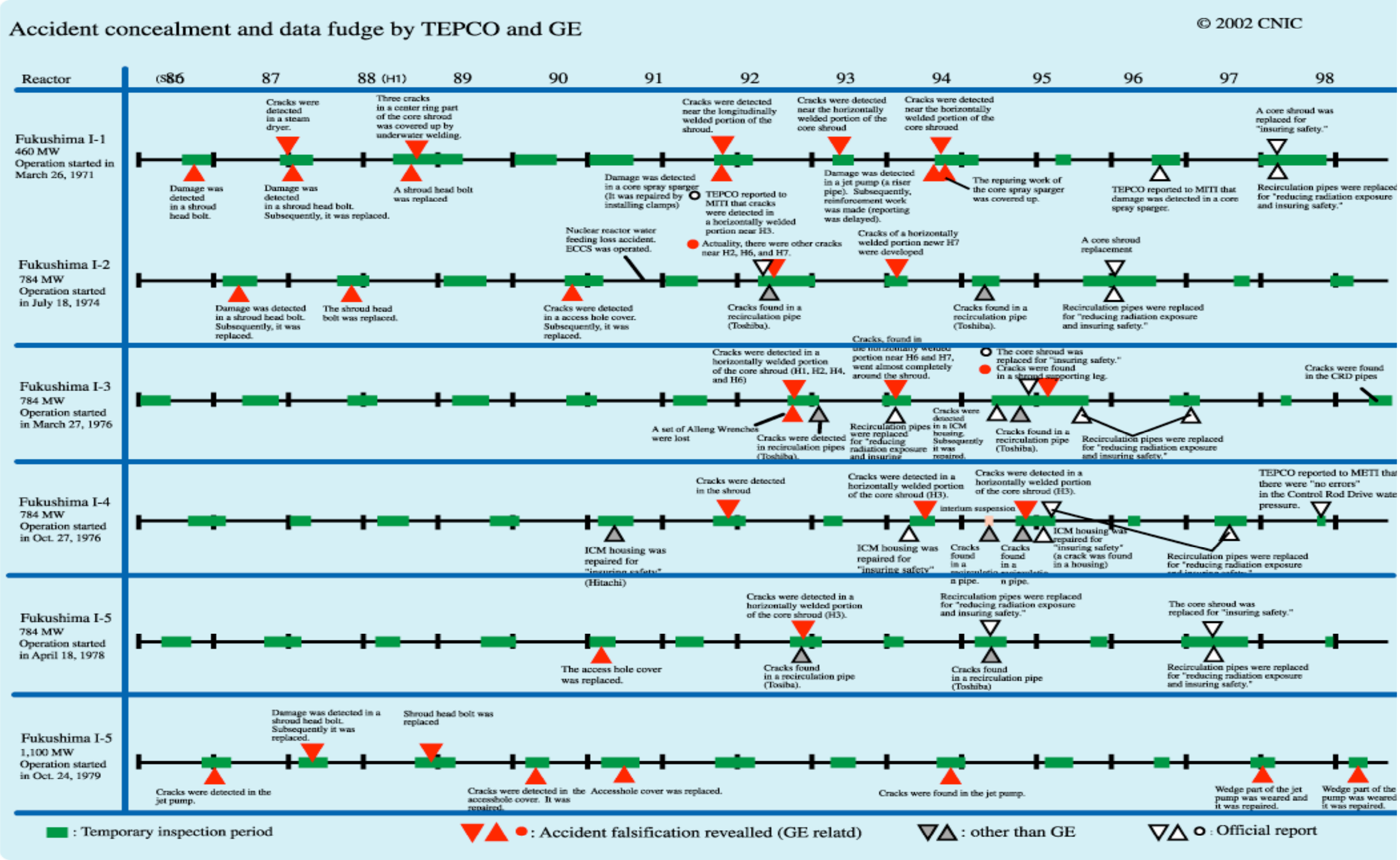
OECD Nuclear Energy Agency
Le Seine Saint-Germain-12
Boulevard des Iles
92130 Issy-les-Moulineaux, France

99-00305/FS-05

Annex 2

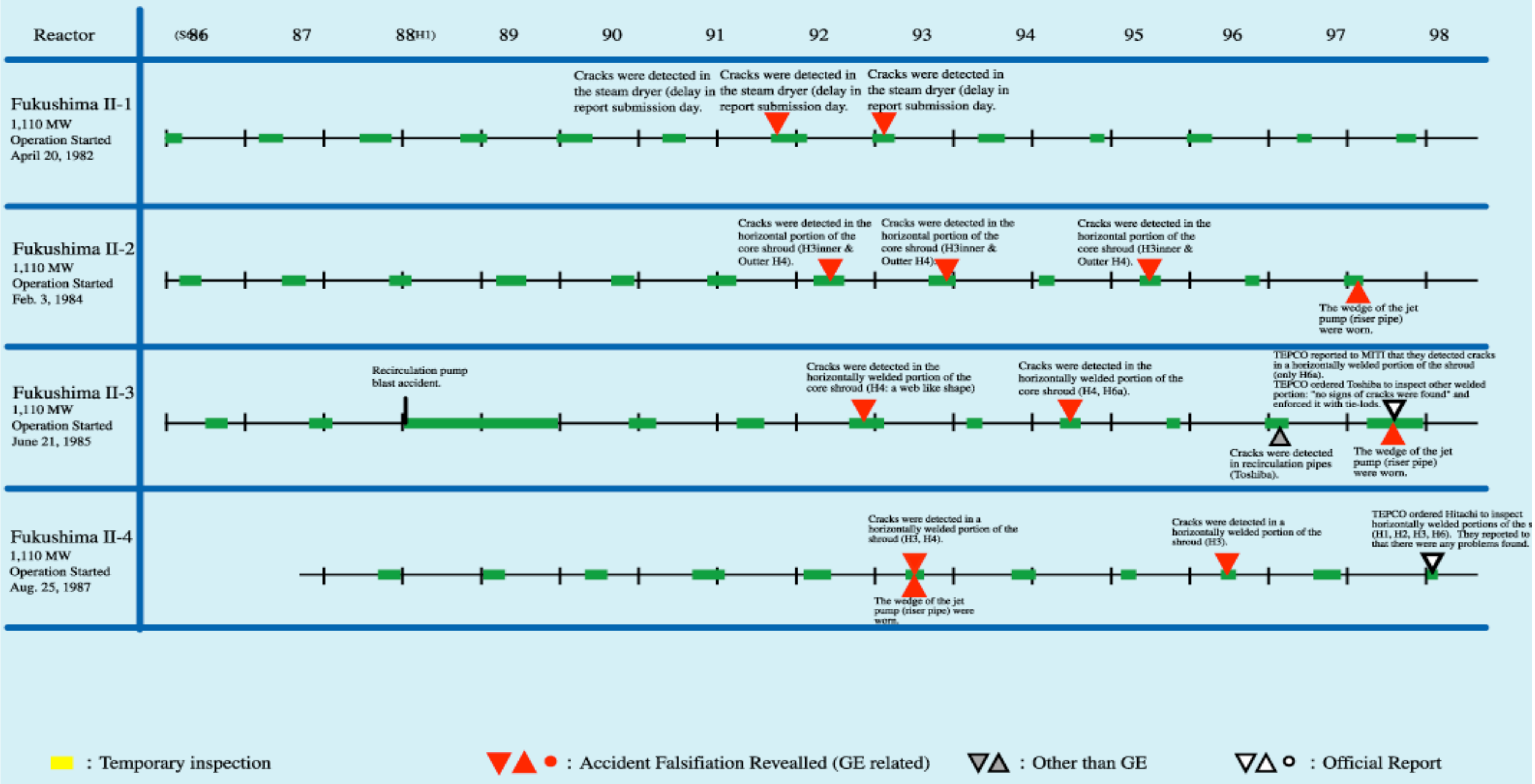
11.2 Chronology of Data Falsification at the Fukushima NPP, Japan

by Citizens' Nuclear Information Center, Tokyo



Accident concealment and data fudge by TEPCO and GE
© 2002 CNIC
Reactor
86
87
88 (H1)
89
90
91
92
93
94
95
96
97
98
Fukushima I-1
460 MW
Operation started in March 26, 1971
Fukushima I-2
784 MW
Operation started in July 18, 1974
Fukushima I-3
784 MW
Operation started in March 27, 1976
Fukushima I-4
784 MW
Operation started in Oct. 27, 1976
Fukushima I-5
784 MW
Operation started in April 18, 1978
Fukushima I-5
1,100 MW
Operation started in Oct. 24, 1979
: Temporary inspection period
: Accident falsification revealled (GE relatd)
: other than GE
: Official report

(2) Accident concealment and data falsification by TEPCO and GE



Annex 3

Biographical Notes on the Authors

Georgui Kastchiev

Senior Scientist at the Institute of Risk Research, University of Vienna, Faculty of Earth Sciences, Geography and Astronomy. G. Kastchiev graduated from University of Sofia in Bulgaria in 1972 as a diploma physicist. In 1972 he started his career as reactor physicist in NPP Kozloduy. He received a Ph.D. in reactor physics and safety from the University of Sofia in 1987. Dr. Kastchiev worked as a lecturer at the Institute of Nuclear Engineering, Kozloduy/Sofia from 1989 to 1993 and as a guest engineer in the AP 600 Project, Westinghouse, USA in 1994. During 1995-1997 Dr. Kastchiev acted as a consultant to the Institute of Risk Research, University of Vienna, Austria, until he was appointed head of the Bulgarian Nuclear Safety Authority in 2002. He worked there for four years and spent one year as a guest professor at the Tokyo Institute of Technology. Since 2006 he is back in the Institute of Risk Research, University of Vienna, Austria.

Wolfgang Kromp

Professor, Ph.D. in Physics, University of Vienna, head of the 'Institute of Risk Research' of the University of Vienna, Faculty of Earth Sciences, Geography and Astronomy, holds forty years of experience in research and teaching at university level, extended research fellowship and visiting professorship at the Max-Planck Institute in Stuttgart, Germany and the Carnegie-Mellon University in Pittsburgh, USA. Research in the area of material related problems, using ultrasonic techniques for material testing and composition; focus on material related questions concerning nuclear safety. He is member of the Nuclear Advisory Board to the Austrian Federal Chancellor, the Scientific Commission of the Austrian Federal Ministry of Defense and the Technical Committee for Standardization ON-K 246 Risk, Safety and Crisis Management of the Austrian Standards Institute. Konrad Lorenz Environmental Award 1991 of the Austrian Ministry of Science and Research. Participation in safety assessments of several nuclear power plants and spent fuel interim storages; research on radioactive contamination and risk perception; socio-economic research on fusion (SERF). Feasibility and risk studies on sustainable energy production from biomass. Study on security of food production in oil reduced agriculture.

Stephan Kurth

Dipl.-Ing, since 1993 with Oeko-Institut e.V. - Institute for Applied Ecology, Darmstadt, Germany. Head of the Plant Safety Group of the Nuclear Engineering & Plant Safety Division. Focus on safety assessment, event analysis, environmental impact assessment and regulation. Member of official national advisory committees dealing with safety issues of nuclear and non-nuclear plants.

David Lochbaum

Director, Nuclear Safety Project, Union of Concerned Scientists (UCS), leads UCS's efforts to ensure the safety of nuclear power in the United States by monitoring civilian nuclear plants to identify and publicize safety risks. Mr. Lochbaum has more than 17 years experience in nuclear power plant start-up testing, operations, licensing, software development, training, and design engineering. He worked at the Hope Creek and Salem (New Jersey), Brunswick (North Carolina), Perry (Ohio), Limerick and Susquehanna (Pennsylvania), Wolf Creek (Kansas), Haddam Neck (Connecticut), Fitzpatrick and Indian Point 3 (New York), Grand Gulf (Mississippi), Browns Ferry (Alabama), and Hatch (Georgia) nuclear plants. In 1992, he and a colleague identified deficiencies in the design for spent fuel pool cooling at the Susquehanna plant and reported their concerns to the plant owner, to the Nuclear

Regulatory Commission, and then to Congress. Their efforts resulted in safety improvements at Susquehanna and at other nuclear plants with similar problems.

Ed Lyman

Edwin Lyman is a Senior Staff Scientist in the Global Security program at the Union of Concerned Scientists in Washington, DC, a position he has held since May 2003. Before coming to UCS, he worked at the Nuclear Control Institute for nearly eight years, first as scientific director, and then as president. He earned a doctorate in physics from Cornell University in 1992. From 1992 to 1995, he was a postdoctoral research associate at Princeton University's Center for Energy and Environmental Studies.

His research focuses on security and environmental issues associated with the management of nuclear materials and the operation of nuclear power plants. He has published articles and letters in journals and magazines including Science, The Bulletin of the Atomic Scientists and Science and Global Security. He is an active member of the Institute of Nuclear Materials Management. In the spring of 2001, he served on a Nuclear Regulatory Commission expert panel on the role and direction of the NRC Office of Nuclear Regulatory Research and briefed the Commission on his findings. In July 2001, he was again invited to a Commission meeting to discuss the licensing of new nuclear reactors in the United States.

Michael Sailer

Dipl.-Ing., since 1980 with Oeko-Institut e.V - Institute for Applied Ecology, Darmstadt/Freiburg/Berlin, Germany, currently Deputy Director of the Institute, Coordinator of the Nuclear Engineering & Plant Safety Division, numerous publications on reactor safety and radioactive waste disposal issues, member of official advisory committees on both national and European levels.

Mycle Schneider

Independent Consultant on Energy and Nuclear Policy. Between 1983 and April 2003 he was executive director of the energy information service WISE-Paris. He has given evidence and held briefings at Parliaments in eight countries and at the European Parliament. Since 2004 he teaches within the International MSc for Project Management for Environmental and Energy Engineering at the *Ecole des Mines* in Nantes. In 2005 he has been appointed as nuclear security specialist to advise the UK Committee on Radioactive Waste Management (CoRWM). In 2006-07 he has been part of a consultant consortium that assessed nuclear decommissioning and waste management funding issues on behalf of the European Commission. Between 1998 and 2003 he has been an advisor to the French Environment Minister's Office and to the Belgian Minister for Energy and Sustainable Development. Since 2000 he is a consultant on nuclear issues to the German Environment Ministry.

Mycle Schneider has provided information and consulting services to a large variety of clients. Media representatives from around the world have inquired for his information, advise or complete features including many TV and radio stations, electronic and print media. His numerous publications cover the analysis of nuclear proliferation, security and safety, as well as environmental and energy planning issues.

In 1997 he was honored with the Right Livelihood Award ("Alternative Nobel Prize") together with Jinzaburo Takagi for their work on plutonium issues (http://rightlivelihood.org/recip.htm).

CEAR No.07-05-29525

IN THE MATTER of a Joint Review Panel established under sections 29 and 40(2) of the *Canadian Environmental Assessment Act* in relation to the New Nuclear Power Plant Project proposed by Ontario Power Generation at the Darlington Nuclear Site, in the Regional Municipality of Durham, Province of Ontario

- and –

IN THE MATTER of an Application for Licence to Prepare a Site filed under section 24(2) of the *Nuclear Safety Control Act* in relation to the New Nuclear Power Plant Project proposed by Ontario Power Generation at the Darlington Nuclear Site, in the Regional Municipality of Durham, Province of Ontario

FINAL COMMENTS OF THE CANADIAN ENVIRONMENTAL LAW ASSOCIATION

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TABLE OF CONTENTS

FINAL COMMENTS OF THE CANADIAN ENVIRONMENTAL LAW ASSOCIATION TO THE JOINT REVIEW PANEL RE: DARLINGTON NEW NUCLEAR POWER PLANT PROJECT

PART I – INTRODUCTION

1. These are the final comments of the Canadian Environmental Law Association ("CELA"), which intervened in the Joint Review Panel ("JRP") hearing under the *Canadian Environmental Assessment Act* ("CEAA") and the *Nuclear Safety Control Act* ("NSCA") in relation to the Darlington New Nuclear Power Plant ("NNPP") Project.[1]

2. With respect to environmental assessment ("EA") matters, CELA's overall position is that the JRP cannot recommend approval of the NNPP Project under CEAA on the basis of the record currently before the JRP. CELA's reasons for its position can be summarized as follows:

(a) there is insufficient information to adequately establish the alleged "need" for the NNPP Project, contrary to section 16(1)(e) of CEAA, section 7.1 of the Environmental Impact Statement ("EIS") Guidelines, and the JRP Terms of Reference;

(b) there is an improper description of the "purpose" of the NNPP Project, contrary to section 16(2)(a) of CEAA, section 7.1 of the EIS Guidelines, and the JRP Terms of Reference;

(c) there is insufficient information to adequately identify and evaluate a reasonable range of functionally different "alternatives to" the NNPP Project, contrary to section 16(1)(e) of CEAA, section 7.2 of the EIS Guidelines, and the JRP Terms of Reference;

(d) there is insufficient information to adequately identify and evaluate "alternate means" of carrying out the NNPP Project, contrary to section 16(2)(b) of CEAA, section 7.3 of the EIS Guidelines, and the JRP Terms of Reference;

(e) there is insufficient information to adequately identify and evaluate the environmental effects (or their significance) of the NNPP Project, contrary to section 16(1)(a) and (b) of CEAA, sections 11.1, 11.3 and 13 of the EIS Guidelines, and the JRP Terms of Reference;

(f) there is insufficient information to adequately describe, at a sufficient level of detail, technically and economically feasible mitigation measures that will be effective in preventing significant adverse environmental effects, contrary to section 16(1)(d) of CEAA, section 11.2 of the EIS Guidelines, and the JRP Terms of Reference;

(g) there is insufficient information to adequately describe, at a sufficient level of detail, the content requirements of an appropriate followup program, contrary to section 16(2)(c) of CEAA, section 15 of the EIS Guidelines, and the JRP Terms of Reference; and

(h) there is insufficient information to adequately demonstrate that the NNPP Project meets the sustainability purposes and precautionary requirements established under CEAA.

3. With respect to the application filed by Ontario Power Generation ("OPG") under the NSCA, CELA's overall position is that the Licence to Prepare a Site ("LTPS") should not be issued to the proponent. CELA's reasons for its position can be summarized as follows:

(a) the Darlington location is inherently unsuitable for the NNPP Project because of the sizeable (and ever-increasing) population living beside and near the site;

(b) the effectiveness of emergency planning and/or mass evacuation measures in the event of a catastrophic nuclear incident at the Darlington site has not been satisfactorily demonstrated;

(c) it is inappropriate to grant an LTPS for a location at which there are already existing reactors and used nuclear fuel storage in close proximity;

(d) there has been inadequate consideration of the various risks – and unacceptable consequences – of accidents and malfunctions over the entire lifecycle of the NNPP Project; and

(e) there has been inadequate consideration of the impacts of routine or accidental emissions of radionuclides from the Darlington site into nearby and downstream sources of drinking water.

PART II – CELA'S COMMENTS ON EA MATTERS UNDER CEAA

(a) Inadequate Consideration of Purpose and Need for the Project

4. With respect to the NNPP Project, OPG was obliged by CEAA and the EIS Guidelines to address the threshold EA planning issues of "need", "purpose", "alternatives to", and "alternative means."[2] As described below, CELA submits that OPG did not satisfactorily address these matters in the EIS or during the JRP hearing.

5. Accordingly, the JRP has been left with inadequate information to discharge its "high standard of care" when considering these mandatory requirements under section 16 of CEAA.[3] In this regard, CELA notes that the JRP's Terms of Reference specifically stated that the scope of the Review will include the important considerations set out in

subsections 16(1) and (2) of CEAA, including "need", "purpose", "alternatives to", and "alternative means."[4]

6. By any objective standard, OPG failed to adequately address "need" and "purpose" in the EIS. Instead, the EIS simply invokes the Energy Minister's 2006 directive,[5] and implies (without elaboration) that the mere existence of the directive wholly disposes of the statutory obligation to address "need" and "purpose" under CEAA.

7. The substantive deficiencies in the EIS regarding "need" were not satisfactorily remedied by OPG presentations, undertaking answers, or responses to information requests during the JRP hearing. For example, OPG: (i) continued to invoke the Minister's directive as justification for the Project; (ii) conceded that it had not conducted a cost-benefit analysis of the Project; and (iii) made a belated attempt to read into the record certain excerpts from Ontario's most recent demand-supply directive. In essence, during three weeks of public hearings, OPG failed to present any detailed information, accurate modeling and credible forecasts which would quantify or otherwise substantiate the need for the NNPP Project. Thus, CELA submits that OPG's efforts at the hearing do not constitute proper or probative evidence of "need" within the meaning of CEAA.[6]

8. During the JRP hearing, certain representations were made by the Ontario government in relation to the alleged "need" for the NNPP Project.[7] However, like OPG, provincial officials at the JRP hearing presented no actual proof or cogent analysis to objectively justify the "need" for the Project.

9. The answers provided by the Ministry of Energy and OPG to Undertakings 75 and 76 do not remedy the paucity of evidence regarding "need" for NNPP Project. In addition, CELA notes that the answers to Undertakings 75 and 76 were filed <u>after</u> the conclusion of the public hearing. As a matter of procedural fairness, CELA strongly objects to the *ex post facto* filing of these undertaking answers outside of the hearing process, which contravenes the public participation purposes of CEAA, and significantly prejudices the ability of interveners to meaningfully respond to the various claims contained within the undertaking answers.

10. With respect to Undertaking 75, the Ministry's answer confirms that the latest supply mix directive must still be reflected in the as-yet undrafted Integrated Power System Plan ("IPSP"), and that the IPSP must still be submitted to the Ontario Energy Board ("OEB"). In addition, the Ministry's answer provides no evidence to verify its assumptions, data analysis or projections regarding peak demand, annual consumption, predicted generation, and anticipated electricity costs. More alarmingly, Tables 3 and 4 suggest that energy from renewable sources (i.e. wind, solar and bioenergy) will flat-line after 2020, when OPG anticipates that new/refurbished nuclear reactors will be put into service. This projection underscores CELA's concern that pouring untold billions of dollars into new nuclear capacity will effectively constrain or "cap" the development of cleaner, cheaper and safer renewable energy projects.

11. The Ministry's answer to Undertaking 75 corroborates the position taken by CELA and other interveners at the hearing that "renewable is doable."[8] The Ministry's own figures for the 2010-2020 period suggest that: (i) total electricity demand will stay relatively flat; (ii) efficiency/conservation measures will offset the projected population growth; and (iii) the complete phase-out of coal generation and sizeable (i.e. 40%) reduction in nuclear generation will be offset by doubling renewable energy generation (hydro, wind, solar and bioenergy), with the biggest increase coming from wind, and a modest increase in natural gas generation. However, in the 2020-2030 period, the Ministry inexplicably predicts a huge increase in total electricity demand (despite the downward trend in demand since 2006), and the Ministry projects no increase in output from renewable energy sources during that decade. Thus, it appears that the Ministry's illogical basis for the NNPP Project is that Ontario may require new nuclear generation in about 15 years, but only if all of the province's energy conservation and renewable energy programs are capped, scaled back or discontinued about 7 years from now.

12. OPG's answer to Undertaking 76 attaches the 2005 Memorandum of Agreement ("MOA") between OPG and Ontario, but fails to append the relevant excerpts from the *Electricity Act*, which places no legislative limits on OPG's ability to pursue non-nuclear generation options.[9] Assuming (without deciding) that the MOA is a legally binding contract between the signatories, it does not amend or supersede the *Electricity Act*. In addition, the MOA can be changed at any time by the Ontario government and, more importantly, the MOA (page 2) leaves the door open to Ontario to direct OPG to pursue non-nuclear renewable energy projects. Indeed, the OPG undertaking answer confirms that it has already been directed by Ontario in March 2011 to convert some existing stations to biomass or natural gas. Thus, OPG's suggestion that it is legally precluded from pursuing renewables is without merit.

13. OPG's refusal to adequately address "need" and "purpose" within the EIS, or during the JRP hearing, is unreasonable, unacceptable, and unsupportable in law for the following reasons:

(a) given the peremptory language of subsections 16(1)(e) and (2)(a) of CEAA (i.e. this JRP assessment "must" consider the purpose of, and need for, the project), there is no merit to the OPG's suggestion that it was free to disregard the threshold question of "need" in these proceedings. Once the EIS Guidelines and JRP Terms of Reference specified that "need" must be considered in this EA process, OPG – and, more importantly, the JRP – is legally obliged under CEAA to fully canvass this key issue rather than sidestep it;[10]

(b) the Minister's directive is, at best, a political statement of governmental intention. However, it does not objectively demonstrate the alleged "need" for the NNPP Project, particularly a project of the size, scale, capacity, and location being proposed by OPG;[11]

(c) the Minister's directive has not been adopted or incorporated within an approved long-term energy plan for Ontario. To the contrary, it must be noted that: (i) the first proposed IPSP was discontinued; (ii) public consultation on the second IPSP has not yet occurred; (iii) the second IPSP must still undergo extensive public hearings before the OEB; and (iv) there is considerable uncertainty as to when – or whether – the OEB will approve the IPSP under the *Electricity Act*. In these circumstances, it remains to be seen whether the so-called "need" for 14,000 MW of nuclear baseload (including 2,000 MW from Darlington) will be eventually upheld – or rejected – by the OEB, having regard for the two-branch approval test for the IPSP (compliance with the Minister's directives and "economically prudent and cost-effective");[12]

(d) the mere fact that Ontario has undertaken some limited pre-consultation on its most recent supply-mix directive does not obviate the legal duty to adequately address "need" under CEAA. Similarly, the fact that some people participated in Ontario's pre-consultation exercise is neither relevant to, nor dispositive of, the question of whether the CEAA requirements regarding "need" have been met in this case;

(e) OPG has failed to adequately "define the problem or opportunity that the project is intending to solve", and OPG's circular description of "purpose" (i.e. to satisfy the Minister's supply-mix directive) fails to "define what is to be achieved by carrying out the project". As currently drafted, OPG's problematic definition of "purpose" simply amounts to a statement that the proponent intends to fulfill the wishes of its shareholder. For EA planning purposes, this statement of purpose is inadequate and unacceptable under CEAA and the JRP Terms of Reference, and should therefore be rejected by the JRP;[13] and

(f) given that the Ontario government is the sole shareholder of OPG, any protestations by OPG that its mandate is "limited" should not be accepted by the JRP. In effect, OPG is inextricably connected to the Ontario government, and the so-called "limits" on OPG's mandate are more illusory than real. Moreover, given the legal linkage between OPG and the Ontario government (and their commonality of interest), both parties should be considered to be co-proponents for the purposes of this EA process.

14. "Need" and "purpose" are arguably two of the most important CEAA considerations in this case, particularly in light of the significant costs and environmental risks posed by the NNPP Project. It is a tenet of sound EA planning that where a project poses environmental risks, the proponent must demonstrate that the project is actually needed. Thus, it is not in the public interest to approve a risky (or costly) project for which there is no demonstrable public need.[14] This principle has been accepted under Ontario's EA legislation,[15] and CELA commends its adoption by the JRP in this case.

(b) Inadequate Consideration of Alternatives to the Project

15. CEAA, the EIS Guidelines, and the JRP Terms of Reference made it abundantly clear that this EA process required "an analysis of alternatives to the project", which was

to include descriptions of "functionally different ways to meet the project's need and achieve the project's purpose from the perspective of the proponent."[16] The EIS Guidelines further specified that OPG must "identify and discuss other technically and economically feasible methods of producing electricity other than the construction and operation of the OPG Darlington NNPP that are within the control and/or interests of OPG (emphasis added)."

16. However, OPG filed an EIS which did not contain any meaningful analysis of functionally different "alternatives to" the NNPP Project. Instead, OPG briefly listed four so-called "alternatives to": (i) do nothing; (ii) smaller nuclear project at the Darlington site; (iii) same nuclear project at a different location; or (iv) non-nuclear generation option. All four options were summarily rejected by OPG without analysis on the grounds that they were "unacceptable" and "inconsistent" with the Minister's directive, thereby leaving OPG to claim that there are no reasonable "alternatives to" within the control or interests of OPG.[17] These EIS claims were repeated by OPG at the JRP hearing.[18]

17. OPG's refusal to properly evaluate "alternatives to" the Project in the EIS, or at the JRP hearing, is unreasonable, unacceptable, and unsupportable in law for the reasons described above regarding "need", and for the following additional reasons:

(a) OPG's one sentence discussion of Option 1 (i.e. "do nothing") fails to include any analysis or criteria to evaluate the biophysical and socio-economic pros/cons of not building the NNPP Project. Indeed, not building the Project may, in fact, be a realistic (if not preferable) outcome;

(b) even if OPG does not intend to "do nothing", proper review of the "do nothing" alternative has long been considered to be an important component of EA planning since such analysis helps provide a comparative benchmark for assessing the environmental impacts and acceptability of the preferred alternative;[19]

(c) OPG's Options 2 and 3 (i.e. smaller nuclear project at Darlington, or same nuclear project at a different site) are essentially variations of the same alternative preferred by OPG, and therefore do not represent functionally different "alternatives to". Indeed, these variations are essentially "alternative means" of carrying out a nuclear generation option, and do not satisfy the requirements of the EIS Guidelines or the JRP Terms of Reference to evaluate functionally different "alternatives to" OPG's new nuclear proposal;

(d) OPG's Option 4 is labeled as "non-nuclear generation" alternatives, but OPG has failed to specifically identify what projects, facilities or activities fall within this category, and has further failed include any analysis or criteria to evaluate the biophysical and socio-economic pros/cons of non-nuclear generation options which are technically and economically feasible;

(e) when asked by the JRP about the underlying rationale for Ontario's insistence upon 50% baseload from nuclear power, the Ministry of Energy could only advise that this has been the *status quo* to date. Significantly, however, the Ministry acknowledged that the baseload number could be set at less than 50%, and could be derived from other cost-effective non-nuclear generation options.[20] Furthermore, the Ministry's musings about these non-nuclear options (or combinations thereof) do not amount to a stringent evaluation of "need" or "alternatives to" that would justify a new nuclear project of the scale, cost and potential impact being proposed in this case;

(f) CELA submits that the reasonable range of "alternatives to" which should have been evaluated within this EA process include all forms of non-nuclear electricity generation, demand management, smart grid development, electricity imports from other jurisdictions, and energy conservation/efficiency options. It is only after this comparative exercise has been properly completed (with public/agency input) that any informed conclusions can be drawn about the "alternative to" (or combinations thereof) that can best supply the required electricity with the lowest cost, fewest adverse environmental effects, and most positive contributions to sustainability;[21] and

(g) the need for serious consideration of alternative (or renewable) energy sources by OPG was repeatedly raised by numerous participants in the JRP hearing,[22] and OPG's stock answer about its "limited" mandate is both unconvincing and unacceptable for the above-noted reasons.

18. The identification, comparison and ranking of "alternatives to" is an essential cornerstone of sound EA planning, and the range of "alternatives to" should be determined by the functions of the project, rather than the business aims of a proponent.[23] Accepting OPG's suggestion that its business mandate (or the Ministry's directive) should define the purpose of the Project unduly constrains the "alternatives to" analysis and ultimately renders the CEAA meaningless.

(c) Inadequate Consideration of Alternative Means of Carrying out the Project

19. CEAA, the EIS Guidelines, and the JRP Terms of Reference made it clear that this EA process was required to evaluate feasible "alternative means" of carrying out the project, and to develop and apply criteria for assessing the environmental effects of each "alternative means" in order to select a preferred alternative.[24]

20. In the EIS, however, OPG failed to specify which particular reactor technology that it intends to construct and operate as the centerpiece of the NNPP Project. Instead, OPG initiated the CEAA process before a vendor or technology has been selected by the Ontario government. Thus, OPG concedes that "for the purposes of this EIS, the Project is not based on a specific reactor type," but on a "set of bounding parameters that, when considered together, form the scope of the Project."

21. OPG's "alternative means" analysis within the EIS and during the JRP hearing is unreasonable, unacceptable, and unsupportable in law for the following reasons:

(a) the competitive process to procure two new nuclear reactors has been suspended by Ontario, and there is considerable uncertainty as to when this process will be completed, or which of the four proposed reactor types (if any) may be selected. Indeed, it appears that OPG is asking for open-ended CEAA approval to build up to four new reactors (not just two) at the Darlington site;[25]

(b) unless and until a vendor (and reactor type) has been selected, it is premature and virtually impossible to: (i) fully identify potential environmental effects, (ii) rigorously assess the significance of such impacts; (iii) determine whether significant adverse effects can be justified; (iv) quantify the multi-billion dollar cost of the NNPP Project; (v) assess the efficacy of proposed mitigation measures; or (vi) determine the content requirements of appropriate followup programs;[26]

(c) various governmental reviewers and interveners correctly stated that their ability to fully assess potential adverse environmental impacts was "challenged" or impaired by lack of design detail or operational information. Several of these persons also correctly concluded that "uncertainties" within OPG's "bounding" exercise precluded meaningful review of "alternative means";[27]

(d) the mandatory CEAA requirements regarding "alternative means," and comparative analysis of their environmental effects, cannot be satisfied by limited (or conceptual) discussion of such matters within this EA process;[28] and

(e) OPG failed to conduct a reasonable site selection process as part of the "alternative means" analysis, presumably because of its mistaken belief that it was duty-bound under the Minister's directive to only consider the Darlington location, rather than comply with the mandatory requirements of CEAA.

22. The analysis of "alternative means", the evaluation of their associated environmental effects, and the selection of a preferred alternative should occur only when the operational details of a project have been developed with sufficient particularity to facilitate meaningful public and agency discussion of the full range of potential environmental effects.[29] In the absence of such critical details in this EA process, CELA submits that there is no air of reality to OPG's overgeneralized discussion of environmental impacts, mitigation measures, or followup/monitoring programs.

(d) Inadequate Consideration of the Followup Program

23. Section 16(2)(c) of CEAA requires a description of "the need for, <u>and requirements of</u>, any followup program in respect of the project (emphasis added)." The EIS Guidelines also stipulated that the followup program in this case must include a robust environmental effects/effectiveness program, as well as other followup actions and compliance monitoring measures. The EIS Guidelines further specified that "<u>the</u>

followup program plan must be described in the EIS in sufficient detail (emphasis added)."[30] The JRP Terms of Reference similarly indicated that the Review would address "the requirements of a followup program."[31]

24. However, OPG failed to address this important matter adequately or at all in its EIS and in the information adduced at the JRP hearing. In the EIS, OPG presented only a "preliminary plan and scope" for developing the followup program, but the EIS itself did not contain an actual followup program, nor any detailed content that was fully responsive to the numerous items specified by the EIS Guidelines.[32] Similarly, at the JRP hearing, OPG simply asserted that "the Followup Program will be established after the EA hearing is complete."[33] Thus, while OPG appears to concede the need for a followup program, OPG failed or refused to specify the detailed requirements of an appropriate followup program at the JRP hearing.[34]

25. OPG's failure to present a sufficiently detailed followup program was duly noted by Natural Resources Canada,[35] Environment Canada,[36]and CNSC staff..[37] While these agencies offered various recommendations for the followup program, CELA submits that such recommendations fall well short of delineating a robust followup program that warrants approval of the NNPP Project.

(e) Inadequate Consideration of Sustainable Development under CEAA

26. CEAA's preamble, purpose and provisions make it abundantly clear that sustainable development is the paramount objective of the legislation.[38] Similarly, the EIS Guidelines in this case expressly required OPG to address various considerations related to sustainable development.[39]

27. However, OPG presented insufficient evidence within this EA process to substantiate its claims about sustainable development. For example, the EIS's sustainability discussion is generally limited to certain sections of Chapters 3 and 6, but primarily consists of standard sustainability definitions and self-serving tables and "scorecards".[40] More importantly, the EIS's Project-specific sustainability conclusions are overgeneralized, unpersuasive, and inherently unreliable since they are premised upon findings contained within the fundamentally flawed environmental impact assessment elsewhere in the EIS.

28. CELA submits that there is no reasonable basis upon which the JRP can conclude that the NNPP Project constitutes sustainable development, or that the Project is the best (or only) option for meeting Ontarians' electricity demands. In short, there is insufficient evidence within this EA process to demonstrate that the Project will move the province towards a desirable, resilient and sustainable energy future,[41] particularly in light of:

(a) the unknown (but likely exorbitant) quantum of the economic costs of the Project over its entire lifecycle, most of which will be borne by future generations;[42]

(b) the likelihood of (or uncertainty about) net environmental effects (i.e. air, water and fisheries), human health risks, cumulative effects, OPG's inability to ensure "zero discharge" from the Project, and "legacy" effects of the Project over its entire lifecycle (i.e. long-term storage/disposal of radioactive waste for countless generations);[43] and

(c) the undisputed and unprecedented need for careful, ongoing implementation of appropriate on-site management, off-site monitoring, and regulatory supervision of the decommissioning phase of the Project for numerous centuries.[44]

29. Accordingly, the NNPP Project represents a major – and wholly unjustified – burden upon current and future generations, especially since other less costly and less impactful alternatives for meeting Ontario's electricity demand were not seriously evaluated by OPG in these proceedings. In short, the social, economic and environmental sustainability of the Project's entire lifecycle has not been proven by OPG within this EA process. Moreover, while reduction of greenhouse gas ("GHG") emissions is often touted as a benefit of nuclear power, CELA submits that the JRP should accord no weight to GHG arguments from OPG and its supporters for several reasons: (i) such claims are not borne out by a careful examination of the carbon footprint of the full lifecycle of nuclear power production; (ii) claimed GHG benefits do not offset or excuse impacts caused by emissions of radionuclides and/or conventional contaminants into air, land and water from nuclear power plants; and (iii) an approval of the multi-billion dollar NNPP Project will significantly hinder progress on GHG gas emissions by delaying, displacing, or effectively "capping" the development of a flexible and de-centralized smart grid, or the expansion of cleaner, cheaper, and emissions-free sources of renewable energy (i.e. wind, solar, etc.).[45]

(f) Non-Compliance with the Precautionary Principle under CEAA

30. CEAA states that projects must be "considered in a careful and precautionary manner… to ensure that such projects do not cause significant adverse environmental effects."[46] Similarly, CEAA imposes a mandatory duty on decision-makers (including the JRP) to "exercise their powers in a manner that protects the environment and human health and applies the precautionary principle."[47] While the precautionary principle is undefined under CEAA, the Supreme Court of Canada has defined and endorsed the principle in the environmental context.[48]

31. CELA submits that the EIS and other information provided within this EA process fails to satisfactorily demonstrate compliance with the precautionary principle under CEAA. For example, no credence should be given by the JRP to OPG's claim that technical or scientific uncertainty was adequately addressed by "conservative" assumptions within the bounding exercise, or by creating a "hypothetical hybrid" of reactor types under consideration.[49] As described below, CELA submits that unless and until a sufficiently detailed project (i.e. reactor type/number, cooling system type, etc.) is presented by OPG, it is virtually impossible to ensure the NNPP Project has been examined and planned in a precautionary manner, as required by CEAA. Moreover,

OPG's conclusions about the precautionary principle are premised upon the questionable and incomplete environmental effects analysis within the EIS, and therefore cannot be regarded by the JRP as reliable or accurate.

32. In light of the numerous outstanding design/operational issues, CELA submits that approving the NNPP Project would be unjustified, premature, and contrary to the precautionary principle entrenched within CEAA. In particular, CELA submits that it would be the antithesis of the precautionary principle to effectively throw caution to the wind, ignore the numerous deficiencies within this EA process, and approve the Project despite the fundamental uncertainties and lack of design details outlined above. Accordingly, if the precautionary principle is to be taken seriously and properly applied in this case, then the JRP must recommend rejection of the Project under CEAA.[50]

33. Because the consequences of a very severe accident at the new nuclear reactors could result in extensive off-site emission of highly radioactive radionuclides (effectively rendering the contamination of the surrounding area irreversible for any meaningful timeframe), CELA submits that the precautionary principle must be strictly applied by the JRP. Since mitigation measures cannot avoid this risk, the only precautionary approach that would fully prevent such irreversible consequences is for the JRP to determine that the Darlington site is not suitable under NSCA, and to find under CEAA that the potential adverse impacts cannot be justified.[51]

34. Other consequential uncertainties which trigger the strict application of the precautionary principle in this case include uncertainties regarding: (i) impacts of climate change upon frequency/severity of extreme weather events (i.e. tornadoes, ice storms, etc.); (ii) ability of the centralized power grid itself to withstand major events and provide backup power to the Project's safety systems; (iii) potential problems in emergency planning or large-scale evacuations if required; and (iv) long-term storage or disposal of fuel waste. These and other uncertainties undermine the fundamental assumptions made by OPG in asserting its new nuclear facilities could overcome such matters; however, such assertions cannot be maintained with any high degree of confidence.

35. Sustainability also requires consideration of the ethical and intergenerational implications of the NNPP Project. Given that the proposal is intended to only partially meet short-term energy demands, but will leave an incredibly toxic legacy to thousands of future generations, CELA submits that the Project must be considered and rejected in that context. Similarly, it is not ethical to entertain a plan to construct a facility that will produce new nuclear waste from new reactors when there is currently no permanent solution to the high level fuel waste and other radioactive waste already being produced from existing reactors.[52]

(g) "Adaptive Management" cannot Salvage the Project

36. In certain situations, the concept of "adaptive management" may be available to address uncertainty about adverse ecological consequences, provided that there are "flexible management strategies" in place which are "capable of adjusting to new

information regarding adverse environmental impacts where sufficient information regarding those impacts and potential mitigation measures already exists (emphasis added)." [53] Thus, the CEA Agency has recognized that there are certain cases where reliance upon "adaptive management" is not appropriate.[54]

37. CELA submits that adaptive management cannot be invoked to "save" the NNPP Project for the following reasons: (i) there is no followup program described in the EIS; (ii) no specific reactor technology has been selected to date; (iii) there is insufficient evidence about environmental impacts (or their significance); (iv) the efficacy of proposed mitigation measures has not been adequately proven in these proceedings; and (v) adaptive management was only briefly discussed at a conceptual level in the EIS.[55] Thus, OPG's promise to practice post-approval "adaptive management" is both hollow and unpersuasive. Moreover, OPG's vague "adaptive management" pledge should not prevent the JRP from recommending rejection of the NNPP Project under CEAA on the grounds that OPG has failed to demonstrate that it can identify, evaluate and manage future environmental risks over the entire Project lifecycle. In short, adaptive management promises cannot trump the precautionary principle entrenched in CEAA, particularly given the proximity of the risk-laden NNPP Project to Lake Ontario, numerous communities, and agricultural lands.

PART III – CELA'S COMMENTS ON LICENCE TO PREPARE A SITE

(a) Darlington Location is Unsuitable for Granting the LTPS

Population and Emergency Planning

38. The JRP should not grant the LTPS for the NNPP Project at the Darlington location for either two or four reactors. The location is not suitable for new nuclear build at Darlington. The populations in the immediate vicinity and in the near-to-medium distance are too great even for two more reactors at the site. Development pressures are increasing and the community is growing quickly.[56],[57],[58],[59] The safety and security of the site in light of the surrounding population has been decreasing, because of the increasing population. A review of evacuation planning was conducted in the EA for only a 10 km zone around the plant.[60],[61] Evacuation of even a 20 or 30 kilometre zone around the Darlington site would be unimaginably difficult with a very large population potentially impacted. OPG has not demonstrated that emergency planning measures for very serious accidents that might require evacuation ranges of 20 to 80 km are in place or could be carried out with adequate protection of the population.[62]

39. Even just within the Region of Durham, the population at present is 620,000 people and is expected to grow to 900,000 by 2031.[63] Much of this population will be within 20 to 80 km from the site, which is a relevant distance given the lessons of the current experience in Japan (see below). This population figure is not inclusive of the municipalities to the west, east, and north of the Darlington site. The existing plan of providing merely for a 10 kilometre evacuation range is not prudent and is highly inadequate.[64] While no one wants a serious accident at a nuclear facility, this eventuality

must be considered, and properly planned for, and if it is not possible to effectively respond to it, then the new reactors must not be built in this location.[65]

40. OPG evaluated only the potential evacuation of a 10 km range, and only assessed the time required to move residents and occupants to a distance at the perimeter of that range. There was no evaluation of the time that would be required to move those residents to the actual evacuation centres in Peterborough and Toronto (which are 50 to 80 km distances from Darlington[66]). No evaluation of evacuation of 20, 30 or 80 km ranges was provided;[67] yet these are the ranges used in the current Japanese nuclear incident by the Japanese government (20 km and 30 km), the U.S. government (50 miles or 80 km) and the Canadian government (80 km). There is no basis in the record for the JRP to find that such evacuation distances could or would be managed appropriately around Darlington in case of a serious accident in order to provide for public safety.[68]

41. In this EA and LTPS application, there has been: (i) no analysis of where residents from this broader vicinity would go for evacuation shelters; (ii) no evaluation of transportation mechanism/routes beyond 10 kilometres (subject to only a limited evaluation of a fifteen km shadow zone in case people opt voluntarily to leave); and (iii) no planning, rehearsal, or provision of emergency supplies for such scenarios. In short, there is insufficient evidence that there are any facilities or locations that could absorb and shelter the numbers of people who would be affected by 20, 30 or 80 km evacuation zones surrounding the Darlington facility. No consideration whatsoever has been given as to how food and safe water would be provided to sizeable populations fleeing from these larger evacuation zones. The JRP must find that these potential effects are too significant to justify granting the LTPS. This finding would be consistent with IAEA Site Evaluation Guidance.

Proximity to other Reactors and High Level Used Fuel Increases Risk

42. The JRP should not grant an LTPS for a location in which new nuclear reactors and their used fuel storage will be aggregated at the same site where there are existing reactors. As demonstrated by the catastrophic accident at Japan's Fukushima Daiichi plant, proximity of multiple reactors in one location leads to much higher potential for disaster in the event of unexpected calamity. Furthermore, the proximity of the high level used fuel storage, even if on an interim basis, massively compounds the high hazard.[69] Hazard from proximate reactors is a highly foreseeable danger and the consequences of such poor planning should be avoided by refusing to allow even more reactors to be added to the four presently in operation at the site. As IAEA Document NS-R-3 states, when "installed nuclear capacity is to be significantly increased, the suitability of the site shall be re-evaluated."

(b) Inadequate Consideration of Risk of Accidents and Malfunctions

Accident/Malfunction Risk is Central to JRP's Decisions

43. In the EIS and at the JRP hearing, the consequences of a severe accident at a new reactor at Darlington were inadequately considered and unpersuasively dismissed by OPG and CNSC reviewers on the basis that there will be future evaluations of safety.[70], [71],[72]. However, accident/malfunction risk is central to the EA itself, which must cover all phases of licensing. The EIS Guidelines explicitly required consideration of risk of accident and malfunction. Accident risk is also central to the NSCA decision on whether to allow the siting of new nuclear reactors at this location. Thus, risk is a central question for the current application for the LTPS, and is a matter squarely before the JRP. According to RD-346, worst case scenarios and maximum *possible* releases (emphasis added) are required to be evaluated,[73] particularly for emergency planning purposes and consideration of local populations. The inadequate consideration of accident/malfunction risk requires the JRP to recommend against approval of this Project under CEAA, and to refuse to issue the LTPS to OPG.

Inadequate Consideration of Accident/Malfunction Risk

44. OPG consistently downplayed and denied risks (or consequences) of very serious accidents, malfunctions, or malfeasance. However, OPG has only provided generic reassurances based on its probabilistic analysis and a general understanding of the type of modelling used for such analysis. CELA submits that there is no basis before the JRP to accept the OPG analysis since, as noted by Mr. Pereira, the "core damage frequencies and large release frequency data are not as yet available for all of the reactor technologies under consideration."[74] The fact that there is a general understanding of modelling methodology is not an adequate substitute for the Panel to reach its own conclusions on accident/malfunction risks.

45. The indisputable fact that catastrophic accidents can happen at nuclear power plants must be admitted, accepted, and the potential consequences evaluated. The opposite is the approach taken in this EA and this LTPS.[75] OPG repeatedly refused to clearly acknowledge that catastrophic accidents, with extensive off-site release of radioactive materials, are possible at the Darlington site.[76],[77],[78] This approach is contrary to that indicated in the IAEA Guide *Site Evaluation for Nuclear Installations*,[79] which states that site evaluation is primarily concerned with "severe events of low probability."[80] Catastrophic accidents must be considered possible in the event that: (i) OPG's probabilistic calculations erred; (ii) there was missing information; (iii) OPG's defence in depth and redundancies failed; or (iv) a combination of unanticipated events led to large releases.[81] Thus, the JRP is left without essential information necessary to its deliberations and the fulfillment of its statutory duties under CEAA and NSCA.[82] It is neither logical nor prudent to grant CEAA approval or an LTPS Licence in the absence of a comprehensive evaluation of the consequences at this location if things go terribly wrong at a new nuclear reactor – that is, beyond the probabilistic analysis.

Unexpected Events Occur

46. Unfortunately, despite computer modelling, engineering design, and probabilistic analysis, the potential for catastrophic events is reasonably foreseeable upon existing information. A current example is the calamity in Japan and the combination of events which led to the crisis, including the location of high level fuel storage as a source of criticality. The engineers in Japan had designed to a very high magnitude earthquake, (i.e. M8.2), but a M9 earthquake struck in the nearby seabed.[83] Furthermore, recent nuclear accidents suggest that it is the unanticipated combinations of events (rather than single isolated events) which result in the most major calamities. Ontario may not encounter an earthquake of the magnitude that occurred in Japan, but it is not inconceivable that Ontario may experience a combination of events that leaves centralized power systems out of service for unknown lengths of time, rendering the backup power plans helpless to maintain critical safety systems.[84],[85] Severe natural catastrophes causing major power failures have occurred in the past decade (i.e. the major ice storm in Ontario and Quebec in 1998; the massive grid failure across eastern North America in 2003, etc.). This is not hypothetical speculation; in the latter example in 2003, one of OPG's operating nuclear reactors was left without backup power for about five hours.[86]

47. OPG advised the JRP that its backup power systems can provide up to three days of power.[87] However, there may be multiple events which challenge the sufficiency of such technical contingency measures. The point here is not to recite plausible scenarios (i.e. severe natural event combined with cascading infrastructure failures), but to stress that despite best efforts in planning, prediction and engineering, unexpected sequences that overwhelm these complex systems, or that exceed even conservative engineering, can and do occur. As a result, a proposal in which the consequences of such failures are unacceptable (as in this case) must be denied.

(c) Safety Systems May Fail

48. When evaluating the suitability of the Darlington site, the JRP must also consider the sufficiency of the evidence in respect of safety systems. It is neither adequate nor appropriate for the JRP to make a decision in reliance upon assumptions of perfect performance of all safety systems. Safety systems may also fail for a variety of reasons, and the same considerations reviewed above may render safety systems incapable of preventing catastrophic results. In addition, part of the system may perform as hoped (i.e. shutdown of fission reaction in the reactor), but this may not necessarily deal with the ongoing need for cooling and removal of heat to prevent re-initiation of fission reactions in the fuel (as occurred in the Japanese accident[88]).

49. While a few passive safety system examples were mentioned in evidence,[89] it was not stated whether any of the potential technologies could operate with entirely passive systems; nor whether there is sufficient backup or redundancy if they themselves fail.[90] While passive safety systems are laudable, the JRP cannot conclude that there are any

entire reactor designs operating, nor within the set of designs before the Panel, which are entirely passive. Large consequence accidents may occur despite these systems, and the timeframes that are available to provide passive safety may be limited without other intervention.[91]

(d) Unacceptable Consequences of Accident Risk at Darlington Location

50. The information in the JRP record outlines the range of radionuclides (source term) which would potentially be released in case of a catastrophic accident at the Darlington site. For example, these substances could include Iodine 131 and Cesium 137.[92], [93] Other radioactive isotopes which could be released in an accident are listed in the OPG dose consequence analysis, such as Cobalt 60, Strontium 90, and numerous other radionuclides.[94] However, as noted earlier, the analysis conducted for this EA and licencing application assumes "bounded" scenarios and not catastrophic scenarios. CELA submits that the JRP must consider the possibility of even more serious accidents, as provided in IAEA Standard NG-G-3.2 dealing with consideration of population distribution in site evaluation.[95] The presence of these radionuclides in the reactor core – or other similar lists for the other reactors under consideration – constitute a high hazard for the surrounding population, thereby indicating that this is not a suitable location for new reactors.[96]

51. While it is not conceded that the Darlington location would be an appropriate site even without existing reactors, CELA strongly submits that the addition of new reactors to a location already holding multiple reactors makes the site completely unsuitable. Any consequences and risks from accidents would be magnified by their proximity to multiple sources of material which can achieve critical chain reactions, both in reactor cores and in used fuel storage. Serious damage to one building or facility is not only a massive risk for that reactor, but it also becomes a massive risk to a neighbouring reactor facility simply due to proximity. Thus, the JRP should find that the site's proximity to large and growing population centres further renders this combination of activities and risks completely unacceptable.

(e) Frequency of Severe Accidents

52. As discussed above, unexpected sequences of events do occur despite modelling and planning. The nuclear power experience to date demonstrates this unfortunate fact (i.e. Three Mile Island in 1979; Chernobyl in 1986; and Fukushima Daiichi in 2011), which only takes into account the most serious of recent nuclear accidents. If earlier severe accidents are considered, the frequency rate is even higher.

53. Probabilistic safety analysis does not guarantee that severe nuclear reactor accidents will never happen. They may happen, and very unfortunately, they do happen.[97] The JRP must make its decision regarding the suitability of the Darlington site on the basis of this reality in terms of risk. In short, the JRP should take a precautionary approach and accept that it is both possible and conceivable that a severe accident on the

scale of calamity could occur in this location from the construction and operation of the NNPP Project.

54. Furthermore, the JRP must find that there are no appropriate measures which can mitigate the potential adverse impacts on populations from a worst case severe accident (or even any less severe accident that nevertheless escapes containment) at the Darlington site that causes a 30 to 80 km evacuation zone to be implemented. There is no evidence before the Panel to substantiate that such an evacuation could be managed, mitigated and the population adequately protected, since this type of scenario was not evaluated in these proceedings. In this regard, a finding by the JRP that the site is unsuitable for new nuclear reactors would be consistent with the IAEA *Safety Standard for Site Evaluation for Nuclear Installations*, NS-R_3.[98] The JRP has no basis on the record to conclude that the radiological risk to the population is acceptably low in the case of very severe accidents with large releases of radioactive materials from containment and beyond the plant boundaries.

(f) Unsuitable Location due to Fuel Waste and other Radioactive Waste

55. The JRP should refuse to grant the LTPS to OPG because there is inadequate provision for interim, short- and long- term storage and handling of high level radioactive spent fuel waste. OPG proposes to add additional high level radioactive waste to the Darlington location for an unspecified time, while longer term options are pursued.[99] This alone creates an unacceptable level of risk at one location, as demonstrated by the Japanese accident.[100] Furthermore, it cannot be assumed, as OPG has done, that there will be any other provision for any high level radioactive spent fuel waste, existing or new.[101], [102]

56. This EA process does not cover any other proposal for fuel waste storage or disposal. Accordingly, the question of whether this location can accommodate and properly provide for the safety and protection of the environment and human health must be fully resolved before the JRP can recommend approval of the NNPP Project under CEAA, or any LTPS can be granted under NSCA. However, the information provided by OPG to date has not adequately answered this question.[103] For example, OPG claimed that it could safely handle the fuel waste on the Darlington site for the hundreds of thousands of years for which it would remain highly toxic, hazardous and a risk to the environment and humanity.[104] This claim should be recognized by the JRP as unsubstantiated and untenable. No human technology has survived such vast timeframes; indeed, no form of known human civilization has yet survived such timeframes.

57. Transportation and storage of low, intermediate, and high level radioactive waste were inadequately considered and described in these proceedings, and the site was not shown to be suitable for these activities over the necessary timeframe of 60 years of operation, decommissioning, and ultimately the hundreds of thousands of years of toxicity of the intermediate and high level waste to be produced by the site. Failure to do so was contrary to the Siting Guideline (RD-346) section 8.2.

58. Moreover, it cannot be assumed that other off-site waste storage or disposal (i.e. the Deep Geologic Repository) will be available for low and intermediate waste since that proposal has not yet been approved; nor should it be assumed that the proposed DGR facility can or will take waste from new build nuclear at the Darlington site.[105]

59. With respect to nuclear waste matters associated with the NNPP Project, CELA hereby adopts and commends the submissions of Northwatch in these proceedings.

(g) Unsuitable Location due to Accident Risk to Ontarians' Drinking Water Supply

60. The Darlington location is unsuitable for the issuance of the LTPS because of the risk of accidents arising from the site's proximity to the drinking water supply for millions of Ontarians. Water treatment plants do not typically treat for removal of radioactive materials. A serious accident with major off-site releases of radioactive materials such as those listed in the Dose Consequence Analysis[106] may see much of that material deposited in Lake Ontario on whose shoreline the reactors would be sited. There is no reasonable alternative to this drinking water source if it is rendered unusable due to a nuclear mishap. Accident/malfunction risks have not been examined in these proceedings in terms of releases to drinking water.[107] Accordingly, the JRP has no basis on which to conclude that the impacts will be fully mitigated or are otherwise justified, which are among the most fundamental questions before the JRP under CEAA. As noted above, this critical matter cannot be deferred to a later Licence to Construct under NSCA since these questions are now squarely before the JRP under CEAA.

61. Very severe accidents which release large portions of the "source term" of radioactive materials contained in reactor cores have not been modelled or examined in these proceedings. Similarly, very severe accidents dealing with the used high level fuel on-site (and their potential impact on drinking water supplies in Lake Ontario) have not been adequately modelled or examined. In addition, potential impacts on inland water supplies (both groundwater and surface water), and downstream surface water along the St. Lawrence River, mean that a serious accident would massively impair the safety of the drinking water supplies of millions of people in the central heartland of Canada and neighbouring jurisdictions (i.e. Quebec and New York State).

62. In these proceedings, the review of impacts on drinking water supplies from very severe accidents, taking account of all users of Lake Ontario for drinking water as well as other drinking water sources potentially impacted, is not sufficient compared to the provisions of the IAEA guidance document *Dispersion of Radioactive Materials in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants*, Safety Guide NS – G – 3.2. In addition, these potential long-term impacts cannot justified in light of the fleeting "benefits" of using the Darlington site to provide a relatively small portion of Ontario's power requirements, particularly when there are viable non-nuclear alternatives, as discussed above.

63. OPG has not demonstrated that the NNPP Project, as presently formulated, would ensure protection of all surface and groundwater supplies, and in particular, drinking

water supplies, as noted by CNSC staff during the hearing. This is, in part, because of the lack of selection of a particular reactor technology.[108] As a result, CNSC staff noted that this would have to be assured at the stage of an application for a Licence to Construct under NSCA. However, CELA submits that this is not an appropriate question to defer to a later Licence, and is one of the central issues on which the JRP must make a finding at this time.

64. In relation to water quality and fisheries impacts arising from the NNPP Project, CELA hereby adopts and commends the submissions of Lake Ontario Waterkeeper in these proceedings.

(h) Unsuitable Location due to Routine Emissions of Radioactive Materials

65. Even in the absence of accidents, routine emissions of radioactive materials make this location completely unsuitable for an LTPS.[109] It is admitted by OPG that in routine operations, each of the proposed plant designs would release a long list of radioactive nuclides.[110] For example, tritium is released from the condenser cooling system radioactive liquid waste management system.[111] In addition, there are leaks from the service water system from time to time.[112]

66. It is also admitted by the CNSC that the "linear no threshold relationship model" is the most appropriate model for calculating cancer and other health effects from exposure to radioactive nuclides.[113] There is a large and growing population in the vicinity of the site.[114] The JRP heard much evidence, concern, and a high level of uncertainty regarding elevated health risks, and increased risk of leukemia, in the vicinity of nuclear plants. On a linear no threshold model (i.e. no lowest dose where effects do not occur), the JRP must find there will be health impacts arising from the NNPP Project. This is because there are admitted routine emissions of a long list of radioactive nuclides, and the most appropriate model indicates effects at any dose on a linear basis.[115]

67. In light of: (i) the high level of uncertainty and public concern regarding the health impacts of the existing reactors, as well as of the proposed new reactors; (ii) the very serious nature of the potential health effects from radioactive emissions during routine operations and incidents or spills (i.e. cancers and leukemias); and (iii) the lack of a lowest dose threshold at which safety should be assured, CELA submits that the population in the vicinity of the Darlington site should not be exposed to the inevitable additional impacts to population health that will result from additional operating reactors.

68. Tritium emissions to air and to drinking water are a hallmark of the CANDU designs due to their use of heavy water. Similarly, with a no lowest dose model, health impacts from these emissions must be found by the JRP to be likely on the basis of the evidence before the Panel. In addition to routine emissions, there are additional health impacts from spills or accidental emissions of tritium from the plant, and these happen with some regularity, such as occurred during the hearing itself.

(i) Lessons from Japan related to Siting New Nuclear Reactors at Darlington

69. The Panel heard a presentation early in the hearing regarding "initial lessons" from the Japanese tragedy. CELA submits that it is far too early to learn any complete lessons from the tragic events in Japan.[116] However, the first and most obvious lesson is that there must be acceptance of the reality of the potential for very catastrophic accidents that exceed the design basis for a nuclear plant. Thus, the key question for the NNPP Project is whether the consequences of such catastrophic accidents would be acceptable at this location – is this a suitable site at which to allow for the potential of such an accident? In answering this question, it is insufficient for the proponent (or JRP) to simply assert that such accidents will not or cannot happen at the Darlington site, or that such accidents have been considered and found to be not "credible".

70. Instead, this question must be faced directly: is locating new reactors at Darlington justifiable, in light of the potential adverse effects of a very serious accident? Would other unfortunate lessons from Japan then apply? Would the fact that emergency and evacuation planning has been limited to 10 kilometres (despite a vast nearby population extending into the GTA) result in an inability to ensure that radiation limits for the public could be met? Would there be an ability to provide full, timely and accurate information to the public? Would the scale and difficulty of the task of protecting the sizeable nearby population even be possible? On the evidence, the JRP cannot conclude or assume that these critically important matters would be appropriately addressed, particularly since the analysis and planning presented to date by OPG has been limited to smaller accidents (i.e. those which do not exceed regulatory limits at the plant boundaries) and smaller evacuation zone (i.e. 10 km).

(j) Failure to Select Reactor Technology for the Darlington Site

71. As noted above, CELA submits that it is inappropriate and premature to proceed with this EA without a choice of reactor technology, primarily because this approach does not allow a credible or complete evaluation of the environmental effects of the Project or the ability to have those effects fully mitigated[117]. This has been borne out by reviewers who have noted how difficult or impossible it is to do an evaluation with no choice of technology.[118] In short, the assurances and representations made by OPG that it can mitigate all environmental effects in a satisfactory manner are speculative, and are not built upon an appropriate evidentiary foundation.

72. Contrary to the opinion of CNSC staff,[119] CELA submits that the utilization of a Plant Perimeter Envelope ("PPE") or "bounding" approach is neither appropriate nor sufficient for the approval of an LTPS under NSCA. Nor is the PPE approach appropriate or sufficient to provide a proper foundation or evidentiary basis for the Panel to find under CEAA that there will be no significant adverse environmental effects, or, for those which cannot be mitigated, that such effects are justified. The PPE approach also creates considerable difficulty in terms of testing the information, and in terms of determining the relevance to the subsequent licensing stages, for the purposes of ensuring that the Panel can meet its mandate in reviewing the EA for the Project as a whole.[120]

73. It became evident late in the process that a fourth reactor technology (i.e. the CANDU 6) was under consideration, and the inadequacy of the PPE approach was demonstrated once this option became a possibility. There was a major lack of information about the CANDU 6 in the EIS because it was not originally one of the potential reactor technologies under consideration, and this lack of information continued into the JRP hearing. There was a late change to the PPE to deal with the CANDU 6, but very limited technical review and assessment was undertaken in relation to this technology within this EA. For example, there was: (i) a lack of an equivalent amount of information in the EA about the CANDU 6 compared to the other technologies: (ii) late provision of the limited information that was generated; and (iii) an inability for interveners' experts to meaningfully review the CANDU 6.

PART IV – CONCLUSIONS

74. For the foregoing reasons, CELA submits that the JRP Report under CEAA should recommend that the NNPP Project not be approved on the basis of record currently before the JRP.[121] By any objective standard, the EA documentation tendered to date in these proceedings can only be regarded by the JRP as fundamentally incomplete in light of the numerous gaps, deficiencies and omissions identified by public/agency reviewers throughout the JRP proceedings.

75. CELA further submits that the JRP should not recommend conditional approval of the NNPP Project under CEAA or the NSCA. In short, terms and conditions proposed within the JRP Report, or developed within subsequent licencing processes, cannot excuse or remedy blatant non-compliance with mandatory EA requirements prescribed by CEAA, the EIS Guidelines, and the JRP Terms of Reference. Since these EA requirements were not properly satisfied within this EA process to date, CELA submits that it would be premature, inappropriate, and contrary to the public interest for the JRP to recommend conditional approval of the NNPP Project, or to defer the substantive content of such conditions to a future date.[122]

76. Accordingly, CELA respectfully requests that the JRP reject the NNPP Project under both CEAA and NSCA.

May 17, 2011

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END NOTES

[1] CELA, "Review of Alternatives in Darlington New Build Environmental Impact Statement"; October 7, 2010) PMD 11-P1.116; Transcript, Vol. 13, pp. 195-242.
[2] CEAA, subsections 16(1) and (2); EIS Guidelines, section 7.1.
[3] *Alberta Wilderness Association* v. *Cardinal River Coals Ltd.* (1999), 30 C.E.L.R. (N.S.) 175 (Fed.T.D.) at paras. 39-41, 52.
[4] JRP Agreement (January 29, 2009), sections 2.2, 4.1(a), 4.2, and Appendix, Part IV; CEAA, section 34.
[5] Final EIS, section 1.1.3.
[6] Transcript, Vol. 13, pp.227-32, 273-75.
[7] Transcript, Vol. 16, pp.67-68.
[8] Ontario Clean Air Alliance Answer to Undertaking 47; Greenpeace, "Presentation to Joint Review Panel", PMD 11-P1.221A, pp.5-14; PMD 11-P1.221, pp.14-15; ; R.Torrie and D.Morrow, *Review of Ontario Load Forecast in the IPSP* (August 14, 2008), pp.2-8; and *Renewable is Doable* (August 2010).
[9] *Electricity Act, 1998*, S.O. 1998, c.15, Sch.A, section 1 and Part IV.1.
[10] Transcript, Vol. 13, pp.198-99; *Friends of the West County Association v. Canada* (2000), 31 C.E.L.R. (N.S.) 239 (Fed.C.A.) at paras.25-26.
[11] Transcript, Vol. 13, pp.208-09.
[12] *Electricity Act, 1998,* S.O. 1998, c. 15, Sch. A, section 25.30(4); Transcript, Vol. 5, pp.156-57, 209-10, 218-19; Transcript, Vol. 7, pp.124-25; Transcript, Vol. 13, pp.201-203; Transcript, Vol. 16, pp.232-34; Transcript, Vol. 17, pp.146, 160-61.
[13] Transcript, Vol. 13, pp.207-08.
[14] Transcript, Vol. 13, pp.199-200, 211-13.
[15] *Re West Northumberland Landfill Site* (1996), 19 C.E.L.R. (NS) 181 (Ont.Jt.Bd.), paras.88,90.
[16] CEAA, section 16(1)(e); EIS Guidelines, section 7.2; JRP Agreement (January 29, 2009), Appendix, Part IV.
[17] Final EIS, section 1.1.4.
[18] Transcript, Vol. 13, pp.227-32.
[19] *Re Metropolitan Toronto (Finch Avenue West) Road Extension Application* (File No. EA 87-01) (Ont.Jt.Bd.), page 13.
[20] Transcript, Vol. 16, pp.18-25, 36-39.
[21] Transcript, Vol. 13, pp.205-06.
[22] Transcript, Vol. 4, pp. 307-08, 314-15; Transcript, Vol. 5, p.216; Transcript, Vol. 6, p. 205; Transcript, Vol. 7, pp.38-39; Transcript, Vol. 8, pp.76, 187-89; Transcript, Vol. 9, pp.43, 203, 223, 226-30; Transcript, Vol. 10, pp. 27-28, 115-16, 125-26, 233, 235-39, 258; Transcript, Vol. 11, p.17, 210, 213-15, 226-27, 275-76; Transcript, Vol. 12, pp.126-27, 158-59, 175-76, 199, 201-04; Transcript, Vol. 13, pp.57-58, 174-75; Transcript, Vol.14, pp.155-56, 266-67; Transcript, Vol. 15, pp.76-80, 127; Transcript, Vol. 16, pp.191-92, 343-45; Transcript, Vol.17, pp.151-56, 195, 205.
[23] *Re SNC Inc. Proposed EFW Facility Application* (File No.CH-87-01) (Ont. Jt.Bd.), p.30; Transcript, Vol. 13, 204-05.
[24] CEAA, section 16(2)(b); EIS Guidelines, section 7.3; JRP Agreement (January 29, 2009), Appendix, Part IV.
[25] Transcript, Vol. 3, pp.131-32; Transcript, Vol. 5, pp.171-72, 212-13; Transcript, Vol. 17, p.149.
[26] Transcript, Vol. 13, pp.212-14.
[27] Environment Canada, "Written Submission of the Department of Environment" (January 31, 2011) PMD 11-P1.6, pp.9-10, 18, 20, 24-26, 28-29, 35-39, 41-43, 60; Environment Canada, "Presentation to Joint Review Panel" (March 23, 2011) PMD 11-P1-6A, pp.14-17, 21; Fisheries and Oceans Canada, "Written Submission from Fisheries and Oceans Canada" (January 31, 2011) PMD 11-P1.7, pp.9, 12; Health Canada, "Written Submission of Health Canada" (January 31, 2011) PMD 11-P1.8, pp.4, 6-11; Ministry of Natural Resources, "Written Submission from Ministry Of Natural Resources" (January 28, 2011) PMD 11-P1.14, p.2; Transcript, Vol. 2, p.27; Transcript, Vol. 3, pp.239, 241, 272, 279, 294; Transcript, Vol. 4, pp.43-44, pp.321-22, 324, 328, 394; Transcript, Vol. 7, pp.102-03, 115-123; Transcript, Vol. 8, pp.30, 175-76; Transcript, Vol. 10, pp.64, 188-89; Transcript, Vol. 11, pp.14-15, 26-27, 31, 136-37, 187, 209-10, 286; Transcript, Vol. 12, p.176; Transcript, Vol. 13, p.56; Transcript, Vol. 14, pp.88, 93, 138-39, 256-57; Transcript, Vol. 15, pp.125, 201-02, 207; Transcript, Vol. 16, pp.276-77.

[28] *Alberta Wilderness Association* v. *Cardinal River Coals Ltd.* (1999), 30 C.E.L.R. (N.S.) 175 (Fed.T.D.) at para.80.
[29] *Friends of the Island Inc. v. Canada* (1993), 10 C.E.L.R. (NS) 204 (Fed. Ct.), para.41; Joint Review Panel Report: Whites Point Quarry and Marine Terminal (2007), pp.25-26.
[30] EIS Guidelines, section 15.
[31] JRP Agreement (January 29, 2009), Appendix, Part IV.
[32] Final EIS, Chapter 11.
[33] OPG, “Written Submission from OPG” (January 31, 2011) PMD 11-P1.1A, p.7.
[34] Transcript, Vol. 1, pp.177-78; Transcript, Vol. 13, p.151.
[35] Natural Resources Canada, “Written Submission from Natural Resources Canada” (January 31, 2011) PMD 11-P1-9, p.4; Transcript, Vol.13, pp.149-50.
[36] Environment Canada, “Written Submission of the Department of Environment”(January 31, 2011) PMD 11-P1.6, Chapter 8 (Summary of Recommendations); Transcript, Vol. 3, pp.239-40.
[37] CNSC, “Written Submission from CNSC” (January 31, 2011) PMD 11-P1.3, pp.5, 160, and Recommendation #27.
[38] CEAA, preamble, sections 2, 4(1)(b) and 4(2); B.Hobby et al., *CEAA: An Annotated Guide* (Canada Law Book, looseleaf), pp.II-26-26.1.
[39] EIS Guidelines, section 2.4.
[40] Final EIS, sections 3.2.6 and 6.1.
[41] Transcript, Vol. 6, pp.198-99, 202, 205; Transcript, Vol. 8, pp.176-78.
[42] Transcript, Vol. 8, pp.189-92; Transcript, Vol. 9, pp.223-24, 226, 245; Transcript, Vol. 10, pp.107-08, 121-22, 131-32, 202, 233-35; Transcript, Vol. 11, pp.17, 141, 180, 290-91; Transcript, Vol. 12, p.190; Transcript, Vol. 15, pp.55-56, 61, 72-77, 83; Transcript, Vol. 16, pp.249-52; Transcript, Vol. 17, pp.156, 196.
[43] Transcript, Vol. 7, pp. 17-18, 21-24, 56-57, 105-115, 130-31, 139-40, 173-74, 233-35; Transcript, Vol. 8, pp.14-18, 26, 37-39, 44-50, 83-84, 282; Transcript, Vol. 9, pp.33-35, 128; Transcript, Vol. 10, pp.52, 81, 192, 194-96, 198-99, 201, 228, 273; Transcript, Vol. 11, pp.177-78, 183-84, 283-84; Transcript, Vol. 12, pp.205-06; Transcript, Vol. 14, pp.87-88, 202-03; Transcript, Vol. 16, pp.203, 247-49; Transcript, Vol. 17, pp.156-57.
[44] Transcript, Vol. 8, pp.70-71, 75, 161-65; Transcript, Vol. 9, pp.35-36; Transcript, Vol. 10, pp.33, 36, 128, 267-68.
[45] NIRS Answer to Undertaking 58; Transcript, Vol. 7, pp.36-38; Transcript, Vol. 8, pp.174-75, 178-80, 182-86, 210-12; Transcript, Vol. 9, pp.94, 201, 233-35; Transcript, Vol. 10, pp.18-20, 91, 112-13, 118, 120, 135-38, 186-87, 202-05, 216, 232-33, 270-71; Transcript, Vol. 11, pp.12-13, 154-59, 214, 230, 276; Transcript, Vol.12, pp.108-09, 130, 206-07; Transcript, Vol. 13, pp.82-83, 177-82; Transcript, Vol. 14, p.262; Transcript, Vol. 15, pp.130, 198-200; Transcript, Vol.16, pp.229-32, 235-39, 350-52; Transcript, Vol. 17, pp.120-24, 151.
[46] CEAA, preamble, section 4(1)(a).
[47] CEAA, section 4(2).
[48] *11497 Canada Ltee v. Hudson,* 2001 SCC 40 at para.31.
[49] Final EIS, section 3.2.7.
[50] Transcript, Vol. 9, pp.38-39; Transcript, Vol. 10, pp.89-90, 132, 148; Transcript, Vol. 11, pp.279-81; Transcript, Vol. 13, pp.80-81; Transcript, Vol. 14, pp.95-96.
[51] Compare to evidence of CEAA witness Mr. Leboeuf, at Transcript, Vol. 2, p. 19, line 5 to p. 20 line 7.
[52] Transcript, Vol. 11, Mr. Roche, pp.35, 36, 50; Transcript, Vol. 17, Dr. Rutherford, p. 118.
[53] *Pembina Institute for Appropriate Development v. Canada* (2008), 35 C.E.L.R. (3d) 254 (F.C.), paras. 32-33, 56.
[54] CEA Agency, *Operational Policy Statement: Adaptive Management Measures under CEAA* (March 2009).
[55] Final EIS, sections 3.2.5 and 11.3.
[56] Transcript, Vol. 3, p.113 line 21 to p.117 line 12 .
[57] Transcript, Vol. 3 .p.122 lines 3 to 9 (Mme Beaudet noting new residential development already under construction in relatively close proximity to the Darlington site); Transcript, Vol. 4, pp.174 to 177 (Mme Beaudet asking questions of Mayor Foster).

[58] While the JRP members explored the question about how to ensure that the population even in the immediate vicinity of the site does not continue to grow such that emergency planning would be compromised, and greater numbers of people would be impacted in the event of a serious emergency, no adequate information or evidence was provided to the Panel on this point; rather, it was evident that there is no sufficient regulatory control over this question: Transcript, Vol. 4, pp.87-102 (questions by Mme Beaudet, Mr. Pereira, and Chair Graham; the Ministry of Municipal Affairs and Housing and CNSC do not exercise regulatory control over development applications within specified distances of proposed or operating nuclear reactors; Transcript, Vol.4, pp.174-177 (plans for residential development are proceeding closer to the site than is supported by the local Municipality in part because approval authority is at a different level of local government). See also Transcript, Vol. 5, pp.66- 67 (Mr. Hefkey, advising that Emergency Management Ontario does not control land use decisions affecting population growth in the vicinity of the existing or proposed new nuclear reactors and takes the decisions of others as a "given"); and Transcript, Vol. 5, pp.77-81 (Mr. Hefkey, despite further questioning from the Chair, confirming that their input to municipal planning decisions is limited and primarily their role at EMO consists of determining that they are asked to plan for 3 km contiguous zone and 10 km primary zone,although municipal representatives sit on their emergency planning committees). See also Transcript. Vol. 5, p..94, lines 11-22 (Mr. Hefkey confirmed that the emergency planning legislation in Ontario, the *Emergency Management and Civil Protection Act*, does not have any provision as to population densities that would be precluded in the vicinity of a nuclear power plant).

[59] Transcript, Vol. 4, p.150, Mayor Foster, lines 19-20 ("We [Municipality of Clarington] are one of the fastest growing communities within the GTA and southern Ontario." Clarington hopes to grow from its current 86,000 people to 140,000 people by 2031; a fifty percent increase in population: *Ibid.*, pp 150- 52.

[60] Transcript, Vol. 3,p.159 line 20 to p.161 line 10 (Mr. Richardson and Ms. Swami); See also CMD 11-P1.2 (CNSC staff report), p. 64.

[61] Transcript, Vol. 4 , p. 71 lines 7 to 11 (Ms. Swami).

[62] Despite the evidence of Mr. Hefkey at Transcript, Vol. 5, pp. 96-97, no assessment of evacuation beyond 10 km has been done for this EA; see evidence cited at endnotes 60 and 61. At best, Mr. Hefkey's testimony about the usefulness of the provincial plan could be considered wishful thinking as there is nothing before the panel demonstrating that hundreds of thousands or millions of people who live within, for example, 80 km of the Darlington site could be evacuated and housed in communities like Belleville or Kingston. Furthermore, an 80 km evacuation range would also extend to the west of the Darlington site, encompassing very large populations which presumably would not be evacuated through routes closer to the site and there is no planning or evaluation in the EA as to where these populations would be evacuated.

[63] Transcript, Vol. 4, pp. 224-27 (question by Chair Graham).

[64] The finding as to whether the site is suitable in order to provide a basis for issuance of a Licence to prepare the site for construction and operation is a matter for the Panel, and not Commission staff. Determination as to suitability must be made by the Commission based on the information available to it, and not based on CNSC staff opinions which are not binding on the Panel. Where information is not available to support the finding of suitability, CELA submits that the Panel must reject the Licence application.

[65] See International Atomic Energy Agency Safety Standard Series, Site Evaluation for Nuclear Installations, NS-R-3 (referenced by the CNSC in RD-346 as providing Guidance to the Canadian Guide).

[66] Transcript, Vol. 5, p.101 (Mr. Hefkey); and *ibid* ., Mr. Hefkey confirmed that the time to actually get to evacuation centres is highly variable and dependant on many conditions and only the time to arrive at the perimeter of a 10 km range from the plant has been evaluated "they're going to take whatever time they're going to take to get there."

[67] Transcript, Vol. 1, pp.199-200 (Ms. Swami). Ms. Swami added that they also did a 15 km "shadow" evacuation analysis (but with no assessment of the time for that extra 15 km to evacuate) – but not beyond that: Transcript, Vol. 4, p.110 (Ms. Swami).

[68] Transcript, Vol. 3, p.157 line 8 to p.15 line 19 (Dr. Thompson confirming that the only scenarios evaluated for evacuation were those in which a population may have to be relocated up to 1 km from the facility (i.e. plant boundary); that more serious accidents with greater distances for evacuation would not meet the regulatory requirements of the Licence to construct, RD-337. See also CMD 11-P1.2 (CNSC staff report), p. 61.

[69] Transcript, Vol. 2, p.84 line 20 to p.85 line 2 (Mr. Frappier).

[70] Transcript, Vol. 2, p.90 lines 13-17 (Dr. Newland).
[71] Transcript, Vol. 2, p.109, lines 5-13 (Mr. Frappier).
[72] Transcript, Vol. 3, p.100, lines 5-20 (Mr. Howden).
[73] RD 346 section 5.4.
[74] Transcript, Vol. 2, pp. 235, 236 (Mr. Pereira question to Dr. Newland).
[75] For example, as noted by Environment Canada: "With respect to atmospheric releases, the atmospheric dispersion modelling was appropriately conducted for the two accident scenarios that were included in the EIS; however, we would point out that an accident scenario involving a high-temperature release of radionuclides was not conducted; in our view remains a gap. And, given the events that are happening in Japan, we would put forward the consideration that such a scenario would be modeled": Transcript, Vol. 3, p.247 lines 4 to 15 (Mr. Dobos); see also Transcript, Vol. 3, p.293. Undertaking 16 by CNSC staff concluded that temperature of the plume would be relatively insignificant, but re-confirmed that only a particular set of accidents that fit the "bounding" scenarios – i.e. up to one in a million predicted frequency – were considered; and only the maximum permitted burnup in terms of release of inventory from the core; i.e. limiting conditions on the radioisotopes that escape the core are assumed.
[76] Transcript, Vol. 1, pp. 203-6 (in response to a question as to whether OPG evaluated accidents that could release radioactivity off-site, OPG said they analyzed "credible" accidents beyond design basis up to 1 in a million.
[77] Transcript, Vol. 1, p.216 (Mr. Vachiearelli confirmed that the designs are for 1 in 100 to 1 in 100,000 year accidents – this is the design basis. He continued to say – "this is the category of events which is fully designed for; safety systems are designed for these events"; see also Transcript, Vol. 1, p. 219 (Dr.Newland discusses briefly provisions for beyond design basis accidents – i.e. beyond design basis – he mentioned only mitigation against hydrogen and more robust containment and "other".
[78] Transcript, Vol. 4, p.301 line 14 to p. 303 line 6 (Mr. Vecchiarelli stated their analysis is meant to "bound the realm of credible accidents"); *Ibid.,* at p. 310 line 5 to p.311 line 11 (anything beyond 1 in a million not considered "credible").
[79] International Atomic Energy Agency Safety Standard Series, Site Evaluation for Nuclear Installations, NS-R-3 (referenced by the CNSC in RD-346 as providing Guidance to the Canadian Guide).
[80] At p..3, section 1.13; the IAEA site evaluation document at pp. 4-5 further states that the objective of site evaluation is as follows: "OBJECTIVE
2.1. The main objective in site evaluation for nuclear installations in terms of nuclear safety is to protect the public and the environment from the radiological consequences of radioactive releases due to accidents. Releases due to normal operation should also be considered. In the evaluation of the suitability of a site for a nuclear installation, the following aspects shall be considered:
(a) The effects of external events occurring in the region of the particular site (these events could be of natural origin or human induced);
(b) The characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive material that has been released;
(c) The population density and population distribution and other characteristics of the external zone in so far as they may affect the possibility of implementing emergency measures and the need to evaluate the risks to individuals and the population.
2.2. If the site evaluation for the three aspects cited indicates that the site is unacceptable and the deficiencies cannot be compensated for by means of design features, measures for site protection or administrative procedures, the site shall be deemed unsuitable."
[81] In fact, CNSC staff did not request OPG to provide such information either; a deficiency which does not mean that the Panel is obliged to accept the information and analysis that has been provided as sufficient. The CNSC requested only analysis of a "limiting credible accident"; a "credible severe accident or beyond design basis accident that has offsite radiological consequences": Transcript, Vol. 2, p.188, lines 5-18 (Dr. Thompson).

[82] For example, Health Canada testified that it "is aware that the Proponent will provide more information concerning accidents and malfunctions during the licensing phase once a reactor design is selected. We advise that the Proponent model a more realistic nuclear accident scenario to more accurately determine potential health effects and doses to workers and the public. This information will also be required for nuclear emergency planning": Transcript, Vol. 4, p.323 lines 1 to 10 (Mr. Basiji). CELA submits that this must not be left to later licensing as it is central both to the current licence and to the EA recommendations by the Panel.
[83] Transcript, Vol. 2, p.80 lines 14 to 19 (Mr. Frappier indicating Magnitude 9 is approximately 8 times stronger than Magnitude 8.2 in terms of energy, and the following aftershocks were significant earthquakes in their own right).
[84] As in the case of Japan: Transcript, Vol. 2, pp.81-82 (Mr. Frappier).
[85] See also Transcript, Vol. 11, pp.53, 54 (Mr. Kamps).
[86] Transcript, Vol. 2, p.104 lines 4 to 9 (Dr. Newland).
[87] Contrary to the lessons learned from the Japan events, as cited by Mr. Frappier which include the capability of the plant to withstand a complete station blackout and loss of back-up power among other things: Transcript, Vol. 2, p.88 lines 1-10 (Mr. Frappier); Transcript, Vol. 2 ,pp.167-68 (Mr. Vecchiarelli describing a variety of back up power and cooling options that may provide days of cooling).
[88] Transcript, Vol. 2, p.81, lines 8 – 13 (Mr. Frappier).
[89] Transcript, Vol. 2, p.93, lines 9-10 (Dr. Newland).
[90] Various examples were given for the reactor technologies by Dr. Vecchiarelli: Transcript, Vol. 1, p.197; Transcript, Vol. 2 pp.134-35.
[91] See Transcript, Vol. 7, pp. 6-11 (Mr. Vecchiarelli); see also Transcript, Vol. 3, p. 13.
[92] OPG Document 397, Dose Consequence Analysis, at p. 6 (CEAA Registry document 46371E).
[93] See also answer to Undertaking 7, CNSC independent analysis of full core inventory of three reactors; CEAA Registry Document 49118E.
[94] Appendix B, OPG Document 397, Dose Consequence Analysis (CEAA Registry document 46371E).
[95] The Objective of NG-G-3.2 in part is noted in the following statement contained therein: Radioactive materials discharged from a nuclear power plant might reach the
public and might contaminate the environment in the region by way of both direct and
indirect pathways. The objective of this Safety Guide is to provide guidance on the
studies and investigations necessary for assessing the impact of a nuclear power plant
on humans and the environment. It also provides guidance on the feasibility of an
effective emergency response plan, in consideration of all the relevant site features.
[96] Dispersion of Radioactive Materials in Air and Water and Consideration of Population distribution in site evaluation, IAEA Safety Standard Series, No. NG-G-3.2, Vienna 2002.
[97] See Undertaking 77 compiled by CNSC reviewing at a high level, 33 nuclear accidents worldwide and the role of human error and other facts in these accidents (human error directly attributable in one-third of the cases; and with a potential role in another third; the remaining third with unknown causes).
[98] At p.9 of the IAEA document, under the heading "Criteria Derived from Considerations of Population and Emergency Planning: "2.27. In relation to the characteristics and distribution of the population, the combined effects of the site and the installation shall be such that:
(a) For operational states of the installation the radiological exposure of the
population remains as low as reasonably achievable and in any case is
in compliance with national requirements, with account taken of
international recommendations;
(b) The radiological risk to the population associated with accident
conditions, including those that could lead to emergency measures being
taken, is acceptably low.
2.28. If, after thorough evaluation, it is shown that no appropriate measures
can be developed to meet the above mentioned requirements, the site shall be
deemed unsuitable for the location of a nuclear installation of the type
proposed."
[99] Transcript, Vol. 11 pp.40-41 (Mr. Roche).
[100] Transcript, Vol. 11, p.52 (Mr. Kamps); see also pp. 67, 68 regarding risk of fuel pools, especially in close configuration; and p,70.

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[101] Transcript, Vol. 11, pp. 40-42 (Mr. Roche).
[102] Also as noted by Mr. Pereira: Transcript, Vol 11, p.108.
[103] This is another example of an issue which CNSC stated may be deferred to a later licencing process; CELA submits that the JRP itself must be satisfied that this integral activity would not cause adverse effects or if not so satisfied, to deny the licence application and the EA. Transcript, Vol. 2, pp. 234, 235 (Mr. Khotylev and Dr. Thompson referring to dry fuel storage requirements and impacts).
[104] Transcript, Vol. 11, pp.88-91 (question of Mr. Pereira to OPG; response of Mr. Sweetnam).
[105] Transcript, Vol. 11,pp. 38-40 (Mr. Roche).
[106] Transcript, Vol. 4, p.317 lines 8 to 21 (Reference to Document "OPG New Nuclear at Darlington, Dose Consequence Analysis in Support of Environment Assessment" CEAA registry document 397).
[107] Transcript, Vol. 3, p.246 line 22 to p.247 line 3 (Mr. Dobos); see also Transcript, Vol. 4, p.324 lines 6 to 14 (Mr. Basiji).
[108] Transcript, Vol. 2, p.198 lines 11-16 (Mr. McAllister); Transcript, Vol. 4, p.324, lines 6 to 14 (Mr. Basiji).
[109] Impact of increasing radioactive nuclide exposures from routine operations and "upset" events and spills, including tritium exposures and pathways, as well as numerous other emissions such as C-14. Emissions of up to four new reactors in the same geographic vicinity directly increases these exposures to the same population base and increases individual and population wide exposures through a variety of pathways.
[110] Transcript, Vol. 4, p.53 (Ms. Swami referring to PPE revised in November 2010 and provided to JRP, tables 4.3 and 4.4; and referred to August submission to JRP IR response providing total tritium emissions for all four technologies)..
[111] Transcript, Vol. 7, pp.58-59 (Ms. Swami).
[112] *Ibid.* p.60 (Ms. Swami).
[113] Transcript, Vol. 7, p.58 (Dr. Thompson).
[114] See references at endnotes 56-59.
[115] For list of routine radioactive emissions, see Revised Plant Parameter Envelope Nov. 2010, CEAA Registry document 46697E, Tables 4.1 to 4.4.
[116] For example, as Dr. Newland testified, "there may be lessons learned on the characterization of external events and on severe accident progression and phenomena;" and Transcript, Vol. 2, p.157.
[117] Transcript, Vol. 2, p.214 line 9 to p.215 line 15 (Mme. Beaudet questions of Dr. Thompson).
[118] Such as CNSC in respect of liquid effluent and surface water: Transcript, Vol. 2, p.196 lines 10-16 and pp.197-198 (Mr. McAllister stating that requirements for additional dry fuel storage which would depend on reactor technology) and Transcript, Vol. 2, p.209 line 20 to p.210 line 2 (Dr. Thompson). An example of the very limited approach to evaluation of accident consequences was provided by CNSC in advising that the approach used was a "safety goal based assessment" because there has been no specific technology selected for the project; a hypothetical "large release frequency" and a "small release frequency" were used for their assessment of adverse effects: Transcript, Vol. 2, p.177, lines 6-22 (Dr. Thompson); lack of information about conventional and radiological effluents since no reactor technology yet selected: Transcript, Vol. 3, p. 241 (Mr. Dobos).
[119] Transcript, Vol. 2, p.193 line 28 to p.194 line 17 (Mr. McAllister).
[120] For example, see Transcript, Vol. 2, p.196 (Mr. McAllister advising that OPG`s "commitment to meet all regulatory guidelines" (as opposed to demonstrating same) was not consistent with the EIS Guidelines. CELA submits that the Panel must not accept such "assurances" of future compliance and in the event that the JRP is not fully satisfied, on all of the information actually before it in this EA and Licence Application, that the OPG met the EIS Guidelines and the requirements of CEAA and NSCA to justify issuance of the Licence, then both should be refused.
[121] Transcript, Vol. 13, pp.215-16.
[122] *Re Steetley Quarry Products Inc.* (1995), 16 C.E.L.R. (NS) 161 (Ont.Jt.Bd.), paras.436-37;Transcript, Vol. 3, pp.141-42, 153; Transcript, Vol. 11, pp.169-71; Transcript, Vol. 13, pp.213-14. "See also sections 20 and 24 of NSCA for the statutory test regarding the LTPS").

Application for Review

to the

Ministry of Municipal Affairs and Housing

Date: September 26, 2016

Canadian Environmental Law Association

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B. SUBJECT MATTER OF REQUESTED REVIEW

Ontario's land use planning regime is improperly encouraging population growth in areas surrounding nuclear power plants with no apparent concern about the negative impact of such growth on the risk to the public and on the viability of emergency planning. There is a serious public safety risk because Ontario has also approved plans to continue operating ten aging reactors sited in the Greater Toronto Area ("GTA") at the Darlington and Pickering nuclear stations. Six million Ontarians live within the GTA.

We request that the Ministry of Municipal Affairs and Housing ("MMAH") review their current acts, regulations and policies, and create new acts, regulations and policies, to restrict land use and population growth around nuclear power plants. This review has become increasingly urgent in light of the lessons learned from the Fukushima Daiichi nuclear accident and the projected consequences of a Fukushima-scale accident in Ontario.

The Applicants request a review of the following existing legislation, regulation or policy pursuant to subsection 61(1) of the *Environmental Bill of Rights, 1993,* SO 1993, c 28 ("*EBR*"):

- Subsection 5.1(2) of the *Emergency Management and Civil Protection Act,* RSO 1990, c E9, which provides that each Minister of the Crown must "assess the various hazards and risks to public safety that could give rise to emergencies and identify the facilities and other elements of the infrastructure for which the Minister .... is responsible that are at risk of being affected by emergencies".

- Sections 3, 4 and 6 of the *Places to Grow Act, 2005,* SO 2005, c 13, which provides for preparation of growth plans. The Applicants request a review of all current and proposed growth plans that apply to areas surrounding Ontario's nuclear power plants, including the Proposed Growth Plan for the Greater Golden Horseshoe, 2016.

- *Planning Act*, RSO 1990, ch P13, which provides the overall framework for land use planning in Ontario and the Provincial Policy Statement, 2014.

The Applicants also request a review of the need for a new act, regulation or policy pursuant to subsection 61(2) of the *EBR* by the Minister of Municipal Affairs and Housing to properly account for the impact of the risk of accidents at nuclear power plants on siting of nuclear power plants and land use planning in Ontario. It is imperative that restrictions on land use are put in place surrounding nuclear power plants in Ontario.

REASONS FOR THE REVIEW

A. Jurisdiction of the Ministry of Municipal Affairs and Housing

The MMAH is responsible for land use planning pursuant to the *Planning Act*.[1] It is responsible for the Proposed Growth Plan for the Greater Golden Horseshoe, 2016 pursuant to the *Places to Grow Act, 2005*. Pursuant to subsection 5.1(2) of the *Emergency Management and Civil Protection Act*, the MMAH must consider the various hazards and risks to public safety that could affect land use planning.

B. Current Status of Canadian Siting Requirements and Population Growth near Ontario Nuclear Power Plants

i. Ontario's land use planning regime is encouraging population growth near nuclear power plants

Ontario's land use planning regime actually encourages increased growth near both the Darlington and Pickering nuclear power plants, rather than heeding the advice of experts to restrict land use in those areas.

The Finnish Radiation and Nuclear Safety Authority accurately summarized why nuclear power plants should be sited far away from large population centres in its 2001 *Safety Criteria for Siting a Nuclear Power Plant*:

> The general principle in the siting of nuclear power plants is to have the facilities in a sparsely populated area and far away from large population centres. What justifies placement in a sparsely populated area is that emergency planning will then be directed at a smaller population group and will thus be easier to implement.[2]

As early as 1988, Provincial Working Group # 8, an arms-length committee struck to advise government, recommended that Ontario examine "the advisability of restricting new housing construction near nuclear facilities."[3] In November 1996, the Royal Society of Canada and Canadian Academy of Engineering ("RSC") advised that the Contiguous Zone, the priority emergency planning area surrounding nuclear power plants, have a small population and that it preferably be restricted to parkland or industrial use:

> The Contiguous Zone, with a boundary approximately 3 km radius around the plant, is an area for which detailed plans can be developed. Because of its limited size relatively fast action is possible. High population density and possible bad weather could make

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[1] *Planning Act*, RSO 1990, c P13, s 1; Canadian Nuclear Safety Commission, Notice of Meeting, *Engagement with Stakeholders: DNNP Joint Review Panel (JRP) Recommendation #43: Land Use Policy,* February 6, 2013 ("CNSC Notice of Meeting – February 6, 2013") (Tab C1)

[2] STUK (Radiation and Nuclear Safety Authority), *Safety Criteria for Siting of Nuclear Power Plant,* 2001*,* p 4 (Tab C2)

[3] Provincial Working Group #8, *The Upper Limit for Detailed Nuclear Emergency Planning,* June 30, 1998, p iv (Tab C3)

> evacuation difficult and this zone should have a small population and preferably be restricted to parkland or industrial park use.[4]

Although Canadian Nuclear Safety Commission ("CNSC") staff recently highlighted the Provincial Policy Statement, 2014 ("PPS, 2014"), the Municipality of Clarington's Official Plan, and the Region of Durham's commitment to update its Official Plan to comply with the PPS, 2014 as advancements on previous land use guidance, these are insufficient tools to truly address siting issues surrounding nuclear power plants.[5]

The PPS, 2014 does not limit population density near nuclear power plants. Nuclear hazards or nuclear power plants are not specifically mentioned. Any land use restrictions that are mentioned are vague. Major facilities, which include energy generation facilities, and sensitive land uses, are to be planned to ensure that they are "appropriately designed, buffered and/or separated from each other" to minimize risks to public health and safety.[6] But, this restriction has not been used to limit population growth near nuclear facilities.

Furthermore, CNSC, Emergency Management Ontario, MMAH, the Ministry of the Environment and Climate Change, relevant municipalities and OPG met to discuss land use planning around the Darlington nuclear power plant in 2013. A September 27, 2013 report, acquired through the *Freedom of Information and Protection of Privacy Act,* stated that the PPS, 2014 alone could not adequately address land use issues near nuclear stations.[7]

The proposed change to the Municipality of Clarington's 2016 Official Plan provides that "sensitive land uses" in the vicinity of the Darlington nuclear generation station will be reviewed in the context of emergency measures planning.[8] This amendment does not limit population growth near the nuclear site.

In fact, the Ontario government is actively encouraging population growth in areas surrounding nuclear power plants through its growth plans.

The 2006 Growth Plan identified downtown Oshawa and downtown Pickering as urban growth areas.[9] Both areas are located within the 10 km Primary Zone for nuclear emergency planning and preparedness surrounding nuclear reactors. The reactors are not mentioned in the growth plan.

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[4] Royal Society of Canada and Canadian Academy of Engineering, *Report to the Ministry of Energy and Environment Concerning Two Technical Matters in the Province of Ontario's Nuclear Emergency Plan*, November 1996, section 6.2, p 31 ("RSC Report") (Tab C4)
[5] Canadian Nuclear Safety Commission, Transcript of Public Meeting, August 18, 2016, pp 50-51 (Tab C5)
[6] Ministry of Municipal Affairs and Housing, *Provincial Policy Statement, 2014*, ss 1.2.6.1, 6.0, pp 13, 44, 48 (Tab C6)
[7] Hardy, Stevenson and Associates, Land Use Planning Workshop: Darlington New Nuclear Project, Discussion and Summary Agreement, September 27, 2013 ("Hardy Workshop Report"), s 5.1.3, p 12 (Tab C7)
[8] Municipality of Clarington, Draft Official Plan 2016, s 3.7.11 (Tab C8)
[9] Ministry of Infrastructure, *Growth Plan for the Greater Golden Horseshoe, 2006,* Office Consolidation June 2013, pp 16-17, 65 (Tab C9)

In the *Proposed Growth Plan for the Greater Golden Horseshoe, 2016*, both downtown Pickering and downtown Oshawa are still listed as urban growth centres under the *Places to Grow Act, 2005*.[10] The Darlington and Pickering nuclear power plants are still not mentioned in the growth plan.

Nuclear hazards and emergency planning have not been mentioned during MMAH's consultation regarding the Growth Plan for the Greater Golden Horseshoe, the Greenbelt Plan, the Oak Ridges Moraine Conservation Plan and the Niagara Escarpment Plan.

The Provincial Nuclear Emergency Response Plan ("PNERP") does not address land use planning.[11] Emergency Management Ontario noted in 2013 that there was "little to no interaction" between it and MMAH on land use policy matters.[12]

ii. Ontario's land use planning has resulted in increasingly dense populations surrounding the Pickering Nuclear Power Plant

The Pickering nuclear site is located in a highly populated region, which will hinder any effort to evacuate the area in case of emergency. The hazard is increasing as land use planning continues to direct further population growth close to the site.

The Ministry of Energy recognized in a January 2010 Briefing Note relating to the continued operation of the Pickering nuclear power plant that its ability to operate for 30 years in a "targeted population growth area" carries the potential for significant regulatory sanction in response to public intervention.[13] The province has taken no action to address this concern.

There are simply too many people living in close proximity to the Pickering nuclear generating station. The population in Durham Region has increased significantly since the Pickering site was chosen.[14] Durham Region's population in 2009 was 614,970 and was projected to grow to 949,100 by 2026. In 2011, there were 280,591 people living in the 10 km Primary Zone.[15] There is also a considerable workforce in the area.[16]

Estimated evacuation times in the 10 km Primary Zone already increased between 2008 and 2016 because of a 14% increase in residential population and additional vehicles from transient

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[10] Ministry of Municipal Affairs and Housing, *Proposed Growth Plan for the Greater Golden Horseshoe, 2016*, May 2016, pp 17-18, 95 (Tab C10)
[11] Canadian Nuclear Safety Commission, Notice of Meeting, *Teleconference – Next Steps on JRP Recommendation #43 – Land Use Policy – Engagement with Stakeholders,* April 23, 2013 ("CNSC Notice of Meeting – April 23, 2013") (Tab C11)
[12] CNSC Notice of Meeting – February 6, 2013, p 2
[13] Cedric Jobe and Rick Jennings (Ministry of Energy), Briefing Note, January 2010 (Tab C12)
[14] Ontario Power Generation, Pickering B Safety Report – Part 1, 2009, Figure 2-3: Historical Population Trends of Ontario and Municipalities around Pickering NGS, p 87 ("Pickering B Safety Report") (Tab C13)
[15] Durham Emergency Management Office, *Durham Nuclear Emergency Response Plan*, May 2016, Table 4, p 23 ("Durham Nuclear Emergency Response Plan") (Tab C14)
[16] Pickering B Safety Report, Section 2.2.2: Industry, pp 39-40

populations travelling through the area, special facilities, schools, day camps, college populations and correctional facilities, which the previous study did not take into account.[17]

Amendment 26 to the City of Pickering's Official Plan, approved by the Ontario Municipal Board on March 4, 2015, targets City Centre South for new residential development to accommodate 6,300 people or 3,400 units by 2031.[18]

The City of Pickering has received an application for a zoning by-law amendment for the former Holy Redeemer Catholic Elementary School to permit condominium development. This site is less than 2 kilometres from the Pickering Nuclear Generation Station.[19]

Durham Regional Official Plan amendment (ROPA 128) approved January 9, 2013 by the Ontario Municipal Board (OMB) designates an area which lies within 3 km of the Pickering Nuclear Generation Station as a Regional Corridor, which are to be planned and developed as higher density mixed-use areas. This 3 km area overlaps with the Contiguous Zone, which requires increased emergency planning due to its proximity to the nuclear station.[20] Along with Highway 401, there are other major transportation routes of national importance that would be disrupted in the event of a severe accident at Pickering, including Highway 2 and the CN and CP Rail lines.[21]

In addition, there are a large number of major airstrips and airports in the area.[22] A nuclear accident would disrupt commercial aviation, and also poses an ongoing risk to the plant itself. International Atomic Energy Agency ("IAEA") Safety Guide NS-G-3.1 states that "the potential for aircraft crashes that may affect the plant site should be considered in the early stages of the site evaluation process and it should be assessed over the entire lifetime of the plant."[23]

iii. Darlington Nuclear Power Plant: land use planning and the Darlington site are on a collision course

Land use planning surrounding the Darlington site has resulted in increased population growth. The Joint Review Panel studying the proposal for new nuclear power plants at Darlington raised significant concerns about land use planning affecting the Darlington site. Those concerns have not been addressed.

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[17] Ontario Power Generation, Pickering NGS Development of Evacuation Time Estimates, April 12, 2016, p ES-2 (Tab C15)

[18] Amendment 26 to the City of Pickering Official Plan, approved by the Ontario Municipal Board on March 4, 2015, s 11.10K(b), p 22 (Tab C16)

[19] City of Pickering, Notice of Public Open House, Applications for Zoning By-law Amendment, and Draft Plan of Condominium, submitted by Madison Liverpool Limited, for the former Holy Redeemer Catholic Elementary School located at 747 Liverpool Road, May 17, 2016 (Tab C17); Google Map, Holy Redeemer Catholic School to Pickering Nuclear Generation Station, September 2016 (Tab C18)

[20] Durham Regional Official Plan Amendment (ROPA 128), approved January 9, 2013, s 8A.2.9, p 59 (Tab C19)

[21] Pickering B Safety Report, s 2.2.4, pp 42-43

[22] Ontario Power Generation, Pickering A Safety Report, 2010, Table 15 (Tab C20)

[23] International Atomic Energy Agency, Safety Guide No. NS-G-3.1, *External Human Induced Events in Site Evaluation for Nuclear Power Plants,* 2002, p 22 (Tab C21)

A November 28, 2005 CNSC Briefing Note contemplated siting concerns with respect to two potential sites for the new Darlington nuclear power plant. The Briefing Note highlighted that the new plant could be located at the existing Darlington site, however major population areas were beginning to encroach on the site. The option of locating the site at Wesleyville was considered advantageous because it was further removed from major population areas.[24]

The population in the current 10 km Primary Zone of the Darlington site is projected to almost double between 2011 and 2055.[25]

The Joint Review Panel assessing the proposal for a new nuclear power plant at Darlington identified significant defects regarding current siting requirements. The Panel recommended that appropriate steps be taken to "evaluate and define buffer zones around nuclear facilities in Canada, taking into consideration the lessons learned from the Fukushima Daiichi nuclear accident. The Panel believes that the Government of Ontario should take appropriate measures to ensure that no residential development takes place in the Contiguous Zone."[26] [emphasis added] No such steps have been taken.

The Panel also made the following recommendations regarding siting requirements, including that the Ontario government prevent sensitive and residential development near the Darlington site boundary:

> Recommendation #43: The Panel recommends that the Canadian Nuclear Safety Commission engage appropriate stakeholders, including OPG, Emergency Management Ontario, municipal governments and the Government of Ontario to develop a policy for land use around nuclear generating stations.
>
> Recommendation #44: The Panel recommends that the Government of Ontario take appropriate measures to prevent sensitive and residential development within three kilometers of the site boundary.
>
> Recommendation #45: The Panel recommends that the Municipality of Clarington prevent, for the lifetime of the nuclear facility, the establishment of sensitive public facilities, such as school, hospitals and residences for vulnerable clienteles within the three kilometer zone around the site boundary.
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> …
>
> Recommendation #59: The Panel recommends that the Municipality of Clarington manage development in the vicinity of the Project site to ensure that there is no

[24] Canadian Nuclear Safety Commission, *Briefing Note – Darlington NGS,* November 28, 2005 (Tab C22)
[25] Ontario Power Generation, *Darlington NGS Development of Evacuation Time Estimates*, December 20, 2015, Table M-4: PZ Population by Study Year, p M-9 (Tab C23)
[26] Joint Review Panel, *Environmental Assessment Report: Darlington New Nuclear Power Plant Project,* August 2011, p 105. (Tab C24) ("Darlington Joint Review Panel")

> deterioration in the capacity to evacuate members of the public for the protection of human health and safety.[27]

The Panel also found that OPG and the Municipality of Clarington may be on a 'collision course' regarding the development of land neighbouring the Darlington site. The Region of Durham growth scenario up to 2056 includes several residential areas contemplated, or being built, very close to the site. Some of the developments are in the contiguous or primary evacuation zones of the Darlington site. Two schools are located within 2.8 kilometres and 3.1 kilometres of the closest planned location for the new reactors at the Darlington site.[28]

Although the Panel ultimately found that appropriate measures are in place to ensure that vulnerable populations including hospitals, schools and retirement homes can be safely evacuated, it also highlighted that it would be prudent to avoid such developments, and other residential developments, within a three-kilometre zone around the project site. The Panel recommended avoiding any further residential development north of Highway 401 in several emergency response sectors, in light of the challenges encountered during the evacuation following the Fukushima Daiichi nuclear disaster. The Panel pointed out that a situation similar to that at the Pickering site, where residential areas are found within three kilometers of the nuclear site, must be avoided.[29]

CNSC, Emergency Management Ontario, MMAH, Ministry of the Environment, relevant municipalities and OPG met to discuss the JRP recommendations in 2013. According to a meeting report, responding to the JRP's recommendation on land use planning requires a "suite of tools from all levels of government with consistent direction". No final report has been released publicly.[30]

iv. CNSC does not regulate land use planning surrounding existing nuclear sites

The CNSC's guidance on siting of nuclear power plants all relate to new nuclear power plants. It does not apply to existing nuclear sites.

Following the Fukushima Daiichi nuclear accident, the CNSC committed to updating its *Integrated Action Plan on the Lessons Learned from the Fukushima Daiichi Nuclear Accident* for both existing and new nuclear power plants. The CNSC commitment included consulting the public on proposed amendments for RD-346: Site Evaluation for New Nuclear Power Plants ("RD-346") before submitting a revised guide to the Commission for approval before the end of December 2013.[31]

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[27] Darlington Joint Review Panel, pp 105, 127
[28] Darlington Joint Review Panel, pp 101, 105
[29] Darlington Joint Review Panel, p 105
[30] Hardy Workshop Report, pp 20-23
[31] Canadian Nuclear Safety Commission, *CNSC Integrated Action Plan on the Lessons Learned From the Fukushima Daiichi Nuclear Accident,* August 2013, p 23 (Tab C25)

In August 2016, the CNSC finally published for consultation its proposed post-Fukushima siting requirements in *REGDOC-1.1.1: Licence to Prepare Site and Site Evaluation for New Reactor Facilities.* The preface states that the amendments aim to ensure that there are "… discussions around emergency planning and preparations for extreme events earlier in a project." However, the guide does not apply to existing facilities unless it is included in the licence or licensing basis for the facility and is instead to be used to assess "new licence applications for reactor facilities."[32]

The pre-Fukushima CNSC guidance, RD-346 and RD-337: Design of New Nuclear Power Plants ("RD-337"), only applies only to new nuclear power plants.[33]

RD-346 identifies key characteristics to consider in siting a nuclear power plant, including population density and population distribution, especially as they relate to emergency planning, and the evolution of population factors over the lifetime of the plant.[34] In particular, RD-346 identifies the planning considerations related to population that must be considered in evaluating the site of a new nuclear power plant:

1. Population density and distribution within the protective zone, with particular focus on existing and projected population densities and distributions in the region including resident populations and transient populations. This data is kept up to date over the lifetime of the NPP;
2. Present and future use of land and resources;
3. Physical site characteristics that could impede the development and implementation of emergency plans;
4. Populations in the vicinity of the NPP that are difficult to evacuate or shelter (for example, schools, prisons, hospitals); and
5. Ability to maintain population and land-use activities in the protective zone at levels that will not impede implementation of the emergency plans.[35]

However, RD-346 offers no criteria for assessing the merits of a site from a safety perspective. As noted, the Darlington Joint Review Panel recommended restrictions on population growth and development of sensitive infrastructure, such as schools, near the facilities. A follow up meeting in September 2013 of federal, provincial and municipal governments concluded that RD-346 and RD-337 are not sufficient for managing land use around nuclear power plants.[36]

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[32] Canadian Nuclear Safety Commission, *REGDOC-1.1.1, Licence to Prepare Site and Site Evaluation for New Reactor Facilities*, August 2013, p I (Tab C26)
[33] Canadian Nuclear Safety Commission, *RD-346: Site Evaluation for New Nuclear Power Plants*, dated modified February 3, 2014, p 1 ("RD-346: Site Evaluation") (Tab C27); Canadian Nuclear Safety Commission, *RD-337: Design of New Nuclear Power Plants,* dated modified February 3, 2014, p 1 ("RD-337: Design of New Nuclear Power Plants") (Tab C28)
[34] RD-346: Site Evaluation, ss 4.0, 5.0, pp 4-6
[35] RD-346: Site Evaluation, s 5.5.3, p 8
[36] Hardy Workshop Report, p 17

RD-337 does not provide better guidance for siting requirements. It notes only that the exclusion zone is based on evacuation needs, land usage needs, security requirements and environmental factors.[37] The plant design is also to consider the population in the surrounding area.[38]

The CNSC's submission to the Convention on Nuclear Safety indicates that it uses the accidents assessed during initial environmental assessments to evaluate site suitability. CNSC does not consider worst-case accidents in environmental assessments and only reviews "accident sequences that could occur with a frequency greater than 10^{-6} per reactor-year of operation."[39] CNSC's RD-337 provides that accidents with a frequency greater than 10^{-6} release less than 10^{14} becquerel of Cesium-137,[40] which corresponds to only 1% of the releases that occurred during the Chernobyl nuclear accident.[41]

The 10^{-6} cut-off is also not aligned with the province's current criteria for detailed off-site emergency planning, which remains the standard of 10^{-7} recommended by the RSC in 1996.[42]

As a result, there is no public information that considers the potential social, economic, environmental and human health consequences of worst-case nuclear accident scenarios at Canadian nuclear sites. There is also no corresponding information available to assess how population density and land use planning may hinder provincial emergency measures in the event of a Chernobyl or Fukushima-scale accident.

The CNSC's use of environmental assessments for siting assessments also implies that siting requirements will only be reviewed at the outset of a nuclear power plant project, not throughout the life of the project as is required by the IAEA.[43] The *Canadian Environmental Assessment Act, 2012* removed the requirement for reactor life-extensions to undergo an EA. There is also no requirement for an environmental assessment for proposals to operate reactors beyond their original design-life.

v. An Act of faith or hubris? CNSC consultants have long been concerned about the siting of nuclear power plants in Ontario.

Ontario's inappropriate siting decisions regarding placement of nuclear power plants near population centres, and growing populations in those areas, have been criticized repeatedly by CNSC consultants.

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[37] RD-337: Design of New Nuclear Power Plants, s 6.5, p 11
[38] RD-337: Design of New Nuclear Power Plants, s 7.4.2, p 14
[39] Canadian Nuclear Safety Commission, *Canadian National Report for the Convention on Nuclear Safety, Seventh Report*, August 2016, p 155 ("Canadian National Report") (Tab C29)
[40] RD-337: Design of New Nuclear Power Plants, s 4.2.2, p 6
[41] Canadian National Report, p 119
[42] RSC Report, section 7.1, p 33
[43] International Atomic Energy Agency, *Site Evaluation for Nuclear Installations*, Safety Requirements No. NS-R-3 (Rev. 1), February 2016, s 5.1, pp 20-21 ("IAEA Safety Standard for Site Evaluation") (Tab C30)

In 2004, R.A. Brown and Associates noted that in determining the design of a nuclear power plant, interactions between the plant and the environment, the availability of off-site services and the population must be taken into account.[44]

In 2005, John W. Beare identified that siting considerations for nuclear power plants were not being considered and had resulted in problematic decisions:

> 19. There are two significant gaps in the Licensing Basis Document. … The safety goals are independent of the site, the size of the exclusion area (if any) and the demographics of the area around the site. I was advised that site considerations do not affect the design requirements for the nuclear power plant but that explanation is difficult to accept.
>
> 20. Before issuing this Licensing Basis Document the Canadian Nuclear Safety Commission should document and publish its siting policy giving quantitative values for the tolerable risk (not unreasonable to use the wording of the Nuclear Safety and Control Act) to individuals and the population around a nuclear power plant site. One weakness of the current siting policy in AECB-1059 is that only radiological risks are addressed. In AECB- 1059 the frequency and radiological consequences of process failures alone and in combination with safety system failures are addressed for individuals and the population, but only the risk to individuals from more serious accidents. These weaknesses in the current siting policy should be remedied.
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> …
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> 27. The main elements of the Canadian approach were in place by 1964. The next year the site for the first two units of Pickering was approved and it was evident then that Ontario Hydro intended to build two more. At the time the only operating experience with CANDU was with the small NPD reactor which had begun operation in 1962. The Douglas Point reactor did not commence operation until 1967 and its initial operating history was anything but smooth. <u>Depending on one's perspective, from the safety point of view the approval of the Pickering site was an act of faith or hubris</u>. At the time, the Pickering site had the highest population density in the world, a population density that has been exceeded by only a few other sites since then. [emphasis added]
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> …
>
> 49. … The risk to the population from a catastrophic failure, including all societal effects such as effects on the economy, environment and land use as well as health, is basically a siting issue. The Reactor Safety Advisory Committee issued what it called the Siting Guide which did not address this basic siting issue.
>
> …

[44] R.A. Brown and Associates, ACR Licensing Basis Project, Licensing Guide: Design, Submitted to Canadian Nuclear Safety Commission, September 2004, ss 5.57, 5.58, p 28 (Tab C31)

> 122. Because this Licensing Basis Document is for the design of nuclear power plants siting considerations have not been included in the safety goals. If siting factors, such as the size of the exclusion zone and demographics, are not included there is no logical connection between the safety objectives in paragraph 2.2 of the Licensing Basis Document and the safety goals.[45]

A 2007 report commissioned by CNSC on siting requirements found important gaps not addressed in the CNSC documents or anywhere else in its licensing framework, including "criteria for the rejection of a proposed site if it is deemed unsuitable", "monitoring of site characteristics over the lifetime of the nuclear facility", and "that there are no insurmountable obstacles to the establishment of suitable emergency measures."[46]

vi. Ontario's emergency response plans only deal with smaller-scale nuclear accidents

The seriousness of the issue of siting requirements near nuclear power plants is compounded by Ontario's current use of smaller-scale accidents as the basis for its emergency plans. The RSC recommended in a 1996 report that "…detailed emergency planning should be done for accidents resulting from a credible series of events which could occur with a probability of approximately 10^{-7} per reactor year."[47] At that time, the RSC relied on a 1995 Pickering A risk assessment, which concluded a Fukushima-scale radiation release was highly unlikely, to choose the basis for offsite emergency planning.[48]

Emergency Management Ontario observed that emergency plans would not be affected by consideration of the accident scenarios outlined in environmental assessments, which CNSC uses to perform siting assessments.[49] Those accidents are much smaller than a Fukushima-scale accident. The Fukushima disaster has shown that industry probability estimates are too unreliable and uncertain to justify excluding major radioactive releases from detailed emergency plans. A precautionary approach, which considers consequences to the public instead of relying on uncertain estimates about the likelihood of an accident, is necessary in light of the lessons learned from the Fukushima accident.

For example, following the Fukushima accident, the German Commission on Radiological Protection (SSK) recommended a more precautionary approach to emergency planning which would reflect an accident's potential to cause harm, rather than its likelihood of occurring:

> …that the range of accidents included in emergency response planning should be

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[45] John W. Beare, *Review of ACR-LBD-001, Licensing Basis Document for New Nuclear Power Plants in Canada*, Draft dated December 2004, paras 19-20, 27, 49, 122, pp 4-6, 13, 31 ("Beare Draft Review") (Tab C32)
[46] Regulatory Site Requirements Needed for New Nuclear Power Plants in Canada, Licence to Prepare Site, June 2007 ("Regulatory Site Requirements"), s 4.8, p 8 (Tab C33)
[47] RSC Report, section 7.1, p 33
[48] Dr. Aadu Pilt, *A Technical Assessment of the Enhanced Planning and Preparedness Arrangements in the Contiguous Zone Surrounding Ontario Power Generation Inc. Nuclear Generating Stations*, May 2002, pp 1-2 (Tab C34)
[49] CNSC Notice of Meeting – February 6, 2013, p 3

> redefined to more closely reflect an accident's potential impact rather than its likelihood. The SSK therefore considers it necessary to expand the range of accidents included in the contingency planning and also add to emergency response planning and planning area considerations the INES 7 accidents whose radiological effects mirrors those of Fukushima.[50]

Germany reassessed the adequacy of its emergency planning zones against Fukushima-scale radioactive releases. The modelling of these accidents lead to recommendations to significantly expand emergency planning zones, including extending the "Central Zone" (similar to Ontario's Contiguous Zone) from 2 to 10 km, extending the "Middle Zone" from 10 to 20 km, and extending the Outer Zone from 25 to 100 km (similar to Ontario's Secondary Zone).[51] These results are similar to the actual use of offsite emergency measures in Japan during the first month of the Fukushima disaster.

Given the RSC and Joint Review Panel's recommendations regarding restricting land use in the 3 km Contiguous Zone were based on maintaining the province's ability to safely evacuate the public in the event of accidents significantly smaller than a Fukushima-scale release, population growth should actually be restricted and managed far beyond the current 3 km Contiguous Zone and 10 km Primary Zone.

vii. Lessons from Fukushima: the social effects of major nuclear accidents are ignored in current siting criteria

The current risk of incompatible land use planning and siting of nuclear power plants without concern for population density in surrounding areas is also compounded because individual risk, but not societal risk, are being considered by Canadian regulators.

The Chernobyl and Fukushima accidents highlighted that nuclear accidents can displace large populations and create significant societal disruption. However, there are no limits on the potential social disruption from a large-scale nuclear accident at an Ontario nuclear site because Ontario's land use planning regime does not restrict population in areas most affected by nuclear accidents.

The limits on risk of social disruption are currently not considered in provincial land use planning requirements. Individual risk calculations do not take into account the total number of people exposed to the hazard, while societal risk looks at the total population exposed. Even if an entity complies with individual risk limits, there may still be significant societal risk.[52] For

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[50] German Commission on Radiological Protection (SSC), *Planning areas for emergency response near nuclear power plants: Recommendation by the German commission on Radiological Protection*, February 2014, p 10 (Tab C35)

[51] Florian Gering, *Updated emergency planning zones in Germany and the importance of release source term*, presentation by emergency management division, Federal Office for Radiation Protection (Tab C36)

[52] Laurène Debesse, *The Use of Frequency-Consequence Curves in Future Reactor Licensing,* submitted in Partial Fulfillment of the Requirements for the Degrees of Master of Science in Technology and Policy and Master of Science in Nuclear Science and Engineering at the Massachusetts Institute of Technology, February 2007, pp 53-54 ("The Use of Frequency-Consequence Curves") (Tab C37)

nuclear power plants, there are three main sources of societal risk: degradation of plant safety, increase of the core inventory, and an increase in the number of people around the plant.[53]

As observed by John W. Beare prior to the Fukushima accident, there are no risk metrics to limit social impacts in the event of a nuclear accident. Federal reactor design criteria only limit the risk of individual fatalities and cancer:

> Limits were placed on the individual and total dose to the surrounding population for postulated serious process failures and dual failures. Dose in the stochastic (probabilistic) range implies a risk of fatal cancer in the future from that dose. Therefore, there were three quantitative safety goals established based on risk. Although this approach put a limit on the risk of early fatality to individuals from a catastrophic failure, no consideration was given to the total risk to the population or to the social and economic effects from a catastrophic failure. The risk of early fatality to an individual from a catastrophic failure is basically a design issue. <u>The risk to the population from a catastrophic failure, including all societal effects such as effects on the economy, environment and land use as well as health, is basically a siting issue. The Reactor Safety Advisory Committee issued what it called the Siting Guide which did not address this basic siting issue.</u> [emphasis added][54]

Former Chairman of the U.S. Nuclear Regulatory Commission Gregory B. Jaczko's observed after the Fukushima accident that according to the industry's individual risk metrics - prompt radiation health and latent radiation health effects – the Fukushima nuclear disaster would not be considered "an unacceptable event":[55]

> So if we look today at our risk models, the most fundamentally missing piece, I believe, is the right way to characterize what we believe as societies are the unacceptable things about nuclear power accidents. But it is a very different way to think about these things than we have done in the past.
>
> And by that, I mean it is the real human consequences that we are dealing with -- evacuations of large populations, perhaps extended relocation of populations; significant effort to clean up, decommission and decontaminate perhaps significant areas of land; the redevelopment and the loss of significant energy infrastructure; and the societal consequences that entails.
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> …

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[53] The Use of Frequency-Consequence Curves, p 59

[54] Beare Draft Review, para 49, p 13

[55] Honorable Gregory B. Jaczko, Chairman of the U.S. Nuclear Regulatory Commission, "*Looking to the Future*," Platts 8th, Rockville, MD Annual Nuclear Energy Conference February 9, 2012, p 5 ("Looking to the Future") (Tab C38)

> It is the intangible health effects of displacing a population from their homes, from their friends, their families, from the schools their children attend -- those are the kinds of intangibles that we don't account for right now in our understanding of consequences.[56]

C. International Standards

IAEA safety standards clearly identify population density and population characteristics near a nuclear power plant as important considerations in decisions about siting nuclear power plants and emergency planning. Ontario is not currently complying with IAEA standards and is instead encouraging population growth in locations near nuclear power plants.

The IAEA's safety standard for *Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants* states:

> The presence of large populations in the region or the proximity of a city to the nuclear power plant site may diminish the effectiveness and viability of an emergency plan.[57]

The IAEA standard requires study of the regional population near the site of a nuclear power plant to evaluate the potential radiological impacts of normal radioactive discharges and accidental releases, and to assist in the demonstration of the feasibility of emergency response plans.[58] Section 5.3 provides that emergency plans must account for the characteristics of the population around the site:

> The external zone includes an area immediately surrounding the site of a nuclear power plant in which population distribution, population density, population growth rate, industrial activity, and land and water uses are considered in relation to the feasibility of implementing emergency measures.[59]

There should be no adverse site conditions which could hinder sheltering or evacuation of the population.[60] The Safety Guide identified factors that may diminish the effectiveness and viability of emergency plans, including population density and distribution in the region, distance of the site from population centres and special groups of the population who are difficult to evacuate or shelter.[61] Site related factors must be reviewed periodically.[62]

Section 5.1 of the IAEA's safety standard for *Site Evaluation for Nuclear Installations* highlights Ontario's responsibility to monitor demographic conditions around a nuclear installation over its

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[56] Looking to the Future, pp 5-6
[57] International Atomic Energy Association, *Safety Standard for Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants*, Safety Guide No. NS-G-3.2, March 2002, s 6.4, p 28 ("IAEA Safety Standard for Dispersion of Radioactive Material") (Tab C39)
[58] IAEA Safety Standard for Dispersion of Radioactive Material, s 5.1, p 25
[59] IAEA Safety Standard for Dispersion of Radioactive Material, s 5.3, p 25
[60] IAEA Safety Standard for Dispersion of Radioactive Material, s.6.1, p 27
[61] IAEA Safety Standard for Dispersion of Radioactive Material, ss 6.3 and 6.4, pp 27-28
[62] IAEA Safety Standard for Dispersion of Radioactive Material, s 6.7, p 28

lifetime.[63] Population density near the nuclear plant is to be closely monitored, with particular attention to densely populated areas and residential centres in the region, and to residential institutions such as schools, hospitals and prisons.[64]

The recent United Nations Sendai Framework for Disaster Risk Reduction 2015 – 2030 also highlights the need for land use planning to account for the risk of a nuclear accident and emergency planning. In particular, disaster risk assessments should be incorporated into land-use policy development and implementation, including urban planning.[65] It is important to formulate public policies aimed at addressing the issues of prevention or relocation of human settlements in disaster risk-prone zones[66], rather than encouraging population growth in these areas.

The IAEA Report on the Fukushima Daiichi Accident recommended that emergency planning zones and areas need to be established with severe nuclear emergencies taken into account. Preparations are necessary to ensure the safe evacuation of special facilities, including hospitals and nursing homes. [67]

All of which is respectfully submitted.

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[63] IAEA Safety Standard for Site Evaluation, s 5.1, pp 20-21
[64] IAEA Safety Standard for Site Evaluation , s 4.11, pp 19-20
[65] United Nations, *Sendai Framework for Disaster Risk Reduction 2015-2030*, para 30(f), p 19 ("Sendai Framework") (Tab C40)
[66] Sendai Framework, para 27(k), p 18
[67] International Atomic Energy Agency, *The Fukushima Daiichi Accident,* Technical Volume 3/5 – Emergency Preparedness and Response, s 3.3.10, p 99-100 ("*Fukushima Daiichi Accident*") (Tab C41)

IAEA
SAFETY
STANDARDS
SERIES

Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants

SAFETY GUIDE

No. NS-G-3.2

INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities.

The regulatory related publications by means of which the IAEA establishes safety standards and measures are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (that is, of relevance in two or more of the four areas), and the categories within it are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides.**

Safety Fundamentals (blue lettering) present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

Safety Requirements (red lettering) establish the requirements that must be met to ensure safety. These requirements, which are expressed as 'shall' statements, are governed by the objectives and principles presented in the Safety Fundamentals.

Safety Guides (green lettering) recommend actions, conditions or procedures for meeting safety requirements. Recommendations in Safety Guides are expressed as 'should' statements, with the implication that it is necessary to take the measures recommended or equivalent alternative measures to comply with the requirements.

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA.

Information on the IAEA's safety standards programme (including editions in languages other than English) is available at the IAEA Internet site

www.iaea.org/ns/coordinet

or on request to the Safety Co-ordination Section, IAEA, P.O. Box 100, A-1400 Vienna, Austria.

OTHER SAFETY RELATED PUBLICATIONS

Under the terms of Articles III and VIII.C of its Statute, the IAEA makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued in other series, in particular the **IAEA Safety Reports Series**, as informational publications. Safety Reports may describe good practices and give practical examples and detailed methods that can be used to meet safety requirements. They do not establish requirements or make recommendations.

Other IAEA series that include safety related sales publications are the **Technical Reports Series,** the **Radiological Assessment Reports Series** and the **INSAG Series**. The IAEA also issues reports on radiological accidents and other special sales publications. Unpriced safety related publications are issued in the **TECDOC Series**, the **Provisional Safety Standards Series**, the **Training Course Series,** the **IAEA Services Series** and the **Computer Manual Series**, and as **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**.

DISPERSION OF RADIOACTIVE MATERIAL IN AIR AND WATER AND CONSIDERATION OF POPULATION DISTRIBUTION IN SITE EVALUATION FOR NUCLEAR POWER PLANTS

The following States are Members of the International Atomic Energy Agency:

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

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FOREWORD

by Mohamed ElBaradei
Director General

One of the statutory functions of the IAEA is to establish or adopt standards of safety for the protection of health, life and property in the development and application of nuclear energy for peaceful purposes, and to provide for the application of these standards to its own operations as well as to assisted operations and, at the request of the parties, to operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of nuclear energy.

The following bodies oversee the development of safety standards: the Commission for Safety Standards (CSS); the Nuclear Safety Standards Committee (NUSSC); the Radiation Safety Standards Committee (RASSC); the Transport Safety Standards Committee (TRANSSC); and the Waste Safety Standards Committee (WASSC). Member States are widely represented on these committees.

In order to ensure the broadest international consensus, safety standards are also submitted to all Member States for comment before approval by the IAEA Board of Governors (for Safety Fundamentals and Safety Requirements) or, on behalf of the Director General, by the Publications Committee (for Safety Guides).

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA for its assistance in connection with the siting, design, construction, commissioning, operation or decommissioning of a nuclear facility or any other activities will be required to follow those parts of the safety standards that pertain to the activities to be covered by the agreement. However, it should be recalled that the final decisions and legal responsibilities in any licensing procedures rest with the States.

Although the safety standards establish an essential basis for safety, the incorporation of more detailed requirements, in accordance with national practice, may also be necessary. Moreover, there will generally be special aspects that need to be assessed on a case by case basis.

The physical protection of fissile and radioactive materials and of nuclear power plants as a whole is mentioned where appropriate but is not treated in detail; obligations of States in this respect should be addressed on the basis of the relevant instruments and publications developed under the auspices of the IAEA. Non-radiological aspects of industrial safety and environmental protection are also not explicitly considered; it is recognized that States should fulfil their international undertakings and obligations in relation to these.

The requirements and recommendations set forth in the IAEA safety standards might not be fully satisfied by some facilities built to earlier standards. Decisions on the way in which the safety standards are applied to such facilities will be taken by individual States.

The attention of States is drawn to the fact that the safety standards of the IAEA, while not legally binding, are developed with the aim of ensuring that the peaceful uses of nuclear energy and of radioactive materials are undertaken in a manner that enables States to meet their obligations under generally accepted principles of international law and rules such as those relating to environmental protection. According to one such general principle, the territory of a State must not be used in such a way as to cause damage in another State. States thus have an obligation of diligence and standard of care.

Civil nuclear activities conducted within the jurisdiction of States are, as any other activities, subject to obligations to which States may subscribe under international conventions, in addition to generally accepted principles of international law. States are expected to adopt within their national legal systems such legislation (including regulations) and other standards and measures as may be necessary to fulfil all of their international obligations effectively.

EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

The English version of the text is the authoritative version.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. The IAEA issues Safety Requirements and Safety Guides pertaining to nuclear power plants and activities in the field of nuclear energy, on the basis of its Safety Fundamentals publication on The Safety of Nuclear Installations [1]. The present Safety Guide, which supplements the Code on the Safety of Nuclear Power Plants: Siting [2][1], concerns the effects of a nuclear power plant on the surrounding region and the consideration of population distribution in the siting of a plant.

1.2. This Safety Guide makes recommendations on how to meet the requirements of the Code on the Safety of Nuclear Power Plants: Siting, on the basis of knowledge of the mechanisms for the dispersion of effluents discharged into the atmosphere and into surface water and groundwater. Relevant site characteristics and safety considerations are discussed. Population distribution, the projected population growth rate, particular geographical features, the capabilities of local transport networks and communications networks, industry and agriculture in the region, and recreational and institutional activities in the region should be considered in assessing the feasibility of developing an emergency response plan.

1.3. In the selection of a site for a facility using radioactive material, such as a nuclear power plant, account should be taken of any local features that might be affected by the facility and of the feasibility of off-site intervention, including emergency response and protective actions (see the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [3], Appendices IV and V). This is in addition to the evaluation of any features of the site itself that might affect the safety of the facility. This Safety Guide recommends methods for the assessment of regional and local characteristics.

1.4. This Safety Guide supersedes four earlier IAEA Safety Guides, namely: Atmospheric Dispersion in Nuclear Power Plant Siting (Safety Series No. 50-SG-S3 (1980)); Site Selection and Evaluation for Nuclear Power Plants with Respect to Population Distribution (Safety Series No. 50-SG-S4 (1980)); Hydrological Dispersion of Radioactive Material in Relation to Nuclear Power Plant Siting (Safety Series No. 50-SG-S6 (1985)); and Nuclear Power Plant Siting: Hydrogeological Aspects (Safety Series No. 50-SG-S7 (1984)).

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[1] To be superseded by a Safety Requirements publication on Safety of Nuclear Power Plants: Site Evaluation, in the Safety Standards Series.

OBJECTIVE

1.5. Radioactive materials discharged from a nuclear power plant might reach the public and might contaminate the environment in the region by way of both direct and indirect pathways. The objective of this Safety Guide is to provide guidance on the studies and investigations necessary for assessing the impact of a nuclear power plant on humans and the environment. It also provides guidance on the feasibility of an effective emergency response plan, in consideration of all the relevant site features.

1.6. This Safety Guide provides guidance on investigations relating to population distribution, and on the dispersion of effluents in air, surface water and groundwater. The guidance is intended to help determine whether the site selected for a nuclear power plant satisfies national requirements and whether possible radiological exposure and hazards to the population and to the environment are controlled within the limits set by the regulatory body, with account taken of international recommendations.

SCOPE

1.7. This Safety Guide provides guidance for the site evaluation stage of a facility, specifically on:

— the development of meteorological, hydrological and hydrogeological descriptions of a plant site;
— programmes to collect meteorological and hydrological data (for surface water and groundwater);
— programmes to collect data on the distribution of the surrounding population in order to demonstrate the feasibility of an effective emergency plan.

1.8. The effects of the proposed plant on the uses of land and water in the region of the site have to be investigated and are covered by this Safety Guide. This is also an aspect that should be considered in the preparation of an emergency plan and in the environmental impact assessment.

1.9. This Safety Guide does not give guidance on dose assessment in relation to the siting of a nuclear power plant. Specific guidance on the calculation of doses and for the identification of characteristics of the site that are relevant to the local and regional radiological impact of a nuclear power plant is given in Refs [4, 5].

1.10. This Safety Guide does not give detailed information on specific methods or mathematical models. Methods for calculating the concentrations and rates of deposition of radioactive material due to the dispersion of effluents in air or water are presented in Ref. [4]. Attention should be paid to the use of environmental data in conjunction with calculational models to ensure that the type of data is appropriate for the regulatory objective.

STRUCTURE

1.11. Sections 2 and 3 provide guidance on the collection of data on the dispersion of radioactive material in air and water. Sections 4 and 5 provide guidance relating to uses of land and water and to the distribution of the population in the region. Guidance on the site related information necessary for the establishment of an emergency plan is given in Section 6. Guidance on quality assurance considerations is provided in Section 7.

2. TRANSPORT AND DIFFUSION OF EFFLUENTS DISCHARGED INTO THE ATMOSPHERE

GENERAL CONSIDERATIONS

2.1. The atmosphere is a major exposure pathway by which radioactive materials that are either routinely discharged under authorization or accidentally released from a nuclear power plant could be dispersed in the environment and transported to locations where they may reach the public.

2.2. The evaluation of the transport in the atmosphere of radioactive materials discharged from a nuclear power plant under normal operational or accidental conditions is a requirement of design and licensing (Ref. [2], para. 503). A meteorological investigation should be carried out to evaluate regional and site specific meteorological parameters. These data should be collected from appropriate elevations above ground in order to obtain realistic dispersion parameters.

2.3. Contamination in the air, on the ground and in water over short and long time periods should be described in the atmospheric dispersion models, with account taken of diffusion conditions in the region. Orographic elevations having significant slopes should be considered in the models.

2.4. The type and extent of acquired and stored meteorological data should allow for reliable statistical analyses to determine the distribution of radiation exposures.

2.5. The effects and consequences for the public and the environment of short term or long term radioactive discharges should be assessed on the basis of meteorological information and site specific conditions relating to land and water uses, population distribution, infrastructure in the vicinity of the site and relevant radiological parameters.

2.6. A detailed meteorological investigation should be carried out in the region. The calculations of the dispersion and concentrations of radioactive materials should show whether the radiological consequences of routine discharges and potential accidental releases of radioactive materials into the atmosphere are acceptable. The results of these calculations may be used to establish authorized limits for radioactive discharges from the plant into the atmosphere (see Ref. [5]).

2.7. The results of the meteorological investigation should be used to confirm the suitability of a site; to provide a baseline for site evaluation; to determine whether local meteorological characteristics have altered since the site evaluation was made and before operation of the plant commences; to select appropriate dispersion models for the site; to establish limits for radioactive discharges into the atmosphere; to establish limits for design performance (for example, containment leak rates and control room habitability); and to assist in demonstrating the feasibility of an emergency plan.

RADIOACTIVE SOURCE PARAMETERS FOR NORMAL AND ACCIDENTAL DISCHARGES IN AIR

2.8. The following properties and parameters should be estimated for radioactive sources:

(a) Radioactivity:
- the rate of discharge of each important nuclide and the total activity of each important nuclide released in a specified period;
- variation of the rate of discharge of each important nuclide;

(b) Chemical characteristics of the material released;

(c) Physical properties of the material released;

(d) Geometry and mechanics of the discharge.

2.9. Information should be collected on the background levels of activity in air due to natural and artificial sources.

PROGRAMME FOR METEOROLOGICAL INVESTIGATION

2.10. A programme for meteorological investigation should be designed to collect and evaluate data continuously also on the following parameters during normal operation of a nuclear power plant:

- — Site specific meteorological parameters relating to calculations of atmospheric dispersion and statistical analyses;
- — Site specific meteorological parameters as specified in the emergency plan; and
- — Site specific meteorological parameters relating to safe operation and confirmation of the design bases for the plant (see Refs [6, 7]).

2.11. The programme of meteorological measurements should provide data for an adequate time period (at least one full year) that are representative of the site before the start of plant construction, and should continue for the lifetime of the plant. In addition, the data should be compared with data collected after the plant is constructed, but before operation, to determine whether changes are necessary to the design bases or to assumptions made in the calculational model.

METEOROLOGICAL DATA NECESSARY FOR THE PROGRAMME

2.12. The meteorological data collected should be compatible in terms of their nature, scope and precision with the methods and models in which they will be used in evaluating the radiation exposure of the public and the radiological impact on the environment for assessment against each regulatory objective.

2.13. Meteorological measurements are often affected by terrain, and local features such as vegetation and ground cover, orographic features and plant structures (such as cooling towers and masts supporting meteorological sensors) as well as building wake effects may influence the representativeness of the data obtained. In collecting meteorological data, care should be taken to prevent local effects from unduly altering the values of the parameters to be measured.

2.14. In order to provide a description of the meteorological conditions, data on the following should be obtained concurrently:

- — wind vectors (i.e. wind directions and speeds),
- — specific indicators of atmospheric turbulence,
- — precipitation,
- — air temperatures,

— humidity,
— air pressure.

COLLECTION OF DATA

2.15. It should be ensured that the data collected adequately represent local meteorological conditions. Activities should be undertaken in accordance with accepted international standards. Data for at least one representative year should be presented. Information should be given to indicate the extent to which these data represent the long term meteorological characteristics of the site. This information may be obtained by comparing the local data with concurrent and long term data from synoptic meteorological stations in the surrounding area.

Siting of the meteorological measurement system

2.16. Meteorological equipment should be installed in such a way as to obtain data representing the dispersion conditions at release points. Examination of the terrain in the range of several kilometres around a nuclear power plant site is necessary. Topographical features of interest include valleys, principal ridges and coastlines. Isolated hills, wooded and forested areas and large artificial structures should be noted. Shallow valleys (less than 100 m deep and 5–10 km wide) should be considered because they can affect lower level winds. Equipment should be properly exposed and should be positioned far enough from any obstacles to minimize their effects on measurements. Ground cover and vegetation should be managed for the duration of the investigation programme, to avoid local influences.

2.17. When the site is near an international border and it is necessary to locate meteorological equipment on the territory of the neighbouring country, an agreement should be concluded for the installation and maintenance of the equipment and for the collection of data.

Wind characteristics

2.18. To gain a better understanding of atmospheric conditions at the site, the positions and settings of equipment should be selected for maximum exposure. In addition, instruments should be capable of obtaining data representing the entire profile of the wind at least up to the height of potential releases.

2.19. If the wind speed or direction does not vary significantly across the region, then the wind speed and direction at a single location representative of the site may be measured in order to obtain wind data continuously at the following levels:

- At an elevation of 10 m, for purposes of comparing and correlating wind data from the site with wind data from the synoptic network of meteorological stations; and
- At the point representing the effective height of discharge[2] (to be evaluated on the basis of preliminary information).

2.20. In other cases, measurements should be made at more than one location. For example, where the effect of sea breezes is important, data from an additional meteorological station further inland should be used in order to evaluate characteristics of the diffusion regime for the sea breeze over land.

2.21. Meteorological data should be obtained at least hourly. The averaging time and the sampling time for the data should be in accordance with the regulatory objective. Instruments should be provided for continuous recording in order to ensure that the data collected can be made readily available at the appropriate locations where they are used.

2.22. Measurements of wind parameters at additional stations should be made concurrently with measurements of other parameters.

Turbulence in the atmosphere

2.23. Fluctuations in meteorological conditions are direct indicators of atmospheric turbulence. Depending upon the model, turbulence should be indicated by the use of data relating to one or more of the following:

- Fluctuations in wind direction (sigma–theta method);
- Air temperature and temperature lapse rate (delta T method);
- Wind speed and solar radiation levels or sky cover during the daytime, and sky cover or net radiation levels at night-time (insulation method); and
- Wind speed at different heights.

2.24. For the purpose of meeting certain regulatory objectives (notably those relating to site evaluation and design), dispersion characteristics of an atmospheric layer may need to be determined by the temperature variation with height between at least two

[2] The effective height of discharge will depend on the buoyancy of the plume and on building wake effects.

measurement levels. These levels should include the level at which the wind is measured.

2.25. The frequency, duration and time of the measurements of temperature variation with height should be concomitant with the wind data. For complex meteorological situations, for example in relation to orography, measurements of turbulence indicators made at the site alone may not be sufficient. Depending on the particular characteristics of the region, it may be necessary to make additional measurements of wind and turbulence indicators a few kilometres from the site. In certain cases, normal discharges of effluents or experimental discharges of tracers are used for the development of a local diffusion model, which is often a general model with adjustments derived from air concentration values measured at the site and in the region.

2.26. In developing site specific diffusion models, sufficient information should be acquired on the space and time distributions of wind and temperature to be able to understand and determine the trajectory of effluents. Such information should be obtained by way of a programme of field measurements. This programme should be planned to be conducted in various seasons and at various times of the day in order to be representative of meteorological conditions over at least one year.

2.27. If atmospheric turbulence is determined by visual observations of sky cover at various times of the day (the insulation method), then the observations of the amount of sky cover and of the height of clouds should be combined with wind data measured concurrently at the site.

Precipitation and humidity

2.28. Precipitation should be reported at least hourly. Measurements of the intensity of precipitation and total precipitation as well as details of the type of precipitation should be used to evaluate the impact of precipitation on airborne concentrations of contaminants and on ground contamination. Data on humidity may also help to determine any effects of cooling towers (for example, icing or fogging on roadways and bridges, and effects of salt drift on vegetation). Air humidity can modify the dispersion of aerosols, as it can increase the coalescence of particulates.

INSTRUMENTATION

2.29. Meteorological instrumentation and systems should be shielded, maintained, serviced and calibrated on a regular basis in order to mitigate harmful environmental effects such as those of sun, lightning, ice, sandstorms and corrosive agents.

2.30. In assessing the accuracy of instrumentation, allowance should be made for errors due to cabling, signal conditioning, recording, solar radiation and the effects of fluctuations in environmental temperature. The accuracy and reliability of equipment should be ensured by means of a quality assurance programme including regular maintenance and inspection.

2.31. When Doppler–SODAR instrumentation is used in lieu of a tall mast to characterize wind vector measurements, a measurement system should still be maintained to record the conditions at the 10 m elevation as well as at other elevations of interest (see para. 2.15).

ANALYSIS AND PRESENTATION OF DATA

2.32. There are two basic steps in the analysis of the data:

(1) Determination of average values of the variables at regular intervals; and
(2) Statistical analysis of these average values.

2.33. The wind vector at different elevations and temperatures should be averaged at least once per hour, while for other variables such as solar radiation levels and precipitation levels the period of integration should be one hour. Wind direction should be averaged as a vector and wind speed as a scalar over the prescribed time period.

2.34. For purposes of site evaluation and design, statistical analyses should be performed to evaluate the effects of both routine discharges and accidental releases.

2.35. Depending on the requirements of the calculational model, analysis for routine discharges may necessitate a joint frequency distribution of wind direction and wind speed for each stability class (three dimensional weather statistics). For effluents subject to washout, account should also be taken of the precipitation class (four dimensional weather statistics).

2.36. Analysis of postulated accidental radioactive releases may involve the probability of occurrence of different sets of meteorological conditions during different periods of time over the duration of the accident, for example, in the first hours of the postulated accident, on the first day, over the first week and over the balance of the duration of the accident.

2.37. The information necessary to perform dose assessments for exposure to radioactive materials includes:

(a) the source term for the discharge of radioactive material to the environment and its variation in time;
(b) atmospheric, physical and physicochemical characteristics governing the transport, diffusion and suspension of radioactive materials;
(c) relevant food-chains leading to humans;
(d) characteristics of resident and transient populations, including their agricultural, industrial, recreational and institutional activities.

MODELLING OF ATMOSPHERIC DISPERSION[3]

2.38. Atmospheric dispersion models should typically be applied in site evaluation and design for nuclear power plants to meet the following objectives:

(1) To derive short term (a few hours) normalized concentrations[4] and deposition values in order to assess the probability of occurrence of high normalized concentrations and contamination levels due to postulated accidents;
(2) To derive longer term (up to one month) time integrated normalized concentrations and deposition values for postulated accidents;
(3) To derive long term (about one year) time integrated normalized concentrations and deposition values for routine operations.

These atmospheric dispersion models serve to calculate concentrations which may be applicable for normal or accidental discharges.

2.39. Once a radioactive gas or aerosol becomes airborne, it travels and disperses in a manner governed by its own physical properties and those of the ambient atmosphere into which it is discharged. The effluent enters the atmosphere with a certain velocity and temperature which are generally different from those of the ambient atmosphere. The effluent motion has a vertical component owing to the effects of vertical velocity and differences in temperature, as long as these continue. This upward rise of the effluent, termed ‘plume rise’, changes the effective height of the discharge point. The path of the effluent is affected by flow modifications near

[3] If the publications referenced in this Safety Guide are used in the modelling of dispersion, the applicability of the model to a particular site and plant state (normal operation or accident conditions) should be verified, because these references do not directly address issues which may arise in site evaluation for nuclear power plants.

[4] The term ‘normalized concentration’ as used here means the ratio of the actual concentration to the release rate.

obstacles such as buildings and structures. The model(s) employed should account for these effects.

2.40. The effluent, while undergoing plume rise, transport and diffusion, may also be subject to processes such as the following:

(a) radioactive decay and buildup of daughter products;
(b) wet deposition:
  - rainout and/or snowout (in which vapour or aerosol is scavenged by water droplets or snowflakes in cloud and falls out as precipitation);
  - washout (in which vapour or aerosol is scavenged below the rain cloud by falling precipitation);
  - fogging (in which vapour or aerosol is scavenged by water droplets in fog);
(c) dry deposition:
  - sedimentation of aerosols or gravitational settling (for particulate diameters larger than about 10 μm);
  - impaction of aerosols and adsorption of vapours and gases onto obstacles in the path of the wind;
(d) formation and coalescence of aerosols; and
(e) resuspension of materials deposited on surfaces.

These effects can be expressed mathematically, and they should be considered in the calculational models when this is appropriate for the regulatory objective.

2.41. Calculational models for atmospheric dispersion should be chosen in accordance with the regulatory objective and, to the extent possible, site and/or plant specific characteristics should be taken into account.

2.42. Methods and mathematical equations used in the models for turbulence indicators and for the calculation of atmospheric dispersion, plume rise and effective stack height, and time integrated concentrations, as well as general procedures for evaluating dispersion and techniques for estimating resuspension of deposited materials, are discussed in Refs [4, 5]. They are not discussed in this Safety Guide.

DATA STORAGE AND DOCUMENTATION

2.43. The raw data should be stored until data qualification and statistical analysis have been performed. Hourly mean values derived from the programme for meteorological investigation should be stored for the lifetime of the facility. Data averaged over shorter periods of time (less than one hour) should be stored continuously for purposes of emergency response and recovery, as they can be used to assess the plume dispersion in the event of an accidental release.

2.44. The programme for regional meteorological investigation and all information relating to it should be documented for the purposes of site evaluation and design, and for use in emergency response plans.

3. TRANSPORT AND DIFFUSION OF EFFLUENTS DISCHARGED INTO THE HYDROSPHERE

GENERAL CONSIDERATIONS

3.1. The hydrosphere is a major exposure pathway by which radioactive materials that are routinely discharged under authorization or are accidentally released from a nuclear power plant could be dispersed to the environment and transported to locations where water is used by or for the population in the region of the site. Radionuclides are transported rapidly in some surface waters such as rivers, and very slowly in groundwater. The dispersion of discharged effluents in surface water and groundwater is discussed separately in this Section.

3.2. A detailed investigation of the hydrosphere in the region should be carried out. Calculations of dispersion and concentrations of radionuclides should be made to show whether the radiological consequences of routine discharges and potential accidental releases of radioactive materials into the hydrosphere are acceptable. The results of these calculations may be used to demonstrate compliance with the national authorized limits for discharges of radioactive effluents [5].

3.3. The information necessary to perform dose assessment relating to exposure pathways in the hydrosphere includes:

- — the source term for the discharge of radioactive material to the environment;
- — hydrological, physical, physicochemical and biological characteristics governing the transport, diffusion and retention of radioactive materials;
- — relevant food-chains leading to humans;
- — locations and amounts of water used for drinking and for industrial, agricultural and recreational purposes;

— dietary and other relevant habits of the population, including special occupational activities such as the handling of fishing gear and recreational pursuits such as water sports and fishing.

3.4. The results of the hydrospheric investigation should be used for the following purposes: to confirm the suitability of the site; to select and calibrate an appropriate dispersion model for the site; to establish limits for radioactive discharges into water; to assess the radiological consequences of releases; and to assist in demonstrating the feasibility of an emergency plan. They should also be used to develop a monitoring programme and a sampling strategy for use in the event of an accidental radioactive release.

RADIOACTIVE SOURCE PARAMETERS FOR NORMAL OR ACCIDENTAL DISCHARGES TO SURFACE WATER AND GROUNDWATER

3.5. The following properties and parameters should be estimated for radioactive discharges:

(a) Radioactivity:
  — the rate of discharge of each important nuclide, and an estimate of the total activity discharged in a specific period and its fixation capacity on soils;
(b) Chemical properties, including:
  — important anion and cation concentrations, and their oxidation states and complexing states (e.g. Ca^{2+}, K^+, Mg^{2+}, Na^+, NH_4^+, HCO_3^-, Cl^-, SO_4^-, NO_2^-, NO_3^-, PO_4^-);
  — organic content;
  — pH;
  — the concentration of dissolved oxygen, and conductivity and concentrations of associated pollutants;
(c) Physical properties of the liquid effluents discharged, including:
  — temperature;
  — density;
  — loads and granulometry of suspended solids;
(d) Flow rates for continuous discharges, or volume and frequency for batch discharges;
(e) The variation of the source term over the duration of the discharge, which is necessary to evaluate the concentrations due to long term releases;
(f) The geometry and mechanics of discharges.

3.6. Any airborne radioactive material deposited on the ground surface or on surface water may be transmitted by infiltration processes into groundwater. The potential for indirect contamination in surface water and possible contamination of groundwater from the surface should be assessed.

MONITORING PROGRAMME FOR SURFACE WATER AND GROUNDWATER

3.7. A monitoring programme should be established for both surface water and groundwater. The purpose of such a programme is to provide a baseline for site evaluation and to determine whether the hydrological characteristics of the region have altered since the site evaluation and before the commencement of plant operation.

3.8. The monitoring programme for groundwater should be initiated about two years before the start of plant construction. The site area should be monitored before the foundation work is begun in order to verify possible changes in the groundwater regime, and monitoring should be continued after construction has finished.

3.9. Groundwater is monitored by means of samples taken from boreholes and wells. The samples can also be taken from groundwater reaching the surface in springs or in natural depressions. The monitoring programme should be continued throughout the lifetime of the plant. Boreholes and wells should be kept in an operable state for the same period of time.

3.10. The monitoring programme for surface water should also commence well before the start of construction of the plant, and should continue for its lifetime.

3.11. All surface water and groundwater in the site region should be sampled regularly, at intervals that will depend on the half-lives of the radionuclides that could potentially be discharged.

SURFACE WATER

Necessary data

3.12. The data necessary for the surface hydrological analysis for a nuclear power plant site come from different sources. The existing hydrometeorological network usually provides sufficient data. These, however, should be verified before being used.

3.13. The data needs presented herein relate to standard calculational methods. For advanced models, the data needs depend on the model being used to satisfy the relevant regulatory objectives. Specific parameters necessary in the models for assessing the aquatic environmental transfer of radionuclides are discussed in Refs [4, 5].

3.14. Typical water bodies in the vicinity of a nuclear power plant range from rivers, estuaries, open shores of large lakes, seas and oceans to human made impoundments. The collection of hydrological data for sites on different types of water bodies is discussed in the following.

Sites on rivers

3.15. For sites on rivers, the hydrological and other information should cover the following:

(a) The channel geometry, defined by the mean width, the mean cross-sectional area and the mean slope over the river reaches of interest (the water level can be computed from the channel geometry and the river flow rate). If there are important irregularities such as dead zones or hydraulic equipment in the stream which could influence the dispersion of the plume, they should be described. Additional downstream measurements of channel geometry should be made as necessary to assess the dispersion process over the river reaches of interest.
(b) The river flow rate, presented as monthly averages of the inverse of daily flows. The inverse rate of flow is used since the fully mixed concentration is proportional to the reciprocal of the flow rate if sediment sorption effects are not considered. The flow rates of other relevant and important water bodies (such as downstream tributaries of the river) should be measured if they affect dispersion.
(c) Extremes in the flow rate evaluated from available historical data.
(d) Temporal variation of the water level over the reaches of interest.
(e) Tidal variations in water level and flow rate in the case of a tidal river.
(f) Data to describe possible interactions between river water and groundwater, and the identification of those reaches of the channel where the river may gain water from or lose water to groundwater.
(g) River temperature, measured at a representative location over at least an entire year and expressed as monthly averages of daily temperatures.
(h) The thickness of the top layer if thermal stratification of water in the river occurs.
(i) Extreme temperatures evaluated from available historical data.
(j) The concentrations of suspended matter measured:
    — at locations downstream of sections where the river is slowed, depleted or fed by tributaries;

— on discrete samples at appropriate intervals (such as every two months for at least an entire year);
— over a sufficient range of flows to establish curves of flow versus sedimentation and/or erosion rate;

(k) The characteristics of deposited sediments, including mineral and/or organic compositions and size classification;
(l) The distribution coefficients for sediments and for suspended matter for the various radionuclides that may be discharged;
(m) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources;
(n) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass;
(o) Spawning periods and feeding cycles of major fish species.

Sites on estuaries

3.16. For sites on estuaries, the following information should be collected:

(a) The salinity distribution determined along several verticals covering different cross-sections of the salinity intrusion zone. The data should be sufficient to delineate the flow pattern, which is directed towards the estuary mouth in the upper layer and towards the inner reaches in the lower layer of a fully or partially mixed estuary.
(b) Evaluations of sediment displacements, the load of suspended matter, the rate of buildup of deposited sediment layers and the movement of these sediments with the tide.
(c) Channel characteristics sufficiently upstream of the site to model the maximum upstream travel of radioactive effluents if applicable.
(d) The distribution coefficients for sediments and for suspended matter for the various radionuclides that may be discharged.
(e) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources.
(f) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass.
(g) Spawning periods and feeding cycles of major fish species.

3.17. Measurements of water temperature, salinity and other relevant water quality parameters in estuaries should be made at appropriate depths, distances and times, depending on the river flow, tidal levels and the configuration of the water body in different seasons.

Sites on the open shores of large lakes, seas and oceans

3.18. For sites located on the shores of large lakes, seas and oceans, the hydrological information should include the following:

(a) The general shore and bottom configuration in the region, and unique features of the shoreline in the vicinity of the discharge. Data on bathymetry out to a distance of several kilometres, and data on the amount and character of sediments in the shallow shelf waters.
(b) Speeds, temperatures and directions of any near shore currents that could affect the dispersion of discharged radioactive material. Measurements should be made at appropriate depths and distances, depending on the bottom profile and the location of the point of discharge.
(c) The duration of stagnation and characteristics of current reversals. After a stagnation, a reversal in current usually leads to a large scale mass exchange between inshore and offshore waters that effectively removes pollutants from the shore zone.
(d) The thermal stratification of water layers and its variation with time, including the position of the thermocline and its seasonal changes.
(e) The load of suspended matter, sedimentation rates and sediment distribution coefficients, including data on sediment movements characterized by defining at least the areas of high rates of sediment accumulation.
(f) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources.
(g) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass.
(h) Spawning periods and feeding cycles of major fish species.

Sites on human made impoundments

3.19. For sites on impoundments, the hydrological information should include the following:

(a) Parameters of the impoundment geometry, including length, width and depth at different locations;
(b) Rates of inflow and outflow;
(c) Expected fluctuations in water level on a monthly basis;
(d) The water quality at inflows, including temperature and suspended solids;
(e) Data on thermal stratification and its seasonal variation for relevant water bodies;
(f) Interaction with groundwater;

(g) Characteristics of bottom sediments (type and quantity);
(h) The distribution coefficients for sediments and for suspended matter for the various radionuclides that may be discharged;
(i) The rate of sediment deposition;
(j) The background levels of activity in water, sediment and aquatic food due to natural and artificial sources;
(k) Seasonal cycles of phytoplankton and zooplankton, with at least the periods of their presence and cyclical evolutions of their biomass;
(l) Spawning periods and feeding cycles of major fish species.

Modelling of radionuclide dispersion in surface water

3.20. Many models are available to calculate the dispersion in surface waters of material originating from routine discharges and accidental releases [4, 5]. Advanced models should be used for particularly complex conditions (see footnote 3).

3.21. The three basic groups of models are the following:

(1) Advanced calculational models transform the basic equations of radionuclide dispersion into finite difference or finite element form. Such models permit most of the relevant physical phenomena to be taken into account in the analysis.
(2) Box type models treat the entire body of water, or sections thereof, as composed of homogeneous compartments. In this type of model, average concentrations are computed for each compartment and transfer constants are set up to relate the variables for one compartment to those in adjacent compartments. Most models dealing with the interactions between radionuclides and sediment are of this type.
(3) Calculational models solve the basic equations describing radionuclide transport with major simplifications made for the geometry of the water body and the dispersion coefficients. This group of models is the one most frequently used in surface hydrological analysis.

In addition, Monte Carlo methods may be used to model water body geometry and to simulate particles.

3.22. Standard calculational models drawn from groups 2 and 3 above are commonly used in the site evaluation for a nuclear power plant. The selection of a model should be based on the type of discharge (surface or submerged), the type of water body (river, estuary, impoundment, large lake or ocean) and the use being made of the water. The magnitude of the source term under normal operation and potential accident conditions, the required accuracy and the type of water affected should be considered in the selection of the model.

3.23. The results from a calculational model should be compared with laboratory data or field data for a specific site. Such validation usually has a limited range of applicability, which should be determined with a full understanding of the model.

GROUNDWATER

General considerations

3.24. A discharge of radioactive material from a nuclear power plant may contaminate the groundwater system in the region either directly or indirectly, via earth, atmosphere or surface water, in the following three ways:

(1) Indirect discharge to the groundwater through seepage and infiltration of surface water that has been contaminated by radioactive material discharged from the nuclear power plant;
(2) Infiltration into the groundwater of radioactive liquids from a storage tank or reservoir;
(3) Direct release from a nuclear power plant; an accident at the plant might induce such an event, and radioactive material could penetrate into the groundwater system. The protection of aquifers from such events should be considered in the safety analysis for postulated accident conditions, and a geological barrier to provide protection should be considered.

3.25. The evaluation of hydrogeological characteristics should determine the following:

- the estimated concentration of radioactive material in groundwater at the nearest point in the region where groundwater is drawn for human consumption;
- the transport paths and travel times for radioactive material to reach the source of consumption from the point of release;
- the transport capacity of the surface flow, interflow and groundwater recharge;
- the susceptibility to contamination of the aquifers at different levels; and
- time and space distributions of the concentrations in the groundwater of radioactive material resulting from accidental releases from the plant.

DATA NECESSARY FOR INVESTIGATIONS OF GROUNDWATER

3.26. Hydrogeological investigation in the framework of site evaluation for a nuclear power plant involves regional and local investigations using comparatively standard surface geophysical surveys and programmes for drilling boreholes for geophysical and tracer studies.

Regional and local hydrogeological information

3.27. Both local and regional information should be collected to identify the hydrogeological system and the preferential flow paths. The information to be collected should include:

- — climatological data;
- — initial concentrations of radionuclides;
- — major hydrogeological units, their hydrodynamic parameters and the ages or mean turnover times of groundwater;
- — recharge and discharge relationships;
- — data on surface hydrology.

Climatological data

3.28. In regions where rainfall makes a substantial contribution to groundwater, hydrometeorological data on seasonal and annual rainfall and on evapotranspiration that have been systematically collected should be analysed for as long a period as they are available. From meteorological (precipitation) data, groundwater recharge should be calculated. Alternatively, tracers (chemical or isotopic) of the water cycle could be introduced to calculate groundwater recharge.

Major hydrogeological units

3.29. Data should be obtained on the types of the various geological formations in the region and their stratigraphic distribution in order to characterize the regional system and its relationship with the local hydrogeological units.

3.30. The geology and surface hydrology of the site area should be studied in sufficient detail to indicate potential pathways of contamination to surface water or groundwater. Any surface drainage system or standing water body accessible from a potential release point in an accident should be identified. Areas from which contaminated surface water can directly enter an aquifer should be determined. The relevant hydrogeological information for surface or near surface discharges includes information on soil moisture properties, infiltration rates, configuration of unsaturated zones and chemical retention properties under unsaturated conditions.

3.31. For consideration of the transport potential of seepage and groundwater in the region of the site (a few tens of kilometres in radius), data on types of aquifers, aquitards and aquicludes, their interconnections and the flow velocities and mean turnover times should be investigated. Such data will permit the regional flow pattern and its relation to the local flow pattern of seepage and groundwater to be characterized. This investigation should include the following data:

— Geological data: lithology, thickness, extent, degree of homogeneity and degree of surface weathering of the geological units;
— Hydrogeological data: hydraulic functions of the unsaturated zone, and hydraulic conductivities and transmissivities, specific yield and storage coefficients, dispersion parameters, and hydraulic gradients of the saturated zone for each geological unit;
— Depth related water ages and mean turnover times;
— Interconnections between aquifers and aquitards without and with groundwater usage;
— The chemical composition of groundwater from the respective aquifers and aquitards in comparison with their lithology;
— Physical properties of the groundwater, especially temperatures, gas contents and density;
— Variations of water levels in wells and mining shafts and in the discharges of springs and rivers;
— Locations of active and potential sink holes in the region.

Water bearing characteristics of the hydrogeological units

3.32. Information on the water bearing characteristics of the main hydrogeological units should be collected, including information on the following properties:

— moisture content;
— porosity and bulk density;
— specific yield for unconfined aquifers and storage coefficients for confined aquifers;
— hydraulic conductivity or permeability;
— transmissivity for fully saturated confined aquifers.

3.33. For the relevant hydrogeological units, information should be collected on the following chemical and physical properties of the groundwater:

— concentrations and oxidation and complexing states of important anions and cations, and their presence in organic compounds;
— contents of organic and biological material;
— pH;
— Eh;
— temperature;
— sorption characteristics.

Interrelationship between groundwater and surface water

3.34. The extent and degree of hydraulic connections between bodies of surface water and groundwater should be identified. Topographic and geological maps should be studied in order to identify lines or areas where such hydraulic connections between surface water and groundwater are present. The amounts of the exchanges should be estimated and their corresponding exchange regimes should be determined.

Modelling of dispersion and retention of radionuclides in groundwater

3.35. Models have been developed to calculate the dispersion and retention of radionuclides released into groundwater. Standard calculational models are generally satisfactory and should be used in most cases. The complexity of the model chosen should reflect the complexity of the hydrogeological system at a particular site.

3.36. Simplified evaluations should be performed with conservative assumptions and data to evaluate the effects of postulated accidental releases of radioactive material to the groundwater. Further, more refined analysis with more realistic assumptions and models should be performed if necessary.

3.37. The direction of groundwater movement and of radionuclide transport is in general orthogonal to the contours at groundwater level. Where this is the case, the standard calculational models should be applied. If aquifers are strongly anisotropic, and water and transported effluents can move over a limited domain through fractures, most calculational models are not valid. Field studies including tracer studies may be necessary and should be considered.

3.38. The analytical models for radionuclide transport in groundwater have several sources of uncertainty. The model used should be validated for each specific application. Validated hydrogeological models that would apply for characteristics similar to those of the site should be considered as a reference for purposes of comparison.

3.39. The documentation generated in a monitoring programme for surface water and groundwater should follow the recommendations made in Section 7.

4. USES OF LAND AND WATER IN THE REGION OF THE SITE

4.1. The operation of a nuclear power plant may affect the population in the surrounding area and the local and regional environment. As part of the environmental impact assessment for the site, the uses of land and water should be investigated. The characteristics of the land and water utilized in the region should also be considered in demonstrating the feasibility of the emergency response plan.

4.2. The investigations should cover:

(a) land devoted to agricultural uses, its extent, and the main crops and their yields;
(b) land devoted to dairy farming, its extent and yields;
(c) land devoted to industrial, institutional and recreational purposes, its extent and the characteristics of its use;
(d) bodies of water used for commercial, individual and recreational fishing, including details of the aquatic species fished, their abundance and yield;
(e) bodies of water used for commercial purposes, including navigation, community water supply, irrigation, and recreational purposes such as bathing and sailing;
(f) land and bodies of water supporting wildlife and livestock;
(g) direct and indirect pathways for potential radioactive contamination of the food-chain;
(h) products imported to or exported from the region which may form part of the food-chain;
(i) free foods such as mushrooms, berries and seaweed.

4.3. Present uses of water which could be affected by changes in the water temperature and by radioactive material discharged from a nuclear power plant, together with the location, nature and extent of usage, should be identified. Changes in uses of water in the region, such as for irrigation, fishing and recreational activities, should also be considered.

4.4. Special consideration should be given to any population centres for which drinking water is obtained from water bodies that may be affected by a nuclear power plant. To the extent possible, future water flow and water uses should be projected over the lifetime of the plant. This may lead to a change in the critical group of the population[5].

4.5. For areas where drinking water is obtained from springs, wells or any other source of groundwater, the movement and quality of the groundwater should be studied.

4.6. The data on different water uses should include data on the following:

(a) For water used for drinking by humans and animals, and for municipal and industrial purposes:
  — average and maximum rates of water intake by users;
  — distance of the intake from the potential source of radioactive discharges;
  — mode of water consumption;
  — number of water users.

(b) For water used for irrigation:
  — rate of water use;
  — area of irrigated land;
  — types and yields of agricultural products, and their usual consumers.

(c) For water used for fishing:
  — the aquatic species fished, and their abundance and yields in water used for commercial, individual and recreational fishing.

(d) For water used for recreational purposes:
  — the number of persons engaging in swimming, boating and other recreational uses, and the time spent on these activities.

4.7. These investigations should cover a reasonably large area in the site region. If a nuclear power plant is located on a river bank, users downstream from the site should be identified. If the site is near a lake, all users of the lake should be identified. If a site is on an ocean coast, users of the sea out to a few tens of kilometres in all directions should be identified.

4.8. Information should be collected on levels of background activity for environmentally relevant substances such as soils, and for vegetables and other foodstuffs.

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[5] The critical group is a group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source.

5. POPULATION DISTRIBUTION

5.1. The distribution and characteristics of the regional population should be studied in the site evaluation for a nuclear power plant. The purposes of the studies should be:

— to evaluate the potential radiological impacts of normal radioactive discharges and accidental releases; and
— to assist in the demonstration of the feasibility of the emergency response plan.

5.2. When a site is near a State's national border, there should be appropriate co-operation with neighbouring countries in the vicinity of the nuclear power plant. Efforts should be made to exchange relevant information. Information relating to the plant should be provided on request to neighbouring countries to permit any potential impacts of the plant on their territory to be evaluated.

5.3. The external zone includes an area immediately surrounding the site of a nuclear power plant in which population distribution, population density, population growth rate, industrial activity, and land and water uses are considered in relation to the feasibility of implementing emergency measures.

5.4. The term 'present population' includes the two categories of permanent population and temporary population. Data on the present population in the external zone should be obtained from local authorities or by means of special field surveys, and these data should be as accurate and as up to date as possible. Similar data should also be collected throughout the region outside the external zone to distances determined in accordance with national practice and regulatory objectives. The data should include the number of people normally present in the area, and the locations of houses, hospitals, prisons and other institutions and recreational facilities such as parks and marinas.

5.5. Information on the permanent population of the region and its distribution should include information on occupation, places of work, means of communication and typical diet of the inhabitants. If a city or town in the region is associated with a major industrial facility, this should be considered.

5.6. The information on the temporary population should cover:

— the short term transient population, such as tourists and nomads; and
— the long term transient population, such as seasonal inhabitants and students.

5.7. The maximum size of the temporary population and its periods of occupancy in the external zone should be estimated. Particular types of institutions such as schools, hospitals, prisons and military bases within the external zone should be identified for the purposes of emergency planning. In the area outside the external zone, estimates of the approximate size of the temporary population together with its periods of occupancy should be made.

5.8. A projection of the present population in the region should be made for:

— the expected year of commissioning of the plant;
— selected years (e.g. every tenth year) over the lifetime of the plant.

5.9. Projections should be made on the basis of population growth rate, migration trends and plans for possible development in the region. The projected figures for the two categories of permanent population and temporary population should be extrapolated separately if data are available.

5.10. Data should be analysed to give both the current and the projected population distribution in terms of direction and distance from the plant.

5.11. The critical group associated with each nuclear power plant should be identified. Critical groups of the population (see footnote 5) with particular dietary habits and specific locations for particular types of activity in the region should be considered. The persons in the critical group may be located beyond national borders.

5.12. The population data collected should be presented in a suitable format and scale to permit their correlation with other relevant data, such as data on atmospheric dispersion and on uses of land and water. The two categories of permanent population and temporary population should be clearly indicated. In general, population data should be presented either in tabular form, or graphically, using concentric circles and radial segments with the site as the origin. More details should be given for areas closer to the site, especially within the external zone.

Considerations relating to radiological exposure

5.13. The results of the study on the characteristics and distribution of the population, together with results obtained in respect of the dispersion of radioactive material discharged into air, surface water and groundwater, should be used in demonstrating that, for a proposed site and design and for normal operations, the radiological exposure of the population in the region remains as low as reasonably achievable and, in any case, will be within the limits set in the national requirements and those established in the Basic Safety Standards (Ref. [3]), even for the critical groups mentioned in para. 5.11.

5.14. Information similar to that mentioned in para. 5.13 should be used to demonstrate also that, on the selected site, the radiological risk to the population that may result from accident states at the plant, including those which may lead to the implementation of emergency measures, is acceptably low and in accordance with national requirements, account being taken of international recommendations.

5.15. If, after thorough evaluation, it is shown that appropriate measures to comply with the national regulatory requirements cannot be devised, and the engineered safety features of the plant cannot be further improved, the site should be deemed unsuitable for a nuclear power plant of the type proposed.

6. CONSIDERATION OF THE FEASIBILITY OF AN EMERGENCY PLAN

6.1. Before final approval of a nuclear power plant site, the feasibility of an emergency plan should be demonstrated. There should be no adverse site conditions which could hinder the sheltering or evacuation of the population in the region or the ingress or egress of external services needed to deal with an emergency.

6.2. The feasibility of an emergency plan should be demonstrated for the nuclear power plant on the basis of site specific natural and infrastructural conditions in the region. In this context, infrastructure means transport and communications networks, industrial activities and, in general, anything that may influence the rapid and free movement of people and vehicles in the region of the site. Other information on the region, such as information on the availability of sheltering, the systems for the collection and distribution of milk and other agricultural products, special population groups such as those resident in institutions (for example, hospitals and prisons), industrial facilities, and environmental conditions such as the range of weather conditions, should be collected for demonstrating the feasibility of an emergency plan.

6.3. Many site related factors should be taken into account in demonstrating the feasibility of an emergency plan. The most important ones are:

- population density and distribution in the region;

— distance of the site from population centres;
— special groups of the population who are difficult to evacuate or shelter, such as people in hospitals or prisons, or nomadic groups;
— particular geographical features such as islands, mountains and rivers;
— characteristics of local transport and communications networks;
— industrial facilities which may entail potentially hazardous activities;
— agricultural activities that are sensitive to possible discharges of radionuclides; and
— possible concurrent external events.

6.4. The presence of large populations in the region or the proximity of a city to the nuclear power plant site may diminish the effectiveness and viability of an emergency plan. In addition, the specific circumstances of any special groups of the population should be recognized and taken into account. The presence of any residents whose evacuation route would necessarily pass near the nuclear power plant may lead to the rejection of a site if no other emergency measure can overcome this difficulty.

6.5. Disastrous external events or foreseeable natural phenomena such as fog or snow may have consequences that can limit the effectiveness of any response to an accident at a nuclear power plant. For example, an event may result in a problem with the infrastructure or in damage to sheltering facilities. In order to ensure that the population in the region can be sheltered and evacuated effectively, consideration should be given to the provision of backup facilities and alternative routes.

6.6. If, upon evaluating the aforementioned factors and their possible consequences, it is determined that no viable emergency plan can be established, then the proposed site should be considered unacceptable.

6.7. It is possible that conditions assessed for the purposes of approval of the site and design will change over time. The site related factors considered in the emergency plan, such as infrastructural developments, should be reviewed periodically during the operational phase of the plant.

6.8. Detailed guidance on emergency planning is available in other IAEA publications [8–11].

7. QUALITY ASSURANCE PROGRAMME

7.1. A quality assurance (QA) programme should be established to cover all the activities recommended in this Safety Guide.

7.2. The process of site evaluation includes the conduct of scientific and engineering analyses and the exercise of judgement. The data used in the analyses and in making judgements should be as complete and as reliable as possible. Data should be collected in a systematic manner and should be evaluated by technically qualified and experienced personnel. The QA programme for site evaluation is part of the overall QA programme for a nuclear power plant (see Ref. [12], Code and Safety Guide QA1).

7.3. All the investigatory programmes and other studies recommended in this Safety Guide, together with the necessary data and information, should be documented for the purposes of site evaluation.

7.4. In order for data to be collected, recorded and retained throughout the lifetime of the plant, the media for recording and storing data should be checked periodically to verify their compatibility with the technology in use (both hardware and software).

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safety of Nuclear Installations, Safety Series No. 110, IAEA, Vienna (1993).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Code on the Safety of Nuclear Power Plants: Siting, Safety Series No. 50-C-S (Rev. 1), IAEA, Vienna (1988) (to be superseded).

[3] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment, Safety Reports Series No. 19, IAEA, Vienna (2001).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory Control of Radioactive Discharges to the Environment, Safety Standards Series No. WS-G-2.3, IAEA, Vienna, (2000).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Extreme Meteorological Events in Nuclear Power Plant Siting, Excluding Tropical Cyclones, Safety Series No. 50-SG-S11A, IAEA, Vienna (1981) (to be superseded).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Design Basis Tropical Cyclone for Nuclear Power Plants, Safety Series No. 50-SG-S11B, IAEA, Vienna (1984) (to be superseded).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Preparedness of Public Authorities for Emergencies at Nuclear Power Plants, Safety Series No. 50-SG-G6, IAEA, Vienna (1982) (to be superseded).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Preparedness of the Operating Organization (Licensee) for Emergencies at Nuclear Power Plants, Safety Series No. 50-SG-O6, IAEA, Vienna (1982) (to be superseded).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Preparedness Exercises for Nuclear Facilities: Preparation, Conduct and Evaluation, Safety Series No. 73, IAEA, Vienna (1985).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Intervention Criteria in a Nuclear or Radiation Emergency, Safety Series No. 109, IAEA, Vienna (1994) (to be superseded).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for Safety in Nuclear Power Plants and Other Nuclear Installations: Code and Safety Guides Q1–Q14, Safety Series No. 50-C/SG-Q, IAEA, Vienna (1996).

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IAEA Safety Standards

for protecting people and the environment

Site Evaluation for Nuclear Installations

Specific Safety Requirements

No. SSR-1

IAEA

International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available on the IAEA Internet site

http://www-ns.iaea.org/standards/

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

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Other safety related IAEA publications are issued as **Emergency Preparedness and Response** publications, **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

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SITE EVALUATION FOR
NUCLEAR INSTALLATIONS

The following States are Members of the International Atomic Energy Agency:

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ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
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BARBADOS
BELARUS
BELGIUM
BELIZE
BENIN
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BRAZIL
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YEMEN
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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA SAFETY STANDARDS SERIES No. SSR-1

SITE EVALUATION FOR NUCLEAR INSTALLATIONS

SPECIFIC SAFETY REQUIREMENTS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2019

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FOREWORD

by Yukiya Amano
Director General

The IAEA's Statute authorizes the Agency to "establish or adopt… standards of safety for protection of health and minimization of danger to life and property" — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered 'overarching' requirements, are expressed as 'shall' statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

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[1] See also publications issued in the IAEA Nuclear Security Series.

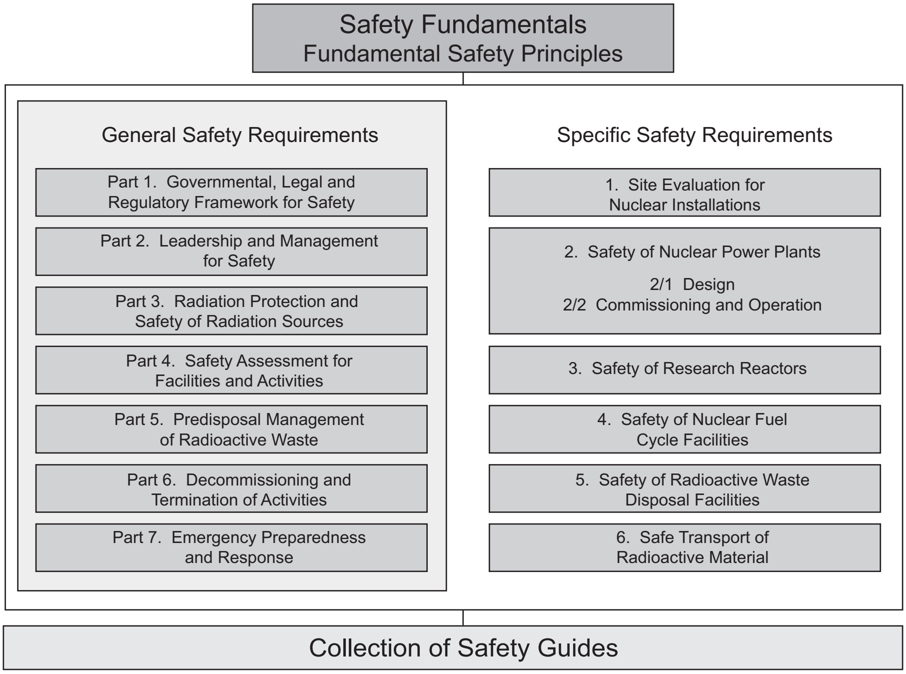

FIG. 1. The long term structure of the IAEA Safety Standards Series.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five safety standards committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of

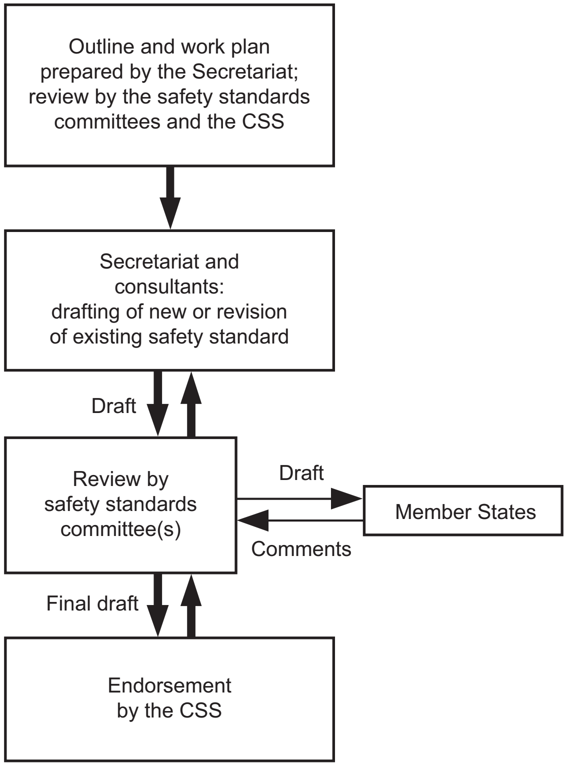

FIG. 2. The process for developing a new safety standard or revising an existing standard.

the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see http://www-ns.iaea.org/standards/safety-glossary.htm). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Requirements publication supersedes the edition of *Site Evaluation for Nuclear Installations* that was issued in 2016 as IAEA Safety Standards Series No. NS-R-3 (Rev. 1)[1]. NS-R-3 (Rev. 1) was a partial revision of IAEA Safety Standards Series No. NS-R-3[2] issued in 2003 and it took into account issues highlighted after the Fukushima Daiichi accident. This publication takes into account developments that have occurred since 2003 in relation to site evaluation for nuclear installations.

1.2. The requirements for site evaluation for nuclear installations established in this publication are intended to contribute to the protection of workers and the public, and to the protection of the environment, from harmful effects of ionizing radiation, in order to meet the fundamental safety objective established in IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [1]. It is recognized that there are steady advances in technology and scientific knowledge in nuclear safety and corresponding advances in what is considered adequate protection. Safety requirements evolve with these advances, and this publication reflects the present consensus among States.

1.3. This Safety Requirements publication establishes requirements for site evaluation for nuclear installations, in order to meet the fundamental safety objective [1]. Several related Safety Guides (see Refs [2–8]) provide recommendations on how to meet the requirements for site evaluation for nuclear installations as contained in this publication.

OBJECTIVE

1.4. The objective of this publication is to establish requirements for:

(a) Defining the information to be used in the site evaluation process;

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. NS-R-3 (Rev. 1), IAEA, Vienna (2016).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. NS-R-3, IAEA, Vienna (2003).

(b) Evaluating a site such that the site specific hazards and the safety related site characteristics are adequately taken into account, in order to derive appropriate site specific design parameters[3];
(c) Analysing the characteristics of the population and the region surrounding the site to determine whether there would be significant difficulties in implementing emergency response actions effectively [9].

1.5. The requirements in this publication are to be applied:

(a) To identify the natural and human induced external hazards that could affect the safety of the nuclear installation;
(b) To assess the interactions between the site and nuclear installation for operational states and accident conditions, over the lifetime of the nuclear installation, including accidents that could warrant the implementation of emergency response actions.

1.6. This publication is intended for use by regulatory bodies in establishing regulatory requirements, and by operating organizations or their contractors in conducting site evaluation for nuclear installations.

SCOPE

1.7. The requirements in this publication apply to all nuclear installations [10], as follows:

— Nuclear power plants;
— Research reactors (including subcritical and critical assemblies) and any adjoining radioisotope production facilities;
— Storage facilities for spent fuel;
— Facilities for the enrichment of uranium;
— Nuclear fuel fabrication facilities;
— Conversion facilities;
— Facilities for the reprocessing of spent fuel;
— Facilities for the predisposal management of radioactive waste arising from nuclear fuel cycle facilities;
— Nuclear fuel cycle related research and development facilities.

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[3] Site specific design parameters are needed for the design of a nuclear installation. The design of a nuclear installation is adequate for a specific site if the actual parameters used in the design envelop the corresponding site specific design parameters.

1.8. This Safety Requirements publication covers site evaluation for both new and existing nuclear installations. For existing nuclear installations, decisions concerning the implementation of new or enhanced safety features will need to consider, as practicable, the safety significance of such features, as well as economic, social and environmental factors.

1.9. The ‘site area’ is the geographical area that contains an authorized facility, authorized activity or source, and within which the management of the authorized facility or authorized activity or first responders may directly initiate an emergency response [9]. The site area is typically the area within the security perimeter fence or other designated property marker.

1.10. The ‘external zone’ is the area immediately surrounding a proposed site area in which the population distribution and density, and land and water uses, are considered with respect to their impact on planning effective emergency response actions [9].[4]

1.11. The word ‘region’ is used generally in this publication to refer to the area surrounding the site and is normally intended to include more than the external zone. The size of this region will be defined for each specific external hazard (see para. 4.14). This region is also sometimes known as the ‘geographical area of interest’.

1.12. The ‘site vicinity’ is smaller than the region and larger than the site area (typically covering a geographical area not less than 5 km in radius).

1.13. The human induced external events considered in this Safety Requirements publication are all of accidental origin. Considerations relating to the physical protection of the nuclear installation against sabotage, and to physical protection against unauthorized removal or sabotage of the nuclear material, are outside the scope of this publication, although such considerations are likely to have significant implications for site evaluation. This publication does not address the threat assessment of malicious acts. Recommendations for the establishment of the design basis threat are provided in IAEA Nuclear Security Series No. 13 [11] and in supporting publications in the IAEA Nuclear Security Series.

1.14. The interfaces between nuclear safety and nuclear security have to be considered and synergies have to be developed so that safety and nuclear

[4] The external zone is the area that would be the emergency planning zones if the installation were in place.

security complement and enhance one another. For example, site specific design parameters for the qualification of structures, systems and components important to safety against natural and human induced external hazards, as required in this publication, can also be used for the qualification of structures, systems and components important for nuclear security against relevant external hazards.

1.15. The siting process for a nuclear installation is divided into two stages:

(a) Site survey, in which candidate sites are identified after the investigation of a large region and the rejection of unsuitable sites;
(b) Site selection, in which the candidate sites are assessed by screening, evaluation, comparison and ranking on the basis of safety and other considerations to select one or more preferred candidate sites.

1.16. The suitability of the site is then confirmed in the site evaluation process. The site evaluation process starts with the second stage of the siting process (i.e. site selection), and continues throughout the entire lifetime of the nuclear installation. The detailed site evaluation (for the selected site) provides input to the preliminary safety analysis report and the final safety analysis report. Site evaluation continues throughout the operational stage of the nuclear installation, and includes monitoring, periodic safety review and other activities to confirm the site specific design parameters as well as safety re-evaluations based on the outcome of periodic safety reviews.

1.17. This publication addresses the evaluation of those site related factors that have to be taken into account to ensure that the site–installation combination does not constitute an unacceptable risk to people or the environment over the lifetime of the nuclear installation. It is recognized that there are other important factors in site evaluation, such as technology, economics, non-radiological environmental impacts and socioeconomic impacts, as well as the opinion of interested parties, including the public. Such aspects of site evaluation are not covered in this publication.

STRUCTURE

1.18. Section 2 of this publication sets out the fundamental safety objective and the safety principles applicable to site evaluation. Section 3 establishes requirements for the application of the management system for site evaluation. Section 4 establishes the general requirements that are applicable to all types of external hazard. Section 5 establishes requirements for specific technical aspects related to the evaluation of natural and human induced external hazards. Section 6 establishes requirements for specific technical aspects related to the evaluation of the effects of the nuclear installation on the surrounding environment (including the atmosphere, the hydrosphere and the biosphere) and on the population. Section 7 establishes requirements for monitoring and periodic review of natural and human induced external hazards and site conditions throughout the lifetime of the nuclear installation.

2. SAFETY PRINCIPLES AND CONCEPTS

2.1. As stated in SF-1 [1]: "**The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation.**" Paragraph 2.1 of SF-1 [1] states:

> "This fundamental safety objective of protecting people — individually and collectively — and the environment has to be achieved without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks. To ensure that facilities are operated and activities conducted so as to achieve the highest standards of safety that can reasonably be achieved, measures have to be taken:
>
> (a) To control the radiation exposure of people and the release of radioactive material to the environment;
> (b) To restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation;
> (c) To mitigate the consequences of such events if they were to occur."

2.2. Paragraph 2.2 of SF-1 [1] states:

> "The fundamental safety objective applies for all facilities and activities, and for all stages over the lifetime of a facility or radiation source, including planning, siting, design, manufacturing, construction, commissioning and operation, as well as decommissioning and closure. This includes the associated transport of radioactive material and management of radioactive waste."

2.3. This Safety Requirements publication establishes requirements for application of the principles of SF-1 [1], in particular Principles 8 and 9:

- "**All practical efforts must be made to prevent and mitigate nuclear or radiation accidents**" (Principle 8 of SF-1 [1]).
- "The primary means of preventing and mitigating the consequences of accidents is 'defence in depth'. Defence in depth is implemented primarily through the combination of a number of consecutive and independent levels of protection that would have to fail before harmful effects could be caused to people or to the environment" (para. 3.31 of SF-1 [1]).
- "Defence in depth is provided by an appropriate combination of [inter alia] … [a]dequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy" (para. 3.32 of SF-1 [1]).
- "**Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents**" (Principle 9 of SF-1 [1]).

2.4. To address Principle 8 of SF-1 [1], site evaluation for a nuclear installation shall characterize the natural and human induced external hazards that could affect the safety of the nuclear installation (see Requirement 1). The site evaluation shall provide adequate input to the design and safety assessment for demonstration of protection of people and the environment from harmful effects of ionizing radiation.

2.5. To address Principle 9 of SF-1 [1], site evaluation for a nuclear installation shall provide adequate input for demonstration of protection of people and the environment from the consequences of radioactive releases. The site evaluation shall identify the site characteristics that could affect the feasibility of planning effective emergency response actions in the external zone.

Requirement 1: Safety objective in site evaluation for nuclear installations

The safety objective in site evaluation for nuclear installations shall be to characterize the natural and human induced external hazards that might affect the safety of the nuclear installation, in order to provide adequate input for demonstration of protection of people and the environment from harmful effects of ionizing radiation.

2.6. The safety objective in site evaluation is derived from the fundamental safety objective established in SF-1 [1]. Demonstration of compliance with the safety requirements established in this publication provides the basis for demonstration of achievement of the safety objective for site evaluation.

3. APPLICATION OF THE MANAGEMENT SYSTEM FOR SITE EVALUATION

Requirement 2: Application of the management system for site evaluation

Site evaluation shall be conducted in a comprehensive, systematic, planned and documented manner in accordance with a management system.

3.1. An integrated management system that meets the requirements of IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [12] shall be established. The management system shall cover the organization, planning, work control, verification and documentation of activities and qualification and training of personnel to ensure that the required quality of the work is achieved at each stage of site evaluation. The management system shall be implemented at the earliest possible time in the conduct of site evaluation for the nuclear installation.

3.2. Site evaluation shall include, as part of the management system, proper quality assurance arrangements covering each activity that could influence safety or affect the derivation of site specific design parameters and other safety related site characteristics. The quality assurance arrangements shall be consistent with regulatory requirements and their application shall be commensurate with the importance of the activity under consideration to safety.

3.3. For each site evaluation activity, including inspection, testing, verification and validation, the acceptance criteria and the responsibilities for performing the activity shall be specified.

3.4. The results of studies and investigations conducted as part of the site evaluation shall be documented in sufficient detail to permit an independent review.

3.5. An independent review shall be made of the evaluation of the natural and human induced external hazards and the site specific design parameters, and of the evaluation of the potential radiological impact of the nuclear installation on people and the environment.

4. GENERAL REQUIREMENTS FOR SITE EVALUATION

Requirement 3: Scope of the site evaluation for nuclear installations

The scope of the site evaluation shall encompass factors relating to the site and factors relating to the interaction between the site and the installation, for all operational states and accident conditions, including accidents that could warrant emergency response actions.

4.1. The scope of the site evaluation shall cover all external hazards, monitoring activities and site specific parameters relevant for the safety of the nuclear installation. In determining the scope of the site evaluation, a graded approach shall be applied commensurate with the radiation risk posed to people and the environment.

4.2. The application of the safety requirements for site evaluation for nuclear installations shall be commensurate with the potential hazards associated with the nuclear installation.

4.3. The level of detail needed in the evaluation of a site for a nuclear installation shall be commensurate with the risk associated with the nuclear installation and the site and will differ depending on the type of nuclear installation.

4.4. The scope and level of detail of the site evaluation process necessary to support the safety demonstration for the nuclear installation shall be determined in accordance with a graded approach.

4.5. For site evaluation for nuclear installations other than nuclear power plants, the following shall be taken into consideration in the application of a graded approach:

(a) The amount, type and status of the radioactive inventory at the site (e.g. whether the radioactive material on the site is in solid, liquid and/or gaseous form, and whether the radioactive material is being processed in the nuclear installation or is being stored on the site);
(b) The intrinsic hazards associated with the physical and chemical processes that take place at the nuclear installation;
(c) For research reactors, the thermal power;
(d) The distribution and location of radioactive sources in the nuclear installation;

(e) The configuration and layout of installations designed for experiments, and how these might change in future;
(f) The need for active systems and/or operator actions for the prevention of accidents and for the mitigation of the consequences of accidents;
(g) The potential for on-site and off-site consequences in the event of an accident.

Requirement 4: Site suitability

The suitability of the site shall be assessed at an early stage of the site evaluation and shall be confirmed for the lifetime of the planned nuclear installation.

4.6. In the assessment of the suitability of a site for a nuclear installation, the following aspects shall be addressed at an early stage of the site evaluation:

(a) The effects of natural and human induced external events occurring in the region that might affect the site;
(b) The characteristics of the site and its environment that could influence the transfer of radioactive material released from the nuclear installation to people and to the environment;
(c) The population density, population distribution and other characteristics of the external zone, in so far as these could affect the feasibility of planning effective emergency response actions [9], and the need to evaluate the risk to individuals and to the population.

4.7. The site shall be deemed unsuitable for a nuclear installation if one or more of the three aspects listed in para. 4.6 indicates that the site is unacceptable and the deficiencies cannot be compensated for by means of a combination of measures for site protection, design features of the nuclear installation and administrative procedures.

4.8. Site suitability shall be assessed on the basis of relevant current data and methodologies. If relevant, conservative criteria shall be developed in relation to site specific accident scenarios, and the consistency of such criteria with the overall site suitability shall be demonstrated.

4.9. A decision regarding the suitability of the site shall be based on the characteristics of the nuclear installation, including planned operations at the site, the amount and nature of potential radioactive releases and their impact on people and the environment.

4.10. For nuclear power plants, the total nuclear capacity to be installed at the site shall be determined at the first stages of the siting process. If it is later determined or anticipated that the installed nuclear capacity (or, for other nuclear installations, the inventory of nuclear material) or its impact has increased to a level significantly greater than that previously determined to be acceptable, the site shall be re-evaluated considering the higher capacity, inventory or impact.

4.11. In the overall evaluation of site suitability, site specific attributes, such as cooling water availability or extreme environmental conditions, and their potential role in affecting the safe and continuous operation of the nuclear installation, shall also be addressed.

Requirement 5: Site and regional characteristics

The site and the region shall be investigated with regard to the characteristics that could affect the safety of the nuclear installation and the potential radiological impact of the nuclear installation on people and the environment.

4.12. Natural phenomena as well as human activities in the region with the potential to induce hazards at the site that might affect the safety of the nuclear installation shall be identified and evaluated. The extent of this evaluation shall be commensurate with the safety significance of the potential hazards at the site.

4.13. The characteristics of the natural environment in the region that could be affected by the potential radiological impact of the nuclear installation shall be investigated and assessed, for all operational states and accident conditions and for all stages of the lifetime of the nuclear installation (see Section 6).

4.14. The size of the region to be investigated shall be defined for each of the natural and human induced external hazards. Both the magnitude of the hazard and the distance from the source of the hazard to the site shall be considered in determining the size of the region to be investigated. For certain natural external events, such as tsunamis and volcanic phenomena, it shall be ensured that the size of the region that is investigated is sufficiently large to address the potential effects at the site.

4.15. The site and the region shall be studied to evaluate the present and foreseeable future characteristics that could have an impact on the safety of the nuclear installation. This includes potential changes in the severity and/or the frequency of natural external events, as well as changes in the population distribution in the region, the present and future use of land and water, the further development of existing nuclear installations or the construction of other facilities that could affect the safety of the nuclear installation or the feasibility of planning effective emergency response actions.

Requirement 6: Identification of site specific hazards

Potential external hazards associated with natural phenomena, human induced events and human activities that could affect the region shall be identified through a screening process.

4.16. The process and associated criteria used in the screening of site specific hazards shall comply with the safety objective for site evaluation and shall be properly justified and documented.

4.17. The scope of evaluation of external events in the screening process shall cover the full ranges of severity and frequency of occurrence relevant for the design and the safety assessment of the nuclear installation, including events of high severity but low probability that could contribute to the overall risk.

4.18. An event might be screened out because it is enveloped by a set of events. However, it shall be ensured that all potential effects of the screened-out event are bounded by this set of events.

4.19. External hazards that are not excluded by the screening process shall be evaluated and then used in establishing the site specific design parameters and in the re-evaluation of the site, in accordance with the significance of these hazards to the safety of the nuclear installation.

Requirement 7: Evaluation of natural and human induced external hazards

The impact of natural and human induced external hazards on the safety of the nuclear installation shall be evaluated over the lifetime of the nuclear installation.

4.20. The site evaluation for a nuclear installation shall consider the frequency and severity of natural and human induced external events, and potential combinations of such events, that could affect the safety of the nuclear installation.

4.21. Information on the frequency and severity of external events derived from the characterization of the hazards shall be used in establishing the site specific design parameters. Adequate account shall be taken of both aleatory uncertainties and epistemic uncertainties in the establishment of site specific design parameters.

4.22. Appropriate methods, supported by numerical models when necessary, shall be used to characterize the hazards relevant for site evaluation and the design of the nuclear installation. A thorough uncertainty analysis of the method and input data shall be performed as part of the hazard evaluation.

4.23. The decision to use deterministic and/or probabilistic methodologies in hazard evaluation shall be based on the nature of the hazard, the availability of data and the applicable requirements for safety assessment.

4.24. Special consideration shall be given to the use of applicable probabilistic methodologies and the use of probabilistic hazard curves representing external events as an input to the probabilistic safety assessment for external hazards. Such probabilistic hazard curves shall be developed with reference to the specific site conditions.

4.25. The evaluation of hazards shall address the possibility that external events can occur in combination, simultaneously or within short time frames. Interrelationships and causality between external events shall be evaluated.

4.26. The results of the evaluation of hazards shall be expressed in terms that can be used as an input for deriving the site specific design parameters; that is, appropriate parameters for describing the severity of the effects of the hazards shall be selected or developed.

4.27. The potential for explosion, chemical releases and/or thermal releases that might affect the safety of the nuclear installation or the dispersion of radioactive material shall be considered in the site evaluation process.

4.28. The potential for interactions between radioactive and non-radioactive substances, such as interactions due to heat or chemicals in radioactive liquid effluents, shall be considered.

Requirement 8: Measures for site protection

If the projected design of the nuclear installation is not able to safely withstand the impact of natural and human induced external hazards, the need for site protection measures shall be evaluated.

4.29. The need for protection of the site against the effects of specific phenomena associated with natural and human induced external hazards shall be evaluated considering adequate safety margins.

4.30. The availability of adequate engineering solutions for implementing measures for site protection shall be evaluated. If such engineering solutions are not available, the site shall be deemed unsuitable.

4.31. If measures for site protection are required to be implemented, uncertainties shall be properly taken into account in the evaluation of extreme values of parameters for describing the severity of natural and human induced external hazards. Measures for site protection shall be classified, designed, built, maintained and operated in accordance with their safety significance.

Requirement 9: Site evaluation for multiple nuclear installations on the same site or on adjacent sites

The site evaluation shall consider the potential for natural and human induced external hazards to affect multiple nuclear installations on the same site as well as on adjacent sites.

4.32. Occurrences of natural and human induced external events and their credible combinations that could affect the safety of multiple installations on the same site or installations on adjacent sites shall be considered. The potential for hazards originating from one nuclear installation to affect other nuclear installations located on the same site or on adjacent sites shall be assessed.

4.33. For identified accident scenarios, the combined effects of accidents at nuclear installations located on the same site or at adjacent and nearby sites on people and the environment shall be evaluated (see Requirement 12).

Requirement 10: Changes of hazards and site characteristics with time

The external hazards and the site characteristics shall be assessed in terms of their potential for changing over time and the potential impact of these changes shall be evaluated.

4.34. The site characteristics and the natural and human induced external hazards that can change over time and which could affect the safety of a nuclear installation shall be identified. The potential consequences of such changes shall be duly assessed for the planned lifetime of the nuclear installation.

4.35. Due account shall be taken of uncertainties in the projections of any potential changes of the external hazards and site characteristics over time by means of appropriate safety margins in the related site specific design parameters.

Requirement 11: Special considerations for the ultimate heat sink for nuclear installations that require an ultimate heat sink

The evaluation of site specific natural and human induced external hazards for nuclear installations that require an ultimate heat sink shall consider hazards that could affect the availability and reliability of the ultimate heat sink.

4.36. As appropriate for the ultimate heat sink under consideration, data for the following shall be evaluated:

(a) Air temperature and humidity;
(b) Water depth and temperature;
(c) Water quality characteristics, including turbidity, suspended solids, floating debris, and chemical and biochemical changes (both natural and human induced changes);
(d) Availability and sustainability of the water flow (for a river), minimum and maximum water level and the period of time for which safety related supplies of cooling water are at a minimum level, with account taken of the potential for failure of water control structures.

4.37. All natural and human induced external events that could cause a loss of the ultimate heat sink shall be identified and evaluated.

Requirement 12: Potential effects of the nuclear installation on people and the environment

In determining the potential radiological impact of the nuclear installation on the region for operational states and accident conditions, including accidents that could warrant emergency response actions, appropriate estimates shall be made of the potential releases of radioactive material, with account taken of the design of the nuclear installation and its safety features.

4.38. The potential effects of the nuclear installation on people and the environment shall be estimated by considering the postulated accident scenarios (including the resulting source terms) and taking into account the feasibility of planning effective emergency response actions at the site and in the external zone. These estimates shall be confirmed when the design of the nuclear installation and its safety features has been established.

4.39. The direct and indirect pathways by which radioactive releases from the nuclear installation could potentially affect the public and the environment shall be identified and evaluated. In this evaluation, specific regional and site characteristics, including the population distribution in the region, shall be taken into account, with special attention paid to the transport and accumulation of radionuclides in the biosphere.

4.40. It shall be demonstrated that the information provided to assess the potential effects on the population associated with accident conditions, including accidents that could warrant emergency response actions being taken in the external zone, is consistent with achieving the safety objective for site evaluation.

Requirement 13: Feasibility of planning effective emergency response actions

The feasibility of planning effective emergency response actions on the site and in the external zone shall be evaluated, with account taken of the characteristics of the site and the external zone as well as any external events that could hinder the establishment of complete emergency arrangements prior to operation.

4.41. Requirement 13 applies also to the infrastructure of the external zone where emergency response actions might be warranted.

4.42. An assessment shall be made of the feasibility of planning effective emergency response actions in accordance with GSR Part 7 [9].

Nuclear installations on the same site and at adjacent or nearby sites shall be considered in the assessment, with special emphasis on nuclear installations that could experience concurrent accidents.

4.43. Any causal relationships between external events and the condition of the infrastructure on the site and in the external zone shall be considered when evaluating the feasibility of planning effective emergency response actions.

Requirement 14: Data collection in site evaluation for nuclear installations

The data necessary to perform an assessment of natural and human induced external hazards and to assess both the impact of the environment on the safety of the nuclear installation and the impact of the nuclear installation on people and the environment shall be collected.

4.44. Data on natural and human induced external hazards with the potential to affect the safety of the nuclear installation shall be collected throughout the lifetime of the nuclear installation. Data shall be confirmed to be relevant (spatially and temporally) to the site, with preference given to the use of site specific data in site evaluation.

4.45. The extent, objectives and scope of the data collection process shall be defined on the basis of the safety objective for site evaluation, and shall be commensurate with the hazard posed by the nuclear installation to people and the environment.

4.46. At a minimum, the data collection process shall include the following:

(a) Information on natural and human induced external hazards, including information on sources of hazards, propagation of hazards and the potential effects on the nuclear installation and on people and the environment;
(b) Information describing site conditions and regional environmental conditions;
(c) Information on the proposed engineering and administrative measures for site protection and mitigatory measures;
(d) Information on the potential impact of the nuclear installation on people and the environment for operational states and accident conditions;
(e) Information required for planning effective emergency response actions on the site and off the site in all environmental conditions and for all states of the nuclear installation;

(f) Information on conditions for access to the site and information for supporting design and development of the site infrastructure.

4.47. Information and records, if available, of the occurrence and severity of important prehistoric, historical and recent natural phenomena shall be obtained as appropriate for the hazard to be evaluated and shall be analysed for reliability, accuracy, temporal and spatial relevance, and completeness.

4.48. The data shall be maintained and reviewed periodically, and/or as necessary as part of a review of the site evaluation within the framework of the periodic safety review of the nuclear installation, for example, to address developments in data gathering techniques and in the analysis and use of data and to confirm that the data remain relevant to the site within the context of evolving hazards.

4.49. The data collected for site investigations shall be of sufficient quality and quantity to support the selected methodology for hazard evaluation.

4.50. The details of the information collected for each hazard shall be appropriate for the distance between the source of the hazard and the site and the potential impact on the site. The sources of uncertainties relating to data collection shall be documented.

5. EVALUATION OF EXTERNAL HAZARDS

5.1. This section establishes requirements for the evaluation of external hazards. These requirements are to be applied as appropriate for the type of nuclear installation as well as the site under consideration.

SEISMIC HAZARDS

Requirement 15: Evaluation of fault capability

Geological faults larger than a certain size and within a certain distance of the site and that are significant to safety shall be evaluated to identify whether these faults are to be considered capable faults. For capable faults, potential challenges to the safety of the nuclear installation in terms of ground motion and/or fault displacement hazards shall be evaluated.

5.2. Capable faults[5] shall be identified and evaluated. The evaluation shall consider the fault characteristics in the site vicinity. The methods used and the investigations made shall be sufficiently detailed to support safety related decisions.

5.3. The potential effect of fault displacement on safety related structures, systems and components shall be evaluated. The evaluation of fault displacement hazards shall include detailed geological mapping of excavations for safety related engineered structures to enable the evaluation of fault capability for the site.

5.4. A proposed new site shall be considered unsuitable when reliable evidence shows the existence of a capable fault that has the potential to affect the safety of the nuclear installation and which cannot be compensated for by means of a combination of measures for site protection and design features of the nuclear installation. If a capable fault is identified in the site vicinity of an existing nuclear installation, the site shall be deemed unsuitable if the safety of the nuclear installation cannot be demonstrated.

Requirement 16: Evaluation of ground motion hazards

An evaluation of ground motion hazards shall be conducted to provide the input needed for the seismic design or safety upgrading of the structures, systems and components of the nuclear installation, as well as the input for performing the deterministic and/or probabilistic safety analyses necessary during the lifetime of the nuclear installation.

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[5] A fault is considered capable if, on the basis of geological, geophysical, geodetic or seismological data (including palaeoseismological and geomorphological data), one or more of the following conditions applies:

(a) The fault shows evidence of past movement or movements (significant surface deformations and/or dislocations) of a recurring nature within such a period that it is reasonable to infer that further movements at or near the surface could occur. In highly active areas, where both earthquake data and geological data consistently and/or exclusively reveal short earthquake recurrence intervals, periods of the order of tens of thousands of years may be appropriate for the assessment of capable faults. In less active areas, it is likely that much longer periods will be required.
(b) A structural relationship with a known capable fault has been demonstrated such that movement of one could cause movement of the other at or near the surface.
(c) The maximum potential earthquake associated with a seismogenic structure is sufficiently large and at such a depth that it is reasonable to infer that, in the geodynamic setting of the site, movement at or near the surface could occur.

5.5. Hazards due to earthquake induced ground motion shall be assessed by means of appropriate methods. The effect of the vibratory ground motion in combination with other seismically induced events, if any, shall be considered. The potential for seismicity due to human activities[6] shall also be considered.

VOLCANIC HAZARDS

Requirement 17: Evaluation of volcanic hazards

Hazards due to volcanic activity that have the potential to affect the safety of the nuclear installation shall be evaluated.

5.6. Capable volcanoes[7] shall be identified and evaluated. The evaluation shall consider the volcanic characteristics of a region of sufficient size to ensure that potentially hazardous volcanic phenomena are considered appropriately.

5.7. The hazards of capable volcanoes shall be evaluated to provide the input needed for determining the site specific design parameters or for re-evaluating the site, as well as for deterministic and/or probabilistic safety analyses performed during the lifetime of the nuclear installation.

5.8. A proposed new site shall be considered unsuitable if reliable evidence shows the existence of a capable volcano that has the potential to affect the safety of the nuclear installation and which cannot be compensated for by means of a combination of measures for site protection and design features of the nuclear installation.

5.9. An evaluation of volcanic hazards that focuses on determining the geological characteristics of volcanic phenomena and their spatial extent will usually be more certain than one focusing on an estimation of the likelihood of occurrence of hazardous phenomena. Volcanic hazards shall be evaluated using appropriate information, methods and models with adequate account taken of the uncertainties.

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[6] Such as construction of dams, mining, and operation of oil wells and gas wells.

[7] A capable volcano is a volcano that has a credible likelihood of undergoing future activity and producing hazardous phenomena, including non-eruptive phenomena, during the lifetime of a nuclear installation concerned, and which may potentially affect the site.

5.10. The effect of volcanic phenomena in combination with other volcanically induced hazards shall be considered. This shall include consideration of volcanic ash fall.

METEOROLOGICAL HAZARDS

Requirement 18: Evaluation of extreme meteorological hazards

Extreme meteorological hazards and their possible combinations that have the potential to affect the safety of the nuclear installation shall be evaluated.

5.11. Meteorological phenomena such as wind, precipitation, snow and ice, air and water temperature, humidity, storm surges and sand or dust storms, as well as their credible combinations, shall be evaluated for their extreme values[8] based on available records. If necessary, efforts shall be made to extend the database on meteorological hazards (e.g. by incorporating historical climate data, numerical models and simulations).

5.12. Appropriate methods shall be applied for the evaluation of meteorological hazards, taking into account the amount of data available (both measured data and historical data) and known past changes in relevant characteristics of the region.

Requirement 19: Evaluation of rare meteorological events

The potential for the occurrence of rare meteorological events[9] such as lightning, tornadoes and cyclones, including information on their severity and frequency, shall be evaluated.

Lightning

5.13. The potential for the occurrence and the frequency and severity of lightning shall be evaluated for the site vicinity.

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[8] Extreme values of meteorological parameters are identified by means of statistical analysis of measurement data for different meteorological parameters.

[9] Rare meteorological events are unlikely to be measured at any specific location because of their very low frequency of occurrence at any single place and the destructive effects of the phenomena, which might result in damage to standard measuring instruments.

Tornadoes and cyclones

5.14. The potential for the occurrence and the frequency and severity of tornadoes, cyclones and associated missiles shall be evaluated for the site. The hazards associated with tornadoes and cyclones shall be derived and expressed in terms of parameters such as rotational wind speed, translational wind speed, radius of maximum rotational wind speed, pressure differentials and rate of change of pressure.

FLOODING HAZARDS

Requirement 20: Evaluation of flooding hazards

Hazards due to flooding, considering natural and human induced events including their possible combinations, shall be evaluated.

Floods due to precipitation and other natural causes

5.15. The potential for flooding in the region surrounding the site due to one or more natural causes, such as storm surge, wind generated waves, meteorological tsunamis or seiches, or extreme precipitation — or due to a combination of such events that have a common cause or a relatively high frequency of occurrence — shall be evaluated.

5.16. Appropriate meteorological, hydrological and hydraulic models shall be developed to derive the flooding hazards for the site, including secondary effects such as debris, ice and sediments. Where available, relevant information from studies of historic and prehistoric floods shall be used to inform estimates of the frequency and magnitude of riverine floods.

5.17. The potential for instability of a coastal area or river channel due to erosion or sedimentation shall be investigated.

Water waves induced by earthquakes or other geological phenomena

5.18. The potential for tsunamis or seiches in the region that could affect the safety of the nuclear installation shall be evaluated. The potential for tsunamis or seiches from phenomena other than seismic sources (e.g. from submarine landslides) shall be evaluated, as appropriate for the region.

5.19. The hazards associated with tsunamis or seiches shall be derived from historical records and any available information on prehistoric floods, as well as from physical and/or analytical modelling. Such hazards shall include potential draw-down and run-up[10] that could result in physical effects on the site.

5.20. The hazards associated with tsunamis or seiches shall be evaluated as appropriate for the region, using nearshore bathymetry and coastal topography, with account taken of any amplification due to the coastal configuration (including artificial structures).

Floods and waves caused by failure of water control structures

5.21. Upstream water control structures such as dams shall be analysed to determine the potential hazard associated with the failure of one or more of the upstream structures, including in combination with flooding from other causes.

5.22. If a preliminary examination of the nuclear installation indicates that it would not be able to safely withstand the effects of the failure of one or more of the upstream water control structures, then the hazards associated with the nuclear installation shall be evaluated with the inclusion of such effects. Alternatively, such upstream structures shall be analysed by methods equivalent to those used in determining the hazards associated with the nuclear installation to demonstrate that the upstream structures could survive the event concerned.

5.23. Flooding and associated phenomena caused by an accumulation of water due to a blockage of rivers upstream or downstream (e.g. caused by landslides or ice), or due to a change in land use, shall be considered.

GEOTECHNICAL HAZARDS AND GEOLOGICAL HAZARDS

Requirement 21: Geotechnical characteristics and geological features of subsurface materials

The geotechnical characteristics and geological features of subsurface materials shall be investigated, and a soil and rock profile for the site that considers the variability and uncertainty in subsurface materials shall be derived.

[10] Draw-down is a lowering of the water level at a coastal site. Run-up is a sudden surge of water up a beach or a structure.

5.24. The static and dynamic geotechnical characteristics and geological features of subsurface materials at the site, including any backfill, shall be established. Laboratory and field based methods shall be used, in conjunction with appropriate sampling techniques and sufficient repetition of each test, to characterize each parameter of the subsurface materials at the site.

5.25. The stability and bearing capacity of foundation materials shall be assessed, including consideration of the potential for excessive settlement under static and seismic loading.

5.26. The physical and the geochemical properties of the soil and groundwater shall be studied by appropriate methods and taken into account in the evaluation of the subsurface material at the site.

Requirement 22: Evaluation of geotechnical hazards and geological hazards

Geotechnical hazards and geological hazards, including slope instability, collapse, subsidence or uplift, and soil liquefaction, and their effect on the safety of the nuclear installation, shall be evaluated.

Slope instability

5.27. The site and the site vicinity shall be evaluated to determine the potential for slope instability (such as landslides, rock fall and snow avalanches), caused by natural or human induced phenomena, which could affect the safety of the nuclear installation. In the evaluation of slope instability, the configuration of the site during and after site preparation activities shall be addressed. The evaluation of slope stability shall also take into account extreme meteorological conditions and rare meteorological events.

5.28. The potential for slope instability resulting from seismic loading shall be evaluated using parameters appropriate for describing the seismic hazards and the soil and groundwater characteristics at the site.

Collapse, subsidence or uplift of the site surface

5.29. The potential for collapse, subsidence or uplift of the surface that could affect the safety of the nuclear installation over its lifetime shall be evaluated using a detailed description of subsurface conditions obtained from reliable methods of investigation.

Soil liquefaction

5.30. The potential for liquefaction and non-linear effects of the subsurface materials at the site shall be evaluated using parameters appropriate for describing the seismic hazards and geotechnical properties of the subsurface materials at the site.

5.31. The evaluation of soil liquefaction shall include the use of accepted methods for field and laboratory testing in combination with analytical methods to assess the hazards.

OTHER NATURAL HAZARDS

Requirement 23: Evaluation of other natural hazards

Other natural phenomena that are specific to the region and which have the potential to affect the safety of the nuclear installation shall be investigated.

5.32. Other natural external hazards, such as wild fires, drought, hail, frazil ice formation, diversion of a river, debris avalanche and biological hazards (e.g. jellyfish, small animals and barnacles) shall be identified and assessed so that the site specific design parameters for these hazards can be derived.

HUMAN INDUCED EVENTS

Requirement 24: Evaluation of hazards associated with human induced events

The hazards associated with human induced events on the site or in the region shall be evaluated.

5.33. Human induced events to be addressed shall include, but shall not be limited to:

(a) Events associated with nearby land, river, sea or air transport (e.g. collisions and explosions);
(b) Fire, explosions, missile generation and releases of hazardous gases from industrial facilities near the site;
(c) Electromagnetic interference.

5.34. Human activities that might influence the type or severity of natural hazards, such as resource extraction or other significant re-contouring of land or water or reservoir induced seismicity, shall be considered.

Aircraft crashes

5.35. The potential for accidental aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of potential changes in future air traffic and aircraft characteristics.

Chemical hazards

5.36. Current or foreseeable activities in the region surrounding the site that involve the handling, processing, transport and/or storage of chemicals having a potential for explosions or for producing gas clouds capable of deflagration or detonation shall be addressed.

5.37. Hazards associated with chemical explosions or other releases shall be expressed in terms of heat, overpressure and toxicity (if applicable), with account taken of the effect of distance and non-favourable combinations of atmospheric conditions at the site. In addition, the potential effects of such events on site workers shall be evaluated.

6. EVALUATION OF THE POTENTIAL EFFECTS OF THE NUCLEAR INSTALLATION ON THE REGION

Requirement 25: Dispersion of radioactive material

The dispersion in air and water of radioactive material released from the nuclear installation in operational states and in accident conditions shall be assessed.

Atmospheric dispersion of radioactive material

6.1. The analysis of the atmospheric dispersion of radioactive material shall take into account the orography, land cover and meteorological features of the region, including parameters such as wind speed and direction, air temperature, precipitation, humidity, atmospheric stability parameters, prolonged atmospheric inversions and any other parameters required for modelling of atmospheric dispersion. If possible, long term meteorological data for nearby locations shall be obtained, evaluated for quality and used.

6.2. A programme for meteorological measurements shall be prepared and carried out at or near the site using instrumentation capable of measuring and recording the main meteorological parameters at appropriate elevations, locations and sampling intervals. Data from at least one representative full year shall be collected and used in the analyses of atmospheric dispersion, together with any other relevant data available from other information sources. The meteorological data shall be expressed in terms of appropriate meteorological parameters.

Dispersion of radioactive material through surface water and groundwater

6.3. A survey programme shall be designed to gather relevant data to characterize the hydrogeological and hydrological parameters at the site and in the region to permit the assessment of the potential movement of radionuclides through surface water and groundwater and the subsequent assessment of the radiological impact. This measurement programme shall be carried out for at least one full year prior to hydrogeological investigations (see para. 6.5). The data shall be expressed in terms of appropriate parameters for surface hydrology and groundwater.

6.4. A programme of surface water investigations (including the interactions between surface water and groundwater) for the region shall be developed. The description of surface water shall include the main physical and chemical characteristics of the water bodies, both natural and artificial, the major structures for water control, the locations of water intake structures and information on water use in the region.

6.5. A programme of hydrogeological investigations for the region shall be developed, including descriptions of the main characteristics of the water-bearing formations and their interaction with surface water, as well as data on the uses of groundwater in the region.

6.6. The programme of hydrogeological investigations for the region shall include investigations of the migration and retention characteristics of radionuclides in groundwater and investigations of the associated exposure pathways.

6.7. The hydrogeological and hydrological investigations shall determine, to the extent necessary, the dilution and dispersion characteristics of water bodies, the re-concentration ability of sediments and biota, the migration and retention characteristics of radionuclides, the transfer mechanisms for radionuclides in the hydrosphere, as well as the associated exposure pathways.

Requirement 26: Population distribution and public exposure

The existing and projected population distribution within the region over the lifetime of the nuclear installation shall be determined and the potential impact of radioactive releases on the public, in both operational states and accident conditions, shall be evaluated and periodically updated.

6.8. Information on the existing and projected population distribution in the region, including resident populations and (to the extent possible) transient populations, shall be collected and kept up to date over the lifetime of the nuclear installation. Special attention shall be paid to vulnerable populations and residential institutions (e.g. schools, hospitals, nursing homes and prisons) when evaluating the potential impact of radioactive releases and considering the feasibility of implementing protective actions.

6.9. The most recent census data for the region, or information obtained by extrapolation of the most recent data on resident populations and transient populations, shall be used in obtaining the population distribution. In the absence of reliable data, a special study shall be carried out.

6.10. The data shall be analysed to obtain the population distribution in terms of the direction and distance from the site. This information shall be used to carry out an evaluation of the potential radiological impact of normal discharges and accidental releases of radioactive material, including reasonable consideration of releases due to severe accidents, with the use of site specific design parameters and models as appropriate.

Requirement 27: Uses of land and water in the region

The uses of land and water shall be characterized in order to assess the potential effects of the nuclear installation on the region.

6.11. The characterization of the uses of land and water shall include investigations of the land and surface water and groundwater resources that might be used by the population or that serve as a habitat for organisms in the food chain.

7. MONITORING AND PERIODIC REVIEW OF THE SITE

Requirement 28: Monitoring of external hazards and site conditions

All natural and human induced external hazards and site conditions that are relevant to the licensing and safe operation of the nuclear installation shall be monitored over the lifetime of the nuclear installation.

7.1. The monitoring of external hazards and site conditions shall be commenced no later than the start of construction and shall be continued until decommissioning. The monitoring plan shall be developed as part of the objectives and scope of the site evaluation.

7.2. The monitoring plan shall include the parameters to be monitored, the type of data to be collected, the methodology for data collection (including the location and frequency of data collection), the necessary resolution and precision of any measurements, data backup requirements, as well as requirements for data processing and analysis.

7.3. Before commissioning of the nuclear installation begins, the levels of background radioactivity in the atmosphere, hydrosphere and lithosphere and in biota in the region shall be measured so as to make it possible to determine any additional radioactivity due to the operation of the nuclear installation.

Requirement 29: Review of external hazards and site conditions

All natural and human induced external hazards and site conditions shall be periodically reviewed by the operating organization as part of the periodic safety review and as appropriate throughout the lifetime of the nuclear installation, with due account taken of operating experience and new safety related information.

7.4. As part of periodic safety review (or as part of safety assessments conducted under alternative arrangements), natural and human induced external hazards and site conditions shall be reviewed throughout the lifetime of the nuclear installation using updated information. Such reviews shall be undertaken at regular intervals (typically no less than once in ten years), and in the event of any of the following:

(a) An update of the regulatory requirements;

(b) Indications of inadequate design against external hazards;
(c) New technical findings, such as the vulnerability of particular structures, systems and components to external hazards;
(d) New information, experience and lessons from the occurrence of actual external events that affected the safety of another nuclear installation or an industrial facility;
(e) Changes of hazards over time for which new information and assessments have become available;
(f) A need to provide additional confidence that there are sufficient margins to prevent cliff edge effects;
(g) As part of a programme for long term operation, or in support of an application for an extension to the operating licence for the nuclear installation;
(h) The development of new methods to analyse hazards that substantially improve earlier estimates.

7.5. The site specific external hazards and the site conditions shall be re-evaluated, as necessary, based on the outcome of the periodic review of site specific hazards or because of new data relevant to the radiological environmental impact assessment or to the safe operation of the nuclear installation.

REFERENCES

[1] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, External Human Induced Events in Site Evaluation for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-3.1, IAEA, Vienna (2002).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-3.2, IAEA, Vienna (2002).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-3.6, IAEA, Vienna (2004).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Seismic Hazards in Site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. SSG-9, IAEA, Vienna (2010).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD METEOROLOGICAL ORGANIZATION, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. SSG-18, IAEA, Vienna (2011).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Volcanic Hazards in Site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. SSG-21, IAEA, Vienna (2012).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Site Survey and Site Selection for Nuclear Installations, IAEA Safety Standards Series No. SSG-35, IAEA, Vienna (2015).

[9] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection, 2018 Edition, IAEA, Vienna (in preparation).
[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2011).
[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, IAEA Safety Standards Series No. GSR Part 2, IAEA, Vienna (2016).

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Yukiya Amano
Director General

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Lessons from Fukushima

February 2012

greenpeace.org

Catalysing an energy revolution

image A mother holds her baby at Yonezawa gymnasium, which is providing shelter for 504 people who either lost their homes to the tsunami, or live near the Fukushima nuclear power station.

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"For a successful technology, reality must take precedence over public relations, for nature cannot be fooled."

Richard Feynman

image Iitate village, 40km northwest of the Fukushima Daiichi nuclear plant. Radiation levels found by the Greenpeace monitoring team are far above internationally recommended limits.

Executive Summary

It has been almost 12 months since the Fukushima nuclear disaster began. Although the Great East Japan earthquake and the following tsunami triggered it, **the key causes of the nuclear accident lie in the institutional failures of political influence and industry-led regulation**. It was a failure of human institutions to acknowledge real reactor risks, a failure to establish and enforce appropriate nuclear safety standards and a failure to ultimately protect the public and the environment.

This report, commissioned by Greenpeace International, addresses what lessons can be taken away from this catastrophe. The one-year memorial of the Fukushima accident offers a unique opportunity to ask ourselves what the tragedy – which is far from being over for hundreds of thousands of Japanese people – has taught us. And it also raises the question, are we prepared to learn?

There are broader issues and essential questions that still deserve our attention:

- How it is possible that – despite all assurances – a major nuclear accident on the scale of the Chernobyl disaster of 1986 happened again, in one of the world's most industrially advanced countries?
- Why did emergency and evacuation plans not work to protect people from excessive exposure to the radioactive fallout and resulting contamination? Why is the government still failing to better protect its citizens from radiation one year later?
- Why are the over 100,000 people who suffer the most from the impacts of the nuclear accident still not receiving adequate financial and social support to help them rebuild their homes, lives and communities?

These are the fundamental questions that we need to ask to be able to learn from the Fukushima nuclear disaster. This report looks into them and draws some important conclusions:

1. The Fukushima nuclear accident marks the **end of the 'nuclear safety' paradigm**.
2. The Fukushima nuclear accident exposes the **deep and systemic failure** of the very institutions that are supposed to control nuclear power and protect people from its accidents.

The end of the nuclear safety paradigm

Why do we talk about the end of a paradigm? After what we have seen of the failures in Fukushima, we can conclude that 'nuclear safety' does not exist in reality. There are only nuclear risks, inherent to every reactor, and these risks are unpredictable. At any time, an unforeseen combination of technological failures, human errors or natural disasters at any one of the world's reactors could lead to a reactor quickly getting out of control.

In Fukushima, the multiple barriers that were engineered to keep radiation away from the environment and people failed rapidly. In less than 24 hours following the loss of cooling at the first Fukushima reactor, a major hydrogen explosion blew apart the last remaining barrier between massive amounts of radiation and the open air.

The nuclear industry kept saying that the probability of a major accident like Fukushima was very low. With more than 400 reactors operating worldwide, the probability of a reactor core meltdown would be in the order of one in 250 years.

This assumption proves to be wrong. In fact, an observed frequency based on experience is higher: **a significant nuclear accident has occurred approximately once every decade**.

One of the principles of modern science is that when observations do not match the calculated predictions, the model and theory need to be revised. This is clearly the case for probabilistic risk assessments used in nuclear safety regulations. However, **the nuclear industry continues to rely on the same risk models** and supposedly extremely low probabilities of disasters, justifying the continued operation of reactors in Japan and worldwide.

This report exposes the systemic failures in the nuclear sector, specifically looking into three issues:

- emergency and evacuation planning;
- liability and compensation for damages; and
- nuclear regulators.

Human rights

In the **introduction,** Tessa-Morris Suzuki, Professor of Japanese History in the College of Asia and the Pacific at the Australian National University – who is also a member of the International Council on Human Rights Policy (ICHRP) – concentrates on the human rights angle of the Fukushima tragedy. She details how **disasters tend to reveal a whole range of cracks or weak points in social, economic and political institutions**, not only in the Japanese but also in an international context.

What becomes clear in her text is that the weaknesses in the regulation and management of Japan´s nuclear power industry have not been 'hidden' faults in the system. To the contrary, people had been aware of, written and warned about them for decades.

Emergency planning failed

In the **first chapter**, Professor David Boilley, chairman of the French Association ACRO, documents how even Japan, one of the most experienced and equipped countries when it comes to handling large-scale disasters, found that its **emergency planning for a nuclear accident was not functional**, and its evacuation process became chaotic, which lead to **many people being unnecessarily exposed to radiation**.

During the height of the crisis, the Japanese government frequently denied there were dangers from radiation releases. For example, on 12 March, the Chief Cabinet Secretary told a news conference that the reactor would not leak a large quantity of radiation, and that people outside a 20km radius would not be affected. Within two weeks of the statement, the government asked people living between a 20 and 30km radius of the disaster to voluntarily evacuate. Then, in late April, the government extended the evacuation zone to specific areas up to 50km. Again in June, July and August, the government asked more people outside the 20km evacuation zone to evacuate.

Governmental data released only later revealed that in a worst-case – but possible – scenario, evacuation would have included the megapolis of Tokyo and other settlements up to 250km away. Clearly, **evacuation planning based on circles with diameters of several kilometres is too rigid and hopelessly inadequate in the case of nuclear power plants**.

Special software for predicting fallout patterns was not used correctly. In some cases, people were evacuated to areas with more, not less, radiation. For example, the software predicted that a school would be in the path of a radioactive plume, yet the school was used as a temporary evacuation centre. Thousands stayed for days in an area that was very highly contaminated. In addition, radiation fallout scenarios developed in the early days of the crisis were never sent to the office of the Prime Minister, where decisions on managing the disaster were being made.

Evacuation procedures of vulnerable people failed. Patients from one hospital and a nearby home for the elderly were sent to shelters: 45 of 440 patients died after staff fled. In another incident, more than 90 elderly people were left without caregivers. Hospitals in Fukushima Prefecture have had to suspend services because hundreds of doctors and nurses in the area resigned to avoid radiation.

The Fukushima crisis also exposed that one of the key principles of nuclear emergency plans – confinement (recommending people to stay in their homes to avoid radiation exposure) – simply does not work in practice. Confinement is only possible for a short period of time, but not for 10 days, which turned out to be the necessary period of time as massive releases of radiation from the Fukushima disaster carried on this long. (Also in the case of Chernobyl disaster, the vast radiation release continued for nearly two weeks).

Communities where people were confined ran out of food, as well as fuel needed for eventual evacuation. In addition, specialised workers – such as drivers, nurses, doctors, social workers and firemen, who were needed to help those confined – were not prepared to stay in an area receiving large amounts of radiation.

The post-emergency situation is also riddled with problems. Pragmatic radiation standards introduced by the government are higher than internationally recommended limits. Japanese authorities keep failing to foresee the scale of problems with contaminated food and crops, and are repeatedly being caught by surprise. The government has insufficient programmes for monitoring and screening radiation levels, leading to scandals that further undermined the confidence of the public and caused unnecessary additional economic damages to farmers and fishermen and to their livelihoods. **Decontamination programmes to clean up highly contaminated areas pose big questions in terms of their effectiveness, costs and negative side effects**.

Lack of accountability

The **second chapter**, based on interviews by Dr David McNeill, the Japan correspondent for *The Chronicle of Higher Education* and journalist for *The Independent* and *Irish Times* newspapers, investigates probably the most dreadful face of the Fukushima accident – the human consequences. Over 150,000 people evacuated; they lost nearly everything and are denied sufficient support and compensation to allow them to rebuild their lives.

Most countries limit the liability of reactor operators to only a small fraction of real damages, which allows the nuclear industry to basically escape paying for the consequences of an accident. The Japanese legislation on liability and compensation stipulates that there is no cap on liability for a nuclear reactor operator – in this case TEPCO – for damages caused to third parties. However, it **does not include any detailed rules and procedures about how and when the compensation will be paid**. Nor does it define who is eligible and who is not. This leaves lots of space for interpretation.

TEPCO has so far **managed to escape full liability and fails to properly compensate people and businesses that have been dramatically impacted** by the nuclear accident. The larger compensation scheme excludes dozens of thousands of people who decided to evacuate voluntarily to reduce their risks of radiation exposure. Some have been offered only $1,043 US dollars as a one-off payment. TEPCO lawyers have also been trying to avoid their duty to pay for decontamination costs by claiming that the radiation, as well as the burden of dealing with it, now belongs to the landowners, not to the company.

Families have been split apart, and have lost their homes and their communities. People have lost their jobs and have had their living costs doubled in some cases – yet the first package of one-time financial support was limited to a rather symbolic $13,045 and arrived from TEPCO only after people were relocated for several months. What was supposed to be the first package of larger compensations began six months later when TEPCO provided people with a 60-page application form, accompanied by another 150 pages of instructions. Many people struggled to understand it, and many others simply gave up, choosing to forget and move on.

Importantly, Japanese law requires that TEPCO has compulsory insurance to cover $1.6bn, meaning that anything over this amount may not be available if the company faces inevitable financial difficulties or a bankruptcy. So far, the company has paid out compensation to citizens in the amount of roughly $3.81bn. The estimates of the real cost of damages are however in the order of $75 to $260bn. Overall costs of the Fukushima accident including compensation and decommissioning the Daiichi plant's six reactors have been projected to reach $500 to $650bn. It is clear already that the government will be stepping in, one way or the other, to bail out TEPCO. Most of the costs of the damage, if ever compensated, will be shouldered by taxpayers.

It is staggering to witness how the nuclear industry managed to build up a system whereby polluters harvest large profits, while the moment things go wrong, they throw the responsibility to deal with losses and damages to the impacted citizens.

Systemic failures

The **third chapter**, by Arnie Gundersen from Fairewinds Associates, looks into how it is possible that an accident like Fukushima happened at all. It finds that an 'attitude of allowed deception' existed between TEPCO and the state institutions in Japan that were supposed to ensure its citizens' safety. This deception characterises the institutional failures in Japan; failures that include **undue political influence on regulation of the nuclear industry**, allowing industry to lead the development of regulations and a dismissive attitude to the risks of nuclear accidents.

For example, even when the problems, weaknesses and scandals of TEPCO came to the surface, regulators never enforced sufficiently strong measures to avoid the same things from happening again and again and again. On occasions when regulators finally requested certain modifications, they allowed many years to go by before these were implemented. This is exactly what proved to be fatal in Japan in 2011.

Image A satellite image shows damage at the Fukushima nuclear power plant. The damage was triggered by the offshore earthquake that occurred on 11 March 2011.

In Japan, the **failure of the human institutions inevitably led to the Fukushima disaster**. The risks of earthquakes and tsunamis were well known years before the disaster. The industry and its regulators reassured the public about the safety of the reactors in the case of a natural disaster for so long that they started to believe it themselves. This is sometimes called the Echo Chamber effect: the tendency for beliefs to be amplified in an environment where a limited number of similarly interested actors fail to challenge each other's ideas. The tight links between the promotion and regulation of the nuclear sector created a 'self-regulatory' environment that is a key cause of the Fukushima Daiichi disaster.

It is symptomatic of this complacent attitude that the first concerns voiced by many of the decision makers and regulators after the accident were about how to restore public confidence in nuclear power – instead of how to protect people from the radiation risks. This has also been the case with the UN's International Atomic Energy Agency (IAEA), which **failed to prioritise protection of people over the political interests of the Japanese government, or over its own mission to promote nuclear power**. The IAEA has systematically praised Japan for its robust regulatory regime and for best practices in its preparedness for major accidents in its findings from missions to Japan as recently as 2007 and 2008.

Lessons to be learned

The institutional failures in Japan are a warning to the rest of the world. These failures are the **main cause of all past nuclear accidents**, including the accident at Three Mile Island in the US and the disaster at Chernobyl in Ukraine. There are a number of similarities between the Chernobyl and Fukushima nuclear disasters: the amounts of released radiation, the number of relocated people, and the long-term contamination of vast areas of land. Also the root causes of the accident are similar: concerned institutions systematically underestimated risks, other interests (political and economic) were prioritised over safety, and both industry and decision makers were not only fatally unprepared, but were allowed to establish an environment in which they existed and operated without any accountability.

Governments, regulators and the nuclear industry have stated they have learnt big lessons from the past. Yet, once again they failed to deliver. How confident can we be that the same will not happen again? But we have a choice. **Mature, robust and affordable renewable energy technologies are available and up to the task of replacing hazardous nuclear reactors**. During the last five years, 22 times more new power generating capacity based on wind and solar was built (230,000MW) compared to nuclear (10,600MW). Renewable power plants built in just the one single year of 2011 are capable of generating as much electricity as 16 large nuclear reactors.This is where the opportunity stands for a nuclear-hazard-free-future.

"For a successful technology, reality must take precedence over public relations, for nature cannot be fooled."

This statement is by one of the leading physicists of the past century, Nobel Prize winner Richard Feynman, written in 1987 in his minority report for a commission investigating the tragic disaster of the Challenger space shuttle. His analysis has astonishing parallels to the nuclear industry. He explains how the socio-economic influences of modern society led to a massive gap between official predictions and real-world risks of disastrous accidents of complex technologies. He notes the fact that, if things go well and accidents do not happen for a while, there is an inevitable watering down of regulation and precautionary principles. He also calls for the consideration of alternative technologies to do the job.

It took two lethal disasters to phase out the expensive and accident-prone space shuttles. Now, **we are living through the second major nuclear reactor disaster in history**. Let's not fool ourselves again: we have a responsibility to use this critically important moment to finally switch to a **safe and affordable supply of electricity — renewable energy**. All the worlds' reactors can be replaced within two decades.

In the meantime, we can learn from Fukushima that **nuclear power can never be safe**. If there is yet another major nuclear accident, the people who will suffer can be given better protection if we hold the nuclear industry and regulators fully accountable and liable. We must **put the nuclear regime under close public scrutiny** and require transparency. But again, while doing so, we have to **phase out dangerous nuclear power entirely**, and do so as soon as possible.

image The empty playground of a local day nursing school in Fukushima City. Before the crisis, the school was taking care of 24 children.

The human consequences of such a lethal explosion are strikingly visible in the village of Iitate, situated on a beautiful plateau in the hills of Fukushima Prefecture.

Introduction: Fukushima and Human Rights

Prof. Tessa Morris-Suzuki

When an earthquake strikes any part of the world, it makes visible hidden forces and fissures that have long existed under the earth, but that have, until that moment, remained invisible. The fault lines that lie deep within the bedrock appear beneath our feet as new cracks in the ground. The immense power of our constantly changing, constantly moving earth becomes terrifyingly tangible.

Similarly, when any disaster – an earthquake, tsunami, flood, major hurricane or volcanic eruption – takes place, it exposes the cracks beneath the surface of social and political systems. These cracks may have been invisible, or perhaps we have always been half-aware of their presence, but have up until now been able to ignore them. In the case of the Great East Japan Earthquake, the triple tragedy of quake, tsunami and nuclear accident exposed a whole range of cracks or weak points not only in Japan's social, economic and political institutions, but also in international institutions.

Most obviously, perhaps, the earthquake and tsunami exposed weaknesses in the regulation and management of Japan's nuclear power industry. This was not really a 'hidden' fault in the system. Rather, it was a weakness that many people had been aware of, and had written and warned about for decades. On my bookshelves, for example, I have a copy of the English-language journal *Ampo*, published more than 35 years ago, in 1975. Under the heading 'Nuclear Reactors: Risking the Ultimate Pollution', this article notes the vulnerability of Japan's new nuclear plants to the risk of natural disasters, and points out that in 1971 (the year when the Fukushima Daiichi plant was commissioned) the US government warned that light water reactors like Fukushima were in danger of experiencing a 'lethal nuclear explosion and widely scattered radioactive fallout' if the emergency core cooling system failed.

Today, the human consequences of such a lethal explosion are strikingly visible in the village of Iitate, situated on a beautiful plateau in the hills of Fukushima Prefecture. Trim farmhouses and a small row of shops line the main road through the village. Restaurants tempt passers-by with billboards offering local beef and mountain vegetables. A steady stream of vehicles flows along the road, but none of them stop. The car parks are empty, the fields devoid of crops. No children play in the school playground. Almost a year after the disaster, tall weeds are flourishing in the greenhouses of Iitate village. Although it is 40km away from the Fukushima No. 1 nuclear plant, Iitate is a ghost town.

Outside the Iitate community hall, the radiation dosimeter carried by one of my travelling companions to measure external radiation reads 13.26 microsieverts an hour – a level around 100 times natural background radiation. When he holds his dosimeter over the drainage culvert in front of the hall, it stops working altogether – the radiation level has gone off the scale. One of the things that you quickly learn in a place like Iitate is that levels of radiation can vary enormously within a relatively small area. Iitate has the misfortune to lie in a spot where the winds from the coast meet the mountains, and quickly became a radiation hotspot due to precipitation. Its inhabitants are among the 150,000 people who evacuated from the area affected by the nuclear accident, and have no idea when they will be able to return home.

Much of the research on the effects of the accident in Fukushima Prefecture today is being carried out not by professional scientists but by ordinary local people with no scientific training, who are desperately trying to make sense of the world around them. In the village of Miharu, for example, a group of local farmers – mostly elderly and mostly women – is growing a range of crops and testing them with radiation measuring equipment provided by the village council. The results are startling. Some crops show dramatically high levels of contamination with radioactive caesium, while others show virtually no contamination at all, and will be sold to consumers around the country with the support of cooperative volunteers. The authorities are not able to correctly control and regulate the radioactivity of the various goods that are sold on the market, in particular food.

In a small shopping arcade in downtown Fukushima City, a group of local citizens has been helping to answer local concerns with an impressive battery of radiation measuring equipment, including a whole-body counter imported from Belarus (one of the countries worst affected by the Chernobyl accident). But the Citizen's Radioactivity Measuring Station, funded by donations and staffed by overworked volunteers, struggles to deal with the constant flow of enquiries and requests for advice. As of late 2011, levels of external radiation in parts of Fukushima City were as much as 10 times the level of natural background radiation, but were still within the range which the government had officially declared 'safe'.

In the face of this uncertainty, many families became divided: spouses and children sent to live in other parts of Japan or even overseas, while the wage-earner remained in Fukushima. After all, even if the risk is small, what parent wants to face the possibility that their child may develop cancer because they failed to act in time?

Evacuation, however, carries its own costs. There are obvious psychological burdens: including those of separation and dislocation, particularly for children who have to change schools and move away from relatives and friends. The financial costs are also high and they will be carried by society at large. But there is a catch: TEPCO's current compensation scheme is modelled on the government directive on evacuation. This means only those who have been compulsorily moved are entitled to claim. So, people from the designated evacuation zones will receive compensation from the power company or government but – since it insists that there are no health risks outside the specified evacuation zones – the Japanese government refused to support the costs of those who chose to leave Fukushima City voluntarily.

In December 2011 the government finally accepted the recommendations made by an advisory panel to give limited sums of assistance to residents of 23 municipalities which lie outside the compulsory evacuation zones, but which have high levels of radiation. But the assistance, which is to be paid regardless of whether residents leave or remain in the area, is a mere fraction of the cost incurred in moving away from the contaminated areas.

Over 100,000 nuclear victims from Fukushima will wait as their claims are processed. Those who are allegedly not entitled to compensation might go to court to settle their claims. Many won't receive anything at all. Lawyers and independent observers state the strategy of TEPCO and the government consists of restraining compensation claims by making them as restricted, bureaucratic and difficult as possible for the Fukushima victims.
A volunteer from the local NGO 'Kodomo Fukushima', established in May 2011, eloquently describes the human dimensions of the disaster. The 240 children who attended three schools in Iitate village have been evacuated, many of them to the officially declared safety of Fukushima City, while their school has been moved to a campus down the hill from Iitate in the nearby town of Kawamata (just outside the evacuation zone). To reach their school, the evacuated children now living in Fukushima City have to board a school bus around six in the morning, returning late in the afternoon. While they are at school, they are not allowed to play or have sports lessons out of doors for fear of radiation. When they return to their families' places of evacuation in Fukushima City, they continue to be exposed to levels of radiation up to 10 times normal background levels. Many are showing signs of fatigue and low levels of immunity, though no one can say whether this is the result of the social disruption they have endured or of raised radiation levels.

Kodomo Fukushima is just one of a number of NGOs working to support the children of the region. It is campaigning to establish sanatoria in other parts of Japan and overseas, where particularly vulnerable children (including but not limited to children from evacuation zones like Iitate) can be sent for periods of two months to lower their radiation levels and restore their mental and physical health. The group's members recognise that responses to the disaster are diverse. Some families want to evacuate; others do not. Many people in the Prefecture may indeed be at negligible risk from radiation; but some are in a situation where anxiety cannot be dismissed as 'overreaction' or calmed by repeated injunctions to 'stop worrying'.

The UN Convention on the Rights of the Child requires states to 'recognise the right of the child to the enjoyment of the highest attainable standard of health'. It is time for TEPCO, the company responsible for the Fukushima accident, local and national governments in Japan, and the world community to fulfil their obligations to the children of Fukushima.

Tessa Morris-Suzuki is a Professor of Japanese History in the College of Asia and the Pacific at the Australian National University, and a member of the International Council on Human Rights Policy (ICHRP). She is co-founder of the AsiaRights network of Asia-Pacific human rights researchers and activists, and editor of the online journal *AsiaRights*.

image A child sleeps in an evacuation centre in Yonezawa.

The catastrophe has just started in Japan. All of this means that the population has to learn how to live in a contaminated environment for decades to come.

01

Emergency Planning and Evacuation

Professor David Boilley

One year after the Fukushima nuclear disaster triggered by the Great East Japan Earthquake on 11 March 2011, Japan continues to struggle with one of the worst nuclear accidents in history. The impacts will last much longer than the consequences of the earthquake and tsunami that triggered the meltdown at the three nuclear reactors in the Fukushima Daiichi nuclear power plant (NPP).

Technology helps Japan to cope with natural disasters. Japan faces about 10% of the world's earthquakes, and the bullet train network, buildings, bridges and other infrastructures have all been adapted to withstand those. But what happened shows that the nuclear industry is not prepared to face natural disasters and societies are not prepared to face nuclear accidents. Even a technologically advanced and organised nation like Japan finds itself unable to address such a disaster.

This chapter describes how the authorities had and still are facing many difficulties in organising the emergency evacuation and decontamination processes, for example:

- The concept of evacuating people based on concentric circles ranging from 5, 20 or even 30km has proven to be too rigid and inadequate.
- Confinement of people is insufficient when dealing with radioactive discharges that last over 10 days.
- Highly contaminated areas had to be evacuated up to 50km from the nuclear plant, and this is still not enough.
- Authorities are not able to adequately control and regulate the radioactivity of the various goods that are sold on the market, in particular food, which can have serious consequences.
- The authorities don't know how to cope with the extended contaminated territories and the huge quantity of radioactive waste.

The full extent of the catastrophe

It is well acknowledged that the Fukushima disaster is a major nuclear accident that has caused long-term contamination to large areas of land and the ocean.

The estimation[1] of the quantity of radioelements released into the environment depends on the organisation that did the calculation. However, they all agree that it is the largest discharge of radioelements into the Pacific Ocean ever observed. The release happened at the junction of two oceanic currents, the Kuroshio and the Oyashio, which increased the distribution of the radioactive pollution. Marine life[2] and sediments[3] continue to be contaminated over large distances. Unfortunately, the situation is still fragile at the plant: TEPCO has faced several small leaks and another major leak[4] is still a possibility.

The atmospheric release of major radioelements is estimated to be between 10%[5] and 40%[6] of the quantity released in the Chernobyl accident. For xenon-133, it is the largest discharge in history, 2.5 times higher than the release at Chernobyl.[7] Fortunately for the Japanese, about 80% of this release went towards the ocean, where it adds to the marine pollution[8]. The crippled nuclear power plant was still releasing radioactive materials into the air at a rate of 60 million becquerels an hour in December 2011, and 70 million becquerels an hour in January 2012[9] .

Although only 20% of the release fell on Japanese land, large portions of the affected areas will remain highly contaminated for decades. The Japanese government has decided that it will take charge of the decontamination of the land where the external irradiation is higher than one millisievert a year[10], in accordance with the internationally agreed maximum allowable dose for members of the public. This roughly[11] represents 13,000km^2. Assuming that it is even possible practically – and costs aside – the government still does not know how to cope with the resulting radioactive waste, which is roughly estimated to be several tens of millions of cubic metres[12].

As pointed out by the official Investigation Committee on the accidents at the Fukushima Nuclear Power Station[13], TEPCO was not prepared to face a nuclear accident. If the company and the responsible authorities had not made so many mistakes at the beginning of the catastrophe, the amount of radioactive pollution released in Japan could have been far lower.

On the other hand, the situation could have been even worse. The worst scenario was avoided thanks to brave workers who faced the danger of explosions and radioactive contamination. According to a report[14] from the head of the Japan Atomic Energy Commission, handed to the Prime Minister on 25 March 2011, a scenario based on the meltdown of the irradiated fuel stored in the pool in Reactor No. 4 could have led to a forced evacuation of up to 170km to 250km, including a large portion of the Tokyo megapolis.

Had the same disaster taken place in a nuclear power plant in the Fukui prefecture, which houses 13 reactors[15] on the coast of the Sea of Japan, it would not have been the Pacific Ocean but metropolises such as Kyoto, Osaka, Kobe and Nagoya, and the Biwa Lake (the biggest lake of Japan) that would have been contaminated. The social, human and economic consequences would have been far more severe.

Japan is probably the best-prepared country to cope with natural disasters. In any other country a magnitude 9 earthquake and a large tsunami would have claimed the lives of far more than the 20,000 people in Japan. In addition, there were up to 448,000 refugees in shelters. In less than a year all the evacuees are in temporary housing.[16]

However, as we will document below, the Japanese authorities gave the impression they were continuously improvising as the events unfolded during the nuclear disaster. They seemed unable to anticipate the events, as if there had been no emergency planning and no precautionary measures taken to address nuclear accidents.

Outline and analysis of emergency planning: a human tragedy

Sequence of events[17]:

Friday 11 March 2011 (note: times are local, JST)

14:46 Magnitude 9 earthquake hundreds of kilometres offshore.

15:27 Several tsunami waves flood the Fukushima nuclear power plant.

16:46 'Nuclear emergency situation' is declared at the Fukushima nuclear power plant.

20:45 Local authorities call for the evacuation in a 2km radius around the nuclear power plant. 2km corresponds to the radius of the emergency drills.

21:23 Central government orders the evacuation in a 3km radius and the confinement of the population within 3 to 10km.

Saturday 12 March 2011

05:44 The Prime Minister issues orders to evacuate in a 10km radius

Around noon: the population seems to be completely evacuated within 3km.

15:36 Hydrogen explosion at the reactor building No. 1.

18:25 The Prime Minister issues orders to evacuate in a 20km radius.

Monday 14 March 2011

475 people remain in hospitals and care centres within the 20km radius.

11:01 Hydrogen explosion at the reactor building No. 3.

The government asks the remaining people within the 20km radius to confine themselves.

Tuesday 15 March 2011

06:14 Hydrogen explosion at the reactor building No. 2.

Early morning: More than 90 patients remain without care in the Futaba hospital.

11:00 During a press conference, the Prime Minister advises the remaining 136,000 people living within 20 to 30km of the nuclear power plant to stay indoors.

The US embassy asks its citizen to evacuate in a radius of 80km.

Friday 25 March 2011

The government asks people living within 20 and 30km of the NPP to voluntary evacuate because it is very difficult to provide food and care.

Friday 22 April 2011

The government extends the evacuation zone to highly contaminated municipalities (Katsurao, Namie, Iitate and parts of Kawamata and Minami-Soma) up to 50km. It forbids access inside the 20km radius.

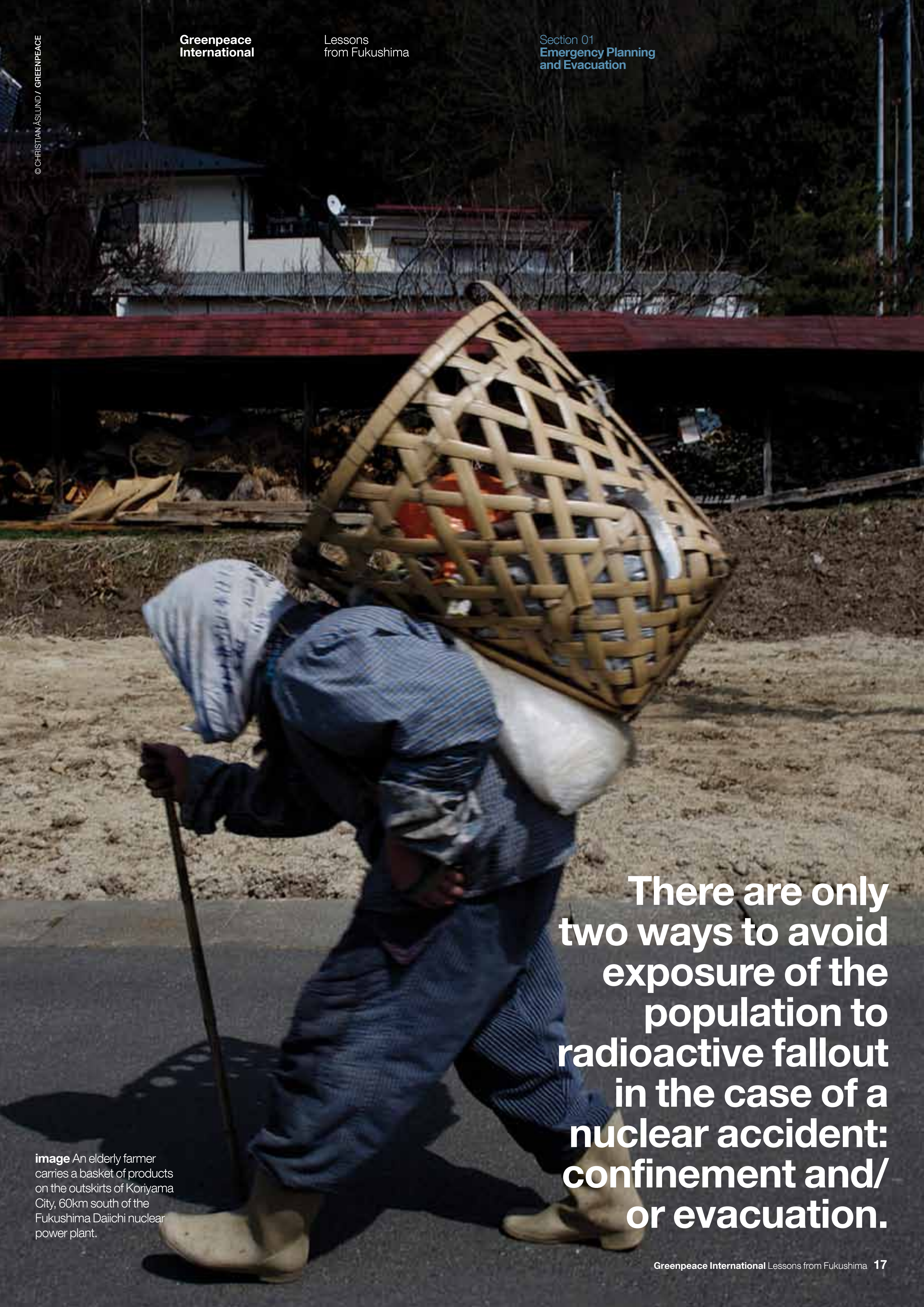

image An elderly farmer carries a basket of products on the outskirts of Koriyama City, 60km south of the Fukushima Daiichi nuclear power plant.

There are only two ways to avoid exposure of the population to radioactive fallout in the case of a nuclear accident: confinement and/or evacuation.

There are only two ways to avoid exposure of the population to radioactive fallout in the case of a nuclear accident: confinement and/or evacuation. Confinement is only possible during a limited period and evacuation relies on complex logistics to inform, displace and shelter the population.

Evacuation during emergencies

The Prime Minister issued the evacuation orders in successive concentric circles of up to 20km. At a news conference on the evening of 12 March, Chief Cabinet Secretary Yukio Edano said, "There will be no leakage of radioactive material in a large quantity. Persons in areas outside of the 20km radius will not be affected." But people in the area were urged to take shelter as a precautionary measure.[18]

The Fukushima Prefecture began measuring radiation levels at various locations from early in the morning on 12 March. At 9am, measurements in the Sakai district in Namie registered 15 microsieverts an hour, and 14 microsieverts an hour in the Takase district, both located at around 10km from the plant. It was more than six hours before the hydrogen explosion at the No. 1 reactor, and there were many evacuees nearby. These readings were uploaded to the website of the Ministry of Economy, Trade and Industry on 3 June.[19]

Later, in April, the authorities extended the evacuation zone to areas up to 50km to the northwest, due to the high contamination of the land. The population living in these territories were directly exposed to the fallout without knowing it. They thought that they were safe, being far beyond the 20km radius. Although Greenpeace specialists measured very high levels of contamination in Iitate, 40km from the damaged reactors, and had already called for its evacuation on the 27 March[20] (both radiation levels and the need to evacuate were confirmed a few days later by the IAEA's team[21], which withdrew its statement again), the authorities suggested the extension of the evacuation zone only on 11 April, and the order came on 22 April.[22]

The Japanese government had special software designed to forecast the fallout in case of an accident and in order to help during the decision making process of where to evacuate. The so-called SPEEDI[23] software cost 13bn yen ($170m US dollars) and theoretically can make predictions of up to 79 hours. Unfortunately, it was not used correctly. Some people were evacuated to places where they were more exposed to the fallout than in their original location.

As officials planned a venting operation at the Fukushima nuclear power plant, certain to release radioactivity into the air, the SPEEDI software predicted that Karino Elementary School would be directly in the path of the plume. The school was not immediately cleared out, but turned into a temporary evacuation centre. So thousands of people stayed for days in areas that were highly contaminated. On the mayor's order, some evacuees were taken by bus to Tsushima. Later on, it appeared that SPEEDI data suggested this area to be dangerous. The evacuees at shelters in the Tsushima district – including about 8,000 residents of Namie – were not told to move farther away until 16 March, five days into the crisis.[24]

The version of SPEEDI run by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) didn't have the ability to evaluate the quantity of radioelements that was released – so called 'source term'. It then arbitrarily assumed that the source term was at 1 becquerel an hour, which leads to indicative results that have nothing to do with reality.[25]

The Nuclear and Industrial Safety Agency (NISA) released the first SPEEDI predictions at 9:12pm on 11 March. Following the initial crisis, the Agency produced 173 pages of predictions based on various scenarios calculated up to 16 March. This complete analysis never reached the Prime Minister's office where the decisions were taken.[26]

Even after the Prime Minister's office learnt of SPEEDI, the results of the simulations were not sufficiently used to protect the populations nor published. During a news conference on 2 May, Goshi Hosono, a special advisor to the Prime Minister, explained that 'there was concern that citizens would panic'[27]. However, the data was provided to US forces via the Japanese Foreign Ministry from 14 March, but it was not until 23 March that the public was officially informed.[28]

Even if SPEEDI would have been used correctly, it is not sure that the information would have reached the exposed populations. Following the earthquake, electric lines were cut. Communications, including mobile phones were not available. There are many stories in the Japanese media of people who stayed home because they were not warned.

It is very important to notice that fallout prediction tools proved to be useless and were not ready to model real world situations. There were not enough sufficiently trained people to interpret them, which contributed to chaos in decision making.

The authorities and TEPCO failed to clearly communicate the information as well as practical conclusions and recommendations to the public. As a result, many people were unnecessarily exposed to high levels of radiation.

Weakness of the emergency evacuation

Despite Japan's experience in dealing with natural disasters the evacuations were not as smooth as expected. The earthquake destroyed many roads. Traffic jams slowed down the evacuation as well as the electricity generators loaded onto trucks to rescue the nuclear power plant.

Weak people who could not leave on their own were extremely vulnerable. This is especially the case for patients in hospitals and care centres. The evacuation of the hospital of Futaba turned out to be disastrous: patients who were unable to walk on their own, including bedridden people with serious conditions, were abandoned for three days without care and food.

Evacuated patients were sent to shelters without medical structures to take care of them. Eventually, 45 of the 440 patients of the Futaba hospital and the nearby nursing home for the elderly died.[29] This happened despite previously worked out guidelines from the central government for evacuating elderly and handicapped people at the time of a natural disaster. In total, there were 840 people at medical and other facilities in the 20km evacuation zone.[30]

A total of 573 deaths have been certified as 'nuclear disaster-related' by 13 municipalities affected by the nuclear crisis. Twenty-nine cases remain pending. A disaster-related death certificate is issued when a death is not directly caused by a tragedy, but by fatigue or the aggravation of a chronic disease due to the disaster.[31]

Hospitals, nurseries and other social facilities with a vulnerable population have proven to be extremely difficult to evacuate in case of emergency. In the case of a serious accident at a nuclear power plant, the emergency evacuation zone can become very large, well beyond 20 or 30km, potentially affecting important infrastructural institutions.

Farmers faced the problem of having to abandon their animals. About 3,400 cows, 31,500 pigs and some 630,000 chickens were abandoned in the 20km evacuation zone, according to the Ministry of Agriculture, Forestry and Fisheries.[32] Most of them died. Others were released into the wild.

Some farmers refused to leave their animals behind and stayed with them or regularly returned to their farms to feed the animals or milk the cows, exposing themselves to the fallouts of the NPP.

Pets were also not accepted in shelters. Some people had to abandon them. Others went to other locations with their pets.

The emergency measures were unrealistic and non-functional when it came to animals. People who had to relocate didn't feel comfortable leaving their animals behind, and didn't know how to provide care to them, which hampered the evacuation.

Long-term confinement and lack of specialised care

In case of a nuclear accident, the first action is to confine people to avoid direct exposure to the radioactive fallout. To ensure staying inside is as safe as possible; one should avoid, by all means, air and dust entering the building. This means turning off ventilation and taping up doors and windows.

These extreme measures are only possible for a short period of time. The massive releases in Fukushima lasted 10 days[33], similar to Chernobyl[34]. Even after 10 days, the situation was too uncertain to let the confined population go out. Such a long confinement is practically impossible, especially with regard to food supplies and possibly the need for special care. Providing food to each house implies risks for the people in charge of distribution.

The virtual message-in-a-bottle posted on the internet by the mayor of Minami-Soma caused a buzz.[35] His testimony is important to understand the difficulties of the local authorities in coping with the situation. All shops were closed. He had to take charge of 20,000 people at the time of the footage[36] (24 March 2011). He particularly complains about the lack of essential supplies for the population ordered to stay indoors as well as the lack of information about the situation at the plant and the dangers they were facing.

According to a survey by an association of Fukushima Prefecture hospitals, conducted in late July, hundreds of doctors and nurses have resigned from nearby facilities since the accident.[37] The survey found that 125 full-time doctors had resigned from 24 hospitals in the prefecture, or 12% of all doctors working at those institutions. As for nurses, 407 had quit from 42 hospitals in the prefecture, representing 5% of the nursing staff at those institutions. Their departures have resulted in some hospitals suspending night-time emergency care and other treatment services.

The survey found that the highest number of doctors left from hospitals in Minami-Soma. Thirteen doctors resigned from four hospitals in the city, including one inside the exclusion zone. The figure represents 46% of the four institutions' total doctors. As for nurses, in Minami-Soma 44 left their jobs at four hospitals, or 16% of those institutions' total nursing staff. The association assumes most of the doctors and nurses who resigned did so due to their desire to leave the area amid concern about radiation exposure.[38]

Experience from both Fukushima and Chernobyl has shown that massive amounts of radiation were being released over 10 days. Confinement, which is one of the key measures in the emergency planning, is practically impossible for these extended periods and authorities don't have alternative solutions in cases of severe accidents. Confined communities in the meantime run out of food and fuel supplies needed. Another major problem is that some of the specialised workers, like drivers, nurses, social workers, medical doctors, and firemen were not prepared to stay in the case of a nuclear disaster.

Screening of the evacuees

Japanese authorities were unprepared to screen the people arriving from the evacuated zones for radioactive contamination. In addition, some evacuees felt uncomfortable being screened by TEPCO employees, while they trusted the university scholars who volunteered for the job.[39]

On 14 March 2011, the Fukushima prefectural government raised the standard for designating people requiring full-body decontamination from 13,000 counts per minute (cpm) or more, based on its radiation emergency medicine manual, to 100,000 cpm or more (cpm is a measure for the amount of radioactive material found inside a person's body). There were fears that, under the original standard, there would be too many people requiring full-body decontamination, preventing the smooth evacuation due to staff and water shortages. Water necessary for decontamination was in short supply due to the interruption of water services by the earthquake.

However, other prefectures kept the initial limit of 13,000 cpm.[40] Due to different standards in the different prefectures, some people were accepted in some shelters and not in others, triggering a lot of confusion. In March 2011 about 1,000 people were contaminated at levels between 13,000 and 100,000 cpm and 102 at levels higher that 100,000 cpm.[41]

Authorities were unable to handle full-body decontamination of large numbers of people and had to adapt their standards. Changing the decontamination rules in the course of the disaster created a lot of confusion and suspicion.

Distribution of potassium iodine

One of the harmful effects of radiation exposure is an increased risk of thyroid cancer due to radioactive iodine fixing itself on the gland. To counter this, potassium iodine (KI) should be ingested within 24 hours before exposure to radiation, or within 3 hours afterwards for it to have at least 50% efficiency.[42] To achieve that, accurate predictions of the fallout are necessary, together with a communication system to warn the affected populations.

Some municipalities surrounding the NPP had ample stocks of potassium iodine. Government disaster manuals require those communities to wait for the central government to give the order before distributing the pills. Tokyo didn't order that pills be given out until five days after 11 March. Two of the towns closest to the plant – Futaba and Tomioka – distributed them to residents without awaiting word from Tokyo. Two communities further away from the plant, Iwaki and Miharu, handed out KI pills to their residents based on their own decisions. While Iwaki residents were told to hold off until the government gave instructions, those in Miharu took the pills, leading to a reprimand from prefectural officials.[43]

The Nuclear Safety Commission (NSC) posted on its website a hand-written note dated 13 March as proof that it recommended distribution and ingestion of the pills. NISA, the main nuclear-regulatory body charged with administering the government's nuclear-disaster headquarters, says the note never came.

Iodine was also not distributed in the shelters. According to official disaster manuals, anyone who has radiation readings of 13,000 cpm should be given KI pills. On 14 March, Fukushima prefecture raised that to 100,000 cpm, in line with its decontamination limit. The NSC was initially cautious about allowing the higher screening benchmark. On 14 March, it issued a statement advising Fukushima to comply with the 13,000 cpm level, noting that this is when the IAEA recommends distributing KI to avoid risking the thyroid gland. However, the NSC relented on 20 March, when in a statement the commission noted 100,000 cpm was permissible according to the IAEA's screening standard in the initial stage of a nuclear emergency.[44]

Iodine pills crucial to prevent future thyroid cancers have proven to be very difficult to administer. Japanese authorities didn't manage to distribute them properly and people were confused about when and whether to use them, all of which in combination with the communication breakdown and loss of trust in authorities led to chaos in implementation. The prophylactic policy based on potassium iodine simply did not work.

Post-crisis evacuation measures: the human tragedy continues

After the initial emergency response came the task of managing the contaminated land. Even though evacuation is a terrible option for the local population, it is a better option than staying in the very contaminated areas. However, in places with low contamination, evacuation is not necessary. In between there is a grey zone where a balance has to be struck between the burden of evacuation and that of radiation exposure or decontamination measures. What should the radioactivity limits be? How should evacuees be best supported? How can the remaining population cope with the threat of radioactivity in their daily life? How should they be informed about radiation risks in a sensitive and balanced way to avoid panic and fear, while at the same time underlining the seriousness to make them stick to measures necessary to reduce the exposure as much as possible?

Evacuation threshold

Massive contamination of the soil can be found far beyond the 20km evacuation limit.[45] This led the Japanese authorities to expand the evacuation zone to Namie, Katsurao and Iitate, as well as parts of Minami-Soma and Kawamata.[46] Some hotspots discovered later forced more people to leave their homes: on 30 June 2011, the central government designated 113 households in Date as radioactive hotspots where cumulative radiation is expected to exceed the government standard and recommended that the people living there evacuate. Date is about 80km directly northwest of the Fukushima No. 1 NPP.[47] On 21 July the government designated 59 households in four areas in the city of Minamisoma, as being located in hot spots recommended for evacuation.[48] On 3 August, 72 new households of Minamisoma were also recommended to evacuate.[49] Altogether, some 150,000 people evacuated to protect themselves from the radioactivity.[50]

The Japanese authorities fixed the radiation exposure threshold – which gives evacuees the right to receive compensation after evacuation – at 20 millisieverts a year, due the external irradiation from the ground contamination. This is the equivalent to the annual limit applied to nuclear workers.[51] However, people working in the nuclear energy industry are carefully monitored, and are entitled to medical care. Among the general population, some people are more vulnerable to radiation exposure, such as children, babies or pregnant women. They need far stricter standards, which is why under normal situations the limit for radiation exposure is fixed at 1 millisievert a year (principle of application of dose limits). This is the very maximum, as the dose should be as low as reasonably achievable (principle of optimisation of protection).[52]

The annual limit set for children of Fukushima is now 20 millisieverts, the same as professional nuclear workers. Just like nuclear workers, school children are equipped with dosimeters to measure the external radiation dose they receive. But, unlike those workers, the children did not choose to be in a contaminated environment.

The population living in the contaminated areas also faces internal contamination as many were directly exposed to the radioactive plume and will continue to be exposed to the risks of inhalation of radioactive dust and ingestion of contaminated food. Independent experts from the French ACRO laboratory have shown that the urine tested from the children of Fukushima is contaminated with caesium.[53] They also measured up to 20,000 Bq/kg of caesium in house dust collected by a vacuum cleaner in a house in the district of Watari in Fukushima City, 50km from the Fukushima reactors and 6,000 Bq/kg in dwellings located as far away as 200km.[54]

The estimated maximum cumulative external dose for evacuees who were living in the area of Koakuto, Namie Town up until 10 May 2011 is 50 millisieverts.[55] As such, the evacuation is justified from the viewpoint of radiation protection. The Fukushima Prefectural government acknowledges that residents near the Fukushima No. 1 plant may have been exposed to up to 19 millisieverts during the first four months of the nuclear crisis. The largest figure corresponds to the residents who evacuated from high-risk areas in the village of Iitate in late June.[56]

The limits set by the government were simply too high and continue to expose especially vulnerable parts of population to unjustifiable risks. The radiation threshold set for the population should include all ways of exposure and decrease with time.

Financial crisis

According to an estimate by the Institute of Economy of the National Academy of Sciences of Belarus, the aggregate financial damage incurred by the Chernobyl catastrophe – including a 30-year mitigation period – is estimated as $235bn US dollars. The health budget has been continuously increasing since the initial estimation to reach $54.32bn for the period 2001-2015. The total cost for the same period is $95bn.[57]

It is too early to know the total cost of the nuclear disaster in Japan. TEPCO will have to pay an estimated 4.54 trillion yen ($59.2bn) in damages over a two-year period, according to a government panel scrutinising the utility's financial standing in connection with compensation payments.[58] The estimates of the Study Committee on TEPCO's Management and Financial Conditions are based on the premise that the problems of at least 150,000 evacuees will continue for two years from the outbreak of the Fukushima disaster. Compensation for damage related to evacuation is estimated at 577.5bn yen ($7.5 bn), on the assumption that evacuees have completely lost the value of their land, buildings and other properties. Damage to business operations and job losses are also included in this category, bringing its total to 1.92tn yen ($25bn).[59] This is more than the cumulated profits from the operation of TEPCO's 17 nuclear reactors.[60]

The company cannot survive without the financial support of the state. On 28 October, it asked for an estimated 900bn yen ($11.7bn) of financial aid from the Nuclear Damage Liability Facilitation Fund, which was jointly established in September by the government and other power utilities with nuclear reactors to cover compensation payments.[61]

This financial burden is probably the biggest obstacle in expanding the evacuation of the population living in the contaminated territories.

The company's financial problems do not end there. The Japan Atomic Energy Insurance Pool, an institution jointly formed by 23 non-life insurers, decided last autumn not to renew its insurance contract with TEPCO for the Fukushima No. 1 plant, given the risks involved in dealing with the unprecedented disaster in Japan. The contract expired on 15 January 2012. TEPCO tried in vain to negotiate with a foreign insurance company that is not part of the institution project.

As a consequence, the company deposited 120bn yen ($1.6bn) in compensation reserves with a government body in case further accidents hit the Fukushima No. 1 nuclear power plant. The crippled Fukushima plant will also be the first ever in Japan not covered by liability insurance.[62]

Utilities operating nuclear reactors are not ready to cover the damage and loss resulting from a severe nuclear accident. The lack of accountability and limited capacity to cover liabilities leads to a situation where profits are privatised by an elite, but most losses and damages are shouldered by the population.

Voluntary evacuation

There is no safe limit of radiation exposure. Whatever the limit chosen for evacuation, people remaining in the contaminated territories should continuously take care in order to reduce their exposure to radioactivity. The fact that the dangers of radiation have even been denied by a number of officials, led on the one hand to a dangerous lack of caution and protective measures among part of population, and on the other to a deepened lack of trust among others who decided to evacuate voluntarily.

Many people relocated on their own during the crisis or afterwards, even if they were not requested or recommended to do so. Some families living in the contaminated territories sent their children away to the homes of relatives or friends. In rural areas, grandparents often remain in the house while the younger generations went away.

Voluntary evacuation is fully justified in many areas, but it also disrupts communities and public services: nurses, medical doctors, teachers and other vital personnel are now missing in the community. Some shops have been forced to close due to the lack of customers. It is estimated that by October 2011 about 36,000 residents voluntarily evacuated. Some 70% to 80% of the 160 households that left to Sapporo consist of a mother and children who felt insecure about their everyday lives and continue to worry about family members left behind in Fukushima Prefecture.[63]

The discrepancy between high radiation limits for evacuation and international standards (as well as Japanese legislation before Fukushima accident itself) led to individuals having legitimate concerns about taking additional action, beyond the government's instructions. Most people who evacuated on a voluntary base are suffering financially as they are not entitled to compensation or other support.

Potentially severe food shortages

Contaminated food can lead to long-term exposure to radioactivity. Over 25 years after the Chernobyl disaster people living on the contaminated land still ingest radioactive elements daily, and some of these people are affected by on-going internal contamination. In 2003-2004, the French laboratory ACRO checked the urine of Belarusian children who came for vacation in France and found that at least two thirds of them were contaminated with caesium-137, up to 68 becquerels a litre.[64]

The situation is very different in Japan. The country imports about 60% of its food but is self-sufficient for its rice. Japanese authorities fixed food contamination limits on 17 March 2011.[65] They are derived from an annual dose of 5 millisieverts if one only eats food at the limit. These limits were hastily extended on 5 April to also include seafood in response to the international concern about the contamination of the sea.[66]

Generally, the transfer of radioelements through leaves is high, whereas the transfer through roots is lower. As a consequence, leafy vegetables and milk were the first contaminated food at the beginning of the crisis because the leaves were directly exposed to the fallouts[67], forcing the authorities to restrict their consumption on 23 March.[68]

On 25 March, komatsuna (Japanese leaf vegetable) were found at 890 Bq/kg of radioactive caesium in suburbs of Tokyo, which is higher than the provisional limit of 500 Bq/kg fixed by authorities after the accident.[69] Radioactive iodine that has a short half-life was also problematic at the beginning of the disaster. Leaf vegetables grown later in the moderately contaminated areas had a smaller contamination level. If the Fukushima disaster had occurred in July, when crops have larger leaves, a greater proportion of the rice production of 2011 would have been too contaminated for human consumption. Similarly, if the Chernobyl disaster had happened in June, a large part of the wheat production of Europe would have been improper for consumption in 1986.

A severe nuclear accident always triggers a severe long-term food problem. The first year is worse, as it can lead to potential food shortages. For countries exporting large amounts of food, a nuclear disaster also closes the export market, challenging the economy. According to the estimates of the Agriculture, Forestry and Fisheries Ministry, 44 countries and territories either banned the import of food items produced in Japan, or demanded that they be inspected when imported, even though they are regarded safe and marketed domestically.[70]

Extended food controls are necessary to protect the consumers, but it is impossible to test everything. The Fukushima prefecture produced 356,000 tonnes of rice in 2011. The prefectural authorities would need about 30 years to check all the rice bags of 30kg with their current equipment.[71]

Monitoring of seafood is also extremely difficult because some fish travel far. In September, a codfish with 87 Bq/kg of caesium was caught offshore of Hokkaido, several hundreds of kilometres from the Fukushima NPP.[72] Monitoring based on the seawater is also difficult because some species can bioaccumulate radioelements: caesium can be concentrated in a fish more than 100 times than in seawater. Therefore, the detection limit of the water should be very low, but accurate measurements take time. In Japan, the detection limits[73] used by the authorities were too high, and were criticised by the Oceanographic Society of Japan[74].

Consumer confidence is also challenged by a nuclear disaster. Authorities who gave the go-ahead to the operation of the nuclear facility are discredited by the accident. As they falsely evaluated the safety of the plant, nobody trusts them anymore. In Japan, the fact that it took several months[75] for the Nuclear and Industrial Safety Agency (NISA) to acknowledge that three meltdowns occurred, completely eroded its credibility.

In addition, Japanese authorities have decided to allow the production of food in the contaminated areas except for those products which exhibited contamination levels above the limit. Such a policy has major weaknesses, as it is impossible to test all foods. Institutions were unable to predict and avoid many problems, such as beef contamination due to feeding cattle on contaminated rice straw[76]. Nor did they expect the tea leaves to exceed the limit as far away as Shizuoka, located at about 300km from the NPP.[77]

Rice is of particular importance in the Japanese diet. The harvest starting in August left plenty of time to prepare for efficient testing. Officially, everything went smoothly as expected until 16 November: Crops harvested in the Onami district of Fukushima City were found to contain 630 Bq/kg of radioactive caesium, exceeding the limit of 500 Bq/kg.[78]

image Greenpeace radiation team experts check crops for contamination in a garden in Fukushima City.

It turned out that 15% of the rice cultivated in this supposedly safe district has shown excessive levels of radioactive caesium.[79] Finally, bans have been imposed on rice shipments from three cities in Fukushima Prefecture.[80] As a consequence, people are reluctant to buy food produced in the vicinity of the contaminated zones. Fukushima prefecture produces about half of the peaches of Japan. During the season, peaches from Fukushima were piling up at the entrance of supermarkets at a very low price without being sold.[81]

Japanese authorities failed to foresee the scale of problems with contaminated food and crops, and were repeatedly caught by surprise in the following months as well as not being able to deal with them. It had a flawed programme for monitoring and screening, leading to scandals that further undermined public confidence and caused unnecessary additional economic damages to farmers and fishermen. An alternative is to prohibit all food products of an extended zone, except those that are tested and meet safety standards.

Unified management of the dose limits

Just after the disaster, the first concentration limits for food were derived from an annual radiation dose of 5 millisieverts. The external radiation limit to evacuate the population was fixed at 20 millisieverts a year. The two levels of exposure need to be added, leading to an actual and unacceptably high limit of 25 millisieverts a year in the contaminated territories.

Japanese authorities have decided to decrease the concentration limit in the food during the spring of 2012 to an annual dose lower than 1 millisievert. Such a decision is welcome, even if the transition between the two standards is problematic.[82] As a consequence, the maximum concentration of radioactive caesium in the food will drop from 500 to 100 Bq/kg. Local authorities sometimes apply stricter standards for school lunches: the city of Fukushima has set a limit of 350 Bq/kg, whereas the Sukagawa municipal government has set a limit of 10 Bq/kg for lunch ingredients.[83]

The central government has also decided to take charge of the cost of the decontamination for the locations where the radiation rate would induce an annual dose higher than 1 millisievert. Japan's Environment Ministry issued a decree on 14 December.[84]

However, the same authorities are considering letting the population come back in the 20km exclusion zone where the contamination level is lower than 20 millisieverts a year.[85]

Japanese authorities considered each way of being irradiated separately, and established separate standards, although the doses from the various ways of exposure should be added. It also wrongly disregarded potential large doses resulting from initial exposure to the radioactive plume and fallout. The lack of transparency and contradicting standards led to further confusion among the public.

The future

There is an urgent need to mitigate the exposure to the radioactive contamination in the areas where populations are still living. This requires open access to the radiation measurements and decontamination of the hotspots. The situation is more complicated for the evacuated lands: will the population be able to come back? For the highly contaminated areas there might be no other way than patiently waiting for the radioactivity to decrease.

Decontamination

The government will rezone the evacuated areas as follows:

- Zones with a radiation level of 50 millisieverts a year or higher will be off-limits for extended periods because they are likely to take years to decontaminate sufficiently for residents to return.
- Zones in which radiation levels are at least 20 millisieverts but under 50 millisieverts a year are considered as restricted zones. The authorities expect that residents may be able to return to these areas in a few years.
- Finally, zones where radiation levels are under 20 millisieverts a year will be prepared for the return of residents once living environments are restored.[86]

Decontamination efforts will start in areas with annual doses of 10-20 millisieverts, where a sizable reduction can be expected and the reduction goal is 10 millisieverts or less. A stricter reduction target of 5 millisieverts a year or less will apply to schools.[87] This is in strong contradiction with international limits of 1 millisievert for any long-term exposure and a stabilised situation.[88]

For all the other areas with an annual radiation exposure of 1 millisievert or more, Japan's Environment Ministry issued a decree on 14 December to clean them up. More than 100 municipalities are implicated. Local governments will measure radiation more closely, work out decontamination plans and implement them with financial support from the central government.

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Japanese authorities failed to foresee the scale of problems with contaminated food and crops.

No decontamination target in terms of dose is given. The decree also requires the central government to dispose of waste with radioactive caesium levels above 8,000 Bq/kg on behalf of local governments, and implement decontamination and radioactive waste disposal in both no-entry and designated evacuation zones close to the nuclear plant. The cost is evaluated to more than a trillion yen ($13bn).[89]

Decontamination is not a simple task. So far, the top soil of all playgrounds in Fukushima's schools was removed. Most of the buildings were cleaned up at the request of the anxious parents. All municipal governments reported that the soil removal had proved to be effective but the volume of soil in 19 municipalities, where data is available, amounted to some 178,000 cubic metres.[90] Cities have also decontaminated hotspots by removing sludge from side ditches and gutters.

According to the Environment Ministry, up to 28m cubic metres of soil contaminated by radioactive substances may have to be removed in the Fukushima Prefecture. This figure is based on the assumption that all the areas, where exposure is 5 millisieverts or more a year, were to be decontaminated, and in the case of forests this would be 100%. It will be even more if one includes some areas with contamination of from 1 to 5 millisieverts a year. Forests occupy about 70% of contaminated areas in the prefecture. The ministry does not believe it will be necessary to remove all contaminated soil, as long as the government restricts the entry of residents in mountainous areas and recovers cut branches and fallen leaves.[91] Removing the first layer of 5cm of the cultivated soils will take off the most fertile part. In forests, it will lead to another ecological disaster.

Guidelines worked out by the Ministry of Environment to decontaminate the cultivated soils recommend only deep ploughing. The national government can extend subsidies for decontamination, on condition that large machines equipped with special agricultural devices are used, which is impossible for most of the small paddies. Some farmers are furious. In addition, the Environment Ministry is aiming primarily to reduce airborne radiation. Reducing radiation levels in agricultural products is beyond its jurisdiction.[92] After a demonstration of decontamination in Iwaki, radiation readings in the field were 0.3 to 0.42 microsieverts/h before ploughing and 0.23 to 0.3 microsieverts/h after.[93]

The city of Fukushima decontaminated hotspots of its Onami and Watari districts in July and August. In the week following the end of the operation, the city took fresh radiation readings at 885 points, of which seven actually registered levels exceeding those found before the decontamination. One gutter measured even showed a rise from 3.67 microsieverts an hour before the cleanup to 4.63 after the work. Radiation increased close to the mountains and in spots where water and soil washed down the slopes.[94]

On 4 December, the government allowed media representatives to observe a model project to remove radioactive materials within the 20km no-entry zone. Prior to the work, the radiation level in the air stood at 20 microsieverts an hour. Afterwards, the level dropped to 6 microsieverts an hour, which is still too high.[95] Caesium is embedded in concrete and roof tiles, and is almost impossible to remove.

The Date municipal government was the first municipality to begin decontamination of houses with a budget of 150m yen ($2m). Decontamination operations were first conducted on 26 households. However, radiation levels dropped to target levels at only four of them.[96]

The financial and ecological cost of decontamination is higher than expected. Japanese authorities rushed into implementation of a large-scale decontamination that appears to be badly planned. There was no transparent discussion about the limit, i.e. what areas are actually worth expensive and difficult decontamination. This is a difficult debate that needs to be conducted democratically and openly, while putting political interests aside.

Empowerment of the population

In the case of a nuclear accident, access to the measurement of radioactivity becomes vital. Authorities have laboratories and experts to answer their questions in order to help them with the decision-making process. Citizens also need detectors, laboratories and experts to answer their own questions and help them make decisions.

Authorities have distributed individual dosimeters to all children and pregnant women of the Fukushima Prefecture.[97] This helped to find hotspots and protect the population. The Fukushima municipal government found that four children of the same family were exposed to between 1.4 and 1.6 millisieverts in September alone. Their residence was located close to a highly radioactive spot, and the family has since moved outside the Fukushima Prefecture.[98]

After a relatively high radiation level of 1.62 millisieverts was recorded in a junior high school student, investigation of the apartment building in Nihonmatsu where the student had lived over a three-month period led to the discovery that highly contaminated crushed stone was used for the foundation. This crushed stone has been used in many other places and the investigation is still ongoing.[99] It would be useful to distribute individual dosimeters to the whole population of Fukushima Prefecture and in other places that are known to be contaminated.

The Fukushima prefectural government's plan for long-term health checks for its 2 million residents is also welcome. In addition, it decided to provide lifetime thyroid gland tests for some 360,000 prefectural residents aged 18 and under. Eligible residents will be tested once every two years until the age of 20, and once every five years thereafter.[100]

Anxious members of the population rushed to buy simple dose rate detectors. Their first findings were not well accepted by the authorities who ignored this 'amateur' work. But alarmed by discoveries of radioactive hotspots far from the Fukushima Daiichi nuclear plant, Japan finally issued guidelines to help citizens and local officials to detect contaminated areas and to clean them safely. "From now on, we must offer equipment and ask people to look well beyond Fukushima to find hot spots," Masaharu Nakagawa, minister of Education, Culture, Sports, Science and Technology, said in an interview.[101] "Citizens' groups have played a very important role in examining their neighbourhoods closely. I really appreciate their contribution."

The residents, with the help of university experts to teach them how to use radiation-measuring devices, created the most accurate map of the contamination of Haramachi Ward in the city of Minamisoma.[102]

The next step in the necessary empowerment of the population is to provide them direct access to laboratories that can analyse the contamination of various kinds of samples. Many citizen initiatives to run independent laboratories have emerged in Japan since 11 March 2011. They need an official recognition and accreditation system.

Japan was previously missing a network of independent measurement stations and laboratories that would be accredited by the authorities and have the confidence of the population. In the initial stages of the accident, authorities were rejecting measurements taken by independent specialists and were even creating obstacles to those who wanted to do their own readings, despite the fact that long-term precautionary measures entail to educating and empowering people in radiation monitoring.

Conclusion

A nuclear accident with massive radioactive fallout is a long-term social disaster. Emergency plans should be well prepared because every mistake can have dramatic consequences. There is no time for improvisation.

Japan, probably the best-prepared country in the world to face natural disasters, seemed unable to anticipate the events that unfolded during the nuclear disaster. This is due to a lack of preparation but also to an inadequacy of the measures taken: confinement proved to be impossible to apply in practice with massive radioactive releases lasting about ten days. Evacuation to avoid direct exposure to the plume was impossible without efficient prediction tools and workable logistics that take into consideration the lack of communication tools, difficult transportation and not enough shelters.

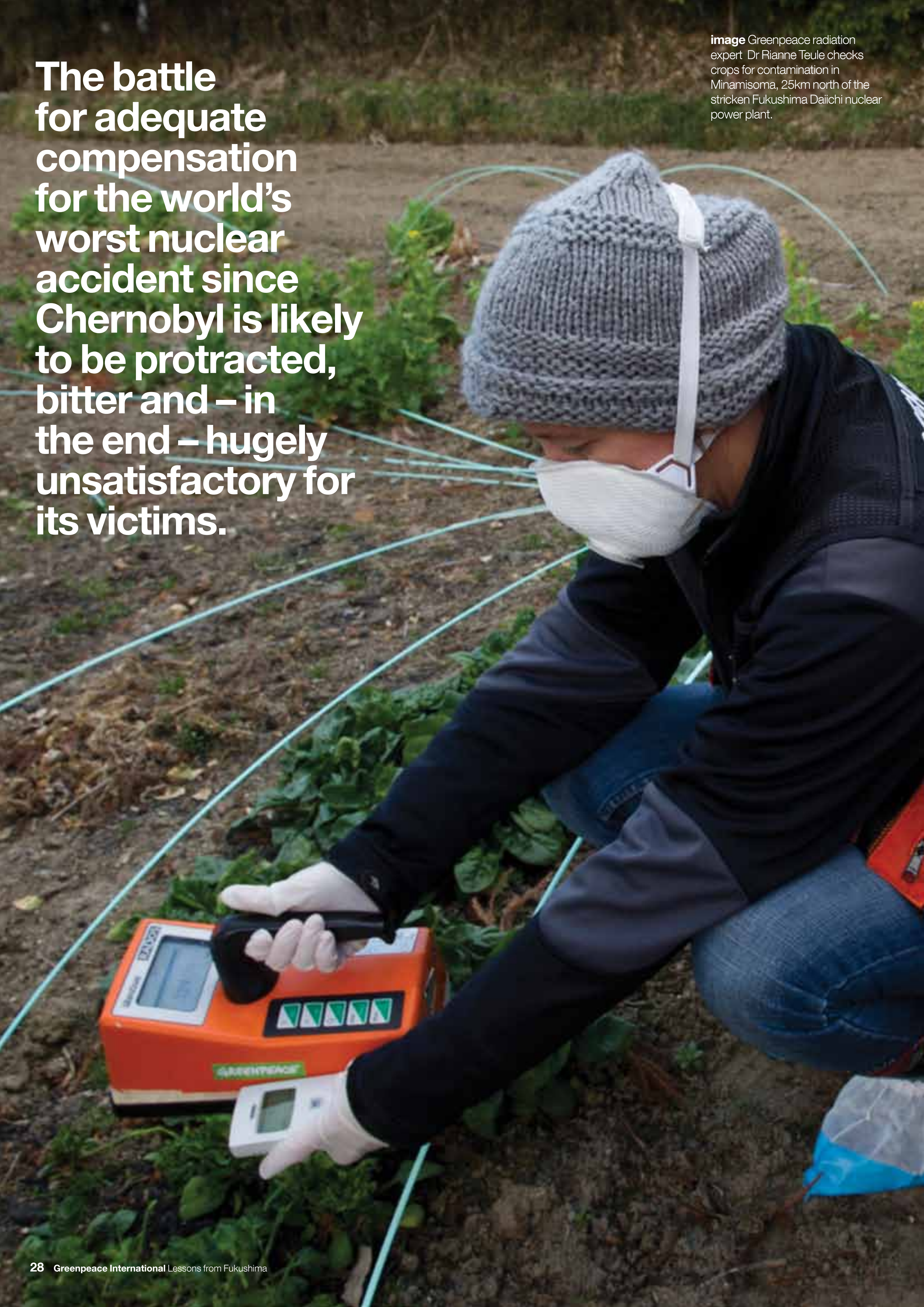
The most vulnerable people are the most in danger in case of a nuclear accident. Bedridden patients and handicapped people are difficult to evacuate in the case of an emergency. In the long term, children living in the contaminated territories are the most at risk.

Nuclear disasters like the ones of Chernobyl and Fukushima also trigger a food and financial crisis that hamper the recovery.

Beyond these technical difficulties, authorities and population should share the same vision of the risks. But confidence and respect is very difficult after a nuclear disaster that challenges the expertise of the authorities that failed to ensure safety.

The catastrophe has just started in Japan. Decontamination has not proven to be efficient on a large scale yet. All of this means that the population has to learn how to live in a contaminated environment for decades to come.

David Boilley is the chairman of the French Association pour le Contrôle de la Radioactivité de l'Ouest (ACRO)[103], which runs a laboratory accredited by French authorities. He has been coordinating ACRO's involvement in Japan, providing radioactivity tests on various samples, and help and advice to several new laboratories. He is Associate Professor of Physics in a French University.



The battle for adequate compensation for the world's worst nuclear accident since Chernobyl is likely to be protracted, bitter and – in the end – hugely unsatisfactory for its victims.

image Greenpeace radiation expert Dr Rianne Teule checks crops for contamination in Minamisoma, 25km north of the stricken Fukushima Daiichi nuclear power plant.

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02

The Fight for Compensation: Tales from the Disaster Zone

Dr David McNeill

In March 2011 Katsuzo Shoji was farming rice, vegetables and rearing cows on a small plot of land in Iitate village, Fukushima Prefecture. Like many others in the area, Mr Shoji's farm was handed down from father to son; his land had been in the family since the 1880s. That history effectively ended on 11 March 2011 when cooling systems at the Fukushima Daiichi Nuclear Power plant, about 40km away, failed and nuclear fuel in three of the plant's reactors began to melt down.

After being forced to abandon their property, Mr Shoji (76) and his wife Fumi (75) live today in temporary housing, which consists of two rooms, in Date, about 60km northwest of the plant.[104] Initially designated outside the 20km compulsory evacuation zone, Iitate was ordered to evacuate in April after non-government observers, including Greenpeace and the International Atomic Energy Agency (IAEA)[105], warned that levels of caesium and other radioactive contaminants exceeded criteria for immediate evacuation.

The Shoji herd has now been slaughtered, the crops dug up and the fields abandoned to weeds. The family has joined about 7,000 other nuclear exiles from the town. Nearly 11 months since the destruction of their land, income and way of life, the Shojis have received a total of some 1.6m yen ($20,900 US dollars), or about 150,000 yen ($1,960) a month. "We have no expectations of being properly compensated, and have given up hope of returning to our homes," says Mr Shoji.[106]

As I write, the family is currently waiting for its claim of roughly 2m yen ($26,100) from Tokyo Electric Power Co (TEPCO), operator of the Fukushima plant. Six months after the crisis erupted, TEPCO paid 1m yen ($13,050) in 'temporary' compensation to the family, and then another 300,000 yen per person for their relocation – the same deal offered to thousands of others.

On 12 September, half a year after the accident began, the utility started sending, mostly through the post, a 58-page application form for compensation that demanded receipts (actual, not copied) for transportation and other fees incurred during the evacuation, bank or tax statements proving pre-disaster income levels, and documented evidence of worsening health since the move.[107] A month later, TECPO received just 7,600 completed forms back – a small fraction from the number ordered evacuated, because the forms were widely considered too arduous and detailed.

One section of the form asked claimants to calculate (with receipts) the cost of returning to their abandoned homes to pick up belongings. Another asked if the claimant had been screened for radiation. The form was accompanied by a 158-page explanation, including 10 pages on how much in travel expenses to claim from every corner of Japan. Compensation payments applied to damages only from 11 March until 31 August, and the process requires applicants to reapply every three months. Criticism of the convoluted application process was so severe that in December 2011 TEPCO was forced to simplify it to four pages.

When the check for 2m yen arrives at the Shoji home, it is supposed to last until November 2012, when the family will have to file another claim. In the meantime, the family head says he has mentally moved on. "I've rented a small allotment and I'm growing vegetables. I don't want to think any more about the loss of my land or getting paid for it because it makes me too sad."

Mr Shoji's story illustrates the systematic weaknesses of the compensation process following the Fukushima nuclear disaster. He is one of an estimated 100,000 from the contaminated prefecture of Fukushima – people who were forced to abandon their farms, homes, schools and jobs between March and May 2011, and live elsewhere.An unknown additional number, estimated by the government as 50,000 at minimum, has moved voluntarily because of radiation fears, ignoring official claims that life inside or around Fukushima Prefecture is safe.[109] Typically, mothers have taken their children out of the prefecture and started new lives as far away as Tokyo, Osaka or Kyushu, splitting up families, often against the wishes of fathers and in-laws.

"My husband didn't agree to the move and tells us to come back home," explains Akemi Sato, a housewife from Fukushima City (about 60km from the nuclear plant), who now lives in Tokyo with her two children aged 7 and 9.[110] "I have to pay my bills in Tokyo and travel to Fukushima to see my husband three or four times a month. It's very expensive and stressful but I didn't see a choice. People say we have a chance to get compensation, but I've been too busy to even think about that or talk to a lawyer."

Mrs Sato and her two children live in rent-free public housing (*toei jyutaku*) provided by Tokyo city. However, she estimates that her cost of living has increased by 100,000 – 150,000 yen ($1,300 – $1,960) a month as she struggles to pay extra bills for utilities, transport and her children's education.[111] Those like Mrs Sato who have voluntarily relocated to escape radiation are not currently entitled to even the same compensation package as the Shojis.

In protest, a small number of victims have refused to play by TEPCO's compensation rules. Fumitaka Naito paid 9.8m yen ($128,000) for a 6,800-tsubo (2.2 hectare) plot of land in Iitate in 2009, now unworkable because of contamination.[112] "My view is what happened is not my fault, so I want the company to provide me with a new farm elsewhere," he says. "I can't wait 20 or 30 years till they compensate me for the land – I'll be dead. But when I saw the compensation form there was no space to write my claim." Mr Naito calculated the cost of his land, equipment and ruined produce and attached a separate sheet of paper claiming about 70m yen ($913,000). A TEPCO official called, queried the claim, and eventually offered 150,000 yen ($1,910). "I told them not to send it. I'm going to fight in the courts instead."

Liability background and strategy

Japan's Act on Compensation for Nuclear Damage (1961), enacted when the nation's nuclear industry was in its infancy, places no cap on the operator's nuclear liability, 'regardless of fault, negligence or intention to harm'."[113] The legislation obliges TEPCO to prepare private insurance (roughly 120bn yen / $1.6bn) per site in the event of nuclear accidents (Fukushima Daiichi's six reactors count as one site). The key part of this legislation reads:

"…'nuclear damage' means any damage caused by the effects of the fission process of nuclear fuel, or of the radiation from nuclear fuel etc, or of the toxic nature of such materials (which means effects that give rise to toxicity or its secondary effects on the human body by ingesting or inhaling such materials); however, any damage suffered by the nuclear operator who is liable for such damage pursuant to the following Section, is excluded."

Crucially, however, the act does not stipulate practical details and rules for applying for compensation. As lawyer Yasushi Tadano explains, it vastly underestimates the financial preparation needed for a large-scale disaster such as Fukushima. "TEPCO's insurance of 120bn yen ($1.6bn) wasn't anywhere near enough to cover the number of victims. At a minimum it will cost 5 trillion yen."($65bn) Moreover, Section 16 says that the government may assist in compensation claims if the claims exceed the operator's liability – subject to Diet (parliament) approval. Section 16 is considered controversial because it makes the government in effect the indemnifier of last resort in a nuclear accident.[114]

Tadano says, "I am opposed to the idea of TEPCO being allowed to survive on public funds because I believe the shareholders and management of TEPCO should be held accountable for this accident first."

The lack of practical details for compensation compelled the government in April 2011, a month after the Fukushima accident, to establish the Dispute Reconciliation Committee for Nuclear Damage Compensation, an organisation designed to establish guidelines – and boundaries – for compensation claims.

On 28 April, the Committee adopted preliminary guidelines for determining the nuclear damage, initially defining them as resulting from instructions by the authorities, such as orders to evacuate, stop farming or fishing.[115] Subsequent 'secondary' and 'interim' guidelines, adopted respectively on 31 May and 5 August, include provisions for 'permanent compensation'.[116] At the time of writing, none of these guidelines stipulates compensation for loss of assets such as homes or farms, or for people who have left Fukushima voluntarily. There is speculation that roughly 1 million people, which is over half the population of Fukushima Prefecture, may be offered 80,000 yen ($1,043) as a one-off compensation payment, in addition to 400,000 ($5,218) per child (under 18) - a figure Hiroyuki

Yoshino, a leading member of the Fukushima Network for Saving Children from Radiation calls 'absolutely unacceptable'. Mr Yoshino, also a resident of Fukushima City, says his wife and four-year-old son have gone to live in Kyoto. "We have to rent an apartment there and run two separate lives. How are we supposed to live? The government doesn't seem to care."[117]

Thus, the 1961 law speaks in fairly general and even generous terms about compensation but the specific guidelines for claims have been decided since the incident itself. The Reconciliation Committee has ring-fenced claims to include only government-designated victims of the disaster, with a possible concession to residents of Fukushima Prefecture outside the evacuation zones who live in sometimes heavily irradiated areas. The Committee accepts the government's controversial recommendations that 'liveable' radiation levels may be up to 20 millisieverts a year, though as we have seen many families with children distrust that recommendation.[118]

"It's now some appointed commission that decides what's claimable, and the problem is that making guidelines after the accident is legally absolutely unacceptable," explains Julius Weitzdoerfer, a German researcher who has compiled one of the most comprehensive reports on liability and the Fukushima disaster.[119]

Moreover, a major question mark hangs over the costs of decontamination in Fukushima, an operation likely to leave a pile of nuclear waste almost 29m cubic metres – enough to fill one of the city's largest stadiums 80 times.[120] Who will pay for it? TEPCO has already argued in court that it is not responsible for the radioactivity showered across Fukushima because it doesn't 'own' it. "Radioactive materials (such as caesium) that scattered and fell from the Fukushima No. 1 nuclear plant belong to individual landowners there, not TEPCO," the utility's lawyers told Tokyo District Court, during a disposition to hear demands, by the operators of the Sunfield Nihonmatsu Golf Club 45km west of the plant that TEPCO decontaminate the property. The owners said they were 'flabbergasted' by TEPCO's argument, but the court essentially freed the utility from responsibility, according to the *Asahi Shimbun*.[121] If the decision holds through legal challenges, local and central governments will be forced to foot the bill instead.

The victims of the Fukushima nuclear disaster face a choice of either waiting for a TEPCO settlement to their claims, if they are entitled under the guidelines, or going to court. As Weitzdoerfer explains, 'voluntary' settlements are 'detrimental to the victims because they might not get as much as they can from the court'. But for social and legal reasons, very few compensation cases end up in Japanese courts. Nevertheless, some lawyers are preparing for battle. "The scale of difference between what TEPCO is offering and what these people need is so large that we're telling people not to bow down and to fight their corner, even if we can't promise that they won't lose," says lawyer Tadano.

In the meantime, lawyers and independent observers say the strategy of TEPCO and the government, during what is likely to be the most expensive liability case in Japanese history is in effect, to suppress compensation claims by making them as restricted, bureaucratic and difficult as possible for the Fukushima victims.

"It's standard practice in these cases," says Martin Schulz, Senior Economist at Fujitsu Research Institute, Tokyo. To illustrate, he points to previous mass compensation claims in Japan, including the most famous of all, the mercury poisoning of food around the town of Minamata in Kyushu island in the 1950s. "It took 40 years to settle those claims. This is how Japanese bureaucracy works."

In the most recent comparable accident to Fukushima, at the Tokaimura nuclear fuel fabrication plant in 1999, 98% of claims were settled within a year of the accident. But, as Weitzdoerfer and others have pointed out, the Fukushima disaster is of a different magnitude. "The two cases are not comparable because evacuation there was for a few hundred meters, lasted a few days, and it was over. Obviously this is completely different."[122]

The current strategy will include keeping elderly people like the Shojis waiting until they die, and peel off all but the most determined claimants, says Yuichi Kaido, a lawyer and antinuclear activist. "They're drawing the time out, paying as little as they can and putting off settling the main most expensive claims so the victims will get fed up and quit."[123] Mr Kaido says the majority of enquiries to the Japanese Bar Association since the 11 March disaster are about the nuclear accident. He estimates that at least 1,000 lawyers are currently in discussion with citizens or groups from the irradiated zones scattered in over 40 different prefectures around the country. "Most people, however, are too busy struggling with new lives to even think of a lawyer or claims."

The medium-term approach is to avoid nationalising TEPCO for as long as possible, to keep the claims at arms length, says Schulz. He and other economists believe the utility is in effect a zombie company: insolvent, unprofitable for at least a decade, and facing imminent nationalisation probably sometime this year.[124] "As long as TEPCO remains a private buffer for claims against the government, it remains helpful," says Schulz. "This is why they are focusing on these limited cases; because as long as they do, they can at least pretend to stay in business."

TEPCO denies these charges and says it is doing its best amid an 'unprecedented' disaster, the line followed since March 2011 when Masataka Shimizu, then company president, said that the tsunami that struck the Fukushima Daiichi nuclear plant was 'beyond our expectations'.[125] Spokesman Hiroki Kawamata denies making the application process deliberately difficult. "From our point of view we were merely trying to cover all bases and make sure there is nothing left out."[126]

TEPCO says that it has already paid out temporary compensation to 160,000 people. Families have been awarded an initial payment of 1m yen ($13,045) each (except for single-person families at 750,000 yen – $9,784), and up to another 300,000 yen ($3,914) per person for the costs of moving out of the designated evacuation areas. Mr Kawamata adds that his company has already paid the first claims of 14,500 people, awarding up to 4m yen ($52,183) each, but admits that the initial compensation of 1m yen ($13,046) will be deducted from this figure.[127] He denies stalling on claims. "They are very complex and we're moving as fast as we can."

About 285 farmers, hundreds of fishermen and small to medium-sized businesses have also been compensated for loss of earnings. After bitter public criticism of its application procedure TEPCO says it has tripled the number of staff to explain how to apply, bringing a total of 7,000 people working in call centres, 14 local offices and company back offices. It says it has paid out a total of 291.7bn yen ($3.81bn) so far, and estimates the total cost over two years at 1.7tn yen ($22.2bn).

The cost, and who pays

The above figure is widely considered a gross underestimate. TEPCO'S current compensation scheme cleaves closely to the government directive on evacuation, meaning only those who have been compulsorily moved are entitled to claim. For now, the scheme also sidesteps the question of abandoned property and other assets since the government line is that evacuees from Futaba, Iitate and other heavily irradiated areas will return to their homes, farms and ports – something that few scientists believe is either possible or desirable.[128] The scheme excludes cities such as Iwaki and Minamisoma, which border the evacuation zone and whose mayor announced that he is suing TEPCO for economic damages.[129] Mayor Katsunobu Sakurai said 27,000 of the town's 70,000 population plan to permanently leave, depriving the town of taxes and likely resulting in eventual bankruptcy.[130]

Finally, the compensation scheme takes no account of the long-term impact on local populations of prolonged exposure to radiation, which is likely to eventually provoke hundreds of lawsuits.[131] As Tadano explains, "The government has made no preparations to offer compensation to radiation victims, but they fear such claims. Radiation is low-level nuclear damage, so they can't see the consequences but they undoubtedly fear that in the future, victims will emerge, and they fear that it will cost most compensation. There is a 20-year limit in the claiming period from the date of the accident. The problem will be what happens after that."

Estimates of the total cost of the Fukushima catastrophe, including compensation, fluctuate wildly. TEPCO was told by an advisory panel in October to prepare for claims of 4.5tn yen ($59bn) in the two years following the disaster, until March 2013.[132] The private research institute, Japan Centre for Economic Research, put the bill over the next 10 years at 5.7tn yen ($74bn) to 20tn yen ($261bn) or higher.[133] But neither figure includes compensation to the fisheries and farming industries, though the latter does budget for the purchase of contaminated land inside the 20km evacuation zone. Some sources calculate the cost of buying up contaminated land alone at about 4tn yen ($52bn).[134] A broader calculation, by the same research institute, puts the entire cost of the disaster, including compensation and decommissioning the Daiichi plant's six reactors, at 40-50tn yen ($520bn – $650bn; a figure that approaches the bill for cleaning up the US subprime banking meltdown in 2008/9.[135]

Despite being at the time of the accident the world's fourth largest power utility, TEPCO – which was established in 1951 and monopolises the supply of electricity to Tokyo (i.e., one third of Japan's total electricity) – cannot deal with this enormous financial liability by itself. The government has so far tacitly though not explicitly accepted this, the prelude say most observers to eventual nationalisation, when these claims will move into the bureaucratic realm – in other words, they will be handled by government, not private bodies.[136] Shifting the burden for the catastrophe from the private to the public has been condemned by, among others, economist Keiichi Oshima, who says the disaster proves again that the capitalist marketplace cannot make nuclear power pay. "The nuclear industry made good profits from ordinary people before the accident but now we are the ones who have to pay for the cleanup."

Under a law rushed through parliament in August, Japan's government has set up a new public-private agency, the Nuclear Damage Liability Facilitation Fund, to keep TEPCO on life support and oversee compensation, from a mix of public cash, bank loans (underwritten by the government) government-backed bonds and money from Japan's 10 electric power companies.[137] In a careful analysis, economist Oshima concludes that although the fund has been packaged as a rapid response to the nuclear victims, it is aimed ultimately at rescuing and preventing the collapse of the nuclear industry. "It doesn't question the industry itself or make its responsibility for the accident clear."[138]

TEPCO subsequently announced plans to sell off properties and other assets to raise over 600bn yen ($7.8bn), as well as raising electricity prices for industrial users last December. It is able to draw on 120 – 240bn yen ($1.6 – $3.1bn) from a government-run insurance fund provided for under the law on compensation for damage from nuclear accidents. However, Japan's biggest business lobby, the Keidanren, has been lobbying the Democrat (DPJ) government to set limits on industry liability for compensating for the disaster.[139] In the meantime, the burden of paying for it is already beginning to rain on the taxpayer.[140]

In November 2011, the government agreed to an 890bn yen ($11.6bn) compensation bailout fund. In late December TEPCO asked the fund for another 690bn yen ($9bn). This probably barely scratches the surface of the total bill. In this context, the reported figure of 4tn yen ($52bn) in final compensation costs has, in the words of lawyer Kaido, 'absolutely no basis in reality'. The government's strategy, therefore, in the coming months and years, will be to limit claims on the public purse. "The government will probably nationalise TEPCO and separate 'good TEPCO' (meaning its generating and supply functions) from 'bad TEPCO' (its liabilities and debts)," says Tetsunari Iida, director of the Institute for Sustainable Energy Policies in Japan. "The government will then, in a bureaucratic manner, try to limit payments."

Conclusion

The battle for adequate compensation for the world's worst nuclear accident since Chernobyl is likely to be protracted, bitter and – in the end – hugely unsatisfactory for its victims. The lawyer Mr Kaido calls it the great legal challenge of the coming years. "How Japan handles it will define our profession for years to come." Economist Schulz notes that as a six-decade monopoly, protected by the bureaucratic state, TEPCO is just doing what it has always done: bungling and ignoring public opinion. "But they shouldn't be allowed to. It borders on outrageous. It is government policy that resulted in this situation. Ultimately it will be the government that will pay."

The key word here is ultimately. Hundreds of thousands of nuclear victims from Fukushima will wait, their lives in limbo, as their claims are processed. Many won't receive anything at all. In the meantime, they will pick up the pieces as best they can. Mothers will raise children hundreds of miles from their fathers. Fishermen will repair their nets and boats and wait for the sea to clear of contamination. A few will go out trawling for debris washed out by the 11 March tsunami, a job that earns them 11,000 yen a day from the government. Farmers like Katsuzo Shoji will either fight in court or abandon their legal claims to avoid being driven mad by TEPCO's Kafkaesque paperwork.

Amid the devastation, a surreal touch: unemployed farmers around Iitate have been offered work cleaning up the crippled nuclear plant, for 12,000 yen ($157) a day. The local town office helped put up the public notices.

Says Mr Shoji: "We're the victims and TEPCO is the perpetrator, but I get no sense at all of the company being guilty."

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He covered the nuclear disaster for all three publications and has been to Fukushima six times since 11 March 2011. He wrote yhis chapter based on interviews with victims and lawyers. He lives in Tokyo with his wife and son.

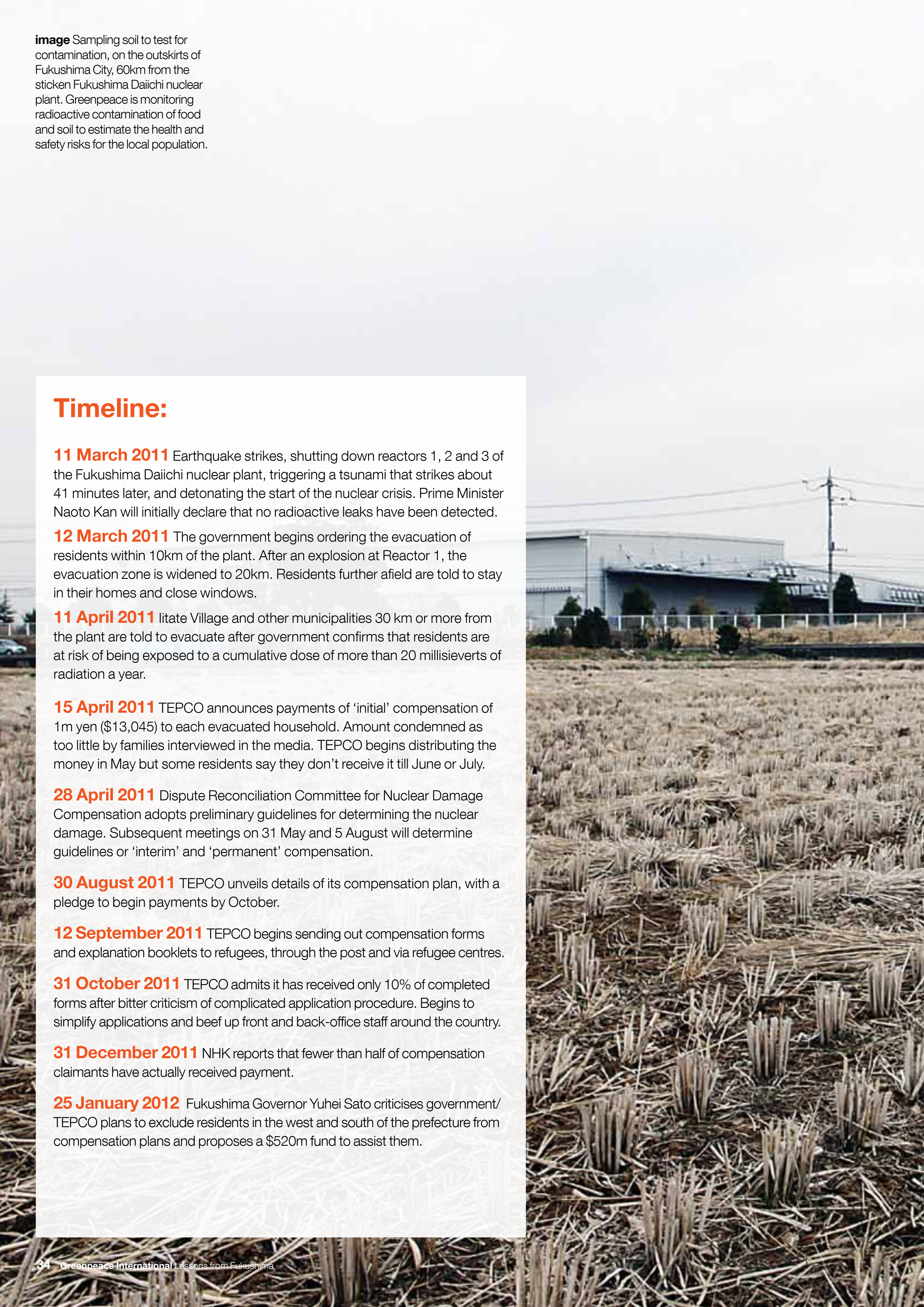

image Sampling soil to test for contamination, on the outskirts of Fukushima City, 60km from the sticken Fukushima Daiichi nuclear plant. Greenpeace is monitoring radioactive contamination of food and soil to estimate the health and safety risks for the local population.

Timeline:

11 March 2011 Earthquake strikes, shutting down reactors 1, 2 and 3 of the Fukushima Daiichi nuclear plant, triggering a tsunami that strikes about 41 minutes later, and detonating the start of the nuclear crisis. Prime Minister Naoto Kan will initially declare that no radioactive leaks have been detected.

12 March 2011 The government begins ordering the evacuation of residents within 10km of the plant. After an explosion at Reactor 1, the evacuation zone is widened to 20km. Residents further afield are told to stay in their homes and close windows.

11 April 2011 Iitate Village and other municipalities 30 km or more from the plant are told to evacuate after government confirms that residents are at risk of being exposed to a cumulative dose of more than 20 millisieverts of radiation a year.

15 April 2011 TEPCO announces payments of 'initial' compensation of 1m yen ($13,045) to each evacuated household. Amount condemned as too little by families interviewed in the media. TEPCO begins distributing the money in May but some residents say they don't receive it till June or July.

28 April 2011 Dispute Reconciliation Committee for Nuclear Damage Compensation adopts preliminary guidelines for determining the nuclear damage. Subsequent meetings on 31 May and 5 August will determine guidelines or 'interim' and 'permanent' compensation.

30 August 2011 TEPCO unveils details of its compensation plan, with a pledge to begin payments by October.

12 September 2011 TEPCO begins sending out compensation forms and explanation booklets to refugees, through the post and via refugee centres.

31 October 2011 TEPCO admits it has received only 10% of completed forms after bitter criticism of complicated application procedure. Begins to simplify applications and beef up front and back-office staff around the country.

31 December 2011 NHK reports that fewer than half of compensation claimants have actually received payment.

25 January 2012 Fukushima Governor Yuhei Sato criticises government/TEPCO plans to exclude residents in the west and south of the prefecture from compensation plans and proposes a $520m fund to assist them.

The leaders chose, in the face of serious warnings, to consciously take chances that risked disaster.

03

The Echo Chamber: Regulatory Capture and the Fukushima Daiichi Disaster

Arnie Gundersen,
Fairewinds Associates

While most nuclear power industry commentators have focused on the sequence of technical failures that led to the ongoing release of radioactivity from the three nuclear reactors in the Fukushima-Daiichi nuclear power plant (NPP), a broader and longer-term analysis reveals that the key causes of the three meltdowns were the institutional failures of political influence and industry-led regulation and the nuclear sector's dismissive attitude towards nuclear risks.

There were numerous red flags indicating potential problems for anyone following TEPCO during the past decade. Crucial vulnerabilities in the Fukushima Daiichi reactor design; substantial governance issues and weak management characterised by major frauds and cover-ups; collusion and loose regulatory supervision; as well as understanding but ignoring earthquake and tsunami warnings, were key ingredients of the March, 2011 disaster. Moreover, all these crucial vulnerabilities had been publicly highlighted years before the disaster occurred. Hence, three main reasons for the disaster can be identified: design and technical issues; governance, management and regulatory weaknesses; and systemic failure of current nuclear safety assessments.

As we will discuss, it was not a simple technological failure or an unpredictable act of Nature that caused the Fukushima Daiichi disaster. A failure of human institutions to acknowledge real reactor risks, a failure to establish and enforce appropriate safety standards and a failure to ultimately protect the public and the environment caused this tragedy. Additionally, it is important to note that institutional failure has been the principal cause of all past nuclear accidents, including Chernobyl and Three Mile Island.[141]

This chapter will show that the heightened risks of earthquakes and tsunamis in Japan and the vulnerabilities of the Mark 1 Boiling Water Reactor (BWR) containment design have been well known to Japanese and international decision makers for decades. Yet TEPCO and its regulators repeatedly ignored these warnings.

It appears that erroneous safety decisions made when Fukushima Daiichi was built in 1970 were perpetuated for more than 40 years because officials did not want to alter the status quo.

Such a conclusion is substantiated by Marc Gerstein in his book *Flirting With Disaster,* which examines why accidents are rarely accidental. According to Mr. Gerstein:

> *"… reasonable people, who are not malicious, and whose intent is not to kill or injure other people, will nonetheless risk killing vast numbers of people. And they will do it predictably, with awareness ... They knew the risks from the beginning, at every stage ... The leaders chose, in the face of serious warnings, to consciously take chances that risked disaster ... Men in power are willing to risk any number of human lives to avoid an otherwise certain loss to themselves, a sure reversal of their own prospects in the short run."*[142]

Caught between the influence of its governmental mandate to promote nuclear power and TEPCO's desire to minimise costs, Japan's Nuclear Industry and Safety Agency (NISA) failed to enforce existing standards and respond to advancements in scientific knowledge on how to mitigate accidents and tsunami risks. The institutional failures that led to the Fukushima Daiichi disaster also provide a reality check on the nuclear industry's claim of 'safe' nuclear power. While the nuclear industry has always asserted that the chance of a severe reactor accident is acceptably low – one significant meltdown for one million years of reactor operation – estimates based on experience, including the triple meltdown at Fukushima Daiichi, shows that a nuclear accident has on average occurred once every seven years.[143]

Nuclear safety in Japan

Many countries operating or building nuclear plants lack a truly independent, properly resourced nuclear regulator. Even though the international Convention on Nuclear Safety requires that national nuclear regulators are separate from bodies tasked with the promotion of nuclear power, there is no effective international mechanism for monitoring compliance, let alone enforcing the rules. The magnitude of this issue is illustrated by the fact that the international community was totally unable to identify and reign in the collusion between the Japanese nuclear industry and its regulator. Outside of Japan, Brazil, India and South Africa came under the spotlight at the 2008 Convention on Nuclear Safety review conference because their regulatory bodies were considered too close to organisations that promote nuclear energy.[144]

In fact, in Japan's nuclear industry it is difficult to even differentiate between the regulator and the regulated. The close relationship between the regulator and TEPCO established the conditions for both institutions to fail in their respective mandates to uphold reactor safety.

From the highest level of government policy, the dichotomic objectives of promoting nuclear power and at the same time being the watchdog over nuclear safety are so closely intertwined that the watchdog role eroded slowly but consistently. The Ministry of Economy, Trade and Industry (METI) oversees both the Nuclear and Industrial Safety Agency (NISA), which regulates the safety of nuclear power, and the Agency of Natural Resources and Energy, which is mandated to promote the growth of nuclear power.

Government and industry relations in Japan have a long history of intertwined personal relationships. This relationship has a unique Japanese word to describe it: *amakudari*, which translates literally as 'descent from heaven'. *Amakudari* describes the practice of high-ranking government officials acquiring high paying jobs in the industries they once regulated, while top industry officials are appointed to government advisory committees and able to shape government policy.[145] This practice of revolving doors is one of the key factors in the erosion of nuclear safety in Japan.

With *amakudari,* the safety regulator and the reactor operator are related, familiar and mutually supportive. Such a relationship is fertile for the Echo Chamber effect: the tendency for beliefs to be amplified and even mythologised in an environment where a limited number of similarly interested actors fail to challenge each others' ideas.

The tight links between the promotion and regulation of the nuclear sector created a 'self-regulatory' environment that is a key cause of the Fukushima Daiichi disaster.[146]

The Japanese regulator NISA has also acted to manipulate public consultations in favour of nuclear power. In 2011, an independent committee found that, in 2006, NISA encouraged TEPCO to plant positive questions at public hearings on new nuclear projects. The panel argued that NISA's collusion with industry and its promotional activities with regards to nuclear power are probably due to its desire to please its governing ministry, which seeks to promote nuclear power.[147]

Tolerating TEPCO's cover-ups

TEPCO has a long history of withholding problematic and disturbing information regarding the safety of its reactor fleet, from both the regulator and the Japanese public. Despite this history and the potential disastrous consequences of equipment failure, NISA has continuously tolerated TEPCO's behaviour and not adhered to its mandate of upholding and regulating nuclear safety. Instead of sanctioning or restraining TEPCO, in some instances NISA even created specific standards that allowed continued operation of TEPCO's deficient reactors. Such lax regulatory conditions created an environment in which TEPCO officials felt they could continue to falsify, omit and withhold information on safety records and inspection records. For example:

- In August 2002, it was revealed that TEPCO had been falsifying inspection records in order to hide cracks in reactor systems at 13 of its 17 nuclear stations, including the Fukushima Daiichi reactors.[148,149] The Japanese nuclear regulator did not carry out any of its own inspections of the reactor systems, instead it trusted the corporation with these crucial safety inspections. As it turns out, employees had been falsifying inspection records since the 1980s.[150] And, even after the cover-up was revealed, the regulators waved away concerns about increased accident risk based upon calculations supplied by TEPCO. In response to TEPCO's deception NISA adopted a special 'defect standard' to allow the company's reactors to continue operating.[151]
- Later in 2002, TEPCO was found to have falsified test data on the air-tightness of the reactor containments of Fukushima Daiichi Unit 1 in the early 1990s.[152] Preliminary tests on containment integrity had shown that the sealing system was inadequate.[153] On 20 September other damage cover-ups in the re-circulation pipe system were revealed in eight of TEPCO's reactors, as well as Onagawa Unit 1 of Tohoku Electric Power Company and Hamaoka Unit 1 of Chubu Electric Power Company. In addition, other cracks in the core shroud were found at Onagawa Unit 1, Hamaoka Unit 4, Tsuruga Unit 1 (Japan Atomic Power Co, Ltd), and Shimane Unit 1. As has been pointed out, this series of cover-ups showed the scandal was not merely with TEPCO but involved most of the nation's electric companies.[154]
- In 2006, TEPCO admitted to falsifying records on coolant water temperatures between 1985 and 1988.[155]
- In 2007, an earthquake triggered a fire and a spill of radioactive liquid at the Kashiwazaki-Kariwa nuclear power plant. TEPCO at first concealed the extent of the damage, such as the leakage of hundreds of gallons of radioactive wastewater.[156]
- Just two weeks before the Fukushima Daiichi disaster began, NISA accused TEPCO of failing to properly inspect equipment at the Fukushima-Daiichi station, including the cooling system equipment and the spent fuel pools.[157]

Following the scandal surrounding TEPCO's 2002 cover-ups, the Japanese government admitted there was a problem with NISA and promised change. Hiroyuki Hosoda, Minister of State for Science and Technology Policy, told an IAEA conference in 2003:

"The falsification of self-inspection records by a Japanese nuclear power plant operator was made public in August last year. This has seriously damaged public confidence in nuclear safety. In response, the Japanese government has drastically revised its nuclear safety regulations. The purpose was to improve the effectiveness of its regulatory system and quality assurance on the part of the operators, thereby enhancing the nuclear safety culture. Japan is making efforts to restore public confidence through dialogue and to restart the plants that were shut down for inspections."[158]

The government's promised reform seems to have had little effect. Regulatory records show that prior to the Fukushima Daiichi disaster, TEPCO had been cited for more dangerous operator errors during the previous five years than any other utility.[159] According to assessments carried out after the 2002 scandals, it has become clear that TEPCO's managers tended to put cost savings ahead of plant safety. Despite the ongoing poor performance, there is little regulatory action to improve the situation.[160]

In the dismal aftermath of the Fukushima Daiichi catastrophe, the Japanese government has once again acknowledged its ongoing issues with its safety regulator, specifically citing the negative influence the METI's promotional policies had on NISA. Before leaving his position, former Prime Minister Naoto Kan initiated a process that would make the nuclear regulator an independent organisation.[161]

Failure to adapt to scientific evidence[162]

The Fukushima Daiichi disaster could have been prevented because TEPCO had information prior to the accidents that the nuclear power station could be subject to a 10-metre tsunami. Also prior to the Fukushima Daiichi accidents, NISA had acknowledged the need to re-evaluate and upgrade earthquake and tsunami protection requirements. Both NISA and TEPCO neglected their responsibilities to protect the citizens of Japan by placing profits ahead of safety.

- Since 1990, Tohoku Electric Power Co, Tohoku University and the National Institute of Advanced Industrial Science and Technology have researched the traces left by the 869 Jogan Earthquake.[163] Their studies have shown that the ancient tsunami was on the same scale as the one on 11 March 2011. Before the disaster, scholars had repeatedly warned that a massive tsunami could hit the Tohoku region in the future. However, TEPCO played down and ignored these reports.
- As early as 1997, TEPCO was aware of the tsunami risk at the Fukushima site and chose to ignore the scientific analyses of increased tsunami risk made by seismologists Katsuhiko Ishibashi and Koji Minoura. A TEPCO representative dismissed their concerns: "I understood what Ishibashi was saying, but if we engineered factoring in every possible worst case scenario, nothing would get built."[164]
- On the heels of the 2004 Sumatra earthquake and tsunami, TEPCO launched a study into tsunami risks. The TEPCO team presented their findings in 2007, putting the probability of a tsunami of 6 metres or more at 10% over a 50-year period. The Fukushima reactors were identified as a particular concern.[165]
- In its annual reports, which have been made public since 2008, the Japan Nuclear Energy Safety Organisation (JNES) has predicted possible damage that a tsunami could cause to Mark 1 nuclear reactors that are about the same size as the Nos. 2 and 3 reactors at the Fukushima plant. One report said if a breakwater extending up to 13 metres above sea level was hit by a 15-metres-high tsunami, all power sources would be knocked out – including outside electricity and emergency power generators. In such a situation, the report said, cooling functions would be lost and the reactor's core would be 100% damaged – a meltdown, in other words. The breakwater at the Fukushima No. 1 plant was 5.5 metres high.[166]

In 2006, NISA even published new guidelines for reviewing seismic hazards to nuclear stations. However, following the 2011 disaster, an IAEA investigative team reviewed the guide and noted it was superficial, because it contained no tangible enforceable criteria and simply relied upon voluntary reviews by TEPCO with no oversight or control by NISA. The IAEA report concluded:

"The guidance provided in 2006 as part of the Seismic Safety Guidelines does not contain any concrete criteria or methodology that could be used in re-evaluation. The only re-evaluation was performed in 2002 by TEPCO on a voluntary basis. Even this work was not reviewed by NISA. Therefore an effective regulatory framework was not available to provide for tsunami safety of the NPPs through their operating life."[167]

Additionally, following the accidents, the IAEA investigators also concluded that the seismic risk to the Fukushima station was underestimated in the original and subsequent evaluations of earthquake hazards because TEPCO failed to consider longer-term historical data, despite this being the recommended practice internationally.[168]

In an unfortunate twist of fate, TEPCO informed NISA that the Fukushima-Daiichi nuclear power plant could be hit by a tsunami exceeding 10 metres while the plant was only designed to withstand a tsunami of 5.7 metres, just four days before the earthquake and tsunami triggered the three meltdowns at the Fukushima Daiichi nuclear station.[169] After the accident, it was revealed that the warning came from an in-house TEPCO 2008 study, that company officials had dismissed and concealed calling it 'unrealistic'.[170]

In its review of the disaster, the IAEA noted the obvious: Japan is internationally recognised for its expertise on tsunami and earthquake risks and Japanese academics and industry experts have assisted countries around the world in understanding and establishing their own tsunami and earthquake risk reviews. In its review, the IAEA, however, observed that 'organisational issues have prevented this expertise to be applied to practical cases' at Fukushima Daiichi, Fukushima Daini and Tokai Dai-ni nuclear power plants.[171]

This institutional failure to apply the Japanese knowledge and expertise on tsunami and earthquake risks to the nuclear sector is underlined by NISA's approval of lifetime extension of a Fukushima Daiichi reactor prior to the accident. Just weeks before 11 March, NISA approved the life-extension Fukushima Daiichi Unit 1 for an additional 10 years without any modifications or even a substantive review of the station's 40-year-old tsunami protections.[172]

Nuclear proponents have attempted to absolve the industry of responsibility for the Fukushima disaster by calling the earthquake and tsunami a 'black swan event' – an extremely unlikely and unforeseeable event that could not be planned for in the reactors' design. A review of the events leading up to the Fukushima disaster shows that TEPCO and NISA ignored scientific information on the potential for such a series of events and failed to prepare sufficiently for the unexpected.

The claim of nuclear 'safety' – a false sense of security

At the heart of claims of nuclear safety is an assumption that accidents, which lead to significant releases of radiation, have a very low probability of occurring. International safety regulators have adopted a nuclear safety paradigm under which, for accidents that are categorised as 'design basis' events, the design of a plant must guarantee no significant radioactive releases will occur. These events are also often referred to as 'credible' accidents. Accidents involving significant radiation releases, like those at Fukushima Daiichi are called 'incredible' or 'beyond design basis' events. These are claimed to be of an extraordinary low probability.[173]

These numbers are the results of PSA (probabilistic safety assessment) studies. However, PSAs cannot provide meaningful estimates for accident frequencies (probabilities), since they cannot take into account all relevant factors (e.g. they cannot cover inadequate regulatory oversight) and the factors that are included are beset with huge uncertainties (e.g. regarding earthquakes).

The designs for all reactors in operation, including the Fukushima Daiichi units, were established in the 1960s. The 'design basis' of reactors was based upon 'reasonably foreseeable' accidents, i.e. accidents that, according to industry experts, could be expected.[174] Also the designs applied the antiquated engineering modelling and methodology available during that time period more than 40 years ago.

In the following decades, accidents involving significant radiation releases that were initially deemed as 'incredible' began to occur, such as Three Mile Island (1979) and Chernobyl (1986). Despite some development in nuclear assessments, e.g. in terms of the kind of accidents taken into account, the nuclear sector did not question the safety paradigm but carried on using the model, i.e. the probabilistic risk assessments, to justify the allowance of certain reactor weaknesses and vulnerabilities.

Regulators and the industry call nuclear power 'safe', because their calculational methodology depicts events that could cause a significant accident, like the one that occurred at Fukushima Daiichi, as extremely unlikely. Reactors were allowed to be constructed in ways that do not allow them to withstand such events. According to probabilistic risk assessments, the chance of a 'beyond design basis' accident, which causes a core melt and a significant radioactive release, is less than once in a million years of reactor operation. The Fukushima Daiichi disaster, however, has shown this theory of nuclear safety to be false.

By 2011, the world had accumulated just over 14,000 years of reactor operating experience.[175] The International Atomic Energy Agency (IAEA) safety guidelines state that the frequency of actual core damage should be less than once in 100,000 years.[176] Hence, with more than 400 reactors operating worldwide, a significant reactor accident would be expected to occur approximately once every 250 years.[177]

Culminating with the Fukushima Daiichi accidents in 2011 there have been five major accidents involving significant fuel melt during the past 33 years: Three Mile Island (a Pressurised Water Reactor) in 1979, Chernobyl (a RBMK design) in 1986, and the three Fukushima Daiichi units (Mark 1 Boiling Water Reactors) in 2011.

Based upon these five meltdowns, the probability of significant accidents is in fact one core-melt for every 2,900 years of reactor operation.[178] Put another way, based upon observed experience with more than 400 reactors operating worldwide, a significant nuclear accident has occurred approximately every seven years.[179]

The theory of nuclear safety espoused by the nuclear power sector has given regulators, reactor operators, and the public a false sense of security. For industries that require a high level of reliability, such as aviation and nuclear generation, institutional failures are the major contributor to real-world accidents. Surveys of nuclear and other high-reliability industries show that 70% of real accident rates are caused by institutional failures.[180] Despite this, the probabilistic risk studies produced by reactor operators to predict the frequency of component failures leading to radioactivity releases do not take into account failures of operators and regulators overseeing the plant. The empirical evidence shows that reactor accidents are more than one order of magnitude more likely than predicted by the nuclear industry's modelling.

This historical record clearly contradicts the industry's claim of nuclear safety. Instead of being low-probability events as asserted by the nuclear industry, reactor meltdowns are regular events with significant consequences. Safety regulators and governments internationally should acknowledge this reality, as was done by Dr Piet Müskens from the Kernfysische Dienst, the nuclear safety regulator in the Netherlands, who stated shortly after the Fukushima accident:

"Due to the problems with the nuclear plant Fukushima 1 in Japan, all countries in the world having nuclear power plants are going to re-investigate and re-evaluate their calculation of the probability of a nuclear meltdown."[181]

For decades, the nuclear industry and its regulators have convinced themselves that the low probability of component failures somehow means that the nuclear technology is a low risk industry.

However, risk is typically defined as probability (or frequency) times consequence. Even a low-probability event could be high risk if the consequences are catastrophic. The majority of nuclear risk studies calculate the *frequency* or probability of events while avoiding true *risk* assessment that incorporates serious consequences. Such convoluted modeling distorts the public and the institutional understanding of the risk posed by nuclear power stations and encourages risky behaviour.

The former president of TEPCO, Tsunehisa Katsumata, described the attitude of allowed deception of regulatory authorities: "The engineers were so confident in their knowledge of nuclear power that they came to hold the erroneous belief that they would not have to report problems to the national government as long as safety was maintained."[182] The overconfidence and denial of nuclear risks are evident in the behaviour of NISA and TEPCO prior to Fukushima.

The international nuclear industry and its regulators have often portrayed public scepticism regarding nuclear safety as irrational. Fukushima, however, has highlighted how public scepticism of industry safety claims is valid.

The potential for similar catastrophic disasters is not limited to Japan. Dozens of existing and planned new reactors all over the world are burdened with similar technological weaknesses that proved fatal at Fukushima Daiichi, have substantial governance and management issues, and operate without effective independent supervision.

Industry promotion vs safety at the International Atomic Energy Agency (IAEA)

The IAEA was founded in 1957 under the auspices of the UN, and its status under the UN gives the false perception of an independent organisation in charge of nuclear safety at an international level. However, its watchdog authority only relates to nuclear weapons. As a matter of fact, the IAEA is a UN body that has a mandate and explicit objective to promote and spread nuclear power. The status of the IAEA is declared clearly at the beginning of its UN charter:

> *ARTICLE II: Objectives. The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose.*[183]

The IAEA, as well as some national regulatory agencies, therefore suffers from the very same problem: an inherent conflict of interest. It is expected to regulate a dangerous technology that it was also created to promote. This dual role for the IAEA leads to systemic bias, since the safety recommendations of the agency can never go so far that they would become an obstacle to the expansion of nuclear power. Furthermore, the IAEA has neither enforcement power nor jurisdiction over nuclear power in any country. Therefore it can only recommend, and often its safety standards are set at the lowest common denominator to make them acceptable to its member countries.

IAEA and Fukushima Daiichi

During the Fukushima Daiichi accident, the IAEA's systemic bias became very apparent. The Agency's first team of experts arrived in Japan on 26 March 2011, two weeks after the accident began.[184] One day later, Greenpeace announced that radiation levels in the village of Iitate, located about 40km from the damaged reactors, were so high that they exceeded the thresholds for evacuation.[185] Greenpeace radiation specialists had already been operating and measuring radiation in the Fukushima region, producing the first truly independent radiation measurements. The Japanese government spokesperson, Mr Nishimura, immediately claimed these findings were unreliable and rejected them.[186]

On 30 March, the IAEA confirmed that the radiation levels in the village of Iitate outside the evacuation zone surrounding the stricken Japanese nuclear plant were above evacution limits, and the IAEA urged Japan to reassess the situation.[187] "The first assessment indicates that one of the IAEA's operational criteria for evacuation is exceeded in Iitate village," said the IAEA's head of nuclear safety and security, Denis Flory. Once again, the government rejected those findings and recommendations. The then chief cabinet secretary Yukio Edano told reporters[188] the situation did not 'immediately require such action'.[189]

Only two days later, the IAEA withdrew its statement. The IAEA officials stated that a 'recomputation done on additional data provided by Japan' showed the average figure was below the evacuation standard set by the IAEA.[190] Fortunately for the citizens of Iitate, the Japanese government finally acknowledged the magnitude of the problem, and ordered the evacuation on 22 April[191] – this was four weeks after Greenpeace first highlighted the need for immediate evacuation, and three weeks after the IAEA backpedalled on its recommendation.

This incident clearly illustrates a structural problem within the IAEA: since its very first days, the IAEA has had a tendency to put politics ahead of science and ahead of the protection of public health. Instead of acting independently the IAEA has preferred to align itself with the positions taken by the Japanese government. This attitude is further illustrated by more detailed reports and evaluations produced by the IAEA in the months following the disaster.

One of the IAEA's responses to the ongoing crisis in Japan was to convene a conference of nuclear power industry experts in June 2011.[192]

This was an invitation-only conference: closed to the press, the public, and worst of all not accessible to most of the independent engineering and scientific experts. Therefore, some experts who uncovered significant flaws in Japan's regulatory process and its emergency management radiation response protocols were prohibited from participating in this alleged scientific review. As anticipated by outsiders, the outcome of this restricted conference was that the IAEA announced no major structural changes to the nuclear safety system.

Also in June 2011, the IAEA published its preliminary report of a fact-finding mission in Japan. Despite multiple failures of the Japanese government and its institutions to not only prevent the accident, but also to effectively mitigate its consequences and provide best protection to the people of Japan (described and documented at other parts of this report), the IAEA praised the Japanese government:

> *"Japan's response to the nuclear accident has been exemplary … Japan's long-term response, including the evacuation of the area around stricken reactors, has been impressive and well organised."*[193]

It should not be surprising that on 12 September 2011, six months after the accident began, and two months after speaking highly of the Japanese government's response to the Fukushima disaster, the Agency urged political leaders and nuclear experts to take measures to restore public confidence in the safety of nuclear production that were shaken by the accidents.[194] Note that political leaders were not urged to protect people from nuclear risks, but to restore public confidence in the safety of nuclear power.

In December 2011, the IAEA once again played the dual role of the public advocate and nuclear regulator. The IAEA stated:

"The reactors at Fukushima Daiichi Nuclear Power Station have achieved a 'cold shutdown condition' and are in a stable state, and that the release of radioactive materials is under control."[195]

Furthermore, the IAEA has continued to commend TEPCO and the Japanese government for their significant progress. The reality is that the nuclear reactors at Fukushima Daiichi are not in cold shutdown, are not in a stable state, and the release of radioactive materials continues to contaminate the ocean as well as migrate throughout the ground water; the radiation continues to contaminate food sources in many varied and unexpected locations including green tea, rice, and beef - to name only a few.[196]

Japan as an example

Before the Fukushima disaster and subsequent nuclear accidents, the IAEA was full of praise for Japan's perfectly functional and reliable nuclear safety regulatory process. According to the IAEA, other countries could learn from Japan in how it enforces proper measures on nuclear reactor operators for major accidents. This report shows that this was clearly not the case.

In June 2007, the IAEA organised the so-called Integrated Regulatory Review Service mission to Japan. Its purpose is 'to help Member States enhance their legislative and regulatory infrastructures, and to harmonise regulatory approaches in all areas of safety'.[197] The IAEA maintained that this process would be 'one of the most effective feedback tools on the application of Agency standards'.[198]

Among its three major findings, the report by this IAEA review team concluded that Japan has 'a comprehensive national legal and governmental framework for nuclear safety in place; the current regulatory framework was recently amended and is continuing to evolve'.[199] It also concluded that 'all important safety elements receive regular due attention by both the licensee and NISA', and stated that, among best practices in Japan, is that 'operating experience for major events has been thoroughly investigated and appropriate countermeasures have been enforced on the licensee'.[200]

Only one month after the 2007 report, a major 7.3 earthquake hit the western coast of Japan and impacted seven operating reactors at the Kaswhiwazaki-Kariwa nuclear power plant site. The IAEA then conducted a study and an evaluation about what lessons were learned from its review. Unfortunately, proper lessons were not identified, rather the Agency used the event to showcase for how safe reactors are, even during a strong earthquake:

"Safety related structures, systems and components of the plant seem to be in a general condition, much better than might be expected for such a strong earthquake, and there is no visible significant damage ... The mission found that there is consensus in the scientific community about the causes of the unexpectedly large ground motions experienced at the plant site during the July 2007 earthquake and, consequently, it has been possible to identify the precautions needed to be taken in relation to possible future events."[201]

Later, in 2010 – just one year prior to the Fukushima Daiichi accident – the IAEA held an international workshop and concluded that in 2007 the Kashiwazaki-Kariwa problem was evaluated by NISA, JNES, TEPCO and a large number of specialised institutions and universities as well as experts in different fields, and that the regulations were reviewed and properly applied.

The IAEA has failed to identify any of the institutional problems and deficiencies in the Japanese nuclear regulatory process – on the contrary, as far back as 2007, it has praised Japan as an example for other regulatory agencies and governments to follow.

The IAEA claimed that lessons from previous major earthquakes were properly examined and this review increased the level of seismic safety for nuclear power in Japan and worldwide. Yet only four years later - those supposedly robust reactors suffered multiple meltdowns and major releases of radiation.

The question remains as to what is the value of the IAEA's January 2012 mission to Japan. It is claimed to be a review of the quality of Japan's reactor stress tests required as a condition prior to Japanese reactors restarting their operation. Not surprisingly, the IAEA had words of reassurance:

"We concluded that NISA's instructions to power plants and its review process for the Comprehensive Safety Assessments are generally consistent with IAEA Safety Standards. The team found a number of good practices in Japan's review process and identified some improvements that would enhance the overall effectiveness of that process."[202]

Conclusions

The Fukushima Daiichi disaster has proven that the nuclear industry's theory of nuclear safety is false. Historical evidence – Fukushima Daiichi, Chernobyl and Three Mile Island – shows a major nuclear accident has occurred somewhere in the world about once every decade. This regular occurrence of reactor accidents contradicts the nuclear industry's claim that such events would occur only once in 250 years.

One lesson, which can be learned again and again from nuclear accidents is: The nuclear industry's risk assessments fail to take institutional failures into account, while human and institutional behaviour are the principal contributor to reactor accidents. A series of these institutional failures set the stage for the Fukushima Daiichi disaster, including a system of industry-led self-regulation, the industry's overconfidence, and its inherently dismissive attitude towards nuclear risks as well as its neglect of scientific evidence.

The standard of self-regulation by the nuclear industry can be found in many places in the world. Also, the Fukushima Daiichi disaster has demonstrated that the safety claims of the nuclear industry and its national as well as international regulators are false.

There are several lessons to be learned from the institutional failures that lead to the Fukushima disaster:

- **Regulatory independence**: The failure of the Japanese regulator to anticipate, acknowledge and enforce standards based upon risks posed to the public was a key cause of the Fukushima Daiichi disaster. This failure can partially be attributed to the Japanese regulator's close affiliation with government policy to promote nuclear policy and its familiar connections with nuclear operators. The nuclear industry is often closely interlinked with its regulators due to the highly specialised nature of nuclear technology. To counteract this tendency, strong structural and policy separation needs to be established between nuclear safety regulators and the industry it purports to regulate.
- **Objective risk assessment and communication**: International governments and regulators should reassess the methodology they use to evaluate nuclear risks, taking into account the empirical record. While nuclear proponents claim a meltdown will only occur once in 250 years, experience has proven that a significant reactor accident has happened once per decade. Such accurate information would assist countries globally to make decisions on their energy futures.
- **Public participation**: As witnessed in Japan, the public assumes the risks of nuclear accidents. While nuclear regulators and operators have viewed reactor risks as a mere mathematical problem, Fukushima Daiichi has given legitimacy to public scepticism of the risk claims. Greater public participation must become part of the process rather than relying only upon the echo chamber that reinforces the industry's blind belief that catastrophic nuclear accidents are improbable.
- **Rigorous nuclear safety and life-extension reviews**: Reactors all over the world require a rigorous review of the design basis against what would be considered modern standards and the new reality after the triple meltdown at Fukushima Daiichi. Given the risk involved, reactor safety reviews and life-extensions should never be rubber stamp procedures.

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Endnotes

1The French Institut de Radioprotection et de Sureté Nucléaire, 26 October 2011 estimated that the amount of Cs137 released into the ocean between 26 March and 8 April 2011 to $22x10^{15}$ Bq, which is 20 times more than the estimation done by TEPCO in June 2011. The same amount of Cs134 should be added. Other radioelements like I131 were also released, but they have a short half life.
http://www.irsn.fr/FR/Actualites_presse/Actualites/Documents/IRSN-NI-Impact_accident_Fukushima_sur_milieu_marin_26102011.pdf
The estimation of the Japanese authorities is available in the Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety - The Accident at TEPCO's Fukushima Nuclear Power Stations, June 2011
http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html

2 Ministry of Agriculture, Forestry and Fisheries, Results of the inspection on radioactive materials in fisheries products, January 2012
http://www.jfa.maff.go.jp/e/inspection/pdf/120127_kekka_en.pdf

3 Ministry of Education, Culture, Sports, Science and Technology (MEXT), Readings of Sea Area Monitoring at offshore of Miyagi, Fukushima and Ibaraki Prefecture - marine soil, 25 January 2012
http://radioactivity.mext.go.jp/en/monitoring_around_FukushimaNPP_sea_marine_soil/2012/01/1350_012514.pdf

4 TEPCO: 45 tons of radioactive water leaked at plant, Asahi, 5 December 2011 and Leaks sprout at 14 spots in Fukushima nuclear power plant, Asahi, 30 January 2012

5 The French Information note of the 22 March 2011 estimated the atmospheric release to $2x10^{18}$ Bq for rare gases, $2x10^{17}$ Bq for the iodine's and $3x10^{16}$ Bq for the caesium's.
http://www.irsn.fr/FR/base_de_connaissances/Installations_nucleaires/La_surete_Nucleaire/Les-accidents-nucleaires/accident-fukushima-2011/impact-japon/Documents/IRSN_NI-Evaluation-radioactivite-rejets_22032011.pdf
The Japanese NISA estimated that the total discharge amounts from the reactors of Fukushima Dai-ichi NPS were approx. $1.6x10^{17}$Bq for Iodine 131 and approx. $1.5x10^{16}$Bq for Caesium 137 (Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety - The Accident at TEPCO's Fukushima Nuclear Power Stations, June 2011)
http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html.
The Austrian ZAMG had results closer to 20% (Unfall im japanischen Kernkraftwerk Fukushima, press release of the 24 March 2011)
http://www.zamg.ac.at/aktuell/index.php?seite=1&artikel=ZAMG_2011-03-24GMT11:24

6 Stohl A, Seibert P, Wotawa G, Arnold D, Burkhart JF, Eckhardt S, Tapia C, Vargas A, Yasunari TJ (2011). Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. Atmospheric Chemistry and Physics, doi:10.5194/acpd-11-28319-2011
http://www.atmos-chem-phys-discuss.net/11/28319/2011/acpd-11-28319-2011.html .
For Cs137 the estimated amount is $35.8x10^{15}$ Bq.

7 $16.7x10^{18}$ Bq for the Xe133; Ibid.

8 Ibid.

9 Amount of radioactive materials released from Fukushima plant up, Mainichi Japan, 24 January 2012

10 Ordinance of the Environment Ministry quoted in Japan to clean up areas with radiation of 1 millisievert or more, Mainichi Japan, 14 December 2011

11 Rough estimation done by the Asahi: Estimated 13,000 square km eligible for decontamination, 12 October 2011
http://www.asahi.com/english/TKY201110110214.html

12 "In late September, the Environment Ministry said that full decontamination in areas above 5 millisievert per year and partial decontamination for areas between 1 and 5 millisievert would involve removing about 29 million cubic metres of surface soil and fallen leaves in forests", Ibid.

13 Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company. 2011. Interim Investigation Report, 26 December 2011
http://icanps.go.jp

14 Tokyo exodus nuke report's worst scenario, 'Migration' plan mulled at height of atomic crisis, The Japan Times, 6 January 2012

15 Fourteen if we include Monju, the experimental fast breeder reactor.

16 Last shelters in Fukushima Pref. Close, The Yomiuri Shimbun, 29 December 2011

17 ACRO, Centrale Nucléaire de Fukushima dai-ichi : Reconstitution des évènements
http://www.acro.eu.org/chronoFukushima2.html

18 The Prometheus Trap / Men in Protective Clothing, a series of the Asahi, episode 2: Radiation information did not make it to residents, Asahi, 16 November 2011

19 Ibid. For an archive of press releases please see: Nuclear and industrial Safety Agency (NISA). 2011. Press Releases.
http://www.nisa.meti.go.jp/english/press/index.html.

20 NGO finds high levels in safe area, The Japan Times, 31 March 2011. Greenpeace radiation team pinpoints need to extend Fukushima evacuation zone Greenpeace International, Press release 27 March 2011.
http://www.greenpeace.org/international/en/press/releases/Greenpeace-radiation-team-pinpoints-need-to-extend-Fukushima-evacuation-zone-especially-to-protect-pregnant-women-and-children-/

21 IAEA data prods Japan to boost radiation monitoring, eye evacuation, Kyodo News, 31 March 2011

22 Govt officially sets new evacuation zone, The Yomiuri Shimbun, 23 April 2011

23 About the SPEEDI scandal see e.g. The Prometheus Trap / The Researcher's Resignation, Asahi, 31 December 2011

24 Eric Talmadge, AP, Radiation forecasts ignored; Namie not warned, Inability to grasp SPEEDI data put Fukushima residents at risk, The Japan Times, 10 August 2011

25 The Prometheus Trap / The Researcher's Resignation, Asahi, 31 December 2011

26 Ibid.

27 Eric Talmadge, AP, Radiation forecasts ignored; Namie not warned, Inability to grasp SPEEDI data put Fukushima residents at risk, The Japan Times, 10 August 2011

28 Radiation-dispersal data was provided to U.S. before Japanese public, Kyodo News, 17 January 2012

29 Families want answers after 45 people die following evacuation from Fukushima hospital, Mainichi Japan, 26 April 2011

30 Ibid.

31 573 deaths 'related to nuclear crisis', The Yomiuri Shimbun, 5 February 2012

32 Japan to cull livestock in no-go zone near Fukushima plant: Edano, Kyodo News, 13 May 2011

33 "Our results indicate that 137Cs emissions peaked on 14–15 March but were generally high from 12 until 19 March, when they suddenly dropped by orders of magnitude exactly when spraying of water on the spent-fuel pool of unit 4 started" (in Stohl A et al, Atmos. Chem. Phys. Discuss., 11, 28319-28394, 2011, doi:10.5194/acpd-11-28319-2011). The French IRSN explains that most of the source term was released between the 12th and the 22nd of March (in Synthèse des informations disponibles sur la contamination radioactive de l'environnement terrestre japonais provoquée par l'accident de Fukushima Dai-ichi. 27 September 2011 http://www.irsn.fr/FR/base_de_connaissances/Installations_nucleaires/La_surete_Nucleaire/Les-accidents-nucleaires/accident-fukushima-2011/impact-japon/Documents/IRSN-NI_Fukushima-Consequences_environnement_Japon-27092011.pdf)

34 "Reactor No. 4 at the Chernobyl power plant exploded on 26 April 1986. Radioactive particles were released over 10 days" in IRSN, The radioactive particles released during the explosion of the reactor were blown over thousands of kilometers by the wind, Information note, undated http://www.irsn.fr/EN/Library/Documents/fiche8_va.pdf)

35 SOS from Mayor of Minami Soma City, next to the crippled Fukushima nuclear power plant, Japan. 24 March 2011.http://www.youtube.com/watch?v=70ZHQ--cK40&feature=player_embedded#!

36 50,000 had already left.

37 Exodus of doctors, nurses adds to Fukushima Pref. woes, The Yomiuri Shimbun, 4 October 2011

38 Ibid.

39 Private communication of scholars involved in the screening

40 Yuka Hayashi, Japan Officials Failed to Hand Out Radiation Pills in Quake's Aftermath, The Wall Street Journal, 29 September 2011

41 Ibid.

42 Smeesters P, Van Bladel L, Accidents nucléaires et protection de la thyroïde par l'iode stable, FANC/AFCN Belgium, 8 March 2011

43 Japan Officials Failed to Hand Out Radiation Pills in Quake's Aftermath, The Wall Street Journal, 29 September 2011 and Tokyo ignored calls to issue iodine during crisis, Asahi, 26 October 2011

44 Ibid.

45 Maps of the contamination drawn by the government are here: http://radioactivity.mext.go.jp/ja/distribution_map_around_FukushimaNPP/ A consortium of universities and research institutes made other maps based on samples. Their results are here: http://www.rcnp.osaka-u.ac.jp/dojo/

46 Govt officially sets new evacuation zone, The Yomiuri Shimbun, 23 April 2011

47 113 households identified as radioactive hot spots, The Japan Times, 1 July 2011

48 Gov't designates new 'hot spots' near Fukushima plant, Mainichi Japan, 21 July 2011

49 More Radiation Hot Spots Designated Near Fukushima N-Plant, Jiji Press, 3 August 2011

50 Local mayors discontent with plan to reclassify no-entry zones, The Yomiuri Shimbun 22 December 2011. Also: http://www.mext.go.jp/b_menu/shingi/chousa/kaihatu/016/shiryo/__icsFiles/afieldfile/2011/12/21/1314459_4_1.pdf

51 20 mSv in average over 5 years in the international recommendations; exactly 20 mSv a year in the French regulation

52 2007 ICRP Recommendations of the International Commission on Radiological Protection ICRP Publication 103; Ann. ICRP 37 (2–4).

53 All the results can be found online at: http://acro.eu.org

54 ACRO, All the dust from vacuum cleaners are contaminated, press release of 15 December 2011. Japanese remove their shoes before entering a house.
http://www.acro.eu.org/CP_ACRO_151211_en.pdf.

55 Masahiro Hosoda, Shinji Tokonami, Atsuyuki Sorimachi, Satoru Monzen, Minoru Osanai, Masatoshi Yamada, Ikuo Kashiwakura and Suminori Akiba, 2011, The time variation of dose rate artificially increased by the Fukushima nuclear crisis, Scientific Reports 1, Article number: 87 doi:10.1038/srep00087
http://www.nature.com/srep/2011/110907/srep00087/full/srep00087.html

56 Fukushima gov't estimates radiation exposure of up to 19 millisieverts, Mainichi Japan, 13 December 2011

57 Department for the Mitigation of the consequences of the Catastrophe at the Chernobyl NPP of the Ministry for Emergency Situations of the Republic of Belarus, A quarter of a century after the Chernobyl catastrophe: outcomes and prospects for the mitigation of the consequences, Minsk 2011

58 TEPCO seeks 690 billion yen more for Fukushima compensation, Asahi Shimbun, 27 December 2011.

59 TEPCO compensation predicted to reach 4.54 trillion yen, The Yomiuri Shimbun, 1 October 2011

60 Estimated to about 4tn yens ($52bn US dollars) by Kenichi Oshima, an environmental economist and professor at Kyoto-based Ritsumeikan University, in 38 years of nuke profit up in smoke?, The Japan Times, 28 June 2011

61 TEPCO seeks 1tr yen for N-compensation, The Yomiuri Shimbun, 29 October 2011

62 TEPCO to deposit 120bn yen for future claims, Asahi, 11 January 2012

63 Voluntary evacuees from Fukushima seek compensation, Asahi, 21 October 2011

64 ACRO, Evaluation de la contamination des enfants de Biélorussie, March 2004
http://www.acro.eu.org/enfantcherno.html
and Du rôle de la pectine dans l'élimination du césium dans l'organisme, December 2004
http://www.acro.eu.org/pectine.html
Résultats d'analyses sur des enfants biélorusses

65 Director-General, Department of Food Safety, Pharmaceutical and Food Safety Bureau, Ministry of Health, Labour and Welfare, Handling of food contaminated by radioactivity, Notice No. 0317 Article 3 of the Department of Food Safety, 17 March 2011
http://www.mhlw.go.jp/english/topics/foodsafety/dl/110318-1.pdf

66 Japan hastily sets seafood radioactivity limit amid overseas concern, Kyodo News, 5 April 2011

67 Positive signs for Japan nuclear crisis but radiation traces found, Kyodo News, 19 March 2011

68 Kan asks Fukushima residents not to eat leaf vegetables over radiation, Kyodo News, 23 March 2011

69 Notice No. 0317 Article 3 of the Department of Food Safety, Ministry of Health, Labour and Welfare, 17 March 2011
http://www.mhlw.go.jp/english/topics/foodsafety/dl/110318-1.pdf

70 Food exports plunged due to nuclear crisis, The Yomiuri Shimbun, 11 January 2012

71 Fukushima plans exhaustive tests of 2012 rice, Asahi, 6 January 2012

72 Reported by the Ministry of Health http://www.mhlw.go.jp/stf/houdou/2r9852000001p90s-att/2r9852000001p95n.pdf

73 9 becquerels per litre for Cs137, 6 Bq/l for Cs134 and 4 Bq/l for iodine

74 Statement of the working group on the support on the quake, Oceanographic Society of Japan, 25 July 2011 http://www.kaiyo-gakkai.jp/main/2011/07/post-157.html

75 Nuclear and Industrial Safety Agency, Regarding the Evaluation of the Conditions on Reactor Cores of Unit 1, 2 and 3 related to the Accident at Fukushima Dai-ichi Nuclear Power Station, Tokyo Electric Power Co. Inc., 6 June 2011
http://www.nisa.meti.go.jp/english/press/2011/06/en20110615-5.pdf

76 In January 2012, the Ministry of Health, Labour and Welfare acknowledged that it has been unable to track the distribution routes of 2,996 cows among 4,626 whose meat is suspected to contain high levels of radioactive caesium. 6.4% of the 1,630 animals tested had radioactive caesium exceeding the government's provisional limit of 500 becquerels per kilogramme (Suspect cattle still untested / Location of nearly 3,000 cows in radiation scare remains unknown, The Yomiuri Shimbun, 27 January 2012)

77 679 becquerels per kilogram of radioactive cesium. Radiation above standards found in Shizuoka tea. Asahi, 11 June 2011

78 Government orders Fukushima to halt rice shipments, Asahi, 17 November 2011

79 15 Pct of Rice Tainted with Excessive Radiation: Fukushima Pref. Jiji Press, 25 November 2011

80 Radioactive cesium content higher in Fukushima fruits, mushrooms, Asahi, 19 January 2012

81 Fukushima farmers in a jam / Fruit growers see orders plunge due to fears over radiation, The Yomiuri Shimbun, 14 August 2011

82 Ministry seeking lower radiation levels for infants, Asahi, 21 December 2011

83 Radiation testing on school lunches differs, The Yomiuri Shimbun, 29 January 2012

84 Japan to clean up areas with radiation of 1 millisievert or more, Mainichi Japan, 15 December 2011

85 No-Go Zone Designation Could Be Lifted with 20 Millisieverts: Hosono, Jiji Press, 15 December 2011

86 Govt speeds rezoning of contaminated areas, The Yomiuri Shimbun, 18 December 2011

87 Road map released for Fukushima decontamination, Asahi, 27 January 2012

88 2007 ICRP Recommendations of the International Commission on Radiological Protection ICRP Publication 103; Ann. ICRP 37 (2–4).

89 Japan to clean up areas with radiation of 1 millisievert or more, Mainichi Japan, 15 December 2011

90 Schools in Fukushima clearing radioactive dirt, but nowhere to dump it, Asahi, 12 August 2011

91 28 million cubic metres of 'hot' soil in Fukushima / Ministry aims to set storage site guidelines, The Yomiuri Shimbun, 26 September 2011

92 Fukushima farmers furious over lack of consideration in decontamination subsidies, Mainichi Japan, 2 February 2012

93 Ploughing technique to fight spread of radiation demonstrated, Mainichi Japan, 4 February 2012

94 Residents near Fukushima mountains face nuclear recontamination every rainfall, Mainichi Japan, 11 October 2011

95 No simple steps to carrying out decontamination work, Asahi, 5 December 2011

96 Decontamination of houses under way, The Yomiuri Shimbun, 16 November 2011

97 Fukushima gives radiation meters to pregnant women and children, Asahi, 26 June 2011

98 Schoolgirl in Fukushima exposed to high level of radiation in September, Mainichi Japan, 2 November 2011

99 Evacuees may move due to radioactive concrete, Asahi, 16 January 2012

100 Fukushima to provide lifetime thyroid tests in wake of nuclear crisis, Mainichi Japan, 25 July 2011

101 Hayashi, Y. 2011. Japanese seek out `Hot Spots´, Wall Street Journal, 19 October 2011

102 Residents near Fukushima nuclear plant make own radiation map, clean contaminated areas, Mainichi Japan, 25 September 2011

103 Association pour le Contrôle de la Radioactivité de l`Quest (ACRO). http://acro.eu.org

104 Personal interview, 4 October, 2 November, 2011 and 16 January 2012

105 Please see section 3.3.1 on how the IAEA first recommended evacuation and then withdrew its statement two days later, after criticism by the Japanese government.

106 Personal interview, 4 October, 2 November, 2011 and 16 January 2012

107 Figures come from TEPCO, Personal interview with Yoshikazu Nagai and Hiroki Kawamata, Corporate Communications Department, 13 January 2011

108 10% of compensation forms filed/TEPCO's arduous application process blamed for claimant's slow response, The Daily Yomiuri, 31 October 2011. http://www.yomiuri.co.jp/dy/national/T111012005321.htm (accessed 23 January 2012)

109 Figures come from TEPCO and from interviews with Hideyuki Ban, Secretary General of the Citizens' Nuclear Information Center.

110 Personal Interview, 14 January 2012

111 Tokyo has the world's highest cost of living, according to The Economist. Pocket World in Figures. 2010. p.90.

112 Personal Interview, 17 January 2012.

113 A copy of this act can be found at:
http://www.oecd-nea.org/law/legislation/japan-docs/Japan-Nuclear-Damage-Compensation-Act.pdf (accessed 23 January 2012).
The operator is exonerated from liability in cases of 'grave natural disaster of an exceptional character,' but at the time of writing it seems that TEPCO has not invoked this exception.

114 Personal Interview, 25 January 2012

115 See X. Vasquez-Maignan, “Fukushima: Liability and Compensation,” published by the Nuclear Energy Agency: http://www.oecd-nea.org/nea-news/2011/29-2/nea-news-29-2-fukushima-e.pdf, 23 January 2012.

116 Ibid.

117 Personal Interview, 14 January 2012.

118 Under normal situations the limit for radiation exposure is fixed at one millisievert a year (principle of application of dose limits). This is the very maximum as the dose should be as low as reasonably achievable (principle of optimisation of protection). See: 2007 ICRP Recommendations of the International Commission on Radiological Protection ICRP Publication 103; Ann. ICRP 37 (2–4).

119 Weitzdoerfer J (2011). “Die Haftung für Nuklearschäden nach japanischem Atomrecht – Rechtsprobleme der Reaktorkatastrophe von Fukushima I” (Liability for Nuclear Damages pursuant to Japanese Atomic Law – Legal Problems Arising from the Fukushima I Nuclear Accident), The Journal of Japanese Law, No.31, 2011 (English summary available only). Personal interview, 25 January 2012.

120 McNeill D (2011). Japan Reveals Huge Size of Fukushima Cleanup, The Irish Times, 29 September 2011. http://www.irishtimes.com/newspaper/world/2011/0929/1224304933758.html (accessed 31 January 2012)

121 Iwata T (2011). TEPCO: Radioactive Substances Belong to Landowners, Not US. The Asahi Timbun, 24 November 2011 http://ajw.asahi.com/article/behind_news/social_affairs/AJ201111240030

122 Ibid. For a report on compensation for Tokaimura, see http://www.oecd-nea.org/law/nlb/Nlb-66/013-022.pdf 23 January 2012

123 Personal Interview, 13 January 2012.

124 TEPCO shares fall on fears that it may be nationalised. BBC News, 28 December 2011.

125 The statement was widely ridiculed. The Daiichi plant’s defense walls were built to withstand a tsunami of just 5.5 metres, perhaps a third the size of the 14-15 metre tsunami that disabled its cooling systems. In 1933, 28-metre waves demolished parts of Aomori, Iwate and Miyagi. A 38-metre wave hit the northeast region in 1896.

126 Figures come from TEPCO, Personal Interview with Yoshikazu Nagai and Hiroki Kawamata, Corporate Communications Department, 13 January 2011

127 Personal Interview, 13 January 2011

128 McNeill D (2011). Learning Lessons from Chernobyl to Fukushima. CNNGO, 28 July 2011. http://www.cnngo.com/tokyo/life/learning-lessons-chernobyl-fukushima-645874 (accessed 3 January 2012).

129 http://www.minyu-net.com/news/news/0106/news9.html (accessed 14 January 2012)

130 Nagata K (2012). Disaster Towns Left in Limbo, The Japan Times, 16 January 2012. http://www.japantimes.co.jp/text/nn20120116a3.html (accessed 16 January 2012)

131 It also makes no provision for the many unexpected consequences of the disaster, such as the irradiation of a newly built apartment building in the prefecture, which used contaminated stones in its construction. Families inside the building will have to be relocated and the building likely destroyed. See “New Condo’s Foundation Radioactive,” The Japan Times, 17 January 2012.

132 TEPCO seeks 690 billion yen more for Fukushima compensation, The Asahi Shimbun, 27 December 2011. http://ajw.asahi.com/article/0311disaster/fukushima/AJ201112270013 (accessed 14 January 2012)

133 Kobori T (2011). Fukushima crisis estimated to cost from 5.7 trillion yen to 20 trillion yen. The Asahi Shimbun, 1 June 2011. http://ajw.asahi.com/article/0311disaster/quake_tsunami/AJ201106010334

134 Japan Center for Economic Research. (JCER). 2011. Report Impact to last Decade or more if Existing Nuclear Plants Shut Down, p.11. 25 April 2011. http://www.jcer.or.jp/eng/research/pdf/pe(iwata20110425)e.pdf

135 Japan Center for Economic Research. (JCER). 2011. Abstract The 38th Middle-Term Forecast, 2 December 2011, p.3. http://www.jcer.or.jp/eng/pdf/m38_abstract.pdf.

136 Japan’s Yukio Edano rebuffs Tepco bailout claim. BBC, 9 December 2011. See also, Japan’s nuclear conundrum: The $64 billion question, The Economist, 5 November 2011: “[T]he longer the government dithers over nationalizing Tepco, the more the costs will rise and the impetus for action will wane.”

137 Government Oks TEPCO compensation framework, The Asahi, 13 May 2011.

138 Ibid

139 Kenichi Oshima (2011). Oshima makes this claim in his book. The lobbying, by its nature, is taking place behind the scenes.

140 Tokyo Shimbun, perhaps the most consistent mainstream media critic of TEPCO and government policy on Fukushima, came to this conclusion early, in July 2011. See “Tokyo Shimbun’s Devastating Critique of Fukushima Compensation Bill,” Japan Focus, 3 August 2011. http://japanfocus.org/events/view/106. (accessed 15 January 2012)

141 Mosey D (2006). Reactor Accidents: Institutional Failure in the Nuclear Industry, 2nd Edition, Nuclear Engineering International Special Publications, 2006.

142 Flirting With Disaster: Why Accidents Are Rarely Accidental by Marc Gerstein with Michael Ellsberg, Union Square Press, C 2008. P286-289

143 A full explanation of the numbers can be found in section 3.2 of this chapter.

144 Trevor Findlay 2010: The Future of Nuclear Energy to 2030 And Its Implications For Safety, Security And Nonproliferation. Part 2 – Nuclear Safety. http://www2.carleton.ca/cctc/ccms/wp-content/ccms-files/nef_part2.pdf

145 Ulrike Schaede, ‘“Old Boy” Network and Government-Business Relationships in Japan,” Journal of Japanese Studies, Vol. 21, No. 2 (Summer, 1995), pp. 293-317.

146 Akira Nakamura and Masao Kikuchi, “What we Know, and What We Have Not Yet Learned: Triple Disaster and the Fukushima Nuclear Fiasco in Japan,” Public Administration Review, November/December 2011, 893-899.

147 Fake questions on N-energy / Report finds 7 cases of events staged to promote nuclear power, The Yomiuri Shimbun, 2 October 2011. http://www.yomiuri.co.jp/dy/national//T111001002465.htm

148 Chihiro Kamisawa and Satoshi Fujino, “Revelation of Endless N-damage Cover-ups: the “TEPCO scandal” and the adverse trend of easing inspection standards,” Nuke Info Tokyo, Citizens Nuclear Information Centre, Nov./Dec 2002, No. 92.

149 Heavy Fallout From Japan Nuclear Scandal, CNN, 2 September 2002.

150 Mufson S (2007). Earthquake Spills Water At Japanese Nuclear Plant, The Washington Post, 17 July 2007.

151 Kazukuki Takemoto, "Looking Back Over the Year of TEPCO's Cover-up Defects," Nuke Info Tokyo, Citizens Nuclear Information Centre, Sep./Oct 2003, No. 97.

152 TEPCO cover up may have involved reactors last defense against radiation leak, Japan Times, 4 October 2002.

153 Ibid.

154 McGraw-Hill (2004). Nucleonics Week, Issues 2 and 48. Newsletter.

155 Japan's nuclear power operator has checkered past, Reuters, 12 March 2011.
http://www.reuters.com/article/2011/03/12/us-japan-nuclear-operator-idUSTRE72B1B420110312

156 Japan nuclear-site damage worse than reported , The New York Times, 19 July 2007.
http://www.nytimes.com/2007/07/19/world/asia/19japan.html?scp=1&sq=kashiwazaki&st=cse

157 Tabuchi H et al (2011). Japan Extended Reactor's Life, Despite Warning, The New York Times, 21 March 2011.

158 "Statement by Mr. Hiroyuki Hosoda Minister of State for Science and Technology Policy Delegate of the Government of Japan At the Forty-seventh General Conference of the International Atomic Energy Agency," September, 2003.
http://www.mofa.go.jp/policy/energy/iaea/state.html

159 Special Report: Japan engineers knew tsunami could overrun plant, Reuters, 29 March 2011.
http://www.reuters.com/article/2011/03/29/us-japa-nuclear-risks-idUSTRE72S2UA20110329

160 Special report: Fukushima long ranked most hazardous plant, Reuters, 26 July 2011.

161 Report of Japanese Government to IAEA Ministerial Conference on Nuclear Safety - Accident at TEPCO's Fukushima Nuclear Power Stations, June 7, 2011, Chapter XII: Lessons Learned So Far, page 12.
http://www.iaea.org/newscenter/focus/fukushima/japan-report/

162 The part on earthquake and Tsunami warnings of this section are based on Daily Yomiuri 17 April 2011: Tepco Ignored Tsunami Warnings for Years. The Daily Yomiuri 12 June 2011: Government, Tepco Brushed Off Warnings From All Sides.

163 National Institute of Advanced Industrial Science and Technology (AIST). 2011. Active Fault and Earthquake Research Center (AFER) Study on the 869 Jogan earthquake tsunami.
http://unit.aist.go.jp/actfault-eq/Tohoku/jogan_tsunami_e.html

164 Clenfield, J. 2011. Vindicated Seismologist Says Japan Still Underestimates Threat to Reactors, Bloomberg, 21 November 2011.
http://www.bloomberg.com/news/2011-11-21/nuclear-regulator-dismissed-seismologist-on-japan-quake-threat.html

165 Special Report: Japan engineers knew tsunami could overrun plant, Reuters, 29 March 2011.
http://www.reuters.com/article/2011/03/29/us-japa-nuclear-risks-idUSTRE72S2UA20110329

166 NUCLEAR CRISIS: HOW IT HAPPENED: Government, TEPCO brushed off warnings from all sides, The Daily Yomiuri, 12 June 2011.
http://www.yomiuri.co.jp/dy/national/T110611002697.htm

167 International Atomic Energy Agency (IAEA). 2011. Mission Report: The Great East Japan Earthquake Expert Mission, 24 May – 2 June 2011. p. 78.

168 International Atomic Energy Agency (IAEA). 2011. Mission Report: The Great East Japan Earthquake Expert Mission, 24 May – 2 June 2011. pp. 71 – 72.

169 Nishikawa J, Sasaki E (2011). TEPCO warned of big tsunami 4 days prior to March 11, The Asahi Shimbun, 25 August 2011.
http://ajw.asahi.com/article/0311disaster/quake_tsunami/AJ201108257639

170 Interim Report by the Investigation Committee on the Accidents at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, December 26, 2011, Executive Summary, section 6, part B, p. 15.
http://icanps.go.jp/eng/111226ExecutiveSummary.pdf

171 International Atomic Energy Agency (IAEA). 2011. Mission Report: The Great East Japan Earthquake Expert Mission, 24 May – 2 June 2011 p.78.

172 METI press release in Japanese:
http://www.meti.go.jp/press/20110207001/20110207001.pdf

173 The IAEA's safety guidelines states "…that accident initiators that have been treated historically as DBAs may have a frequency that is lower than 10–5 per year." See: International Atomic Energy Agency (IAEA). 2001. Safety Assessment and Verification for Nuclear Power Plant, No. NS-G-1.2, 2001, p. 43.
http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1112_scr.pdf

174 Thompson, G. 2008. Design and Siting Criteria for Nuclear Power Plants, January 2008, p. 13.
http://www.greenpeace.org/canada/Global/canada/report/2008/1/GP_IRSS_NPP_22-1-08.pdf.

175 World Nuclear Association. 2011.
http://www.world-nuclear.org.

176 International Atomic Energy Agency (IAEA). 2001. Safety Assessment and Verification for Nuclear Power Plants, Safety Guide, p. 73.

177 100,000/400=250

178 14,500 reactor years divided by 5 core-melt = one core-melt in 2,900 reactor years. Dr. Gordon Thompson, New and Significant Information from the Fukushima Daiichi Accident in the Context of Future Operation of the Pilgrim Nuclear Power Plant, Institute for Resource and Security Studies, 1 June 2011. Commissioned by the Office of the Attorney General, Commonwealth of Massachusetts.

179 2,900/400 = 7.25

180 Waddington JG (2009). Challenges to the regulation of Generation III reactors and the nuclear renaissance, Proceedings Volume 1, International Nuclear Law Association Congress 2009, Toronto, Canada.

181 DePers (2011). Kansen ramp kerncentrales nader bekeken, 31 March 2011.
http://www.depers.nl/binnenland/557957/Berekening-kernramp-onduidelijk.html

182 Speech by Tsunehisa Katsumata, "Reconstruction After Misconduct: The Pursuit of Excellence,"" 2003.
http://www.tepco.co.jp/en/news/presen/pdf-1/0310-e.pdf

183 International Atomic Energy Agency (IAEA). 2011. The Statute of the IAEA.
http://iaea.org/About/statute.html

184 International Atomic Energy Agency (IAEA). 2011. Fukushima Nuclear Accident Update Log. Full Update, Staff Report. 14 April 2011.
http://www.iaea.org/newscenter/news/2011/fukushimafull.html

185 Greenpeace radiation team pinpoints need to extend Fukushima evacuation zone. 2011. Greenpeace International, Press release, 27 March 2011.
http://www.greenpeace.org/international/en/press/releases/Greenpeace-radiation-team-pinpoints-need-to-extend-Fukushima-evacuation-zone-especially-to-protect-pregnant-women-and-children-/

186 Japan rejects Greenpeace argument for expanding evacuation zone, Reuters, 28 March 2011.
http://www.trust.org/alertnet/news/japan-rejects-greenpeace-argument-for-expanding-evacuation-zone

187 IAEA raises alarm over Japan evacuation, AFP, 30 March 2011

188 Japan not to widen nuclear evacuation zone. RTTNews, 31 March 2011.
http://www.rttnews.com/Story.aspx?type=msgn&Id=1588065&SM=1

189 Japan nuclear crisis: Pressure to widen evacuation zone, BBC, 31 March 2011
http://www.bbc.co.uk/news/mobile/world-asia-pacific-12916688

190 Tamakawa, T. 2011. IAEA becomes minor player in nuclear crisis, The Asahi Shimbun, 6 April 2011.
http://www.asahi.com/english/TKY201104050205.html

191 Govt officially sets new evacuation zone, The Yomiuri Shimbun, 23 April 2011

192 International Atomic Energy Agency (IAEA). 2011. Ministers' Declaration envisions strengthened nuclear safety regime, 20 June 2011.
http://www.iaea.org/newscenter/news/2011/confsafety200611-3.html

193 International Atomic Energy Agency (IAEA). 2011. Press Releases, IAEA Fact-finding team completes visit to Japan, 1 June 2011 http://www.iaea.org/newscenter/pressreleases/2011/prn201107.html

194 United Nations Radio. 2011. Confidence in nuclear power 'deeply shaken': IAEA chief, 22 September 2011.
http://www.unmultimedia.org/radio/english/2011/09/confidence-in-nuclear-power-%E2%80%98deeply-shaken%E2%80%99-iaea-chief/

195 International Atomic Energy Agency (IAEA). 2011. Cold Shutdown Conditions declared at Fukushima, 16 December 2011.
http://www.iaea.org/newscenter/news/2011/coldshutdown.html

196 For references see the following:

The Mainichi Daily News. 2012. Excessive radioactive cesium levels found at 38 Fukushima rice farms, 8 February 2012.
http://mdn.mainichi.jp/mdnnews/news/20120204p2g00m0dm012000c.html;
The Mainichi Daily News. 2012. High radioactive cesium levels detected in worms 20 km from nuke plant, 8 February 2012.
http://mdn.mainichi.jp/mdnnews/news/20120206p2a00m0na008000c.html; Koh, J. 2012. For Japan Locust Eaters, A Plague of Cesium? The Wall Street Journal, 13 January 2012.
http://blogs.wsj.com/japanrealtime/2012/01/13/for-japan-locust-eaters-a-plague-of-cesium/;
Fujimura, N. 2011. Mushrooms join growing list of radioactive threats to Japan´s food, Bloomberg, 13 August 2011.
http://www.bloomberg.com/news/2011-08-13/mushrooms-join-growing-list-of-radioactive-threats-to-japan-s-food-chain.html;
United Press International (UPI). 2011. Miyagi beef cattle shipments banned, 29 July 2011.
http://www.upi.com/Top_News/World-News/2011/07/29/Miyagi-beef-cattle-shipments-banned/UPI-71821311912119/

197 International Atomic Energy Agency (IAEA). 2007. International Regulatory Review Service (IRRS). Report to the government of Japan, Tokyo Japan, 25 to 30 June 2007
http://www.meti.go.jp/press/20080314007/report.pdf

198 International Atomic Energy Agency (IAEA). 2007. International Regulatory Review Service (IRRS). Report to the government of Japan, Tokyo Japan, 25 to 30 June 2007
http://www.meti.go.jp/press/20080314007/report.pdf

199 Ibid.

200 Ibid.

201 International Atomic Energy Agency (IAEA). 2007. IAEA issues report on Kashiwazaki-Kariwa nuclear plant, 17 August 2007.
http://www.iaea.org/newscenter/news/2007/kashiwazaki-kariwa_report.html

202 International Atomic Energy Agency (IAEA). 2012. IAEA Mission completes review of Japanese nuclear safety assessment process, 31 January 2012.
http://www.iaea.org/newscenter/news/2012/missioncompletes.html

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DURHAM NUCLEAR AWARENESS,
SLOVENIAN HOME ASSOCIATION &
THE CANADIAN ENVIRONMENTAL LAW ASSOCIATION

Comments on Ontario Power Generations' Review of the Environmental Impact Statement and Plant Parameter Envelope for the Darlington New Nuclear Project in the Context of the Proposed BWRX-300 Reactor

Prepared by:
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M.V. Ramana, Professor and Simons Chair in Disarmament, Global and Human Security

March 20, 2023

I. INTRODUCTION

Durham Nuclear Awareness (DNA) and Slovenian Home Association (SHA) together with the Canadian Environmental Law Association (CELA) and the expert review by Dr. M.V. Ramana,[1] submit this written report in response to the Canadian Nuclear Safety Commission's (CNSC) Notice of Participant Funding dated October 24, 2022 to review the environmental impact statement and plant parameter envelope for Ontario Power Generation's Darlington New Nuclear Project.[2]

DNA, SHA, and CELA's (herein, "the intervenors") report is the result of a review of two Ontario Power Generation (OPG) documents which have been made available to the public: *Use of Plant Parameters Envelope to Encompass the Reactor Designs being Considered for the Darlington Site* and *Darlington New Nuclear Project Environmental Impact Statement Review Report for Small Modular Reactor BWRX-300*. In addition to reviewing the documents submitted by OPG, this report considers the CNSC's jurisdiction pursuant to the *Nuclear Safety and Control Act* (NSCA), which requires that in making a licensing decision, the CNSC ensure the adequate protection of the environmental and human health. In meeting this objective, per section 24(4) of the NSCA, the intervenors' findings and concerns are itemized below. Our recommendations, including suggested licence and licence condition revisions are summarized in **Appendix A.**

II. INTEREST AND EXPERTISE OF THE INTERVENORS

i. Durham Nuclear Awareness

Durham Nuclear Awareness (DNA) is a citizens' group with a longstanding interest in the Darlington Nuclear Generating Station. DNA was first organized in 1986 in the wake of the Chernobyl disaster and born out of a need for people in Durham Region to come together, learn & empower themselves.

As a volunteer group of concerned citizens, DNA dedicates themselves to raising public awareness about nuclear issues facing Durham Region, and fostering greater public involvement in the nuclear decision-making process. DNA has appeared on numerous occasions before the CNSC and has a lengthy history lobbying for critical public health and safety measures, including improved emergency planning and baseline health studies, and setting standards for tritium in

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[1] M.V. Ramana is the Simons Chair in Disarmament, Global and Human Security and Professor at the School of Public Policy and Global Affairs, University of British Columbia, Vancouver, Canada.

[2] Canadian Nuclear Safety Commission, "Notice of Participant Funding" (24 October 2022), *PFP funding opportunities* (website), online: https://nuclearsafety.gc.ca/eng/the-commission/participant-funding-program/opportunities/participant-funding-review-environmental-impact-statement-plant-parameter-envelope-darlington.cfm

drinking water. DNA continues to advocate for upgrades to nuclear emergency plans to ensure the protection of communities in the event of a nuclear accident.

ii. Slovenian Home Association

SHA is a non-profit cultural organization dedicated to the preservation of Slovenian culture, language, heritage and identity in Canada. Many Slovenians reside in the vicinity of the Pickering and Darlington nuclear plants and are concerned about the proposed plans to expand nuclear power generation within the region, particularly with OPG proposing novel reactor technology at the Darlington site. Much of these concerns stem from emergency planning for nuclear accidents.

SHA members are not aware of what to do in case of a nuclear alert from the Province of Ontario. Some questions posed to SHA by its members include: *Should they be prepared to evacuate or stay at home? Where is their closest evacuation center? How to protect themselves by staying at home?* Despite emergency planning being a heavy concern for its members, SHA not been made aware of any public information meetings where the details of the actions taken by the citizens, in case of a nuclear alert, were discussed. SHA would welcome an opportunity to distribute emergency preparedness instructions to its members and to organize and host a preparedness workshop on the topic of emergency preparedness.

iii. Canadian Environmental Law Association

CELA is a non-profit, public interest law organization. CELA is funded by Legal Aid Ontario as a speciality legal clinic to provide equitable access to justice to those otherwise unable to afford representation for environmental injustices. For nearly 50 years, CELA has used legal tools to advance the public interest, through advocacy and law reform, in order to increase environmental protection and safeguard communities across Canada.

CELA has been involved in number of nuclear facility licensing and regulatory matters before the CNSC including federal environmental assessments. CELA also maintains an extensive library of public legal education materials related to Canada's nuclear sector on its website.[3]

iv. Dr. M.V. Ramana

Expert review of this submission was provided by M. V. Ramana, Professor and Simons Chair in Disarmament, Global and Human Security at the School of Public Policy and Global Affairs (SPPGA), University of British Columbia. M. V. Ramana has extensive knowledge of small modular nuclear reactor designs and expertise in analyzing the multiple risks associated with these

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[3] Canadian Environmental Law Association, online: www.cela.ca

and accompanying adverse environmental effects. His research interests are in the broad areas of international security and energy supply, with a particular focus on topics related to nuclear energy and fissile materials that can be used to make nuclear weapons. He combines technical skills and interdisciplinary methods to address policy relevant questions related to security and energy issues.

III. BACKGROUND

A. Project Summary

When OPG entered the environmental assessment process to construct a new nuclear power plant at its Darlington site, there had not been a specific technology selected. In order to continue with the assessment at that time, a bounding approach was adopted, and a Plant Parameter Envelope (PPE)—a concept used in the United States—was implemented to consider various reactor designs in the assessment of environmental effects. This is the first and only nuclear project in Canada to rely on a PPE for a licencing application, and to the Intervenors' knowledge, is not being used in other jurisdictions when preparing nuclear power generation site licences.[4]

In the original licence application from 2009,[5] federal environmental assessment and the CNSC's deliberations at that time considered three water cooled designs: two pressurized (light) water reactor designs, and one pressurized heavy water reactor design.

In October 2020, OPG announced that "it is advancing engineering and design work with three grid-scale Small Modular Reactor (SMR) developers: GE Hitachi, Terrestrial Energy and X-Energy" for the Darlington nuclear site.[6]

In 2011, the Joint Review Panel overseeing the Environmental Assessment of the New Nuclear Power Plant Project released its Environmental Assessment Report. The first recommendation within the report stated:

> The Panel understands that prior to construction, the Canadian Nuclear Safety Commission will determine whether this environmental assessment is applicable to the reactor technology selected by the Government of Ontario for the Project. Nevertheless, <u>if the selected reactor technology is fundamentally different from the specific reactor</u>

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[4] The Intervenors submit that the nuclear licencing regime in the United States is more prescriptive than that of Canada. As a result, the use of a PPE within a Canadian nuclear project's licence application is supplanting from a different context, and therefore doesn't translate.

[5] *Use of Plant Parameters Envelope to Encompass the Reactor Designs Being Considering for the Darlington Site*, by Ontario Power Generation (2009).

[6] *Feasibility of Small Modular Reactor Development and Deployment in Canada.*, by SaskPower, Energie NB Power & Ontario Power Generation (2021), online (pdf): https://www.opg.com/documents/feasibility-of-smr-development-and-deployment-in-canada-pdf/, at 24.

> technologies bounded by the plant parameter envelope, the Panel recommends that a new environmental assessment be conducted [emphasis added].[7]

The PPE was designed to predict the adverse effects for a select group of reactor technologies.[8] To determine whether the selected reactor technology is "fundamentally different" from the specific reactor technologies bounded by the PPE, the Joint Review Panel explained that "the selection of a reactor technology that is not one of the four designs considered will require careful review to confirm the continued applicability of the assumptions and conclusions of this environmental assessment."[9]

Now that OPG has selected the GE BWRX-300 reactor technology for the proposed reactor at the Darlington site, this technology must be compared to the bounding parameters of the PPE and the findings within the EIS from 2009.

B. Scope of Review

For the purpose of determining whether the proposed BWRX-300 reactor technology fits within the parameters of the 2009 Environmental Impact Statement (EIS) and the Plant Parameter Envelope (PPE), the Intervenors reviewed a number of documents released by OPG and the CNSC, including, but not limited to:

- Project Description for the Site Preparation, Construction and Operation of the Darlington B Nuclear Generating Station Environmental Assessment (2007)
- The 2009 EIS;
- Use of Plant Parameters Envelope to Encompass the Reactor Designs Being Considered for the Darlington Site (2009);
- The Joint Review Panel's Environmental Assessment Report (2011);
- The BWRX-300 Preliminary Safety Assessment Report (2022);
- The EIS Review Report (2022)
- The Use of PPE to Encompass Reactor Designs being considered for the Darlington Site (2022);
- The Darlington New Nuclear Project Licence to Construct Application Plan (2022);
- Darlington New Nuclear Project Environmental Impact Statement Review Report for Small Modular Reactor BWRX-300 (2022);
- The executive summary of the Canadian Nuclear Safety Commission's Combined phases 1 and 2 pre-licensing vendor design review for the BWRX-300.

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[7] *Joint Review Panel Environmental Assessment Report: Darlington New Nuclear Power Plant Project*, by Joint Review Panel, Environmental Assessment (2011), at iv, *emphasis added.* [**EA Report**].
[8] *Ibid*, at 45.
[9] *Ibid*.

In addition to these documents, the Intervenors considered federal and provincial legislation, various CNSC REGDOCs and CMDs, international nuclear standards documents, and academic studies regarding nuclear power and small modular reactors.

IV. PRELIMINARY MATTERS & PROCEDURAL CONCERNS

Transparency and disclosure of documents of critical value should be a priority in licencing stages

In many prior submissions to the CNSC for the Darlington site, the Intervenors have requested the CNSC direct the public release of studies and accident modelling.[10] We again bring this concern to the attention of the Commission in regard to the ongoing public non-disclosure to the public of the Provincial Nuclear Emergency Response Plan (PNERP) Technical Study from the Office of the Fire Marshall and Emergency Management (OFMEM).

While CELA has obtained a copy on request, CELA has repeatedly requested that the CNSC direct CNSC staff to obtain the PNERP Technical Study from the OFMEM and make it publicly available.[11] Presently, for members of the public to obtain a copy of the PNERP Technical Study, they must submit a request through the OFMEM website or contact the CNSC for a copy. There is no indication for how long it will take for either entity to respond such a request. Because the CNSC has been given permission by the OFMEM to share the Technical Study with anyone who requests it, the CNSC should make this report publicly available on the CNSC website.

The importance of this study to public health and safety cannot be underestimated. As the CNSC has previously stated, the PNERP Technical Study examines "the planning basis for the Pickering, Darlington, Bruce Power and Fermi 2 areas through robust modelling" and once released, "Ontario licensees plan to revise their training programs for new emergency response staff accordingly."[12] Previous correspondence from OFMEM has indicated that the impact on drinking water supply in the event of a nuclear accident was part of the technical study.[13] Now that OPG has selected a specific SMR technology to be situated at the Darlington site, it is crucial for the CNSC to consider

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[10] *See for instance:* DNA, *DNA Request for Ruling* (2015); DNA, *DNA Submission for the Application to Renew OPG's licence for the Darlington Nuclear Generating Station (CMD 15-H8.29)* (2015) at p 6 citing September 21, 2015 letter to Ms. Theresa McClenaghan, Canadian Environmental Law Association from CNSC Commission Secretary Marc Leblanc [**DNA 2015]**

[11] *See* Sara Libman, *Submission by the Canadian Environmental Law Association to the Canadian Nuclear Safety Commission Regarding the Regulatory Oversight Report for Canadian Nuclear Power Generating Sites: 2021* (CELA, 2022), Requested Action no. 5, online (pdf): https://cela.ca/wp-content/uploads/2022/09/1493-Submission-to-CNSC-ROR-NPGS-2022.pdf.

[12] CNSC, Transcript November 6, 2019, online (pdf): http://www.suretenucleaire.gc.ca/eng/the-commission/pdf/2019-11- 06-Meeting-Final-e.pdf (last visited May 2021), at p 137

[13] CNSC, Transcript November 8, 2018, online (pdf): http://www.nuclearsafety.gc.ca/eng/the-commission/pdf/2018-11- 08-Meeting-e.pdf (last visited May 2021).

how the choice of the BWRX-300 reactor design impacts the findings in the PNERP Technical Study related to drinking water supply, as the information about these technology was not available during the preparation of the PNERP Technical Study. The PNERP Technical Study provides a specific discussion surrounding the offsite dose consequence results for the Design Basis Accidents (DBA), Beyond Design Basis Accident (BDBA) and Severe BDBA scenarios modelled from the DNGS vacuum building.[14] How the BWRX-300 reactors would impact the original findings of offsite dose consequences for DBA, BDBA and Severe DBA from the Darlington site needs to be determined.

In prior licensing hearings, many public interest intervenors including DNA and CELA have sought clarification from the CNSC setting out the plans and arrangement made to protect drinking water supplies as required by the PNERP.[15] We remain of the view that as all of Ontario's nuclear reactors are located on the Great Lakes - which supplies the drinking water to 40 million Canadians and Americans - it is not only necessary to protect drinking water supplies, but require contingency planning in the event of an accident. With the PNERP Technical Study not being easily accessible for members of the public, there is no publicly available study of drinking water and contingency planning in the event of an accident. Without such a study, it is not possible to reliably evaluate new nuclear proposals.

In a similar vein, the Intervenors raise the issue of ease of access for reviewing documents related to the review of OPG's application of the EIS and PPE to the BWRX-300 reactors. When reading through the *Preliminary Safety Analysis Report*, there are references and pinpoints to documents that are not quickly available to read. In order to access these referenced documents, an individual needs to either reach out to OPG or the CNSC for access. While the Intervenors have been provided with participant funding to compensate for the time needed to review and comment on materials, a member of the public who simply wishes to submit a comment on the www.letstalknuclearsafety.ca website may not have the luxury of time to compile a list of documents they would like to read, contact either OPG or the CNSC and the wait to receive the documents to see if they are relevant for their comment. There is also no indication as to how long an information request would take to be fulfilled, and whether the documents will be shared at all; the Intervenors had requested a number of documents from OPG and the CNSC prior to the deadline to submit a written comment, and at the time of this report's submission, the request has not even been acknowledged. The Intervenors submit that this further diminishes the capacity for members of the public to meaningfully engage with the materials provided for these public commenting periods.

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[14] ENERCON, "Technical Study Report on the Provincial Nuclear Emergency Response Plan (PNERP)", Emergency Management Ontario, (March 7, 2019), at p. 41

[15] Ontario, "Provincial Nuclear Emergency Response Plan (PNERP), Master Plan" (2017), online (pdf): https://files.ontario.ca/books/solgen-emo-pnerp-master-plan-2017-en-2022-01-06.pdf, at ch 2.2.5(f).

To increase transparency, the Intervenors submit that OPG should be required to make all non-confidential documents readily available for public viewing, either via hyperlinks within documents, or through an archived database on their website. Information must be shared with the public in a timely manner.

Recommendation No. 1: As the PNERP Technical Study has been released by the province of Ontario to the CNSC, we request licensing documents be revised to directly respond to its findings.

Recommendation No. 2: Because the CNSC has been given permission by the OFMEM to share the PNERP Technical Study with anyone who requests it, the CNSC should make this report publicly available on the CNSC website.

Recommendation No. 3: The CNSC should review the PNERP Technical Study and as part of the review of the EIS and the PPE within the context of the proposed BWRX-300 reactor technology, demonstrate the sufficiency of contingency planning for the protection of drinking water, such as Lake Ontario, in the event of an emergency.

Recommendation No. 4: To increase transparency, the Intervenors submit that OPG should be required to make all non-confidential documents readily available for public viewing, either via hyperlinks within documents, or through an archived database on their website. Information must be shared with the public in a timely manner.

V. ACTION REQUESTED OF THE COMMISSION

The Intervenors submit OPG's proposed deployment of up to four GEH BWRX-300 small modular reactors (SMRs) for the Darlington New Nuclear Project (DNNP or Darlington site) does not fit within the parameters of the Environmental Impact Statement (EIS) or the Plant Parameter Envelope (PPE). The following shortfalls will be discussed in greater detail throughout this report:

A. The BWRX-300 reactor is 'fundamentally different' from the variety of technologies captured within the EIS and PPE approved under for the federal environmental assessment (EA) of this project;

B. OPG's two documents, *Use of Plant Parameters Envelope to Encompass the Reactor Designs being Considered for the Darlington Site* (*Use of PPE 2022*)[16] and *Darlington New Nuclear Project Environmental Impact Statement Review Report for Small Modular*

[16] *Use of Plant Parameters Envelope to Encompass the Reactor Designs being Considered for the Darlington Site*, by Ontario Power Generation (October 2022), online: https://www.opg.com/powering-ontario/our-generation/nuclear/darlington-nuclear/darlington-new-nuclear/#documents [***Use of PPE 2022***]

> *Reactor BWRX-300* (*EIS Review Report*)[17], fail to adequately address the significant changes in our understanding of the likelihood, types, and consequences of nuclear accidents which have occurred since their 2009 licence application, EIS and EA and thus, these documents are no longer current nor validly reflect present circumstances or current knowledge.

We request that a new environmental assessment be conducted for the BWRX-300 reactor(s) due to the above reasons.

In the alternative that the CNSC deems the BWRX-300 reactor design to be consistent with the parameters of the PPE and EIS (which the Intervenors submit it is fundamentally different), we submit that a before a licence to construct (LTC) process commences, the aforementioned issues must be resolved in order to bring the selected reactor technology within the approved parameters of the EIS and PPE.

A. The BWRX-300 reactor is 'fundamentally different' from the variety of technologies captured within the EIS and PPE

This concern of the intervenors results from having reviewed the long list of documents mentioned above as well as other relevant and available supporting materials. We have also reviewed the 2009 Environmental Impact Statement (EIS), and the 2012 environmental assessment (EA) completed by a Joint Review Panel (JRP) under Canada's previous environmental assessment legislation, *Canadian Environmental Assessment Act*.[18]

A thorough review of these documents indicate that the selected technology, BWRX-300 reactor, is fundamentally different from various forms of technology previously considered to shape the EIS and the PPE for this project site. The proposed BWRX-300 reactor is significantly different from various forms of technology previously considered to shape the EIS and PPE for this Project site. Significant changes to the reactor design means that the applicability of the assumptions and conclusions developed in the PPE are not transferable to the BWRX-300 reactor technology. As a result of significant differences in the reactor design, waste management requirements, and unique safety concerns, which are discussed below, the BWRX-300 does not fit within the parameters of the PPE or EIS and thus warrants a new environmental assessment specific to the selected technology

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[17] Ontario Power Generation, *Darlington New Nuclear Project Environmental Impact Statement Review Report for Small Modular Reactor BWRX-300*, by Ontario Power Generation (October 2022), online: https://www.opg.com/powering-ontario/our-generation/nuclear/darlington-nuclear/darlington-new-nuclear/#documents [***EIS Review Report***]

[18] *Canadian Environmental Assessment Act*, SC 1992, c 37 [CEAA 1992]

i. Reactor Design

The Intervenors submit that the BWRX-300 reactor technology proposed by OPG is significantly different from the technologies considered by the existing PPE and the EIS.

Table 1 in the 2009 document *Use of Plant Parameters Envelope to Encompass the Reactor Designs Being Considered for the Darlington Site* includes a number of parameters, including 9.33, 9.3.4, 9.5.2, and 10.1.2, that deal with the potential events that could be of greatest environmental consequence: design basis and severe (beyond design basis) accidents.[19] These deal with the airborne and liquid releases of radioactivity to the environment during accidents. Calculation of these parameters would require a full consideration of all potential accidents, and these will be very different from the potential accidents to be considered in the case of AP1000, EPR, and ACR-100. This becomes clear when looking through the list of the emergency cooling systems of the four different reactor designs in *EIS Review Report*: the BWRX-300 is the only one that uses a Passive Isolation Condenser System (ICS).[20]

Unlike CANDU designs and the EPR that include some kind of an emergency core cooling system, whose reliability is well understood, there are significant uncertainties about passive safety systems like the ICS. In 2016, France's Institut de radioprotection et de sûreté nucléaire published an extensive report explaining why passive safety systems have unique challenges, for example with regard to "producing conclusive probabilistic safety assessments (PSAs), in particular due to the difficulty of assigning failure probabilities to passive safety systems under all conditions covered by PSAs, and the lack of operational feedback on the reliability of such systems under accident conditions".[21]

In the case of ICS, the system relies on "motor operated valves" that have to start operating "during transients, for instance, upon high reactor pressure or low reactor water level".[22] There are various other possible routes to the failure of the safety system, including due to causes like excessive fouling of pipes and insufficient water in the pool. Such failure modes simply do not exist in the case of the EPR design or various CANDU designs.

Further, in its pre-licensing vendor design review, the Canadian Nuclear Safety Commission (CNSC) listed a number of "technical areas that need further development in order for GEH to

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[19] Ontario Power Generation, "Use of Plant Parameters Envelope to Encompass the Reactor Designs Being Considered for the Darlington Site" (2009) at pp. 36-38.
[20] *EIS Review Report*, *supra* note 17, at 11.
[21] IRSN, *Considerations on the performance and reliability of passive safety systems for nuclear reactor*s, (2016), online: http://www.irsn.fr/EN/newsroom/News/Pages/20160107_Considerations-on-the-performance-and-reliability-of-passive-safety-systems-for-nuclear-reactors.aspx (last visited Feb 4, 2016), at 5.
[22] Burgazzi, Luciano, "Passive System Reliability Analysis: A Study on the Isolation Condenser" (2002) 139:1 Nuclear Technology 3–9, at 5.

better demonstrate adherence to CNSC requirements."[23] Specifically, the CNSC identified "severe accident analysis and the corresponding engineered features credited for mitigation" as needing further detail, and not demonstrably meeting "the requirement for 2 separate, independent and diverse means of reactor shutdown, or else an alternative approach, with justification".[24] Because these have not been demonstrated, and there is inadequate detail available about the BWRX-300 (more on this below), it is not clear how OPG could have carried out a safety assessment and come up with reliable numbers for parameters related to design basis and beyond design basis accidents.

So far, the BWRX-300 design has not been licensed by the Canadian Nuclear Safety Commission (CNSC) or any other nuclear safety regulatory authority. In the absence of regulatory approval, there is not even a minimal guarantee that this design will perform safely. Further, a separate concern is that GE-Hitachi might choose to revise the BWRX-300 design in the future. There is historical precedent for such a concern. The BWRX-300 is based on GE-Hitachi's Economical Simplified Boiling Water Reactor (ESBWR) design, which was submitted for licensing to the U.S. Nuclear Regulatory Commission in 2005.[25] That design was changed nine times; the NRC finally approved revision 10 from 2014.[26] Therefore, there is reason to be concerned that the BWRX-300 design might be revised.

All these factors give us reason to question the claim about the compatibility of the BWRX-300 with the other large reactors in *The Use of PPE to Encompass Reactor Designs being considered for the Darlington Site* document of 2022[27].

Recommendation No. 5: OPG should carry out a full-fledged severe accident analysis taking into account the challenges of estimating the reliability of the Passive Isolation Condenser System in order to show how the BWRX-300 design will adhere to CNSC requirements.

Recommendation No. 6: OPG must address how it intends to ensure the proposed reactors twill meet the requirement for 2 separate, independent and diverse means of reactor shutdown.

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[23] CNSC, "Executive Summary: Combined phases 1 and 2 pre-licensing vendor design review –General Electric Hitachi Nuclear Energy" (March 15, 2023), online: https://nuclearsafety.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/geh-nuclear-energy-executive-summary.cfm

[24] *Ibid.*

[25] Office of Nuclear Reactor Regulation, "Acceptance of The General Electric Company Application for Final Design Approval and Standard Design Certification for The Economic Simplified Boiling Water Reactor (ESBWR) Design," United States Nuclear Regulatory Commission (December 1, 2005), online (pdf): https://www.nrc.gov/docs/ML0532/ML053200311.pdf.

[26] United States Nuclear Regulatory Commission, "GE-Hitachi Design Control Document Tier, Revision 10." nrc.gov (April 14, 2014), online: https://www.nrc.gov/docs/ML1410/ML14104A929.html

[27] *Use of PPE 2022, supra* note 16.

ii. Waste Management

Our understanding of the risks involving spent fuel and potential accidents involving such fuel has evolved significantly since the understanding captured in the 2009 PPE and EIS.

Since the 2011 Fukushima disaster, nuclear safety analysts have come to appreciate how risky it is to accumulate spent nuclear fuel from nuclear power plant operation and store it in a cooling pond at the reactor site. At Fukushima, spent fuel in the dense-packed pool of the Unit 4 reactor was in danger of overheating and caching fire. The radioactivity source term from such a potential fire was much greater than from just one of the reactors. Had this fire broken out and had the wind been blowing toward Tokyo, 35 million people might have required relocation.[28]

This understanding of the risks associated with dense packing of nuclear fuel is absent in the 2009 PPE and thus requires a more careful and fulsome analysis of the potential environmental and public health impact associated with any reactors built in Darlington. At the same time, the situation with any plans for permanent disposal of spent fuel remains the same as it was in 2009: there is still no geological repository operating in Canada, and thus there is no option but on-site storage of spent fuel and radioactive waste from nuclear power plants.

Recommendation No. 7: OPG should conduct a thorough assessment of the hazards associated with spent fuel fires at the Darlington nuclear power plant.

iii. Accidents and Malevolent Acts

Upon reviewing the *EIS Review Report* and the *Use of PPE 2022*, there is insufficient information to determine whether the BWRX-300 technology aligns with the parameters of safeguarding against malfunctions, accidents, and malevolent acts. With an absence of information regarding the BWRX-300 model's approach to mitigating accidents and malevolent acts, it is not possible to confirm that this proposed technology adheres to the conclusions within the PPE and the EIS regarding the significance of adverse environmental effects.

<u>Accidents</u>

While the *Preliminary Safety Analysis Report* indicates that a malevolent large aircraft crash is analyzed in the Security Annex, large civil aircraft accidents have been screened out due to the

[28] Richard Stone, "Near Miss at Fukushima is a warning for U.S." (2016) 352:6289 Science 1039–1040, at 1039; Committee on Lessons Learned from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants, *Lessons Learned from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants: Phase 2* (2016), online: http://www.nap.edu/catalog/21874 (last visited May 28, 2016); Frank N von Hippel & Michael Schoeppner, "Reducing the Danger from Fires in Spent Fuel Pools" 24:3 Sci Glob Secur 141–173, at 141.

Quantitative criteria indicating a low frequency of events (frequency of <1.0E-7/yr).[29] The Intervenors submit that the low frequency of commercial aircraft accidents should not be a reason to screen out the risk, as the CNSC requires licensees to respect the precautionary principle.[30] This means that lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation.[31] The Intervenors submit that a low frequency of events does not eliminate the uncertainty of the hazard. The *Preliminary Safety Analysis Report* notes that the reactor building is designed to withstand large aircraft impact,[32] but it is unclear whether waste storage facilities are designed to withstand such an impact as well. The Intervenors request that OPG analyze the hazards associated with and impacts due to a commercial aircraft accident, no matter how unlikely such an accident might be deemed.

<u>Multi-Unit Reactor Accidents</u>

During the licence renewal hearing in 2021, the Intervenors recommended that the potential for and effects of a multi-unit reactor accident is among the detailed review which must be updated in light of SMRs being proposed for the Darlington site.[33] Engineers and other technical experts rely primarily on the use of multiple protective systems, all of which would have to fail before a radioactive release could occur. This approach is known as "defense-in-depth," and it is often advertised as an assurance of nuclear safety. However, as demonstrated by the 2011 accidents at the Fukushima Daiichi nuclear plant, there are occasions when multiple safety systems do fail at the same time - and these occur far more frequently than technical analysts seem to assume.[34] Indeed, one of the reactors that underwent an explosion at Fukushima was a 460MW reactor – a size not dissimilar to the proposed 300MW BWRX-300 reactor.

Fukushima revealed the dangers of building multiple reactors in a single location; accidents at one reactor increases the likelihood of accidents at nearby reactors, and therefore complicating emergency actions. The Intervenors maintain that it would be prudent to assume that a large release could well include early releases from several sources simultaneously.

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[29] *Ontario Power Generation Inc. Darlington New Nuclear Project: BWRX-300 Preliminary Safety Analysis Report*, by Ontario Power Generation, Revision 0 (2022), at 2-21. [**Preliminary Safety Analysis Report**]

[30] CNSC RegDoc-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures,* Version 1.2 at s 2.1.

[31] CNSC, *Glossary of CNSC Terminology,* REGDOC-3.6.

[32] *Preliminary Safety Analysis Report*, *supra* note 29 at 15-132.

[33] Kerrie Blaise & M.V. Ramana, "Comments on Ontario Power Generations Nuclear Power Reactor Site Preparation Licence for the Darlington Site", CELA (3 May 2021), online (pdf): https://cela.ca/cela-and-durham-nuclear-awareness-written-intervention-to-cnsc-for-opgs-site-licence-renewal-at-darlington/, at 11 [2021 Site Licence Renewal Submission]

[34] M. V. Ramana, "Beyond Our Imagination: Fukushima and the Problem of Assessing Risk" (19 April 2011), *Bulletin of the Atomic Scientists*, online: https://thebulletin.org/2011/04/beyond-our-imagination-fukushima-and-the-problem-of-assessing-risk/

While the *Preliminary Safety Analysis Report* provides a discussion of the defence-in-depth approach for the BWRX-300 reactors, it does not clarify how the Darlington Nuclear Generating Station (DNGS)—the existing CANDU reactors at the Darlington site—fit into the analysis. As mentioned within the *EIS Review Report*, the DNGS is currently being refurbished, and dismantling will not occur until approximately 2055.[35] With the timeline, the DNGS would still be in operations during the deployment of the BWRX-300 reactors. As a result of proximity, a nuclear accident at the DNGS would have an impact on the BWRX-300 reactors, and vice versa.

Therefore, emergency measures need to be accordingly modified and the size of zone that might have to be evacuated should be expanded. The concept of a multi-unit accident at the Darlington site extends beyond the four proposed BWRX-300 reactors because of the pre-existing nuclear power station at the Darlington site, and this must be reflected in OPG's emergency planning.

Malevolent Acts

The recent war in Ukraine emphasizes the risk that conflict and malevolent acts pose to nuclear power generating sites, as no nuclear power plant in the world has been designed to operate under wartime conditions.[36] While the likelihood of the Darlington site being subjected to militarized conflict is admittedly extremely low, that was the case with the Tsunami inundating the Fukushima Daiichi nuclear plant. The subsequent events showed a lack of preparedness for rare accidents. The lesson is that the threats of military activities and malevolent acts should not be ignored in the analysis of the BWRX-300 technology. Upon reviewing the *Preliminary Safety Analysis Report*, the Intervenors have identified a number of concerns with the mitigation of malevolent acts.

For instance, when screening site specific hazards, large military aircraft have been screened out on the grounds that because large bombers, large cargo planes, fuel tankers, or heavily armed jet fighters do not fly in the vicinity of the Bowmanville airspace, a large military aircraft accident cannot occur at or close enough to the site to affect BWRX-300.[37] The Intervenors submit that while it is highly unlikely that a large military aircraft would be within the airspace near the Darlington site, the possibility of the hazard impacts should not be omitted, especially now that we are living in an era in which military conflict is resulting in military occupation of nuclear power generation sites. The Intervenors request that that OPG revisit hazards of a large military aircraft accident in proximity to the BWRX-300 reactors.

In terms of assessing the hazards associated with drones, OPG notes that "the impact of drones hitting the BWRX-300 Structures Systems and Components (SSCs) is bounded by small aircraft

[35] *EIS Review Report*, *supra* note 17 at 90.

[36] *The World Nuclear Industry Status Report*, by M Schneider & A Froggat, WNISR (October 2022), online (pdf): https://www.worldnuclearreport.org/IMG/pdf/wnisr2022-lr.pdf, at 27.

[37] *Preliminary Safety Analysis Report*, *supra* note 29 at 2-21.

crash,"[38] and refers to the United States Nuclear Regulatory Commission's review of impact of drones on U.S. Nuclear Power Plants, which states:

> The technical analysis concluded that U.S. nuclear power plants do not have any risk-significant vulnerabilities that could be exploited by adversaries using commercially available drones to result in radiological sabotage, theft, or diversion of special nuclear material (essentially the reactor fuel).[39]

Based on this analysis, OPG decided that drones are screened out of the external hazards assessment. Considering the wide variety drone types, the malevolent use of drones may extend beyond crashing into reactor's structures, and may involve drones that are not commercially available (i.e., military equipment). Therefore, it is important that OPG conducts a hazard assessment of malevolent drone use on SMRs like the BWRX-300 reactor model, even if the likelihood of such an event occurring is low.

Recommendation No. 8: The Intervenors submit that the low frequency of commercial aircraft accidents should not be a reason to screen out the risk. OPG must analyze the hazards associated with and impacts due to a commercial aircraft hitting the reactor building, or the waste management facilities, or any of other facilities and buildings located on the Darlington site.

Recommendation No. 9: The potential for and effects of a multi-unit accident must take into consideration the relationship between the existing reactors of the Darlington Nuclear Generating Station and the proposed BWRX-300 reactors.

Recommendation No. 10: OPG needs to revisit the hazard assessment of a large military aircraft accident in proximity to the BWRX-300 reactors.

Recommendation No. 11: OPG should conduct a hazard assessment of malevolent drone use on SMRs like the BWRX-300 reactor design, even if the likelihood of such an event occurring is low.

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[38] *Ibid* at 15-133.

[39] *Ibid*. Note: the technical analysis itself is classified, and so the details of this study are not available to the public in order to understand its applicability to SMRs like the BWRX-300 reactors. See: U.S.NRC, "Drones and Nuclear Power Plant Security" (4 November 2020), online: https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-drone-pwr-plant-security.html#analysis.

iv. Decommissioning Phase

The EIS Guidelines for the DNNP required that the EIS include a preliminary decommissioning plan, and that the EIS should specifically identify the following:

> The preferred decommissioning strategy, including a justification of why this is the preferred strategy. It must also include end-state objectives, the major decontamination, disassembly and remediation steps; the approximate quantities and types of waste generated; and an overview of the principal hazards and protection strategies envisioned for decommissioning.[40]

The decommissioning of a nuclear reactor is a complex process, involving the reactor's shut-down, deactivation, and its decontamination.[41] Without a specific technology being selected at the time the EIS was prepared, the discussion of decommissioning was broad and only offered a high-level overview of the potential decommissioning plans. With the selection of the BWRX-300 reactor technology, it was expected that OPG would provide more detail on the preferred decommissioning strategy however, the *EIS Review Report* does not provide such details on a more tailored decommission phase for the DNNP site.

In the *EIS Review Report*, OPG states "as the decommissioning strategy for the BWRX-300 has not been established, it is assumed that the overall approach and principles to be applied for decommissioning of the BWRX-300 reactors are consistent with those described in the EIS."[42]

OPG's claims that the BWRX-300 reactors' effects are anticipated to be similar as considered in the EIS.[43] Without a preliminary decommissioning plan for the BWRX-300 reactors available for review, the Intervenors submit that it is not possible to determine whether the decommissioning of these proposed reactors will actually fit within the parameters of the EIS. With the fundamentally different elements of reactor design and waste management requirements for the proposed BWRX-300 reactors, more information is required to understand the preferred decommissioning strategy for the selected technology.

For example, the BWRX-300 reactor requires a substantially deeper foundation than the reactors assessed in the EIS, as the BWRX-300 foundation embedment is 38m below grade compared to a

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[40] Ontario Power Generation, *Environmental Impact Statement: New Nuclear - Darlington Environmental Assessment*, by SENES Consultants Limited & MMM Group Limited (2009), at p. 12-1. [**2009 EIS**]

[41] Kerrie Blaise & Shawn-Patrick Stensil, "Chapter 9: The Evolution of Decommissioning Planning: Tracing the Requirements to Consider Radioactive Wastes and Social Risk of Nuclear Power Plants" in *Nucl Non-prolif Int Law* (ASSER PRESS, 2021), at 228.

[42] *EIS Review Report, supra* note 17, at 42.

[43] *Ibid.*

maximum of 13.5m[44] below grade for all of the reactors considered in the EIS. One of the concerns with decommissioning land-based SMRs is the decommissioning of underground elements, as "…decommissioning of underground designs may lead to increased magnitude and profile of effects to soil quality depending on the method of decommissioning (e.g. complete removal vs. decommissioning in situ)."[45] The *EIS Review Report* does not analyze how the greater foundation depth of 38m would impact the decommissioning a BWRX-300 reactor in comparison to the technologies previously considered within the EIS.

According to the *EIS Review Report*, "the phases of decommissioning described in the EIS are Preparation for Safe Storage, Safe Storage and Monitoring (if required), and Dismantling, Disposal, and Site Restoration."[46] Despite OPG having selected a type of reactor technology, the *EIS Review Report* falls silent on whether monitoring is a required phase of decommissioning for the BWRX-300 reactors. The Intervenors submit that without a decommissioning plan designed specifically for a BWRX-300 reactor, it is not possible to determine whether the technology selected by OPG is in compliance with the EIS. We request that the CNSC require OPG to outline a non-theoretical decommissioning plan for the BWRX-300 reactors before any further assessments occur for the DNNP site.

Recommendation No. 12: Without a decommissioning plan designed specifically for a BWRX-300 reactor, it is not possible to determine whether the technology selected by OPG is in compliance with the EIS. We request that the CNSC require OPG to outline a detailed and non-theoretical decommissioning plan for the BWRX-300 reactors before any further assessments occur for the DNNP site.

B. OPG's review of the EIS and PPE in the context of the BWRX-300 reactor fails to adequately address the significant changes which have occurred since 2009

The intervenors submit that the *Use of PPE 2022* and the *EIS Review Report* both fail to adequately address the many significant changes which have occurred since the 2009 licence application and EIS and the 2012 EA, such that these documents are no longer current and fail to reflect present circumstances. Over the course of the last decade, there has been significant changes across the province requiring a new analysis of how BWRX-300 reactors would interact with public awareness, land use planning and site suitability, emergency planning, and climate change.

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[44] *Ibid* at 10.

[45] International Atomic Energy Agency, "Considerations for Environmental Impact Assessment for Small Modular Reactors", IAEA-TECDOC-1915 (2020), at 14.

[46] *Ibid*.

i. Public Awareness

Since 2009, the population within the Greater Toronto Area has rapidly grown. The population growth rate from 2016 to 2021 for the distant suburb of Toronto (areas located 30 minutes or more from downtown Toronto) was +9.4%.[47] As the population and population density in the Greater Toronto Area continues to grow, including in population and density in close proximity to multiple nuclear facilities, public awareness is critical to effectively responding to accidents. However, most citizens in the Greater Toronto Area are not aware that they live within the Ingestion Planning Zone – extending 50km from nuclear facilities - of not one but two very large nuclear generating stations. Even fewer are aware that Durham Region is now slated to host Canada's first grid-scale SMRs. If an accident similar to the Fukushima disaster were to occur here – a serious multi-unit accident involving a large radiation release – evacuation will become necessary.

Despite the history of nuclear operations in Durham Region, most people do not know:

1. Who is responsible for nuclear emergency plans in Ontario/Durham Region? This became evident on January 12, 2020, when thousands of Ontarians were awoken by an alert from the Province of Ontario indicating that an incident was reported at the Pickering nuclear power plant. Following the alert, the public was unsure who to look to for authoritative messaging. Indeed, there was a dizzying number of government departments and agencies involved.

   As an independent review by Global Public Affairs found,[48] most CNSC staff explained that the January 12 incident tested the CNSC because there was no existing communications protocol for non-nuclear emergencies and that no previous training or exercise had focused on what to do in the event of a false alert.[49] Further, while staff agreed that the false alarm event served as an important learning opportunity, serious concerns were raised regarding staff resources, noting that CNSC would be hard-pressed to fully staff a 24/7 emergency communications group for a sustained period.[50]

2. What information sources should citizens rely on should an emergency occur? Related, if the emergency coincides with a power outage (whether induced or pre-existing due to weather, for instance) how confident is the CNSC that citizens will promptly be informed of necessary, potentially lifesaving information?

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[47] Statistics Canada, "Map 1: Urban spread is continuing in the census metropolitan area of Toronto while its downtown is growing more rapidly before"(9 February 2022), online: https://www150.statcan.gc.ca/n1/daily-quotidien/220209/mc-b001-eng.htm.

[48] *Global Public Affairs Independent Review of the Canadian Nuclear Safety Commission's Response to the January 12, 2020 Pickering False Alarm and CNSC Management Response*, by CNSC, CMD 20-M11, online (pdf): https://www.nuclearsafety.gc.ca/eng/the-commission/meetings/cmd/pdf/CMD20/CMD20-M11-A.pdf.

[49] *Ibid*, at 12.

[50] *Ibid,* at 20.

3. What does sheltering-in-place mean? Which homes are more suitable for sheltering in place? Most are not familiar with the concept of sheltering in place let alone aware that the International Atomic Energy Agency (IAEA) and according to guidelines from the International Commission for Radiological Protection (ICRP), many North American homes are not suitable for "sheltering."

4. How do citizens re-unite with their family members? Who is responsible for making an evacuation plan and where are evacuation centres located? Do schools, colleges, day care centres, senior homes and hospitals have evacuation plans in place?

5. What to do citizens do if they do not own a vehicle or are incapable of driving them due to age or ill health?

DNA and CELA had previously posed these questions to the CNSC in their 2021 licencing renewal submissions to convey the fact that until answers to these questions becomes public knowledge, there is not the requisite level of public awareness regarding emergency response to proceed with licensing the Darlington site for new nuclear. We submit that these public preparedness issues remain a concern in the community. Despite laudable public pronouncements from the IAEA, ICRP and the CNSC about the need for clear communications to the public about emergencies ahead of time, most citizens are completely unprepared.[51] The materials provided by OPG relating to the selection of the BWRX-300 technology do not provide particulars on improving public awareness about emergency preparedness. DNA, SHA and CELA submit that these questions are very relevant to the discussion of BWRX-300 reactors proposed for the Darlington site, as public awareness is essential to effective emergency planning in the event of a severe accident at one or more of the proposed reactors. The Intervenors further submit that emergency preparedness instructions must be assessed in light of the types of accidents and releases that this particular technology may have.

Recommendation No. 13: As a condition of siting new nuclear, the CNSC should require ongoing public education and clear communication about emergency preparedness and protective actions.

Recommendation No. 14: Emergency preparedness instructions must be assessed in light of the types of accidents and releases that the BWRX-300 reactor technology may have.

ii. Land Use Planning & Site Suitability

The assessment of site suitability for new nuclear power is an important and distinct decision stage which requires thorough review of the potential impacts of operations and accidents on the surrounding environment and population. Since 2009, the Greater Toronto Area has seen

[51] *DNA 2015*, *supra* note 10, at 9.

substantial growth in total population, population density, while also seeing a substantial change in how the Province of Ontario is using the Greenbelt in response to this growth in population. These contemporary changes have a significant role in assessing site suitability at the Darlington site for up to four SMRs. The CNSC must apply its jurisdiction and expert judgment to the question of suitability of a site in relation to OPG's selection of the BWRX-300 reactor technology.

The *Nuclear Safety and Control Act* (NSCA) requires the CNSC to limit risk to Canadian Society.[52] As seen with past nuclear accidents, such as Fukushima, societal disruption is a key effect of nuclear accidents. It is apparent that the siting of nuclear power stations in highly populated areas increases the potential societal disruption in the event of accident. Therefore, the CNSC has a clear responsibility under the NSCA to assess the potential for a site to exacerbate social disruption in the event of a nuclear accident. When re-evaluating site suitability upon the disclosure of new information, such as the selection of the BWRX-300 reactor technology, changes and developments in land use surrounding the project site must be assessed.

The JRP's *Joint Review Panel Environmental Assessment Report* (EA Report) provides the Panel's recommendations for the DNNP resulting from the 2011 Environmental Assessment process. Based on this Report, land use planning within Durham Region is central to issue of constructing and operating new nuclear plants at the Darlington site. For instance, Recommendation #43 recommended that the CNSC "…engage appropriate stakeholders, including OPG, Emergency Management Ontario, municipal governments and the Government of Ontario to develop a policy for land use around nuclear generating stations"; and Recommendation #59 recommended that "the Municipality of Clarington manage development within the vicinity of the Project site to ensure there is no deterioration in the capacity to evacuate members of the public for the protection of human health and safety."[53]

The *EA Report* was released twelve years ago, and in the time that has passed since the JRP provided these recommendations related to land use and development changes in the region encompassing the DNNP site, there has been considerable growth and development occurring across Durham Region and the rest of the Greater Toronto Area.

DNA and CELA have previously expressed concerns to the CNSC that the continued urbanization and population growth surrounding the Darlington site makes it increasingly unsuitable for the continued operation of a nuclear station.[54] These concerns extend to the proposed construction of

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[52] *Nuclear Safety and Control Act*, SC 1997, c 9. **[NSCA]**
[53] *EA Report, supra* note 7, at 105 and 127.
[54] See for instance: *Blaise & Ramana*, *supra* note 33.
The issue of land use planning and population density has long been a concern with responsible nuclear plant planning. *See*: Kenneth Pearlman & Nancy Waite, "Controlling Land Use and Population Growth Near Nuclear Power Plants" (1984) 27:1/3 Wash U J Urb Contemp L., online (pdf): https://journals.library.wustl.edu/urbanlaw/article/7941/galley/24774/view/.

up to four BWRX-300 reactors at the Darlington site, and it is essential that the CNSC consider population growth projections in line with the project lifespan of the four reactors proposed by OPG, which are projected to operate during the span of 2029-2095.[55]

According to the *EIS Review Report*, OPG has been actively monitoring land use within 10 km of the DNNP site since 2011, including the review of planning and development applications. OPG noted that new development is occurring within urban areas (Oshawa, Courtice, Bowmanville, and Newcastle), and that "this pattern of growth and development is consistent with the latest provincial plans, which, representing the most noteworthy changes in land use at a policy level, seek to focus urban growth within existing urban areas, while maintaining limited development within the Greenbelt and Oak Ridges Moraine."[56]

OPG's determination that growth within the region is maintaining limited development within the Greenbelt and Oak Ridges Moraine is not accurate to the rapidly changing development landscape within Ontario. On December 8, 2022, *Bill 39, Better Municipal Governance Act, 2022* reached Royal Assent. Schedule 2 of this act repeals the *Duffins Rouge Agricultural Preserve Act*, *2005.*[57] Through repealing this Act, the Greenbelt becomes more fragmented, and is opened up to development within Durham Region.[58]

The Intervenors submit that due to the rapidly changing Greenbelt landscape in the region encompassing the DNNP site, the population growth within the region may not align with the projections of the Ontario's Growth Plans. The Intervenors request that the CNSC require OPG to address how planned and unplanned density growth within Durham Region is considered for emergency planning for the DNNP site.

Intervenors further submit that the *EIS Review Report* fails to go into sufficient detail about how construction, operation, and decommission phases of the proposed technology would comply with Ontario's Growth Plans and Ontario's Provincial Policy Statement (PPS). The CNSC has a responsibility to determine whether the siting of BWRX-300 reactors remains appropriate in light of the external factors of population growth and density, as these factors have a direct correlation with the requirement to properly protect the public in an accident.[59] The CNSC's obligation to

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[55] *EA Report*, *supra* note 7, at 18.
[56] *Ibid,* at 36-37.
[57] Legislative Assembly of Ontario, *Better Municipal Governance Act, 2022*, 39.
[58] Theresa McClenaghan & Zoe St Pierre, "Submission on Bill 39, Repeal of the Duffins Rouge Agricultural Preserve Act" (30 November 2022) online: https://cela.ca/submission-on-bill-39-repeal-of-the-duffins-rouge-agricultural-preserve-act/
[59] *For example,* Paragraph 3(1.1)(b) of the *General Nuclear Safety and Control Regulations* states the CNSC may require any other information that is necessary to enable it to determine whether the applicant will make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.

protect the health and safety of the public is highly relevant with OPG proposed a new technology for the Darlington site that is not already utilized at the site.

The Intervenors request that the CNSC confirm whether CNSC staff have reviewed the PPS to ensure land use compatibility in the vicinity of major facilities, which includes energy generation facilities. The intervenors submit specific regard should be given to population density and growth around nuclear generating stations and impacts of new and additional nuclear on the implementation of emergency measures and existing plans. The Intervenors submit that the smaller physical footprint and energy output of four BWRX-300 reactors (in comparison to the models considered in the EIS and PPE) does not exclude this technology from being re-assessed from a site suitability perspective.

Recommendation No. 15: The CNSC must exercise its jurisdiction and fulfill the federal constitutional jurisdiction over nuclear site approval. Any siting decision must ensure the protection of the public and environment for the intended lifespan of the new nuclear development. This decision must also account for changes in land use, population density, climate and environmental factors. No amount of subsequent regulatory action short of license termination can adequately protect the public if an unsuitable site is selected.

Recommendation No. 16: With recent legislative changes in Ontario opening up sections of the Greenbelt to development, the CNSC should require OPG to address how unplanned density growth within Durham Region is considered for emergency planning for the DNNP site.

Recommendation No. 17: The CNSC should direct CNSC staff to review the current and planned provincial land use directions under the *Places to Grow Act* and other indications of provincial intent to continue increasing density in this area; to ensure land use compatibility in the vicinity of major facilities, which includes energy generation facilities. Specific regard should be given to population density and growth around nuclear generating stations and impacts of new and additional nuclear on the implementation of emergency measures.

iii. Emergency Planning

Land use planning and site suitability are interconnected with appropriate emergency preparedness when the CNSC is fulfilling its obligations to limit harm to Canadian society. The JRP's *EA Report* emphasized the important role of emergency planning in recommendation #46, which states:

> Given that <u>a severe accident may have consequences beyond the three and 10-kilometre zones evaluated by OPG</u>, the Panel recommends that the Government of Ontario, on an ongoing basis, review the emergency planning zones and the emergency preparedness and

> response measures, as defined in the Provincial Nuclear Emergency Response Plan (PNERP), to protect human health and safety [Emphasis added].[60]

Despite the JRP noting that a severe accident may have consequences beyond the three and 10 km zones evaluated by OPG, to date, OPG has only been monitoring the land use in the 10 km surrounding the Darlington site.[61] The Intervenors submit that this narrow scope of land use monitoring is inadequate for evaluating the appropriate emergency preparedness plans for the BWRX-300 reactors.

Since the EIS was prepared and the EA was concluded, there has been substantial growth in Ontario, which means that mere compliance with the emergency preparedness at the time of the EIS's drafting is insufficient to reflect the health and safety concerns of the present and future population in the Greater Toronto Area.

According to the *Preliminary Safety Analysis Report*, the revised Darlington Evacuation Time Estimate, which OPG has made available to off-site planning authorities, relies on the 2016 National Census Data with per-decade population projections out to 2088, as well as current and forecasted infrastructure.[62] Additionally, OPG noted in this report that "in the first quarter of 2023, OPG will issue an updated Darlington Site Evacuation Time Estimate based on 2021 national census data and will subsequently be shared with stakeholders."[63] The Intervenors submit that this information should have been made available to the stakeholders prior to the submission deadline for commenting on the *EIS Review Report* and *Use of PPE 2022*. With the proposed BWRX-300 reactors projected to be in operations in 2095, having updated population projections are essential in determining whether OPG is preparing adequate emergency plans and accurate Site Evacuation Time Estimates.

The Intervenors submit that before a determination can be made as to whether the BWRX-300 reactor fits within the parameters of the EIS and PPE, the updated Darlington Site Evacuation Time Estimate and emergency planning models based on the 2021 Census data must be made available.

The population growth that has occurred in the region since the EA requires a modernized, robust emergency planning approach for the BWRX-300 reactors proposed for the DNNP site. The Fukushima Daiichi nuclear plant accident in 2011 serves as sombre reminder that a lack of emergency preparedness for a large scale accident will increase the severity of tragedy surrounding such events. With the Fukushima disaster, there were areas as far away as 50 km from the site had

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[60] *EA Report*, *supra* note 7, at 106, *emphasis added.*
[61] *EIS Review Report, supra* note 17, at 36-37.
[62] *Preliminary Safety Analysis Report, supra* note 29, at 2-172.
[63] *Ibid.*

to be evacuated due to high radiation levels, despite the initial evacuation limit of a 20 km radius mandated in the evacuation orders.[64]

In the original EIS, OPG discussed the Evacuation time estimate for the Emergency Planning Zone around the Darlington site. OPG noted that "this zone includes two evacuation regions of 3-km and 10-km radii from the DN site, each of which is further divided into Protective Zones."[65] As the aftermath of Fukushima revealed, planning to evacuate people based on concentric circles ranging from a radii of 5-30km is too rigid and inadequate for protecting the public during a serious nuclear disaster.[66] The Intervenors submit that OPG must provide more information on how emergency planning for BWRX-300 deployment will encompass a larger range of the population in the event of a severe nuclear incident.

During the 2021 licencing renewal application hearing for the Darlington site, DNA and CELA submitted that that section 15 of the proposed Licence Conditions Handbook, which currently lists a series of site specific environmental conditions, be amended to include documentation showing how OPG will ensure that it controls the use and occupation of land within 20 km of the site to maintain safety margins for the fifth level of defence in depth by preventing the intensification and development of residential dwellings. This includes conformance to revised Growth Plans and Ontario's PPS. This action is in furtherance of the Government of Ontario's establishment of a 20 km Contingency Zone in its 2017 PNERP to address the potential of a severe accident.

The Intervenors submit that OPG must ensure that it controls the use and occupation of land within 20 km of the site to maintain safety margins for the fifth level of defence in depth by preventing the intensification and development of residential dwellings to comply with the establishment of a 20 km Contingency Zone in accordance with PNERP.

Another key element within emergency planning is being prepared for the worst possible outcome. One of the factors which contributed to the Fukushima disaster were the shortcomings in safety culture. According to the International Atomic Energy Agency (IAEA):

> A major factor that contributed to the accident was the widespread assumption in Japan that its nuclear power plants were so safe that an accident of this magnitude was simply unthinkable. This assumption was accepted by nuclear power plant operators and was not

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64 *Lessons from Fukushima*, by Greenpeace (February 2012), online (pdf): https://www.greenpeace.org/usa/research/lessons-from-fukushima/, at 18 [**Greenpeace**].
65 *2009 EIS, supra* note 40, at 7-48.
66 *Greenpeace, supra* note 64, at 15.

> challenged by regulators or by the Government. As a result, Japan was not sufficiently prepared for a severe nuclear accident in March 2011.[67]

With this assumption that the plant could cope with anything, whether it be a technology issue or environmental event, there was a lack of regard for an extremely rare event—i.e., a 9.0 magnitude earthquake and tsunami would impact the plant on such a large scale. Both the EIS and the *EIS Review Report* appear to be silent on the impacts of multiple events simultaneously impacting the Darlington site, e.g., an extreme weather event occurring during a nuclear event at the operating CANDU units at the Darlington Nuclear Generating Station. With OPG determining within the *EIS Review Report* that "no residual adverse effects are anticipated from any malfunctions and accidents related to BWRX-300 deployment,"[68] the Intervenors are concerned that the lessons from Fukushima remain unlearned and worst-case scenarios are not being considered for emergency planning. The Intervenors submit that the CNSC and OPG must ensure that the authorities in charge of emergency planning are sufficiently prepared for a severe nuclear accident.

Recommendation No. 18: Before a determination can be made as to whether the BWRX-300 reactor fits within the parameters of the EIS and PPE, the updated Darlington Site Evacuation Time Estimate and emergency planning models based on the 2021 Census data must be made available.

Recommendation No. 19: OPG must provide more information on how emergency planning for BWRX-300 deployment will encompass a larger range of the population in the event of a severe nuclear incident.

Recommendation No. 20: OPG must ensure that it controls the use and occupation of land within 20 km of the site to maintain safety margins for the fifth level of defence in depth by preventing the intensification and development of residential dwellings to comply with the establishment of a 20 km Contingency Zone in accordance with PNERP.

Recommendation No. 21: The CNSC and OPG must ensure that emergency planning authorities are sufficiently prepared for a severe nuclear accident.

iv. Climate Change

In the *EIS Review Report*, OPG concludes that BWRX-300 deployment does not change the original EIS's determination that there are no medium or high risk interactions between the climate change parameters and the Project due to mitigations incorporated in the Project design.[69] Since

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[67] Laura Gil, "Fukushima Daiichi: The Accident", (IAEA) *A Decade of Progress after Fukushima Daiichi: Building on the lessons learned to further strengthen nuclear safety*, (March 2021), online (pdf): https://www.iaea.org/sites/default/files/bulletindecadeafterfukushima.pdf, at 15.

[68] *EIS Review Report, supra* note 17*,* at 87.

[69] *EIS Review Report, supra* note 17, at 82.

the EIS was prepared, there has been much more information surrounding the impacts of climate change.

The frequency of extreme-weather events in the last decade increases the likelihood of direct and indirect effects on nuclear facilities, and one of the risks posed is a facility shutting down due to a lack of cooling capacity.[70] With rising temperatures, an increase in water temperatures pose a two-fold risk for nuclear cooling capacity: insufficient temperature for cooling purposes, and increase in algal blooms. With the BWRX-300 reactor's design using once through lake water cooling, the qualities of the water cooling the reactor are crucial. Water being drawn for cooling purposes needs to be a suitable temperature to fulfill its cooling duties inside the reactor, and algae can create blockages at water intake pipes and thus prevent adequate water supply to the reactor for cooling purposes. Without sufficient cooling, a reactor's "fuel can overheat, become damaged, and eventually melt, releasing highly radioactive materials into the environment."[71]

The dangers of climate change are already being observed at Ontario nuclear power generating sites: the weighing down of the fish diversion barrier in Lake Ontario by the Pickering nuclear power plant was attributed to algae loading and the rapid water temperature changes related to lake conditions.[72] This also was the explanation provided for increased fish impingement during a recent CNSC's regulatory oversight review for nuclear power plants.[73] Significant amounts of algae have also clogged cooling water intakes causing Pickering's reactors to go temporarily offline.[74] One concern with the impacts of climate change relevant to SMRs is increasing water temperatures, as the BWRX-300 would depend on Lake Ontario's water for cooling the reactor.

The *Preliminary Safety Analysis Report* briefly touches upon lake water temperature, and refers to the use of statistical summary of ambient water temperatures near Darlington Nuclear for date ranges of 1984-1996, 2011 and 2012.[75] The Intervenors submit that this data is outdated, and that data on ambient water temperature needs to updated in a timely fashion in order to understand temperature trends for a long term range. A detailed climate analysis needs relevant data, and

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70 Ali Ahmad, Andrei Covatariu & MV Ramana, "A stormy future? Financial impact of climate change-related disruptions on nuclear power plant owners" (2023) 81:101484 Util Policy April 2023., at 3.

71 *"Advanced" isn't always better: Assessing the Safety, Security, and Environmental Impacts of Non-Light Water Nuclear Reactors*, by Edwin Lyman (Union of Concerned Scientists), March 2021, at 24.

72 Algal blooms causing reactor shutdowns is not a recent phenomenon in Ontario, with both Pickering and Darlington sites being shut down by algal blooms, which has cost millions of dollars in lost power generation caused by shut downs, as reported back in 2007. *See:* Tyler Hamilton, "Algae prompt reactor shutdown", *Tor Star,* (10 August 2007), online: https://www.thestar.com/business/2007/08/10/algae_prompt_reactor_shutdown.html

73 Kerrie Blaise, *Submission by the Canadian Environmental Law Association to the Canadian Nuclear Safety Commission Regarding the Regulatory Oversight Report for Canadian Nuclear Power Generating Sites: 2019* (CELA, 2020), online (pdf): https://cela.ca/wp-content/uploads/2020/12/CELA-to-CNSC-ROR-NPGS-with-Appendices.pdf

74 *Ibid.*

75 *Preliminary Safety Analysis Report, supra* note 29, at 2-59.

without it, it cannot be determined as to whether the BWRX-300 reactors will be able to operate sufficiently if Lake Ontario's ambient temperature is substantially higher in the future. The Intervenors request that OPG provide updated information on ambient water temperature trends for Lake Ontario and compare that with the allowed range of inlet temperatures for the BWRX-300 reactor design.

With algae already being an issue at the Pickering nuclear plant, it is an important risk to evaluate the resultant risks to the proposed nuclear plant too. The *Preliminary Safety Analysis Report*, acknowledges that substantial clumps of algae have the potential to cause blockages or restriction issues at water supply system intakes.[76] In terms of managing algae, OPG notes that "…the Pumphouse/forebay structure is designed to prevent clogging by algae and exceptional quantities of fish and to stop them from entering the cooling systems."[77] It is unclear however, whether the effectiveness of the intake tunnel and lakebed intake structure, and travelling water screens take into account increased volume of algal blooms associated with an increase in lake water temperature. Additionally, OPG's materials do not explain what would be the consequences if these mechanisms fail and algae entering the water supply system intake. The Intervenors request additional studies be conducted on the impacts of an increase in algal blooms due to climate change impacts on Lake Ontario. The modelling for managing aquatic species' interactions with water intake equipment needs to be adapted for the worst case-scenario due to climate change.

Recommendation No. 22: OPG should provide updated information on ambient water temperature trends for Lake Ontario and compare that with the allowed range of inlet temperatures for the BWRX-300 reactor design.

Recommendation No. 23: Additional studies should be conducted on the impacts of an increase in algal blooms due to climate change impacts on Lake Ontario. The modelling for managing aquatic species' interactions with water intake equipment needs to be adapted for the worst case-scenario due to climate change.

VI. CONCLUSION

For the foregoing reasons provided in this report, DNA, SHA, and CELA submit:

(1) The BWRX-300 reactor technology is fundamentally different from the bounding parameters within the Environmental Impact Statement and the Plant Parameters Envelope for the Darlington New Nuclear Project, and therefore a new environmental assessment specific to the BWRX-300 technology is required.

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[76] *Ibid* at 2-49.
[77] *Ibid* at 3-77.

(2) In the alternative, before moving on from this pre-licencing stage to commence the licence to construct process, OPG must produce a substantial amount of information and updated data which was missing in order to complete an assessment of the bounding parameters for the selected technology. Any new resources produced by OPG should be subjected to a public review and commenting process.

Sincerely,

On behalf of

CANADIAN ENVIRONMENTAL LAW ASSOCIATION
DURHAM NUCLEAR AWARENESS
SLOVENIAN HOMEOWNERS ASSOCIATION

Sara Libman
Legal Counsel

APPENDIX A - SUMMARY OF RECOMMENDATIONS

Recommendation No. 1: As the PNERP Technical Study has been released by the province of Ontario to the CNSC, we request licensing documents be revised to directly respond to its findings.

Recommendation No. 2: Because the CNSC has been given permission by the OFMEM to share the PNERP Technical Study with anyone who requests it, the CNSC should make this report publicly available on the CNSC website.

Recommendation No. 3: The CNSC should review the PNERP Technical Study and as part of the review of the EIS and the PPE within the context of the proposed BWRX-300 reactor technology, demonstrate the sufficiency of contingency planning for the protection of drinking water, such as Lake Ontario, in the event of an emergency.

Recommendation No. 4: To increase transparency, the Intervenors submit that OPG should be required to make all non-confidential documents readily available for public viewing, either via hyperlinks within documents, or through an archived database on their website. Information must be shared with the public in a timely manner.

Recommendation No. 5: OPG should carry out a full-fledged severe accident analysis taking into account the challenges of estimating the reliability of the Passive Isolation Condenser System in order to show how the BWRX-300 design will adhere to CNSC requirements.

Recommendation No. 6: OPG must address how it intends to ensure the proposed reactors twill meet the requirement for 2 separate, independent and diverse means of reactor shutdown.

Recommendation No. 7: OPG should conduct a thorough assessment of the hazards associated with spent fuel fires at the Darlington nuclear power plant.

Recommendation No. 8: The Intervenors submit that the low frequency of commercial aircraft accidents should not be a reason to screen out the risk. OPG must analyze the hazards associated with and impacts due to a commercial aircraft hitting the reactor building, or the waste management facilities, or any of other facilities and buildings located on the Darlington site.

Recommendation No. 9: The potential for and effects of a multi-unit accident must take into consideration the relationship between the existing reactors of the Darlington Nuclear Generating Station and the proposed BWRX-300 reactors.

Recommendation No. 10: OPG needs to revisit the hazard assessment of a large military aircraft accident in proximity to the BWRX-300 reactors.

Recommendation No. 11: OPG should conduct a hazard assessment of malevolent drone use on SMRs like the BWRX-300 reactor design, even if the likelihood of such an event occurring is low.

Recommendation No. 12: Without a decommissioning plan designed specifically for a BWRX-300 reactor, it is not possible to determine whether the technology selected by OPG is in compliance with the EIS. We request that the CNSC require OPG to outline a detailed and non-theoretical decommissioning plan for the BWRX-300 reactors before any further assessments occur for the DNNP site.

Recommendation No. 13: As a condition of siting new nuclear, the CNSC should require ongoing public education and clear communication about emergency preparedness and protective actions.

Recommendation No. 14: Emergency preparedness instructions must be assessed in light of the types of accidents and releases that the BWRX-300 reactor technology may have.

Recommendation No. 15: The CNSC must exercise its jurisdiction and fulfill the federal constitutional jurisdiction over nuclear site approval. Any siting decision must ensure the protection of the public and environment for the intended lifespan of the new nuclear development. This decision must also account for changes in land use, population density, climate and environmental factors. No amount of subsequent regulatory action short of license termination can adequately protect the public if an unsuitable site is selected.

Recommendation No. 16: With recent legislative changes in Ontario opening up sections of the Greenbelt to development, the CNSC should require OPG to address how unplanned density growth within Durham Region is considered for emergency planning for the DNNP site.

Recommendation No. 17: The CNSC should direct CNSC staff to review the current and planned provincial land use directions under the *Places to Grow Act* and other indications of provincial intent to continue increasing density in this area; to ensure land use compatibility in the vicinity of major facilities, which includes energy generation facilities. Specific regard should be given to population density and growth around nuclear generating stations and impacts of new and additional nuclear on the implementation of emergency measures.

Recommendation No. 18: Before a determination can be made as to whether the BWRX-300 reactor fits within the parameters of the EIS and PPE, the updated Darlington Site Evacuation Time Estimate and emergency planning models based on the 2021 Census data must be made available.

Recommendation No. 19: OPG must provide more information on how emergency planning for BWRX-300 deployment will encompass a larger range of the population in the event of a severe nuclear incident.

Recommendation No. 20: OPG must ensure that it controls the use and occupation of land within 20 km of the site to maintain safety margins for the fifth level of defence in depth by preventing the intensification and development of residential dwellings to comply with the establishment of a 20 km Contingency Zone in accordance with PNERP.

Recommendation No. 21: The CNSC and OPG must ensure that emergency planning authorities are sufficiently prepared for a severe nuclear accident.

Recommendation No. 22: OPG should provide updated information on ambient water temperature trends for Lake Ontario and compare that with the allowed range of inlet temperatures for the BWRX-300 reactor design.

Recommendation No. 23: Additional studies should be conducted on the impacts of an increase in algal blooms due to climate change impacts on Lake Ontario. The modelling for managing aquatic species' interactions with water intake equipment needs to be adapted for the worst case-scenario due to climate change.

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Blog: Neighbours of a Nuclear Plant – What Residents of Durham Region Should Know about Nuclear Energy

English

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Canadian Nuclear Safety Commission (CNSC), new nuclear, nuclear, nuclear licensing, nuclear safety, nuclear waste, public consultation, small modular reactors (SMR)

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Ontario's power grid has become increasingly reliant on nuclear energy. Currently, Ontario is home to three active nuclear stations – two of them are in Durham Region, within 30km of each other; the Pickering and Darlington generating stations.

With over 696,000 Durham residents living near these two stations, it is crucial that every person is fully informed about nuclear activity in their backyards. Decisions about nuclear power will have direct effects for everyone living in the region. **While accidents are unlikely, the aftermath can be catastrophic.**

The Darlington nuclear generator units are currently under refurbishment and the plant is also awaiting the Canadian Nuclear Safety Commission (CNSC) to determine whether a 15-year-old environmental assessment applies to a proposal for new Small Modular Reactors (SMR) at the same site.

Similarly, the Pickering generator is currently licensed to operate until the end of this year. However, Ontario Power Generation (OPG) is seeking to extend its license (again) to operate some of those units beyond its original operating life span. The province has also asked OPG to pursue refurbishment (essentially reconstruction) of the units at Pickering to operate for several more decades.

Emergency Preparedness

English

A local nuclear awareness group, Durham Nuclear Awareness (DNA), is composed of Durham residents who advocate for public education of all nuclear decisions occurring in their communities. One of their main concerns is that, alarmingly, many residents in Durham's community are under informed of what they should do in the case of a nuclear accident.

"Since the late 80s DNA has advocated for improved emergency planning, our goal has been to try and raise awareness in the Durham Region about nuclear power because most people don't know about it." said Gail Cockburn, long-time member of DNA.

According to a poll conducted in 2018, **54 percent of respondents were unaware of any emergency response plans in case of a nuclear accident**, a clear indication of the need for stronger awareness efforts.

So, what are the current emergency plans in place for residents? The Durham Nuclear Emergency Response Plan (DNERP) outlines evacuation plans for up to 50 km radius from a station, and pre-distribution of potassium iodine (KI) pills for a 10km radius. Stay in place (sheltering) and evacuations are highlighted as potential key procedures in the event of an emergency for residents living within 50km of the stations.

However, the effectiveness of these plans relies on public knowledge of what should be done and what their next steps would be. People living in Durham Region are reassured by the message from the officials that a nuclear accident is very unlikely. **However, an ongoing concern is that if a severe emergency is not considered likely, then inadequate resources and planning may result. This was a main finding in Japan after the Fukushima-Daichii earthquake and resulting nuclear accident.**

"A nuclear accident, if one happens, it's a rare thing. But if it happens, it's a very chaotic event. It's not something that most people expect to happen on any given day. And there are always going to be uncertainties when you try to translate these paper exercises (emergency plans) into the real world," said Dr. M.V. Ramana, global affairs professor at the University of British Columbia and advisor of DNA.

Despite the local support of nuclear energy from the government and commercial groups, it is imperative that local residents who would face the brunt of any potential threats are aware of the risks to themselves and their communities. For Brennain Lloyd, long-time member of Northwatch, an environmental advocacy group and lead nongovernmental organization on nuclear waste, this begins with residents simply asking questions.

English

"I think that they should just ask questions. I think if they have a question about nuclear energy, they should send that question to OPG, and to CNSC," said Lloyd.

People have a say in what happens in their communities, and according to Lloyd they shouldn't stop asking questions until they are satisfied.

"And they should wait for their answer, and when they get that answer, if it's not satisfactory then they should write to their MPP and to their MP and say, 'I asked this question, and I'm not satisfied with the answer. Can you please get me an answer'," added Lloyd.

Impacts of Nuclear Waste

For host communities, nuclear activity can have adverse effects on the environment. While nuclear energy is often said by the industry to be a "clean" energy source, nuclear waste poses a serious threat to its surrounding environment. According to an article published by Earth.org "toxic materials remain highly radioactive for tens of thousands of years, posing a threat to agricultural land, fishing waters, freshwater sources and humans."

For Durham Region storage of nuclear waste is a major concern due to the close proximity to Lake Ontario.

"People in Durham Region should be very concerned about the dry storage container system at Darlington and Pickering. They are immediately on the shoreline of Lake Ontario and they're inserting more (containers) in between the current dry storage buildings and the lake, which means they're more vulnerable to extreme weather events," said Lloyd.

When it comes to long term management of nuclear waste, there is no current sufficient plan – dry storage is the sole short-term plan for storage of nuclear waste.

"They don't have any plan for long term management of the waste at the reactor station, they plan to put the waste in a deep geological repository. Well, they've been working on that deep geological repository idea since 1977. We're in the third round of them trying to design and build and site a deep geological repository, they haven't been successful yet," said Lloyd.

Promoting Nuclear Awareness in Durham Region

Despite the potential risks to the environment and ultimately our own health, nuclear energy is a significant piece of the Ontario electrical system. Living in a nuclear community is simply the reality for people in Durham Region. However, residents can be proactive in keeping themselves informed and their community leaders accountable for all nuclear activity happening in their backyards.

Local residents in the community have taken it upon themselves to get involved in nuclear activity in their communities. Oscar Koren is the vice president of the Slovenian Home Association (SHA). After approaching CELA with nuclear concerns, Koren was connected to DNA in 2022, hoping to get some answers for concerned members of SHA who live in close proximity to the Pickering generating station.

“They (SHA members) have a concern about the (emergency) plans, because they don’t know what they should do in case of an emergency”, said Koren.

Koren believes there is confusion and lack of knowledge of emergency preparedness plans for his members and their families. He hopes for “security and knowledge” for members of his association.

“If something happens, let’s say some sort of an accident, our members that live in the vicinity, we’d like to know what’s the plan? What should they do?”, added Koren.

Much like Koren, many residents have taken matters into their own hands, hoping to educate themselves and spread awareness on nuclear energy in their community.

An IT professional and long-time resident of Durham Region who prefers not to be named makes it a point to be fully aware of nuclear activity in Durham, and suggests that “simply getting people talking, and asking their politicians to start talking about these subjects,” is the best practice to increase critical awareness on nuclear energy.

Knowing that nuclear energy in Ontario will be around for many years to come, the local IT professional urges for honest communication from the government and nuclear decision makers.

“If we’re going to have these colossal multi reactor facilities, let’s be honest about them,” added the IT professional.

Other people living in Durham, have little to no prior knowledge of emergency preparedness, environmental impacts, or general nuclear topics. CELA spoke to residents of Durham Region – here’s how they responded when we asked what they’ve been told about emergency response plans:

English

"I mean we've never talked about it, at school, at home, or anywhere really, I guess they'll let us know what to do if something bad ever happens." said 23-year-old Pickering, Ont., resident Onelia Osbourne.

"I think we'll get some sort of notice if we ever need leave or something, but I'm not too sure about what exactly we're supposed to do," said 48-year-old Pickering, Ont., resident, Chantale Theodore.

"I don't feel I am properly prepared to respond to a nuclear accident, the only step I know in case of an emergency is to take an iodine pill (which I learnt in elementary school). Since then, I have never been taught a plan or discussed it with anyone, which now that I think about it is so bad because I'm 15 minutes away from the nuclear plant," said 20-year-old Rheanne Johnson, from Pickering, Ont.,

Many residents of Durham are reassured by the belief that an accident is very unlikely to occur. However, it is important to learn from historic nuclear catastrophes and ensure that individuals, families, and communities are well educated and prepared for the unlikely event of an accident.

How can you get involved?

According to Durham Region's Growth Management Study, the population of Durham is forecasted to grow to 1.3 million by 2041. As the region continues to expand, it is important that all residents at the very least have a general understanding of what it means to live near these stations.

For residents wondering how they can begin educating themselves and their community about nuclear activity, Executive Director of the Canadian Environmental Law Association Theresa McClenaghan, suggests the following:

1. Educate yourself on emergency preparedness plans in your community. Access the PNERP and DNERP for information on evacuation plans, sheltering and KI pills.
2. Visit Preparetobesafe.ca to order KI pills for yourself and your family.
3. Get engaged in your community by attending license hearings, summits, webinars etc.
4. Be sure to submit comments in writing to Ontario Power Generation, the Ontario Ministry of Energy, and the regulator, the Canadian Nuclear Safety Commission, about major nuclear decisions taking place in Durham Region.
5. Visit the CNSC's calendar of commission proceedings page for details on relevant public hearings.

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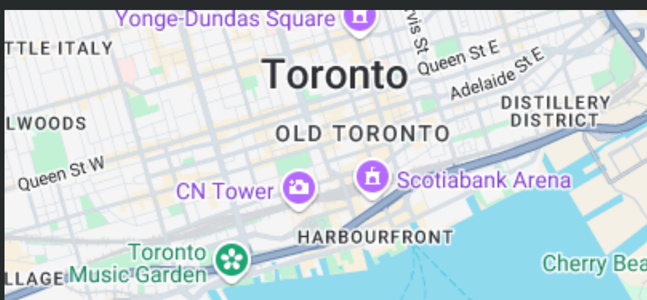

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